CONNECTIONS

The EERI Oral History Series

Robert Park

Thomas Paulay

Robert Reitherman
Interviewer

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Earthquake Engineering Research Institute

New Zealand Society for Earthquake Engineering Inc

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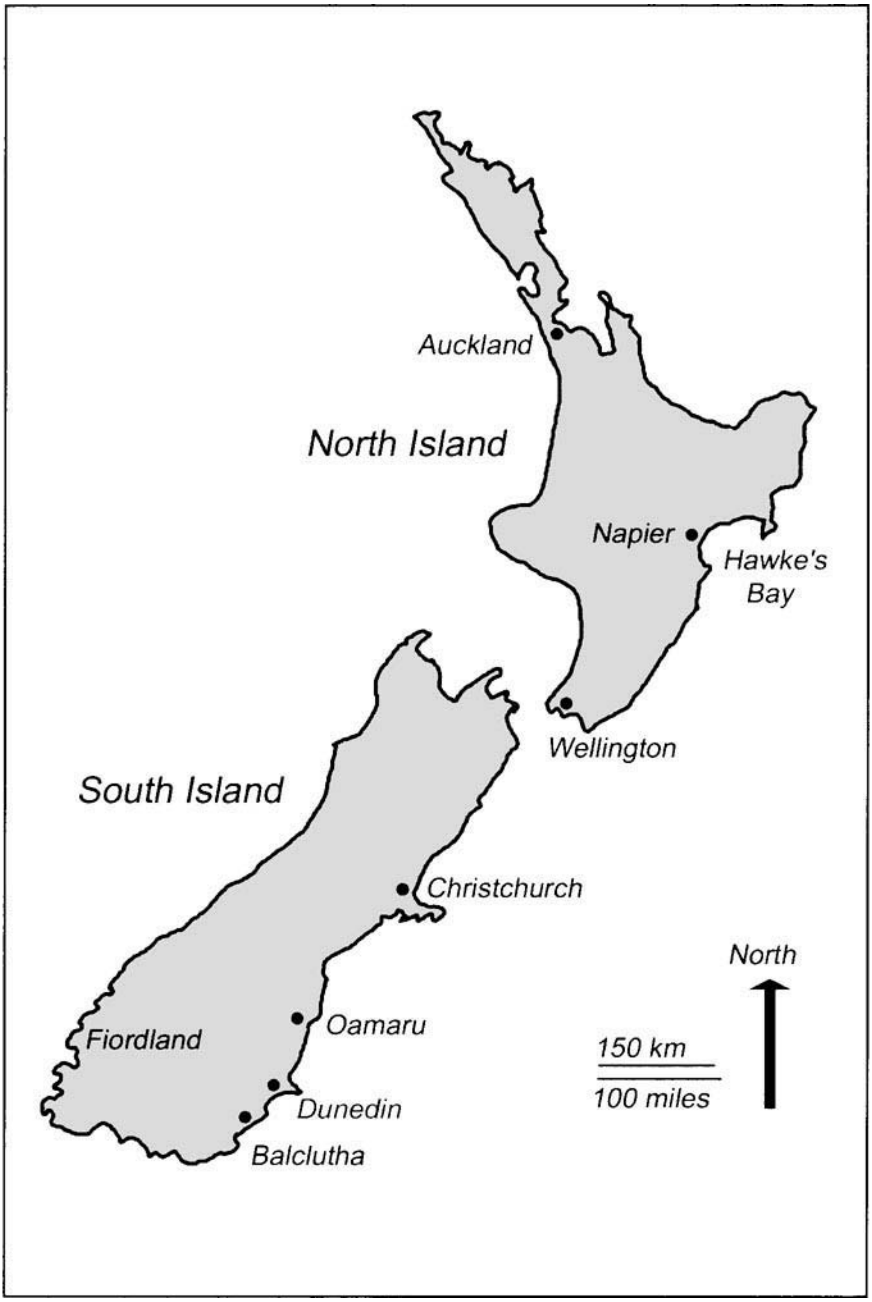

Schematic map of New Zealand showing places mentioned in the Park and Paulay oral histories.

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The EERI Oral History Series

This is the twelfth volume in *Connections: The EERI Oral History Series.* The Earthquake Engineering Research Institute initiated the *Connections* series to preserve the recollections of some of those who have had pioneering careers in the field of earthquake engineering. Significant, even revolutionary, changes have occurred in earthquake engineering since individuals first began thinking in modern, scientific ways about how to protect construction and society from earthquakes. The *Connections* series helps document this significant history.

Connections is a vehicle for transmitting the fascinating accounts of individuals who were present at the beginning of important developments in the field, documenting sometimes little-known facts about this history, and recording impressions, judgments, and experiences from a personal standpoint. These reminiscences are themselves a vital contribution to our understanding of where our current state of knowledge came from and how the overall goal of reducing earthquake losses has been advanced. The Earthquake Engineering Research Institute, founded in 1948 as a nonprofit organization to provide an institutional base for the then-young field of earthquake engineering, is proud to help tell the story of the development of earthquake engineering through these *Connections* volumes. EERI has grown from a few dozen individuals in a field that lacked any significant research funding to an organization with nearly 3,000 members. It is still devoted to its original goal of investigating the effects of destructive earthquakes and publishing the results through its reconnaissance report series. EERI brings researchers and practitioners together to exchange information at its annual meetings, and via a now-extensive calendar of conferences and workshops. EERI provides a forum through which individuals and organizations of various disciplinary backgrounds can work together for increased seismic safety.

The EERI oral history program was initiated in 1984 by Stanley Scott (1921-2002). Scott was a research political scientist at the Institute of Governmental Studies at the University of California at Berkeley and had been active in developing seismic safety policy for many years. He was a member of the California Seismic Safety Commission from 1975 to 1993, and received the Alfred E. Alquist Award from the Earthquake Safety Foundation in 1990.

Scott initiated the oral history project in 1984 with his first interviewee, Henry Degenkolb. The Regional Oral History Office at the University of California at Berkeley eventually approved the interview project on an unfunded basis, and Scott continued his interviews following his retirement from the university in 1989. For a time, some expenses were paid from a small grant from the National Science Foundation, but Scott did most of the work pro bono. Scott's work summed to hundreds of hours of taped interview sessions and thousands of pages of transcripts. Were it not for him, valuable facts and recollections would have been lost. In fact, many of the people he interviewed early in the project have now passed away.

The first nine volumes of *Connections* were published during Scott's lifetime. Manuscripts and interview transcripts he bequeathed to EERI will eventually result in posthumous publication of several other volumes. The Oral History Committee has now expanded the program to include additional interviews with subjects who have: 1) outstanding, career-long contributions to earthquake engineering; 2) valuable first-person accounts to offer concerning the history of earthquake engineering; and 3) backgrounds that span the various disciplines included in the field of earthquake engineering.

The events described in these oral histories span research, design, public policy, broad social issues, and education, as well as interesting personal aspects of the subjects' lives. EERI hopes that the *Connections* Oral History Series will offer insights into the history of earthquake engineering and the influential figures who shaped its progress.

Published volumes in *Connections: The EERI Oral History Series*

Henry J. Degenkolb	1994
John A. Blume	1994
Michael V. Pregnoff and John E. Rinne	1996
George W. Housner	1997
William W. Moore	1998
Robert E. Wallace	1999
Nicholas F. Forell	2000
Henry J. Brunnier and Charles De Maria	2001
Egor P. Popov	2001
Clarence R. Allen	2002
Joseph Penzien	2004
Robert Park and Thomas Paulay	2006

EERI Oral History Committee

Robert Reitherman, Chair
William Anderson
Roger Borcherdt
Gregg Brandow
Ricardo Dobry
Robert Hanson
Loring A. Wyllie, Jr.

Foreword

This volume originated in a brief conversation at the 2003 Pacific Conference on Earthquake Engineering held at the University of Canterbury in Christchurch, New Zealand in February 2003. Chris Poland, then president of the Earthquake Engineering Research Institute, Tom Paulay, and I were having a casual conversation at one of the morning breaks. As I had recently assumed the job of shepherding EERI's oral history program, I mentioned to Chris that perhaps the series should broaden its geographic scope beyond the U.S., and none could be worthier additions than Tom and his colleague Bob Park. Chris wholeheartedly agreed. Tom, in his usual gentlemanly manner, politely dissented and said there must be dozens of more worthy subjects elsewhere.

The vote that day was two to one against Tom, and the full Oral History Committee of EERI later ratified the decision unanimously. Hence, this wonderful addition to the EERI series. Discussions between the New Zealand Society for Earthquake Engineering and EERI led to the happy result that this book has the imprimatur of both organizations, and thereby greater accessibility to an international readership. As an American, I may be accused of bringing coal to Newcastle, but it is such high-grade ore, and imported under the auspices of the country's own NZSEE, that I hope none of the fellow citizens of Professors Park and Paulay will mind.

The in-person interviews were primarily conducted a little over a year after the 2003 Pacific Conference on Earthquake Engineering, during the week surrounding another event at the University of Canterbury, the Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park, which was held on July 11, 2003. Both Bob and Tom graciously consented to my infringement on their time just when numerous colleagues and former students were visiting from New Zealand and abroad. Tom's wife, Herta, was not only a gracious hostess during my frequent intrusions into the Paulay home in Christchurch for interviews, but will also be found by the reader as a quoted contributor. Both Bob and Tom spent considerable hours after the initial interviews reviewing drafts of the manuscript and answering additional questions. The late Bob Park finished his final review and editing of the manuscript in October, 2004, two weeks prior to his fatal heart attack in Christchurch on November 3, 2004, at the age of seventy-one.

A large number of other individuals assisted my efforts. In the United States, I conferred with several people who have had technical expertise in the earthquake engineering areas that were prominent in the careers of Tom and Bob and who also knew them well. Jim Jirsa and Sharon Wood of the University of Texas at Austin and Loring Wyllie of Degenkolb Engineers suggested fruitful lines of questioning regarding reinforced concrete design. Wyllie was also the member of the EERI Oral History Committee who was the designated reviewer for this volume and corrected several errors I would have missed. Catherine French of the University of Minnesota related information from her visiting scholar stay at the University of Canterbury, as did Joe Maffei and José Restrepo concerning their Ph.D. days. André Filiatrault related background information about his time in New Zealand and the 1995 Great Hanshin (Kobe) Earthquake reconnaissance effort of the NZSEE led by Bob Park. The specialized earthquake engineering collection overseen by librarian Chuck James at the University of California at Berkeley Earthquake Engineering Research Center was extensively used, and it once again proved how valuable a resource it is to the researcher.

In New Zealand, a number of people must be acknowledged. Nigel Priestley talked with me over the phone prior to the interviews with Bob and Tom to provide background information, and authored the Personal Introduction to this volume. Richard Sharpe of the New Zealand Society for Earthquake Engineering similarly contributed prior to the first interviews, and suggested several lines of questioning. Sharpe subsequently arranged for the NZSEE-EERI joint publication and wrote the Preface for the Society. He also skillfully applied his editorial curry comb to the entire manuscript and spotted a number of detailed items that needed correction and inconsistencies that would otherwise have slipped through. Richard Fenwick and David Hopkins, the men who delivered the summary addresses for Tom and Bob, respectively, at the July 2003 Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park, were quite helpful over the phone, in person, and in providing excellent documentation in their Symposium papers that has been used and cited extensively in this oral history volume. David Hopkins provided information about his father, Harry, who figured significantly in the careers of both Tom and Bob. David Brunsdon, from the organizing committee of the 2003 Paulay and Park Symposium, assisted me in making excellent use of that opportunity to gather background material for the interviews and in adding documentary material to this volume.

At the University of Canterbury Civil Engineering Department, assistance was always prompt and enthusiastic. Conversations with University of Canterbury faculty members Desmond Bull, Athol Carr, Peter Moss, and John Mander provided useful information, and Bruce Deam, another faculty member, excavated old scrapbooks of visiting scholars and provided a copy of the useful history of the engineering school at Canterbury that is cited several times in this volume. Melody Callahan provided the keys to the department's storehouse of classic photos of laboratory research and other university scenes going back five or more decades. Correspondence with Bob and Tom was facilitated by Louise Barton, Allison (Pat) Roberts, and Catherine O'Shaughnessy. Journalist Alastair McKenzie's participation in the joint interview session with Tom and Bob (the final section of this volume, entitled "A Conversation with Bob Park and Tom Paulay") was helpful, as was his article in the magazine of the Institution of Professional Engineers of New Zealand that is also cited. Correspondence with Bill Robinson added interesting background information. Robin Shepherd provided details regarding the early years of the New Zealand Society of Earthquake Engineering, as did Graeme Beattie concerning the Ministry of Works. Conversation with Ivan Skinner, a man with long involvement in all things seismic in New Zealand, was both enjoyable and valuable. A close colleague of Tom Paulay's from Switzerland, Hugo Bachmann, kindly provided photographs.

Gail Shea, consulting editor to EERI, carefully reviewed the entire manuscript and prepared the index, as she has on previous *Connections* volumes. Eloise Gilland, the Editorial and Publications Manager of EERI, was also essential in seeing this publication through to completion.

Robert Reitherman
October 2005

Preface

The New Zealand Society for Earthquake Engineering is very pleased to be associated with this volume of *Connections*. In the lead-up to the 2003 Paulay and Park Symposium, which the reader will find referred to several times in these pages, the Society's Management Committee was preparing to commission its own oral history of these two outstanding members. On hearing that the Earthquake Engineering Research Institute was planning to come to New Zealand to undertake an identical task, the Management Committee recognised that this was an opportunity for the two similarly-minded organisations to work together and jointly honour these leaders in earthquake engineering. EERI's desire for Bob and Tom to be the subject of a volume in the Oral History Series also brought home to many of us New Zealand earthquake engineers that "our" Bob and Tom are international citizens. This is amply reinforced by the stories these two tell in their interviews.

Those of us who were lucky enough to be studying in the Civil Engineering Department at the University of Canterbury in the late 1960s and early 1970s will remember it as a supportive environment, one that nurtured developments in the seismic design of reinforced concrete. It was exciting at the time, and historic in retrospect. Faculty members were ramping up the computing and analysis capabilities, interacting with the leading structural engineers in both the public and private sectors, and eliciting financial support for procuring everything from more laboratory space, offices for graduate students, shaking tables, and shaking machines for bridges and buildings. As both oral histories note, Professor Harry Hopkins had a pivotal role in all of this.

Today, wherever New Zealand earthquake engineers travel in the world, we receive the benefit of being recognised as somehow connected to the work of Park and Paulay. From Kathmandu in Nepal to Bucharest in Romania, their *Reinforced Concrete Structures* book, and Tom's volume co-authored with their colleague, Nigel Priestley, entitled *Seismic Design of Reinforced Concrete and Masonry Buildings*, have inspired and guided those seeking to improve the resilience of their communities to the awful power of earthquakes.

The passing of Bob so soon after the completion of the interview process certainly brings home the importance of recording these oral histories for future generations. We not only salute Bob and Tom for their huge contribution to the work of the Society, but also thank them for sharing with us their personal stories in such detail.

The New Zealand Society for Earthquake Engineering is grateful to EERI for the well-researched and sympathetic way in which such exciting histories have been elicited from our much-respected members. This volume will be distributed to all members of the New Zealand Society for Earthquake Engineering and will be eagerly read all over New Zealand.

Richard Sharpe
Past-President NZSEE
July 2005

Personal Introduction

It's difficult to write objectively about two men who have been as influential on one's own career as Tom Paulay and Bob Park have been on mine. One's own history tends to get in the way of objectivity. It is also, I find, difficult to write a composite personal introduction about two very different men. Bob Reitherman's skilled interviewing of Tom and Bob, presented in this volume of *Connections*, has provided a detailed chronology of both men's private and professional lives, and there is little point in here providing a redundant chronology. Instead, I would like to concentrate on my personal view of these two great earthquake engineers, which has been developed over the last forty-two years—almost my entire student and professional life.

My first contact was with Tom—I was one of his "victims" as he calls his students—in my second professional year (third year of university studies). This was in 1962, Tom's second year teaching at Canterbury. It took us students half of the year to cope with his accent. Readers will learn that he promised to teach "in Hungarian, but with a strong New Zealand accent"—still the only foreign language in which I claim to be fluent.

Tom captivated the whole class of sixty-odd students with his contagious energy and enthusiasm. Although it was only his second year teaching at Canterbury, Tom's theatrical skills were already well developed. Tom is a big man, and as those who know him will attest, is even bigger than life. He is also rather deaf, and has been since a Second World War injury. He used this in teaching—not as a disability, but as a theatrical prop, an excuse to propel himself around the classroom in response to some poor student's question on the pretense that he couldn't hear it. He would stride up the tiered lecture room to the vicinity of the student, bend his ear towards the student, and demand a repetition. The rest of the class loved it rather more than the "victim," who might be persuaded against unnecessary interruptions in the future.

The energy Tom displayed in these lectures kept us in thrall. In this oral history he claims to have been rather precise in his lecturing times. What he is not telling you is that this was the formal, morning lectures he is talking about. On Tuesday and Thursday afternoons, there were the three-hour design classes, during which additional "top up" lectures were occasionally given (i.e., twice a week). On more than one occasion I recall (with sworn and notarized support from others in our class) that these continued for the full three-hour duration of the design class. No one without his energy and charisma could have gotten away with this. We learned a huge amount in these classes. In particular, we learned to revere equilibrium, a trait that I find difficult to instill in current students.

My introduction to Bob came four years later, in 1966. This was the final year of my doctoral studies, and as I had been without an advisor for eighteen months, Bob Park took over. Technically, I was Bob's first graduate student at Canterbury, but since it was only for a few months of the writing-up stage, this honour really belongs to David Hopkins. Bob provided quiet encouragement, and attempted to impose some of his natural sense of order on a rather unfocused dissertation.

For ten years after my doctorate, I saw Bob, and especially Tom, only infrequently—at conferences, and the occasional technical study group. However, the impact they were having on seismic design in New Zealand was very apparent. I had a research position with the Ministry of Works (MoW) that allowed me access to decision-makers in the MoW in a way I might not have had as a design engineer. In particular, I had a lot of contact with Otto Glogau, Chief Structural Design Engineer, and Hans Huizing, Chief Bridge Design Engineer. Both were brilliant men, and Otto, in particular, was one of the four men I feel were almost equally central to the key developments in New Zealand earthquake engineering that occurred in the 1970s: Bob and Tom of course, Otto Glogau, and John Hollings. John Hollings was a partner of Beca Carter Hollings and Ferner, a large consulting firm, and the originator of the concept of capacity design, which was later extended and refined by Tom and Bob. During this period of time I also had considerable contact with John Hollings, as I moonlighted for his firm as a proof engineer on a number of their major structural designs. It was through Otto and John that I was at least partially aware of the exciting developments going on in New Zealand seismic design.

It was Bob who persuaded me to apply for a faculty position at Canterbury. The bureaucracy in the MoW was pushing me towards a more administrative position, for which I was singularly ill equipped, and I was contemplating joining John Hollings's firm full time. While attending the annual conference of the New Zealand National Society for Earthquake Engineering at Wairekei, in the centre of the North Island, Bob and I found ourselves in the same golf foursome during a free afternoon. The other two players were competent golfers, which Bob and I most definitely were not. We spent most of the time hacking our way up the rough together while the other two managed to stick to the fairways. Interspersed with numerous profanities, occasioned by our golfing incompetence, we discussed my future plans, and Bob informed me of a faculty position that was open at Canterbury, and encouraged me to apply. Up to that point I had not given an academic career a moment's thought.

I spent the next ten years at Canterbury, working closely with both Tom and Bob. My position was in structural design, and my main responsibility was taking a little of the load of design classes off Tom. At the same time, I took some of the concrete structural analysis lectures from Bob. My research at this time was more closely aligned with Bob's interests, and we co-supervised a number of graduates, mainly in the field of seismic response of bridges and confinement of concrete. There was also a considerable amount of professional committee and code development work that involved all three of us.

During my ten years at Canterbury, I began to really appreciate the strengths and differences of the two men. Bob was extremely efficient at everything he did, which is what made him the superb administrator that he became in the latter half of his career. His orderly mind was apparent in his committee work, his organization of research, and in his lecture notes—which I used following Bob's pancreatic attack in 1977, when I had to take over his lectures. This attack was extremely severe, and Bob lost the first of his nine lives at this stage. After a lengthy time in hospital, Bob was instructed by the doctors that due to the damage to his pancreas, he should never touch alcohol again. I think his resolve on this issue lasted about two weeks.

Being an efficient administrator also requires a love of intrigue and power, which Bob certainly had. He also loved the research side of his career, and grew somewhat frustrated in his last years at Canterbury that he was not able to indulge in research activities to the extent he would have liked. He loved committees, and was always better prepared, and hence more effective, than anyone else at committee meetings.

Tom, on the other hand, did not enjoy administration, and tended to avoid it. His work for committees has been prodigious, but my sense is that he has always preferred to participate as a corresponding member, and has shared my frustration with the need for compromise—essential in developing committee consensus documents. Bob treated this as a challenge, and enjoyed the small victories. Tom's view of right and wrong (structurally and personally) has made him less suited to this process. Both men, however, loved the social aspects of meetings—particularly technical conferences—and were never happier than in an informal group of peers with a glass of wine in hand. Bob loved the gossip, and Tom loved the stories and jokes, of which he has an endless supply, many of which are of dubious moral provenance. Contacts with the top international experts in earthquake engineering have always been a matter of extreme pleasure for them both.

Their close contacts with the engineering profession in New Zealand had a great deal to do with the quick acceptance of their ideas on earthquake engineering. In the 1970s, Bob had particularly close contact with the MoW, while Tom's contacts tended to be more with the consulting profession. Consultants were always approaching him for advice on difficult "real life" problems, for which he rarely accepted payment (perhaps the occasional case of wine). This close contact also worked the other way, in that practitioners were well aware of the real problems that designers (either governmental or private) were facing in applying the new concepts of ductility and capacity design. Later, as the MoW faded in terms of national importance, and as Bob moved more into research in precast concrete, his contacts were more consultant-oriented, and helped make precast concrete the dominant structural material for buildings in New Zealand.

There is no doubt that the publication by Wiley and Sons publishers in 1975 of Bob and Tom's *Reinforced Concrete Structures*, which put forward a simple, elegant, and comprehensive seismic design philosophy for concrete buildings, had a huge impact not only on New Zealand's design fraternity, but internationally. I doubt if any design-oriented book has had such an impact on international seismic design, and this influence is still developing. Largely as a consequence of "The Book" international contacts were forged with a large number of countries—initially U.S.A., Japan, and Canada, and then the countries of Central and South America and Europe. These contacts were based on personal relationships developed between Tom and Bob and key researchers in these countries, which both men found to be some of the most important and enjoyable parts of their professional lives.

The influence of Bob and Tom during this period of my career cannot be overstated, though I regretfully have to admit that none of Bob's efficiency and organizational skills rubbed off on me. I worked with each of them on a number of papers and reports, though a little surprisingly, I only recall one paper (on beam-column joints) that was co-authored by the three of us. Bob and I started writing a text on prestressed concrete structures that unfortunately was never completed due to Bob's excessive workload.

With Tom, I gradually developed the confidence to hold lengthy discussions on aspects of seismic design philosophy. There is a pure, sharp pleasure in discussing new ideas at the edge of one's knowledge with a quick, superior, and receptive mind. In time, our familiarity with each other's viewpoints enabled these discussions to be carried out in a kind of verbal shorthand, which was, and still is, exhilarating. These discussions shaped the direction of my research for the remainder of my academic career.

Before I left for the University of California at San Diego in 1986, Tom and I had started preliminary discussions about a design text to act as an extension to *Reinforced Concrete Structures*, which had been published in 1975, just before I returned to Canterbury to join the faculty. We worked on this for the next five years. Because of the physical separation between Canterbury and San Diego, it was essential, particularly in the final stages, to get together and resolve minor differences. I recall in particular a two-week period in 1990 when Tom and Herta stayed with Jan and me in the southern California Sierras as we knocked the book into shape, as the most enjoyable, and intellectually profitable technical experience of my life. My responsibility was largely to translate Tom's Hungarian/Germanic sentence structure into English, but I learned a huge amount from the contact with Tom at this time—not just technically, but also about intellectual rigour in presentation of material.

Tom, Bob, and myself are separated in age by almost exact multiples of ten years (e.g., 80, 70, 60) give or take a few months, and we developed a habit of celebrating our cumulative age (e.g., 204) when possible, by a dinner with our wives. The exact date on which this should occur was debated on technical terms—should it be a simple arithmetic mean of the dates, or should they be weighted by the individual age? I'm not clear that this weighty problem was ever resolved, despite the assistance of many a glass of wine.

By 1999, I was spending more time back in New Zealand, and was there when Bob had his stroke and heart attack, which cost him several more of his nine lives. He was not expected to survive, but not only did he do so, he managed to resume both his technical and international committee work, despite constraints imposed by partial paralysis of his left side, and advice by doctors and his wife against international travel. This activity continued until his untimely death in 2004.

Tom has also continued to be active technically, and some of his finest work has been published in the past five years: simple, elegant, and of great significance. It is the sort of work that makes one think, "That's so obvious, why did no one see that before?!" To produce such work at any stage of one's career is noteworthy, but to do so when pushing eighty years is exceptional. But then, everyone knows that that is exactly what Tom is.

Tom has for years been part of an "elderly gentlemen's walking club" which, on fine Wednesday mornings, gathers and spends a few hours walking some track in or near Christchurch, followed by a pint or so and a pie at a local watering hole. Bob informally joined the group on November 3, 2004. During the walk he suffered a fatal heart attack. Tom was with him when he died on the track. Bob's death is a great loss to the national (New Zealand) and international earthquake engineering community.

Tom continues to live in Christchurch, and still provides technical discussions of papers published in the key international earthquake engineering journals with a fearsome clarity of intellect. Long may he do so!

M. J. Nigel Priestley
April 2005

CONNECTIONS

The EERI Oral History Series

Robert Park

Chapter 1

Growing up in Fiji

Law had been running in the family, but I managed to avoid that profession.

Park: This is a bit overwhelming you know, this idea of these interviews.

Reitherman: I think it's a terrific idea. Obviously you belong in this oral history series, and there's great support for this volume devoted to you and Tom Paulay—support in New Zealand, the U.S., and elsewhere. Let's just start at the beginning. Where were you born?

Park: I was born in Suva, the capital city of Fiji.

Reitherman: And that was in 1933?

Park: Yes.

Reitherman: What was it like growing up in Fiji?

Park: It's what you would imagine a tropical island to be: nice beaches, nice sea, and hot and humid of course. I was in boarding school at that time. Life was fine, I enjoyed it. My father used to sail quite a lot. We used to sail to the outlying islands, these little coral atolls, and camp there for a while. Beautiful sea, beautiful wind—the southeast trade winds were the normal wind.

Reitherman: Have you sailed much since?

Park: It used to be my main hobby. I did a bit of competitive sailing in Christchurch and enjoyed it very much.

Reitherman: Actually, I was coached to plant that question in these interviews by some of your acquaintances, who said that even by New Zealand standards of sailing, you set a very high mark. What is your earliest memory of Fiji?

Park: When I was growing up in Fiji, I went once with my parents to New Zealand, where my father was born. We flew. Those were the days when PanAm was very prevalent in the Pacific. I was two years old. I very distinctly remember sitting on an elephant in the Auckland zoo.

Reitherman: How did your family end up in Fiji?

Park: My father was born on the west coast of this island, the South Island of New Zealand, and he went to Fiji when he was about thirty or so to establish a law practice. He did court proceedings and normal transactions. His father was the crown prosecutor for Westland, which is the western region of New Zealand's South Island. The crown prosecutor is the person who brings forth the charges to various people who have been caught by the police doing things. So he was a hard old man! Law had been running in the family, but I managed to avoid that profession.

Reitherman: What was your father's name?

Park: James Stobie McIntyre Park. A somewhat cumbersome name with those three Christian or given names. He had to write it all out on many documents. That's actually why I haven't got a middle name—the name is just Robert Park. He said one given name is enough!

Reitherman: And your mother's name?

Park: My mother's maiden name was Loma Twentyman. She was born in Sydney, Australia. Her forebearers came from England, and my father's came from Scotland.

Reitherman: How big was the city of Suva, was it fair-sized?

Park: Probably only ten or twenty thousand, I guess. Mostly people of darker skin, the indigenous Fijians, who are Melanesian, and the East Indians who were brought in to work the sugar fields as indentured labourers. The population was roughly fifty-fifty, indigenous Fijian and East Indian. There were very few Europeans, just a few thousand.

Reitherman: Do you remember what your house was like?

Park: The house was a wooden bungalow. It had lots of big open windows and verandahs, so the breeze could flow through. There were servants, which was a normal practise for the tropics at that time. I had two sisters, one of whom is still living—in fact, near you in northern California, in Fairfield.

The Coming of the Second World War

Park: That house was near the town of Nadi, right near where the international airport now is. During the Second World War, the U.S. came in, in a big way. Fiji was a sort of staging post in the Pacific. The troops would come in and camp there before being sent to battle. They developed a huge airport in Nadi, which is now the international airport. Anyhow, at that stage, my parents were living on the west side of the main island, where Nadi is, having moved from Suva.

Reitherman: You must have been about eight years old when Pearl Harbor, Wake Island, Guam, Malaya, and the Philippines were attacked by the Japanese in December 1941. There must have been the fear that Fiji would be next. Do you remember much about how the Second World War affected Fiji?

Park: Well, it was a very threatening situation for Fiji. The Japanese were quite close, actually, and there were reconnaissance planes flying overhead all the time. The schools closed down for a while. The place was very quiet. So we greeted the American arrival with great relief, because it was a way of protecting the place.

Completing School, Leaving Fiji

Reitherman: Did the schools reopen? Was it somewhat normal later on?

Park: Yes, schools reopened and got back to normal. Eventually, I finished my schooling there at seventeen, in 1950, completing what the English call the Sixth Form. Fiji was a colony of England at that time.

Reitherman: Then you had to decide what you were going to do. Was your main goal to go to college?

Park: Yes, my main aim was to get a higher education and escape Fiji! Well, there was absolutely no prospect there for a young white boy, with the coming up of the independence of the Crown colony and that sort of thing. The job prospects were very bleak. So the first thing was to get overseas, to get out of there. That was my main objective. My father was very keen for me to do law, but I resisted that. I was very much influenced by an uncle who was high up in the Ministry of Works in New Zealand at the time, in Dunedin south of here [south of Christchurch]. He was especially proud of a reinforced concrete bowstring truss bridge that he designed in Balclutha in the South Island, south of Dunedin. I've seen it several times. He did other things of course, but he loved that bridge. And so it was really his influence that got me into civil engineering. I told my father that I didn't want an office job...which is precisely what I eventually got.

Chapter 2

Going to College at the University of Canterbury

Harry Hopkins was very much a concrete man. He initiated my love of concrete. So my specialty became concrete structures. It's as simple as that.

Reitherman: You then went to college in New Zealand?

Park: First, I started at the University of Otago in Dunedin, New Zealand, because initially I wasn't sure what I wanted to do. I was thinking about both mining engineering and civil engineering. So, I tried my first year there at Otago. I didn't do very well, because the schooling in Fiji had been poor. The grammar school in Suva was a second-rate outfit, and I didn't get a very good background to enter university. I had to fill many gaps in the first year at Otago. I came up to Canterbury the next year.

Reitherman: Was that the old campus on Worcester Street in the heart of Christchurch, which is now the Arts Centre?

Park: That's right. Later, Harry Hopkins played an important role in the plans to move the university to the Ilam[1] campus, where the engineering school had the room to grow. I'll mention Hopkins again later. On the old campus, the engineering school was housed in what used to be an old high school. It was a rabbit warren in there. It was so overcrowded.[2]

Reitherman: But it must have had a nice feel to it, the views from one courtyard to another, the architecture all unified with the handsome gray stonework. Today, preserved as the Arts Centre, it's a beautiful place.

Park: Yes, it was very hard to shift to Ilam. The old place had a town-and-gown atmosphere about it. The staff could just walk about the town and intermingle. When we moved to Ilam, we were remote from the town's activities. But we had to come out here to expand. To accommodate the larger number of students, the Christchurch campus had put up a number of prefabricated huts around those lovely old buildings. They had been brought from various places in the Pacific after the Second World War and re-erected here. The first laboratory for structures was in a prefab hut.

Reitherman: Was the move to Ilam the event that put University of Canterbury "on the map" as a center of earthquake engineering? Going from a campus with a prefab hut housing the Structures Lab to a place that was to become known for its experimental capabilities?

Park: Yes, the new lab at Ilam was reasonably well equipped—fairly rudimentary, but not too bad. So that was the start. The first use of the buildings at Ilam was in 1960. The rest of the university gradually followed engineering, and by the mid-1970s, the rest was out here too.

The Structures Lab on the new campus is a large portal frame building, with no internal columns, very good for apparatus and large-scale experimentation.

Reitherman: So by the time you arrived in Christchurch to attend Canterbury, you knew you were attracted to civil engineering, rather than mining engineering, but that still left a number of different fields from which to choose—civil is such a broad subject area. Did you imagine yourself being one particular kind of civil engineer?

Harry Hopkins

Park: I was into structures. Harry Hopkins was very much a concrete man. He initiated my love of concrete. So my specialty became concrete structures. It's as simple as that.

Reitherman: What was he like, Professor Hopkins? I've read a bit about him and talked with his son, David.

Park: He was a man's man. He was very much a services man. He had been in the Royal Air Force during the Second World War in Britain. He was used to discipline. He also had a great love of sport. He liked to combine sport and scholarship. A rather gruff man at times,

1. Ilam (pronounced eye'-lum) is a residential district of Christchurch approximately four kilometers from the city center.
2. One measure of the overcrowding was the fact that to make more rooms, a hallway was reduced from ten to three feet in width by the insertion of windowless offices along one side. Diana Neutze and Eric Beardsley, *Design for a Century: A History of the School of Engineering, University of Canterbury 1887-1987.* University of Canterbury, Christchurch, New Zealand, 1987, p. 117.

Henry (Harry) James Hopkins (1912-1986)*

BE, Bsc, University of Western Australia
MA (Oxon), Rhodes Scholar, Brasenose College, Oxford
Chief Structural, Engineer Courtaulds, Ltd. Coventry, England
Squadron Leader, Royal Air Force, England, Second World War, Distinguished Flying Cross, pilot of Mosquito and Halifax aircraft
Senior Lecturer, University of Western Australia, 1948-1951
Professor and Head, Civil Engineering Department, University of Canterbury, 1951-1978
Dean, School of Engineering, University of Canterbury, 1955-1958, 1964-1967
President, New Zealand Institution of Engineers, 1966-1967, FNZIE
Author, *A Span of Bridges*
Named for Hopkins is the Hopkins Lecture established by the University of Canterbury and the Institution of Professional Engineers New Zealand (IPENZ)
Order of the British Empire (OBE)

Neutze and Beardsley, *Design for a Century*, p. 113 and 327; David Hopkins, personal communication, 2005.

and autocratic. (He'd never get away with that now—we all fancy the democratic way!) Very strong character. A great leader. He either loved you or disliked you. He loved me, so it was all right.

Reitherman: For the benefit of readers who aren't familiar with the English university system and the terminology used to describe different types of faculty, would you please define Professor, Reader, and Lecturer.

Park: The Professor here is the same as the full Professor in the U.S., but here the rank of Professor is awarded only to a very small number of faculty in a given department. Reader is about equivalent to full professor in the U.S. Senior Lecturer is about equivalent to associate professor in the U.S. Lecturer is about equivalent to an assistant professor in the U.S. That was the English terminology. We have discussed often in New Zealand the idea of going to the U.S. system, to use terms that are more widely understood, but we have clung to the old English system.

Reitherman: When Hopkins became head of the Civil Engineering Department at the University of Canterbury, that was in—

Park: In 1951, the year he arrived from Western Australia.

Reitherman: —in 1951, and that coincided with the time when civil engineering began to come into its own at the university. From the book on the history of the School of Engineering,[3] it seems that prior to that, civil engineering was largely subsumed under one branch or another of engineering, especially mechanical.

Park: Hopkins was a strong man, so he became a very dominant professor in the faculty. He did very well in competing for resources among the others.

Reitherman: Speaking of dominant figures in the history of engineering at Canterbury, Robert Julian Scott could be mentioned, who along with Edward Dobson was one of two founding Lecturers in the School of Engineering, going back to its early years and its inauguration in 1887. Dobson is described as a "strong man who knew his own mind and spoke it." [4] And as for Scott, he's similarly described as strong-willed. Scott's name also arises in connection with the R. J. Scott Medal from the Royal Society of New Zealand. You were the first recipient.

Park: Scott and Dobson were before my time. Scott was a mechanical engineer, with a specialty in railways. Quite a dominant character who left his mark. He used to sail a boat in Lyttelton Harbour and took staff out as crew and bossed them around endlessly. Quite a guy, actually. He was a pretty tough cookie, and very effective in building up the school, although he built up the mechanical engineering side, not civil. There's a portrait of Scott in the Engineering building at Canterbury, and you can tell by looking at him that he was quite a tyrant!

Reitherman: When did you start your undergraduate studies at University of Canterbury?

Park: In 1952, the year after Hopkins came. But I was doing intermediate, general courses in my studies at that time and didn't have any classes with him that year.

Reitherman: Hopkins taught all the concrete courses?

Park: Yes, except for design. He also taught the mechanics courses.

Reitherman: At that point, in the early 1950s, how many instructors were there in civil engineering?

Park: Well, I would guess probably about eight at various levels. They weren't all exactly high-flyers. The place in those days was basically a technical college. The definition of a university is a place that has staff to conduct teaching and research. At that time in 1951, there was hardly any research going on. They were just teachers, technical staff. It was mainly Hopkins who turned that around and got research going on at Canterbury. He started to

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3. Ibid., Neutze and Beardsley. The authors divide that history into three periods: the founding era from the beginnings in 1887 until retirement in 1923 of Robert Julian Scott (1861-1930); the second, interim, period during which "the theory and practise of engineering throughout the world was expanding, but the Canterbury College School of Engineering was isolated in a backwater of its own," (p. 113); and the golden age, beginning with the planning (1950s) and construction (1960s) of the new Ilam campus and the growth of research from then onward. This third period, especially regarding civil engineering, occurred under the leadership of Hopkins (head, or chair, of the civil engineering department, from 1951-1978) and Bob Park (head from 1978-1992), who were also central figures in the campus-wide development of engineering facilities and programs and the rise of the university in general.
4. Ibid., Neutze and Beardsley, p. 25-26.

get better quality staff who could initiate research, as well as do the teaching. He did a lot to develop the School of Engineering, and the Civil Engineering Department.

Reitherman: When you were an undergraduate, do you recall others besides Harry Hopkins who influenced your career?

Park: Oh, yes. There was a man by the name of Lyall Holmes, who started the Holmes Consulting Group. It's quite a big firm now, and has offices in all the major cities in New Zealand.[5] He taught design at the university when I was a student. But he was so busy consulting that he had very little time for the university at all. In fact, he wanted me to join him in consulting. But what I wanted was his job, the Lectureship at the university. I eventually got his job when he resigned to become a full-time consultant. But he was very much a tower of strength in our department. He actually was the guy who started the widespread use of reinforced concrete block construction in New Zealand. Hollow concrete block filled with grout and reinforcing wasn't a very common form of construction in New Zealand at that time. He basically instigated that when he became a consultant. Providing for the reinforcement of the block walls allowed the New Zealand block industry to grow, so that the material could be used for multi-storey buildings. Unreinforced concrete block construction was previously only used for small houses or very ordinary small structures.

5. Auckland, Wellington, Christchurch, Hawke's Bay, Queenstown, Tauranga, and an office in Sydney, Australia.

Hawke's Bay Earthquake of 1931

Reitherman: When you were an undergraduate, did you ever study earthquake engineering?

Park: No, not really. That was a neglected part of the curriculum. We knew the basics, but it was very rudimentary. There had been a book written in New Zealand by Crookes,[6] which you may have heard about. Crooke's book was based on then-current Japanese and California static design methods. There was also an earlier book by Charles Reginald Ford.[7]

Reitherman: Did the Hawke's Bay earthquake of 1931 cause New Zealand to become more interested in seismic design?

Park: Absolutely. The outcome of that earthquake was the start of it all. It did huge damage in Napier and Hastings up on the east coast of the North Island. Up to that time, the buildings had been built according to the old European style, in unreinforced masonry, mainly brickwork, or stone masonry, without any provision for earthquakes at all, and they performed very badly during the Hawke's Bay

6. Crookes, S. Irwin Jr., *Earthquake Resistant Buildings*. Leightons Ltd., Auckland, New Zealand. 1940, 209 pp. Crookes was a consulting engineer and Senior Lecturer in Building Construction at the School of Architecture of Auckland University, and his book "served as a 'bible' for most of the older generation of New Zealand engineers and architects and the basic principles contained therein are as valid today as when the book was written." "Lead Article," *Journal of the New Zealand Society for Earthquake Engineering*. Vol. 1, no. 1. June/July 1968.

7. Ford, Charles Reginald, *Earthquakes and Building Construction*. Whitcombe and Tombs, Auckland, New Zealand, 1926, 114 pp.

earthquake. But there were some frame buildings built of steel or reinforced concrete that performed quite well. This led to a great swing to the use of frame structures. The Hawke's Bay earthquake caused a huge change in building design direction.

Reitherman: You point out in your Hopkins Lecture[8] that, as a result of the earthquake, a Buildings Regulation Committee was set up by the government, chaired by Professor J.E.L. Cull, chair of the Civil Engineering Department of the University of Canterbury (at that time Canterbury College). That led to the 1935 Standard Buildings By-Law.

Park: The seismic design procedure was still very rudimentary, with an equivalent static lateral load of 0.1g applied to the dead load, plus some live load. It was elastic design, with a twenty-five percent increase in working stresses for concrete, and no concept of ductility. But there was knowledge of the importance of tying things together. For example, all the footings had to be connected. And the horizontal resistance had to be symmetrically located or else torsion taken into account. So, some initial concepts of seismic design were there, but at a very basic level.

Since then, there have been a lot of unreinforced masonry buildings throughout New Zealand that have been retrofitted. Constructing a building of unreinforced masonry isn't allowed today, though these provisions took a while to be implemented.

It was in 1965 that the New Zealand Standard Model Buildings By-Law explicitly introduced ductility requirements. Three decades after the first seismic regulations, we had the concept of ductility introduced, but it was only in the regulations in general form. [9]

The Commentary on the 1965 Standard can be cited to illustrate the state of seismic design for various materials at that point: reinforced masonry was reserved for use with "structures of minor importance," reinforced concrete was relegated to use for "intermediate" structures, while steel was to be used for "taller structures and for those of importance to the community." Precast concrete wasn't considered part of a seismically resistant system at all.

Reitherman: In your Hopkins Lecture, you point out that "It is fortunate that almost seventy years have elapsed since the 1931 Hawke's Bay earthquake without a major earthquake striking an urban area. However, New Zealanders must not be complacent in their consideration of earthquakes." Is it difficult to keep motivating people to take steps to reduce earthquake risks?

Park: It is. As an engineering professional, without being alarmist, we try to make people

8. "Improving the Resistance of Structures to Earthquakes," Hopkins Lecture, August 16, 2000, *Bulletin of the New Zealand Society for Earthquake Engineering.* Vol. 34, no. 1, March 2001, pp. 1-39.

9. Here, Park quoted the 1965 ductility provision from his 2000 Hopkins Lecture, "All elements within the structure which resist seismic forces or movements and the building as a whole shall be designed with consideration for adequate ductility." Park noted in his lecture that "No guidelines were given as to how 'adequate ductility' was to be achieved."

aware that there are possibilities of other shakes to come. The EQC, the Earthquake Commission, which provides the earthquake insurance, runs a lot of TV and other advertisements, to make people aware of the possibility of earthquake damage.

Reitherman: It's interesting that with regard to those structural materials that ranked lower in desirability for use in seismic-resistant systems as of 1965—namely reinforced masonry, reinforced concrete, and precast concrete—New Zealand has made major advances with respect to all three. The reinforced masonry work by Paulay and Priestley,[10] your reinforced concrete text with Paulay,[11] and your work to integrate research into practice to make precast and prestressed concrete respectable members of the seismic structural materials family,[12] come to mind. I know we'll come back to Priestley and Paulay again, and I think we'll also touch on Lyall Holmes again when it comes to the topic of prestressed concrete.

10. Paulay, Thomas and Nigel Priestley, *Seismic Design of Reinforced Concrete and Masonry Buildings.* Wiley and Sons, New York, 1992.
11. Park, Robert and Thomas Paulay, *Reinforced Concrete Structures.* Wiley and Sons, New York, 1975.
12. Park, Robert, "A Perspective on the Seismic Design of Precast Concrete Structures in New Zealand," *Journal of the Prestressed Precast Concrete Institute.* Vol. 40, no. 3, May-June 1995, pp. 40-60.

The Hawke's Bay Earthquake

The Hawke's Bay earthquake, which occurred on February 3, 1931, had a magnitude of 7.9, an epicenter approximately 20 km north of the city of Napier (nape'-ier), and a relatively shallow focal depth. Modified Mercalli Intensities of VIII to IX+ were estimated around Hawke's Bay. These MMIs are now estimated to be similar to the level of shaking associated with a 475-year mean recurrence interval throughout the region, which includes approximately 200 km of coastline and about a dozen towns or cities.*

The fatality total in 1931 was 256, which is nearly 90 percent of all fatalities documented for New Zealand earthquakes since 1840.± Damage to buildings was widespread in Napier and in neighboring Hastings, and unreinforced masonry damage was extensive. As Professor Park notes, the good performance of some kinds of buildings was an indication that specific construction features could improve the seismic performance of a building. As was the case with the 1906 San Francisco, California and the 1923 Tokyo, Japan earthquakes, the Hawke's Bay earthquake had serious fire damage, which accounted for the near-total loss of several blocks of Napier's business district near the sea. There were ground failures of several kinds, including liquefaction and large landslides. Ground failure accounted for the breakage of underground water mains, which hindered response to the fire, which eventually spread to the nearby town of Ahuriri. In the city of Hastings, the water system remained functional and the fire was successfully stopped.

Seismologists studied the large number of aftershocks, surface faulting, and the tectonic uplift, which caused several tens of square kilometers of previously submerged land to rise above water level. Because the Hawke's Bay earthquake was recorded on seismographs around the world, seismologists were able to study and infer the travel paths of various kinds of waves through the interior of the earth.

The 1931 Hawke's Bay earthquake is one of the prominent cases where an earthquake put its stamp on the entire city planning and architectural character of a city.£ Wooden buildings burned in the fire that followed the earthquake, unreinforced masonry structures partially or completely collapsed, and steel was too dear a material to have been extensively used. Consequently, lowrise reinforced concrete was the common choice for the city's rebuilding. As was also the case in the 1693 Sicilian earthquake and the 1755 Lisbon earthquake, reconstruction changed the face of a city almost overnight by rebuilding in then-contemporary styles. This also happened in the city of Napier. Earthquake engineering concerns were significant, in addition to architectural motives, and Napier was rebuilt in the then-contemporary style, Art Deco. To this day, it maintains its unique appearance.

* Van Dissen, Russ and Kelvin Berryman, "Paleoseismology: Digging Up Past Earthquakes," *TEPHRA*, New Zealand Ministry of Civil Defence, June 1998.

± Chapman, Nicky, *Facts New Zealand*. Bateman, Auckland, New Zealand, 2002, p. 20.

£ McGregor, Robert, *The New Napier: The Art Deco City in the 1930s*. The Art Deco Trust, Napier, New Zealand, 1999.

Chapter 3

Getting a Master's and a Ph.D.

And I never really left Christchurch until I went to England. I got sort of caught up in the place.

Reitherman: After you received your undergraduate civil engineering degree from Canterbury, did you go straight on to get your master's there?

Park: I went to work for a little while at the Christchurch Drainage Board. That was very dull, actually, as you can imagine—designing sewer pipes and what have you. Then I thought I might go to Australia, to work on the Snowy River scheme where they were diverting water from the coastal region through the mountains to irrigate the dry interior. The chief engineer there was a guy named Hudson, who was a New Zealander. Many Kiwis went over there to work with him. That sounded pretty good to me, so I was about to go over there when I went to see Harry Hopkins about another matter.

Hired by Harry Hopkins to Teach at the University

Park: Then Hopkins said to me, "Why don't you come back and get your master's degree?" I told him, "Well, I'm married now." I got married in 1956 to my wife, Kathy. He then said, "I'll match your salary." So he gave me an Assistant Lectureship, which is a very lowly teaching position, and matched the salary I was getting at the Christchurch Drainage Board. I came back and got my master's on those conditions. And I never really left Christchurch until I went to England for my Ph.D. I got sort of caught up in the place.

Reitherman: Your master's in engineering degree was conferred with distinction. Please describe what "with distinction" means.

Park: Well, roughly ten percent of the master's students would get "with distinction." It just meant you graduated with very high grades. Mine was the first with distinction in civil engineering at Canterbury.

Reitherman: You obtained your undergraduate degree in 1955; when did you finish your master's?

Park: 1957.

Reitherman: And your master's work was on prestressed concrete slabs?

Park: Which were going to be used for bridges, that was the idea.

Reitherman: What was prestressed concrete like in those days? It was a relatively new idea, wasn't it?

Park: Oh, absolutely. It was in its early stage of development. The theory was basic, but there was a lot of application. Eugene Freyssinet[13] was the father of prestressed concrete. He made it work, quite simply by using high-strength steel. If you prestress concrete using ordinary mild steel, you can't stress it up high enough to maintain the prestress, since the yield strength is too low, and you'll lose your prestress with creep.

Reitherman: What did you teach at Canterbury when you were working on your master's? Reinforced and prestressed concrete?

Park: I taught mechanics, actually. I taught reinforced concrete eventually, of course, and theory of structures. But those students when I started out, only a year or two younger than me, gave me a hard time!

Reitherman: Did you find that teaching, however difficult it initially was, made you better understand the subject matter?

Park: Oh, yes. The best way to understand a subject is to teach it.

Reitherman: How would you typically teach? Would you go to the blackboard and start to sketch a truss, for example?

Park: We used to write down almost everything on the blackboard, explaining as we went. Then all the students would write it down, and of course they needed to copy your drawings as you went. So, it wasn't like a theatrical performance, because there was so much writing on the board. And questions, of course, and a few jokes.

Reitherman: You must have liked it since you stuck with it for so long.

Park: Well, I was interested in the research, mainly. That was really what kept me there.

13. The Freyssinet Award of the Institution of Professional Engineers New Zealand, which Bob Park was awarded twice, in 1992 and 1997, is named for Eugene Freyssinet (1879-1962).

Going to England for a Ph.D.

Park: Then I decided to go to England, because I realized I'd always be the boy if I stayed at Canterbury.

Reitherman: How did you end up at the University of Bristol?

Park: Well, quite by chance, actually. It was an advertisement I saw and applied for. It was for a Lectureship there. I got it and went. My wife didn't really want to go. I said we'd go for two or three years; it was over six.

Reitherman: Now, you didn't go there just as a Ph.D. student, you went there to also be an instructor?

Park: Yes, that's right, I went as a Lecturer. I did a doctorate while I was on the staff. I enrolled in 1960 and finished in 1964. I worked on membrane action in two-way concrete slabs. Their strength is very great if they can arch between the beams. There had been some full-scale load tests, which had shown that the strength is enormous, providing that the lateral resistance around the sides was adequate. So I did a doctorate on that, predicting the strength of those floors with membrane action.

Reitherman: And the topic of yield lines in concrete floor systems was part of your thesis?

Park: Yes. That's part of the prediction of the membrane action; the slab breaks up into yield line patterns, and it finally fails.

Reitherman: Who was your thesis advisor at Bristol?

Park: A man by the name of Pugsley.[14] He was really an aeronautical engineer. He had been involved for many years in airship design—not the design of aeroplanes, but airships, dirigibles—he had a big reputation. He was very much a metal man. "Metal structures are the way of the future, Park," he would tell me. (He always called me "Park.") He tried to talk me out of concrete, but I wasn't budging.

Reitherman: Now at that point, at Bristol in the 1960s, I believe you were dealing with gravity loads only, not seismic. Later on, did you apply those ideas you learned in England to seismic design? How a concrete component yields and deforms, the sequence of the states of behavior from the initiation of a mechanism on up to the point where the structure becomes unstable? Did those ideas you studied for your doctorate turn out to be relevant to your later career specialization?

Park: Absolutely. In those days I was involved in what was called ultimate strength theory, and I really worked very hard on that, inspired by books such as that by Ferguson.[15] When I was in Bristol, I read everything I could on ultimate load failure of concrete structures. This gave me a very good background, actually. I found that when I returned to New Zealand and became involved in seismic design, obviously one must be concerned about the structure going to an inelastic state, when mechanisms of various sorts start to form. This is part of ultimate strength theory—strength in the context of inelastic deforma-

14. Sir Alfred Pugsley (1903-1998) was Head of Structural and Mechanical Engineering at the Royal Aircraft Establishment in Farnborough in the Second World War years of 1941-1945, then spent the rest of his career in the Civil Engineering Department of the University of Bristol.

tions. So what I had done in England led very naturally into seismic design.

Ductility is, of course, a central concept in earthquake engineering, but we use it also in gravity load design of concrete moment-resisting frames and slabs. We needn't use the initially calculated bending moment distribution from elastic theory in design, because we can relax those requirements a little and rely on moment redistribution, as long as we satisfy statics with the new moment distribution.

Reitherman: Wasn't ultimate strength design a new idea in the 1960s?

Park: Yes, very much so. But there were pioneers like Ferguson who were pushing in this new direction. You get a much better idea of the real safety factors, the load factors. You can get a proper balance of the hierarchy of failure—flexure before shear if you design properly. There were some load combinations where the working stress design method was definitely unsafe.

Reitherman: Did you ever meet Ferguson?

Park: Yes! He was a sort of hero of mine, a thinking person. And so was Chet Seiss, of the University of Illinois. Seiss was a great concrete man and a mentor of Mete Sozen.

Reitherman: What was it like living in Bristol? Did you enjoy it?

Park: I did, but my wife Kathy didn't, and I had promised her we would return to New Zealand. My wife died early last year. She was bipolar, and was very up and down. It eventually got the better of her. But to answer your question about life in Bristol, well, the housing was basic. We lived in a place that was two houses side by side, joined in the middle. The rooms were small, the weather was dreadful. We had three young children at the time, one of whom has become an engineer with the Holmes Consulting Group here in New Zealand. But I enjoyed the collegial aspect of the university very much, actually. Good people. And you were right in the middle of so many different places. You could hop on the ferry and be in Italy or France without too much trouble. So, those were some advantages of being there. Not a very comfortable lifestyle, though, compared with New Zealand.

Reitherman: Today, BLADE, the Bristol Laboratory for Advanced Dynamic Engineering, is a big research establishment. But was that laboratory there at Bristol when you were there?

Park: No, that has all happened since I left in 1965. About that time, Roy Severn took over from Pugsley. Severn was using eccentric mass shakers to shake dams and bridges, doing in situ vibration tests. He was very good in dynamics. They have a six degrees-of-freedom shake table there, which is working well. I don't think

15. Ferguson, Phil M., *Reinforced Concrete Fundamentals*. Wiley and Sons, New York. First edition, 1958; the 1998 fifth edition is by Phil Ferguson, John Breen, and James Jirsa. The Ferguson Structural Engineering Laboratory of the University of Texas at Austin is named after Professor Ferguson (1899-1986), who joined the faculty there in 1928, was chair of the Civil Engineering Department from 1943-1957, and was elected president of the American Concrete Institute in 1959. (W. R. Woolrich, *Men Of Ingenuity from Beneath the Orange Tower*. Engineering Foundation, University of Texas at Austin, 1964.)

they've used all the degrees of freedom to represent earthquakes, but the capability is there.

Reitherman: How do you mean that?

Park: Well, it would be very complicated testing if you tried to program each of the degrees of freedom individually. They're also doing work with the automotive and aircraft industries. They're mainly dynamics people rather than earthquake people; there is a difference. Most people that work in structural dynamics are in another world from earthquake engineering, because we are concerned more with inelastic behaviour. The dynamics people, at least in England, are mostly concerned with elastic behaviour.

Reitherman: Have you been back to Bristol just to visit?

Park: Yes, I've been back lots of times. I have many friends there. I enjoy visiting because of my very warm friendships with people. When I went to Bristol in 1959, it was very much recovering from the Second World War, with new buildings and things. There's also a lot of history there with the buildings, railway stations, and bridges.

Harry Hopkins and Bridges

Reitherman: You mention bridges. After my first phone call with David Hopkins to get more information to prepare for these interviews, I realized, "Oh, this H.J. Hopkins person, the Harry Hopkins of the University of Canterbury, is the father of the consulting engineer David Hopkins, whom I've known a little bit over the years." So one little light bulb went on. In a subsequent conversation, I naively asked David why the portrait of his father at the university has the Pont du Gard in the background. The Pont du Gard easily makes it onto my personal list of the 100 structures in the world one should see, and it is the only one of those I've spent a pleasant afternoon beneath, swimming and lounging on warm slabs of rock by a river's edge. And another light bulb went on—David explained that Harry Hopkins was the Hopkins who wrote the book—the classic book—entitled *A Span of Bridges*,[16] a book I've had ever since college. It's beautifully illustrated and presents engineering principles so clearly—a great book.

Park: Yes, Harry taught that very much when he was a professor, of course. The arch and suspension bridges were taught thoroughly. With regard to concrete, he used to wax on and on about Robert Maillart and his bridges, beautiful bridges. He had a huge slide collection of bridges, also cathedrals and other buildings. Harry was very keen to write a book devoted just to New Zealand bridges. There are some early suspension and concrete arch bridges here, for example.

Reitherman: I drew a lot of material from *A Span of Bridges* when I taught an architecture course on structures one year at Berkeley, substituting for a professor on leave. Bridges are such clean structures, unlike buildings whose structures are clouded by cladding, partitions, ceilings, and so on. Hopkins's book has great

16. Hopkins, Harry J., *A Span of Bridges: An Illustrated History*. David and Charles, London, 1970, and Praeger, New York, 1970. "Span" referred not only literally to what bridges do, but also to the long time span his book encompassed.

historical information in it, going back to Robert Hooke and the early beginnings of engineering.

Park: Yes, Hooke was quite a figure.

Reitherman: Concerning bridge design and building design, let's return to what we were talking about over dinner, about the fact that in Japan there is a very distinct division between building engineering and bridge engineering, not only in practice, but in the engineering schools. In the U.S., at least at the undergraduate level, you wouldn't expect such specialization in a civil engineering program. But in the world of practice, they are two distinct professions. Consulting engineers either design buildings or bridges. You've been extensively involved with both buildings and bridges in your career. Is that unusual in New Zealand?

Park: No. The problems, or at least concepts in some cases, are quite similar, such as the need to decide where you can accept yielding under seismic demands. Bridges often have pile foundations that could yield at depth if they're not designed properly, damage which is very difficult to verify and repair. We did research to develop design procedures for pile reinforcement, pile caps, and connections of piles to pile caps. I worked on that with a graduate student. Engineers in practise here do tend to specialize in one or the other, but there are many who do both. My oldest son, Robert, has been a bridge engineer for the Holmes Consulting Group in Wellington, New Zealand, which of course is a firm that also designs many buildings.

Reitherman: I see that Joe Maffei's Ph.D. under you was on a bridge topic, but now he's a structural engineer with Rutherford & Chekene in California, a consulting firm that does buildings. Having a bridge engineering background and ending up a building structural designer is unusual in the U.S., however. I know you have another connection with bridges in that you have been very involved in a New Zealand committee that developed seismic design provisions for bridges, but for the moment, let's continue chronologically with the story of your return to New Zealand after your Ph.D.

Chapter 4

Returning to the University of Canterbury

And the more research you do, the more things you seem to have left to do. You keep uncovering things you have to do.

Reitherman: When you returned to the University of Canterbury in 1965 after receiving your Ph.D. from Bristol in 1964, the university was not yet famed for the earthquake engineering research that was to be performed by you, Paulay, Priestley, and other faculty such as Athol Carr, Peter Moss, and David Elms. But as of that time, was it already a pre-eminent civil engineering center?

Park: Yes, it was the biggest department in the University and had the most students, and historically it was the university where civil engineering was centered in New Zealand.[17]

17. Neutze and Beardsley note in *Design for a Century* that until the development of the second School of Engineering in the country in Auckland, Canterbury's school of engineering was also referred to as "the National School of Engineering."

School of Engineering at Canterbury

Reitherman: I read in *Design for a Century*[18] that even up to the late 1980s, civil was only second to electrical and electronic engineering as the largest department in the school of engineering. I've spoken with many civil engineering professors from the U.S. and other countries, and invariably when the discussion gets around to the place of their department in the hierarchy of their institution, they tell sad stories about how civil engineering used to be more central to their engineering school and even to the whole university. They complain that computer science or electrical engineering has become the hot field for attracting students and money, and for producing deans of engineering schools.

Park: Civil engineering at Canterbury is still obtaining very good students, and the profession needs our graduates. We can't provide enough, actually. Of course, as a structural person, I lament the intrusion of environmental engineering, which has affected many civil engineering departments—now they're usually called civil and environmental engineering departments. We're one of the few that hasn't changed our name: we have environmental engineering courses within civil engineering, but don't call the discipline "civil and environmental engineering." The resources of the Civil Engineering Department have become very spread out, and there is a constant battle among the former civil disciplines and the environmental engineers to try to pull staff positions in their direction. I was under pressure for the fifteen years I was department head to get on the band wagon and make it a department of civil and environmental engineering, but I resisted.

Reitherman: Haven't you just recently introduced a specialized master's degree in earthquake engineering?

Park: Yes, a master's in earthquake engineering, comparable to a master's degree in fire engineering or construction management, for example.

Reitherman: How exactly did you return to Canterbury?

Park: I got my Ph.D. in 1964 and came back in 1965. I wrote to Harry Hopkins and said that I wanted to come back. He offered me a job without advertisement.

Reitherman: What was your first title or position?

Park: Senior Lecturer.

Reitherman: So you were at the top of the rank of Lecturers?

Park: Yes, I was approaching associate professor, you might say. Then I was promoted to a Reader. As I've explained, Professor is a title and a position limited to fewer of the faculty than in the U.S., and there were only two Professors in the department. Then, in 1968, the other full Professor in the department, besides Hopkins, went to Australia. So there was a vacancy for a full Professor, and I applied for it and got it, at the age of thirty-five, which was thought to be very unusual, a very young age.

Reitherman: Was your early rise to professorship level partly because the university

18. Ibid., Neutze and Beardsley.

could see how you were contributing on the research front?

Park: I would never have got there today that quickly. I got there on the basis of about twelve publications. More on the basis of my potential rather than what I had achieved, and I had the power of Hopkins pushing. He liked me. I guess he could see some potential.

Reitherman: Did he hire some of the other people that did earthquake engineering at Canterbury, like Lyall Holmes?

Park: Yes, Tom Paulay included. They say Hopkins was a very good chooser of people. He had a very intuitive way of seeing if people had what it took. The main thing was that he pushed people that were capable of doing it, and encouraged them with resources. We have a Hopkins Lecture Trust Fund set up at the university now, set up by individual contributions but mostly by the family of Harry Hopkins himself—it's a big family. Each year there is a Hopkins Lecture—you have a copy of the Hopkins Lecture I gave in 2000. This year [2003] Tom O'Rourke is coming from the U.S. to give that lecture. David Hopkins did it in 2002. The family also donated the money for the oil painting portrait of Hopkins that hangs at the university. It was done by a painter named Bill Sutton, recently deceased, who was a very well-known painter in New Zealand.

Reitherman: In that portrait, besides the Pont du Gard aqueduct, representing Hopkins's love of bridges and his book on bridges, there's some sort of tower in the background.

Park: It's a water tower next to our Structures Laboratory building; it's still there. It's the source of the head of water for the hydraulics lab experiments, and Harry designed it himself. He loved it.

Reitherman: What were the civil engineering laboratory facilities like when you moved into the new facilities at Ilam?

Park: There were three main laboratory wings coming off the main engineering building core—civil, mechanical, and electrical, with a smaller fourth wing for chemical—they have been there since day one, since 1960. The civil wing has been lengthened. Originally, they were rather empty of equipment. We had the space, but not the equipment.

Now, the Structures Lab needs more space, and John Mander is leading the effort to get a new addition built.[19]

Reitherman: Was the testing apparatus made by Dartec a key piece of equipment the lab acquired?

Park: Ah, a love of my life that was, the Dartec testing machine. In the early days, we did a lot of tests on columns that were small-scale, quarter-scale or something like that. There are problems modeling bond and other aspects of small-scale specimens, and it's difficult to convince engineers you have good results when you are testing at a small scale.

I could see the need for a 1,000-tonne (10 MN) capacity compression machine at the time, and it was installed in 1978 for a cost of about NZ $300,000, which converts to something over

19. "Bringing a New Era of Earthquake Resistant Buildings to the World: University of Canterbury Seismic Laboratory Building Appeal." Department of Civil Engineering, University of Canterbury, 2003.

several million New Zealand dollars today. That may not sound like much to you, but it was almost all raised from outside the university. The longer it took to raise the funds from a variety of sources, such as various government agencies, the more the price of the machine went up. I had quite a thick stack of correspondence in the file by the time we finally got it. Since then, it's been an absolute godsend. We still use it almost continuously. It has four meters of clearance between the top and bottom platens. When the huge crate was delivered, Harry Hopkins rang up the head of the facilities office, and when the guy came over and saw it, he almost fainted. We had to dig a pit, contend with a high groundwater table, and Nigel Priestley designed the reinforced concrete box the machine is founded on.

For the inaugural test, we had a big ceremony and had the Vice-Chancellor come over to push the button. Unbeknownst to me, one of the master's students, Eleanor Trout, had conspired with the technicians and Tom Paulay—and with the Vice-Chancellor in on the joke—to have loud fireworks go off when the button was pushed. It was quite deafening and a hell of a shock.

We've been able to do full-scale testing of columns, piles, beam-column joints, and there have been many theses made possible by that machine—John Mander's thesis, for example. John took my spot when I retired.

The column tests were badly needed, since at that time there was a severe restriction on the maximum design compressive load that columns were permitted to carry. Those tests and associated theoretical analyses by a number of graduate students permitted seismic design with more heavily loaded columns, providing that they were properly confined by transverse reinforcement.

Reitherman: What other equipment has been added?

Park: Strong floors,[20] more hydraulic actuators and pumping capacity, a shake table, new data logging, and instrumentation.

First Ph.D. Student: Nigel Priestley

Park: Nigel was my first doctoral student, although I got him only at the end of his doctoral studies when I returned from England. He's absolutely bright, the best of them all, really. And he has very strongly held viewpoints. Nigel went from Canterbury to U.C. San Diego and worked with Frieder Seible. San Diego has risen because of their good work—very well thought-out research, on-time projects, good recommendations, good reporting.

Reitherman: What was Priestley's thesis topic?

Park: Continuous prestressed concrete beams.

Reitherman: From a seismic standpoint, or for gravity loads?

Park: Not from a seismic standpoint; it was ultimate strength theory for gravity loads. After

20. In a structures laboratory, a "strong floor" isn't just any strong floor capable of carrying heavy weight; it is a floor designed with anchorage points that can provide large reaction forces to resist tension or shearing forces that are exerted when structural specimens are tested, as well as downward compressive forces. A "reaction wall" is the same thing, only oriented vertically.

Ph.D. Students of Robert Park*

Student	*Date of Thesis*
M.J. Nigel Priestley†	1966
D. C. Hopkins	1969
D. C. Kent	1969
R.W.G. Blakeley	1971
S. Islam	1973
G. K. Wilby†	1975
K. J. Thompson	1975
C. W. Beckingsale†	1980
J.B. Mande†	1983
F.A. Zahn†	1985
Pam Hoat Joen	1987
D. Whittaker	1987
Soesianawati Watson	1989
Hitoshi Tanaka	1990
P.C. Cheung†	1991
J.M. Restrepo	1992
Bing Li	1993
F. Yanez†	1993
Li Xinrong	1994
Shigeru Hakuto	1995
J. Maffei	1996
F.J. Crisafulli†	1997
Total: 22	

†Co-supervised with other staff

Forty master's degree students not shown

* Hopkins, David C., "Robert Park: Research Contributions 1958 to 2002," *Symposium To Celebrate the Lifetime Contributions of Tom Paulay and Bob Park.* University of Canterbury, Christchurch, New Zealand, July 11, 2003.

receiving his Ph.D., he went to work for the Ministry of Works, the government public works agency, at its central laboratory in Wellington. He didn't end up being very happy running the Structures Lab there. I played golf with him once and said, "Hey, Nigel, why don't you come back and join our faculty?" and he did. We were lucky to have him for a few years until he went off to San Diego in 1986. They offered him salary increases until he couldn't possibly refuse. So I say (he's my dear friend you know) that they stole him!

He's a very gifted person. He's written books on design and he hasn't really worked as a designer. He just picked it up as he went along. I'm a bit like that too, I'm not really a professional designer at all, but I've been writing things on seismic design for years.

Reitherman: There are other places that have had famous earthquake engineering professors, but why is it that all three of Canterbury's famous "Ps," Park, Paulay, Priestley, have emphasized design, as compared to, say, analytical method development, or only laboratory experimentation?

Park: We see design as just the final application of what you do. For me, quite honestly, I wouldn't be involved in anything that didn't have a good design application. There's so much—I'll be unkind—research being done that has little application, Ph.D. theses that are gathering dust on the shelves that really have no use for anything. We've mingled and interacted with the design profession so much. We're not professional designers in our day-to-day work, but we know what they need—they've told us. So we have programs going on in those areas, and I find that very satisfying. To me, the development of the New Zealand seismic code is a very important part of our work.

Second Ph.D. Student: David Hopkins

Reitherman: Your second Ph.D. student was David Hopkins, the son of Harry Hopkins, and a consulting engineer prominently involved in the earthquake engineering field today.

Park: He was very bright, very mature. He loved sport. I had a couple of run-ins with his father about that. I remember one Easter, David was picked to play for the University of Canterbury cricket team at the Easter Tournament in 1968 at Wellington, which would have been his seventh tournament appearance in a row, but I advised him not to go, saying it would be better if he stayed back and did a bit more work on his thesis. When Harry found out about this, he got angry, and told me off for interfering with his son's sporting life and criticizing me for holding David back in Christchurch to study.[21] He told me, "You are my son's thesis advisor, but you can't interfere with his sporting life!" Harry was very much a man for combining sport and scholarship.

21. The other University of Canterbury cricket team members had an eventful trip from Lyttelton Harbour to Wellington on the passenger-vehicle ferryboat *Wahine*. Two storms changed course as the ship traveled in the night, storms which were not detected rapidly enough by the meteorological monitoring of the time to provide warning. By chance, these storms converged at Wellington, creating hurricane-force winds and massive waves just as the *Wahine* arrived at dawn on April 10. The ship could not control its course, went aground on rocks within the harbor, and sank. Of the 734 people on board, 51 died in the attempt to abandon the ship and reach lifeboats while the *Wahine* was listing more than forty-five degrees. *New Zealand Maritime Record*, New Zealand National Maritime Museum, http://www.nzmaritime.co.nz/wahine.htm, and Wellington City Libraries, http://www.wcl.govt.nz/wellington/wahine.html.

Advising Ph.D. Students

Reitherman: What was your general method of advising a Ph.D. student? For example, how was a thesis topic decided upon?

Park: I offered the students a list of topics with a synopsis of what they could do with each one. They would go away and think about it and come back and we would discuss it.

The interaction between the student and the supervisor is very important. The student has to be comfortable with you. I wouldn't take on a student who didn't feel comfortable with me. Apart from the topic, you have to ensure that the interaction is sweet.

A lot of the topics on my list were from input from the practitioners. And the more research you do, the more things you seem to have left to do. You keep uncovering things you have to do. We always have a chapter at the end of the thesis that is suggestions for future work, and a number of future thesis topics came from those suggestions.

I have been very fortunate with the high quality of my Ph.D. and master's degree students. They have been the lifeblood of my research. It has been a privilege to supervise them, and I am proud of how well they have done.

Foreign Researchers Attracted to Christchurch

Park: You know some of the students who have graduated from here or faculty who have visited. I think you know André Filiatrault? He has worked with José Restrepo, who came here for his Ph.D. from Columbia. Do you know José?

Reitherman: A little, and I called him up before coming here to interview you and Tom. He said he shopped around the world to see where he should do his Ph.D. and his first choice was Canterbury. It's really quite a story—how such top students from so many countries have made their pilgrimage here to Christchurch.

Park: Well, I've given lectures in most Latin American countries, China, and Japan. I met José Restrepo in 1985 in Bogotá, while giving lectures there with Mete Sozen. José was on our staff after getting his Ph.D., but the larger amount of funding in the U.S. drew him away to the University of California at San Diego. We've also had an Erskine Fellowship to allow our own engineering staff to visit overseas and to bring visitors to New Zealand. We've had a couple of dozen earthquake engineering faculty from overseas come here that way, Catherine French, Jim Jirsa, and so on. For a while, Catherine was by herself here in Christchurch with three small children, spending time with them and working through the night reading and writing. A real dynamo. Tom O'Rourke was another of the Fellows, and he really took a liking to the place—he comes to New Zealand quite regularly.

Reitherman: It's interesting you bring up the Erskine Fellowship. I got on the Air New Zealand flight in Los Angeles to fly here and by chance the person sitting next to me was Mary Comerio from Berkeley, who was flying here with her daughter to begin a few months' visit to the University of Canterbury on an Erskine Fellowship. So I had a little in-flight briefing on the fellowship program. She's looking forward to her time here very much.

Park: It's been very good for us to have these outside influences from the rest of the world. It's a good program for everyone.

Reitherman: But don't you think it's true that Canterbury—a rather small place—has taught the rest of the earthquake engineering world—a rather large place—more than the rest of the world has taught Canterbury?

Park: Well, that's for you to touch upon, not me. We've just been working away. We've been lucky. People of the caliber of Tom Paulay, Nigel Priestley, and perhaps myself, can be thought of as making a difference.

Now, however, we're all somewhat removed from the University, retired like Tom and I. Although Nigel has homes here in Christchurch, he is not often here and is involved with the ROSE School in Pavia [European School for Advanced Studies in Reduction of Seismic Risk, Pavia, Italy], having left the University of California at San Diego.

Visiting Faculty at the University of Canterbury Studying Earthquake Engineering and Related Subjects Up to 1996*

Paul Jennings	1970: earthquake engineering
Mikolaj Wegrzyn	1975-76: soil mechanics
Norby Nielsen	1976: earthquake engineering
Donald Hudson	1977: strong-motion seismology
Victor Rutenberg	1978: dynamic analysis of buildings
Mike Uzumeri	1979: concrete
Gerard Pardoen	1979-80: full-scale structural testing
Ronald Scott	1981: soil mechanics
Milos Novak	1983: dynamics of structures
Michael Collins	1983: concrete
Israel Rosenthal	1983: prefab buildings
Donald Anderson	1983-84: earthquake design
Paul Jennings	1985: earthquake engineering
Hugo Bachmann	1985: concrete
He Limin	1986-87: masonry
Dai Ruitong	1987: concrete & masonry
Takeshi Arakawa	1987: concrete
Jim Evans	1987: solid mechanics
W.K. (Dick) Tso	1987: earthquake engineering
Mario Rodriguez	1989: concrete
Don Yigiang	1989: engineering seismology
Nishiyama Minehiro	1989-90: concrete
Katsuchi Ijima	1990-91: structural dynamics
Richard Fenwick	1990-91; 2000: concrete
Jim Jirsa,	1991: concrete
Xinrong Li	1990: concrete
Jack Moehle	1991: concrete
Zhen-Ping Du	1991-1993: transportation vulnerability
Thomas O'Rourke	1992: soil mechanics
Nigel Priestley	1992: concrete and masonry
André Filiatrault	1994-1995: earthquake engineering
Hugo Bachmann	1996: concrete

*Department of Civil Engineering, University of Canterbury.

Serving as Deputy Vice-Chancellor of the University

Reitherman: You became Deputy Vice-Chancellor of the University of Canterbury in 1993 and served till 1999. Tell me about that position.

Park: In 1992 I had finished my term as HOD, Head of Department (we don't call it "chair" here) after fifteen years, and I was looking forward to having more time to devote to my own research. But I was pulled out of the Civil Engineering Department by the then-Vice-Chancellor to be his Deputy. In a New Zealand university, the Vice-Chancellor is the academic head and manages the university. There's a Chancellor as well. The terminology is English in origin. The Chancellor heads the University Council that concerns itself with governance, while the Vice-Chancellor is responsible for management. Vice-Chancellor sounds rather secondary, but it isn't. The job I had, Deputy Vice-Chancellor, was the second in charge to the Vice-Chancellor.

The Vice-Chancellor at that time, a fellow called Bert Brownlie, who is now retired—also born in Fiji, I knew him in school—didn't like to delegate much, so he tried to do everything himself. But it got to the point where that wouldn't work. So, I was brought in and I took on the building programme for the campus and chaired the research committee that distributed research funds, along with being on other committees. It was a very demanding job, very hard to also keep publishing under those conditions.

Reitherman: David Hopkins has a very interesting paper for your upcoming symposium[22] in which he tabulates your papers, year by year. In the seven years prior to your becoming Deputy Vice-Chancellor, you published on average twelve papers per year. In the six years that you took on the Deputy Vice-Chancellor job, you published an annual average of eleven—almost no difference in output.

Park: I always made sure I had time to supervise graduate students and get on with some research. You have to, otherwise you just get swamped with administration and do nothing else. I very carefully allocated my time, and had to be efficient in not wasting any time.

Reitherman: Concerning the building program at the Ilam campus, right from the start it seems that there was a need for more buildings, even with a new set of facilities providing much more space than at the old campus in the middle of Christchurch.

Park: Absolutely. Brownlie, the Vice-Chancellor, squirreled away surpluses for a number of years, but eventually it became noticed by the Ministry of Education, and the university was told that if it didn't need the funds, it would have to give them back to the government. Brownlie then embarked on a huge building programme.

Reitherman: Aside from the investment in facilities, who paid for the rest? Who paid for the individual research projects?

Park: The system here is that the universities receive from the national government a dollar amount for each full-time student and are free

22. Hopkins, David C., "Robert Park: Research Contributions from 1958 to 2002," *Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park*, 2003.

to use it pretty well as they like, for staffing, facilities, and for research. There was some internal money for research from this bulk grant. Gradually, the outside agencies built up their research funding. We obtained money from the Ministry of Works, which was the old Public Works Department, and from the National Roads Board, the University Grants Committee, and those sorts of organizations. Of course, there are many more funding agencies now than there were in those days.

Chapter 5

Reinforced Concrete Slabs and *Reinforced Concrete Structures*

You need to have a capacity design method in which you have a proper hierarchy of strength, and hence you can make a structure perform in the best possible manner during an earthquake.

Writing *Reinforced Concrete Slabs* with Bill Gamble

Reitherman: Let's talk about one of your well-known textbooks, *Reinforced Concrete Slabs*.[23]

Park: I was always interested in plastic theories for slabs. Yield line theory was originated by K.W. Johansen,[24] a Dane, and the strip method of analysis by A. Hillerborg,[25] a Swede—

23. Park, Robert and William L. Gamble, *Reinforced Concrete Slabs*. Wiley, New York. First edition 1980; second edition 2000.

24. Professor K.W. Johansen published this theory in his doctoral thesis at the Technical University of Denmark in Copenhagen. "Brudlinieteorier," *Jul. Gjellerups Forlag*. 1943, 191 pp.

interesting that they both are Scandinavians. I was always interested in this area, and while visiting the University of Illinois, I got to know Bill Gamble. I appreciated his involvement in the early slab testing at Illinois in the 1950s and 1960s with almost-full-scale floor tests. So, I asked Bill to be a co-author, and he came here and mostly authored his part of the book while he was here. I first asked Mete Sozen to be the co-author, but he declined, and he suggested Gamble. At that time, Meta was at Illinois; now he's on the faculty at Purdue University. Bill took a bit of risk coming in with me on the book, collaborating with someone who had no real reputation in the U.S. at that stage.

Reitherman: Concerning slabs, is it true that to realistically include the slab on top of a moment-resisting frame in a laboratory test requires much more work than to test the bare frame?

Park: Quite right, much more difficult, but more realistic. In the Trilateral Cooperative Research Program on Beam-Column Joints, after the initial meeting in California in 1984, we decided that each country would design test specimens according to its own codes. We can talk more about that. Patrick Cheung was the Ph.D. student who did the work on the New Zealand side. He tested interior and exterior frames, both with slabs.[26]

25. Hillerborg, A., "Jamviktsteori for armerade betong plattor," *Beton*. Vol. 41, no. 4, 1956.

Writing *Reinforced Concrete Structures* with Tom Paulay

Reitherman: The reinforced concrete book you wrote with Tom Paulay, the famous book called *Reinforced Concrete Structures*, was published in 1975.[27] It's hard to find a more widely used text in earthquake engineering and structural engineering. There must have been some period of time preceding its publication in the mid-70s during which it developed. How did it all start?

Park: By what we call Extension Study Seminars. These are seminars we put on at the university for professional engineers, to bring them in for refresher courses and introduce new ideas. Tom and I did these for years, and in particular in the early years, the emphasis was on how to bring them up to speed on ultimate strength design, to get them away from working stress design. For these seminars, we wrote extensive notes. In fact, I have them here [Park picks up the volumes from the table in his house in Christchurch]. There were two main volumes. This one is on slab yield line theory, which was to form the basis for the book I wrote with Bill Gamble. And this volume is ultimate strength design of reinforced concrete structures, which was to form the basis for the

26. Cheung, P.C., T. Paulay, and R. Park, "New Zealand Tests on Full-Scale Reinforced Concrete Beam-Column-Slab Subassemblages Designed for Earthquake Resistance," *Design of Beam-Column Joints for Seismic Resistance*. Special Publication SP-123, American Concrete Institute, 1991, pp. 1-37.

27. Park, Robert and Thomas Paulay, *Reinforced Concrete Structures*. Wiley and Sons, New York, 1975.

book I wrote with Tom Paulay. We kept increasing the quantity of notes. This one has the date of 1969 on it, so it's probably one of the later sets or maybe the last one.

Reitherman: This is yet another indication of the extent to which engineering in academia and engineering in practice in New Zealand are closely integrated. Then you sent your notes to a publisher?

Park: We sent it to John Wiley publishers and they got Dr. Eivind Hognestad, from the Portland Cement Association in Skokie, Illinois, to review our notes on ultimate strength design of reinforced concrete structures. He was one of the giants in the concrete field. Do you know Gene Corley?

Reitherman: Yes, a little, but not going back very far.

Park: Gene would know Hognestad very well, because Hognestad was originally his boss. Hognestad wrote a very flattering review of the notes. The book was based largely on the ACI-318 building code, and Hognestad was amazed we could figure out the reasons why ACI-318 was written the way it was when we hadn't been on the committee.

Reitherman: How were these seminar notes put together? These are very nice illustrations in these seminar notebooks. Was the lettering done by having drafters use technical pens in stencil guides, all in ink?

Park: Yes. In those days we had draftspeople, one or two in the department, who were kept busy all the time. And the text was typed up from our handwritten notes.

Reitherman: It's a luxury today to make numerous corrections and just push a button on your computer to save the changes and go on.

Park: Of course, in those days, if the typist made an error, it was a painful process to correct it, using white-out and so on.

Reitherman: Do you and Tom have plans to bring out a second edition?

Park: We probably never will. Tom and I have talked this over many times. Calling it a classic is probably overdoing it, but it has a lot of good basic material that will not become outdated. It's been translated into a few languages. When I first went to Chongqing in China in 1987, I wondered why they invited me over there to give lectures. I found that they had reprinted complete copies of our book published by Wiley—pirate copies. And they had also translated it into Chinese and published that pirate version as well! I've seen pirate versions published in Taiwan, Hong Kong, and Singapore also. Hopefully, the pirate publishing will stop.

Bank of New Zealand Building: A Need for Improved Seismic Design of Reinforced Concrete

Reitherman: When you returned to New Zealand with a Ph.D., your work on ultimate strength design provided a foundation for your subsequent work in seismic design, but you had not yet become one of the founders of capacity design as an earthquake engineering philosophy. It must have been the practical nature of the earthquake subject in a highly seismic place such as New Zealand that provided your motivation for selecting earthquakes as a major theme in your career.

Park: What really initiated my interest in seismic design was that in the 1960s there was a large building being designed in Wellington, the Bank of New Zealand Building. Tom Paulay and I went up to a session with the consultants, and after a long meeting we decided that the BNZ Building could not be designed with sufficient confidence in reinforced concrete. There were too many things you didn't know to do properly, as compared to structural steel. The result of the uncertainty was to push us into more concrete research.

So the Bank of New Zealand Building was designed in structural steel, and they were a very long time in the building of it because the boilermakers, the workers who did the onsite welding, went on strike for months, indeed years, while the partially-built building stood there as a rusty skeleton. In the meantime, concrete buildings were built around it.

Tom Paulay and I were very lucky because, when we started working on concrete in the late 1960s, things were changing. Tom and I actually pulled New Zealand through from working stress design of concrete to ultimate strength design by writing what eventually became the reinforced concrete book we wrote together. So we struck it lucky, you might say, right at that time when the change was happening, in the late 1960s.

Origins of Capacity Design

Park: Interest in seismic design for reinforced concrete was also increasing in many countries. A book published by the Portland Cement Association (PCA) by experts in the U.S.[28] was being widely read. That Blume, Newmark, and Corning book was also being widely used for design here. Newmark contracted Mete Sozen to produce content for the book on reinforced concrete, and it was done very well. But there were parts of it that were a bit lacking. For example, it did not provide guidance for the design of beam-column joints.

Reitherman: I thought that book might come up, so I went through it recently, not remembering much about it from having read it a long time ago. Someone had told me that you could find the strong column-weak beam concept articulated in that book, but I don't think you really can. Capacity design's goal of protecting certain portions of the structure and ensuring that other links soften first can't really be found in that book in explicit form. There's one section where they go through a hypothetical design of a twenty-four-story building, and it says in one brief sentence that it is interesting to note the factor of safety in a particular column is much higher than in the beam framing into it. They didn't start off that design example saying the *intent* is to make the column stronger than the beam and then explain why. They simply note this column-beam strength relationship in the sample calculations in passing. If the authors had a broader strategic concept of seismic design in mind, what we would call capacity design today, a strategy of having the designer

28. Blume, John A., Nathan Newmark, and Leo Corning, *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions*. Portland Cement Association, Chicago, IL (now located in Skokie, Illinois). 1961. Re-published in a 1992 edition.

carefully plan *where* inelastic behavior would occur and then detail there for ductility, they didn't clearly document it in that book. In my reading of it, although it's a classic work, it doesn't quite lay out a capacity design strategy for achieving a hierarchy of inelastic behavior.

Park: Yes, it lacks a complete philosophical approach to seismic design. It is very good on details, though it neglects the beam-column joint. It's a great book, actually. There was a lot of work on the ductility of columns and beams that Mete had done. Those were the days when the PCA was a huge influence. That book was written as an answer to the steel industry, to say that concrete could be used for tall buildings in seismic regions. Some thought that all the answers were there in the U.S., but when we looked at the BNZ building in Wellington, we could see that all of the design aspects had not yet been properly thought about.

The idea of capacity design was really the brainchild of a design engineer here, John Hollings.[29] That's the start. The goal was to protect some regions of the structure by making them stronger. The reasoning for it—I'll take a little bit of credit for that. And in the reinforced concrete book written with Tom, there's quite a long section on it actually. It demonstrates that you can get very high ductility demand on columns and undesirable plastic hinge formation there when the weak column-strong beam condition applies. Almost every earthquake demonstrates this with some pancake-type collapses. The Olive View Hospital in the San Fernando, California earthquake of 1971 was a classic example of what we would call the wrong approach—weak columns in the lower storey. Olive View Hospital was very interesting because there were spirally-reinforced columns at some places in the ground storey. Other columns of L-shape had transverse reinforcement of ordinary ties and the larger spacing typical of the time and had severe damage. The spirally-confined columns hung in there very well.

You need to have a capacity design method in which you have a proper hierarchy of strength, and hence you can make a structure perform in the best possible manner during an earthquake. Take an ordinary beam, for example. If a beam fails with diagonal cracking, it fails in shear, a brittle failure after displacement reversals, with little energy dissipation, pinched hysteresis loops—it's not a good way to go. So you make the shear strength high enough to ensure that shear failure won't occur, and that instead, flexural failure will occur first. When I say "failure," I don't mean collapse, I mean yielding, plastic hinging.

29. Hollings, John P., "Reinforced Concrete Seismic Design," *Bulletin of New Zealand Society for Earthquake Engineering*. Vol. 2, no. 3, 1969, pp. 217-250. This paper was originally published by the University of Canterbury as part of a short course the year before, thus pushing the documented origins of capacity design at least as far back as 1968. Hollings accentuated the basic elements of capacity design with a simple metaphor: the engineer must make parts of the structure behave as if made of lead and direct the inelastic deformation to occur in those regions, while the rest of the structure is as brittle as glass and must be protected. The "strong-column/weak-beam" phrase and "capacity design" are not used in the paper. Hollings was a principal in Beca Carter Hollings and Ferner Ltd., Consulting Engineers, New Zealand.

It's the same in bridge columns. You design them to have ductile hinging at a given location, such as at their bases, where you have the ductile detailing. Without the ductile detailing, capacity design wouldn't work. Capacity design and ductile detailing work together.

Reitherman: Capacity design is a contribution for which you and Tom Paulay must take a large amount of credit. Can you offer a simple analogy that can be understood by readers who have no engineering background?

Park: The one that Tom uses is that if you pull on a chain hard enough, you'll obviously find the weakest link. If that weakest link is ductile, it will stretch significantly. If that link is brittle, you will get a sudden fracture and a catastrophic failure—the chain breaks. The analogy extends to a frame loaded laterally by an earthquake. If the initial failure occurs in a brittle element, or if you have a soft-storey failure of a building due to the brittle behaviour of the columns of a storey, you can have a catastrophic result. Therefore, we make the beam yield first, because we can make a beam yield in flexure in a ductile manner and develop plastic hinges very reliably. The ductile beam is analogous to the ductile link in the chain.

Reitherman: I suppose the other thing to say, to keep the analogy parallel, is that we are not pulling on this chain steadily, as if hanging a weight from it, in which case a yielding link could continue to yield, the material would stretch like soft candy, neck down to a small cross-section, and break. "The" earthquake is a number of discrete and very brief bursts of displacements in any given direction—brief tugs on the chain. Earthquakes are difficult enemies to contend with, but that dynamic characteristic that makes the loading so difficult to analyze is also what saves us. If the physics of earthquakes were such that the structure were to be accelerated in one direction for five or ten seconds in a row, ductility would be no defense.

Park: Absolutely. The cyclic nature of the loading is quite important. And when there are relatively long pulses to the ground motion, they can cause serious problems.

Earthquake Engineering Then and Now

Reitherman: Before we leave the 1961 Blume, Newmark, and Corning publication, let me read to you the very first sentence in the book and ask you a question about it. "Considerable knowledge has been gained in the last three decades"—that would have been the 1930s, the 1940s, and the 1950s—"about the phenomena of ground motion, the characteristics of structures and their behavior in earthquakes. In addition, much has been learned about the response of various vibrating systems to such motion." With hindsight, let's put that into historical perspective. As of 1961, the 1940 El Centro record with its 1/3g peak ground acceleration was still the centerpiece of the world's collection of strong motion records. The Alaska, Niigata, Caracas, San Fernando, and other instructive earthquakes of the next ten years had yet to take place. Shake table experiments and full-scale cyclic testing of modern form hadn't occurred. None of the work you, Paulay, Priestley, and others were to accomplish in earthquake engineering had yet begun.

From that 1961 vantage point in history, some very knowledgeable people seemed to be saying that the basic problems had been solved or were at least well-understood on the basis of the work done in the 1930-1960 period. Is it fair to say with today's hindsight that instead there was much left to be learned in the following decades, and, in fact, we don't have it all figured out even today?

Park: Perhaps we can note that the confidence you quote was a bit premature, having the benefit now of reflecting on subsequent developments. As of the 1960s, the dynamics had advanced a lot, but the actual nonlinear behaviour of real structures was not well understood.

But I'd like to note that the U.S. has been the leader in this field—people like Newmark, Bertero, Penzien, Sozen, Chopra, and others. They've been absolute giants. Although we tend to have disagreements about this and that, I respect U.S. seismic engineering, very much indeed.

Has Reinforced Concrete Changed, or Just Its Design?

Reitherman: In your career to date, have you seen major changes in the materials themselves that are used to make reinforced concrete structures? Or have the materials stayed mostly the same and the advancements have come only in design methods?

Park: There have been great improvements in concrete, both in strength and in workability, which have been very helpful to designers and contractors. The early concrete was typically 3,000 psi, about 20 mega Pascals (MPa) in SI units. Nowadays, it would be difficult to make concrete that weak! We typically use 30 or 40 MPa for construction in New Zealand, and it's easy to make concrete with strengths up to 80 MPa, which is about 7,000 psi, with use of silica fume. So the possibilities are there for designers to take advantage of high-strength concrete. Typically in the U.S., the ACI code has no upper limit on concrete strengths, except for some provisions that apply to shear and anchorage.

An advantage of high-strength concrete is that in the lower columns of tall buildings, where the axial load level is very high, you can use a column with smaller cross-section. Also, it is more durable.

As well, there have been developments in the use of high-strength reinforcing steel. Typically in the U.S., you use Grade 60, 60 ksi yield strength steel, about 414 MPa. We've been using 430 MPa, a little higher, for many years now. Now coming along there is G500 MPa steel, and the Japanese have been making 1000 MPa or 1200 MPa steels. The challenge in the future will be how to use these high-strength steels efficiently. An obvious application is for confining steel for columns, because the higher the strength of the concrete, the more confinement you need to make it ductile. One of the committees of the "fib" (International Federation for Structural Concrete) that I am co-convening is on high-performance materials.

Fiber-reinforced concrete is another development in the material, providing a concrete that is very resistant to wear, more resistant to impact loads. For example, it is a good material to resist many repetitions of loading on a warehouse floor. It also improves ductility. The fibers can either be steel or a polymer. It's not widely used here yet, it's largely a proprietary sort of product.

Reitherman: I see that as far back as 1973 you wrote a paper with D.C. Kent on "Cyclic Load Behaviour of Reinforcing Steel,"[30] so obviously you have been concerned about the properties of the steel, not just the concrete for some time. And then recently, at the 2003 Pacific Conference on Earthquake Engineering held here at Canterbury, there was quite a spirited discussion about an earthquake engineering controversy surrounding the new Grade 500 steel.

Park: First of all, as far as I'm concerned, the main use of Grade 500 steel is for transverse steel, to confine the concrete of a column. When you use it for longitudinal steel, you can have problems. You have very high bond stress, which means that when the beam bars pass through columns, there is the danger of slip.

The other problem is overstrength. In capacity design, you need to know the maximum likely strength of a reinforced concrete section in flexure, which depends on the maximum likely yield strength of the steel. For Grade 300 or 430 steel, the overstrength factor is about 1.25. For Grade 500, it has been found that you can get very high overstrengths—the overstrength factor might be 1.4.[31]

30. *Strain, Journal of the British Society for Strain Measurement.* Vol. 9, no. 3, July 1973, pp. 98-103.

When a structure with Grade 500 steel deflects under an earthquake up to the first yield displacement, with the yield displacement being roughly proportional to the yield strength of the steel, the yield displacement will be higher. The displacement ductility factor is defined as the ultimate displacement divided by the yield displacement. In design, we often use a displacement ductility factor of four to six for frames. If the yield displacement is high, the displacement ductility factor must be reduced for a given interstorey drift.

The net result is that in New Zealand, some of us are not very keen on using Grade 500 steel for longitudinal reinforcing in beams. The problem does not exist so much for columns. Unfortunately, the only reinforcing steel manufacturer in New Zealand, Pacific Steel in Auckland, has already withdrawn the Grade 430 steel—so the designer is stuck with Grade 500 or 300 for the time being. In the U.S., this couldn't happen, because there are so many bar manufacturers.

31. When an earthquake imposes the anticipated maximum displacement on that beam, its flexural strength could be 40 percent larger than that associated with the specified yield strength of the steel. This can change the intended hierarchy of the strengths of beams and columns and defeat the capacity design intent of achieving a stronger column-weaker beam condition.

Chapter 6

New Zealand and Its Innovative Approaches to Seismic Design

Good seismic design in reinforced concrete is a new technology—it's really only a bit more than twenty years old, which surprises a lot of people.

Reitherman: New Zealand is known for its innovations in the earthquake engineering field, and for the way it has sometimes differed from other countries with respect to seismic design philosophy.

Trilateral Program: Different Countries, Different Design Philosophies

Reitherman: In the mid- to late 80s, there was a research program with regard to the seismic design of reinforced concrete—the Trilateral Cooperative Research Program on Beam-Column Joints, involving New Zealand, Japan, and the U.S., and then there was some involvement from the People's

Republic of China. Here's a quote and a paraphrase from Hiroyuki Aoyama: "An international dispute broke out in the 1980s between designers in the United States and New Zealand."[32] He concluded that the U.S. researchers came away satisfied with the validity of their design procedures, but the New Zealanders proposed something of more importance for the future of earthquake engineering, namely a transition from an empirical to a rational approach.

Park: The University of Tokyo is the number one university in Japan, and the reinforced concrete chair is the most important in Japan. At that time, it was occupied by Hiroyuki Aoyama, who is now retired.[33]

The U.S. approach is based more on test results, thus Aoyama's reference to the empirical approach, whereas in New Zealand, we have tried to use models of joint behaviour. We have observed the experimental results, and on that basis, we have created models that attempt to imitate the behaviour of the joint.

The origin of the Trilateral Program was that there were some thinking people in the U.S. who realized that great differences were arising between the New Zealand approach for beam-column joints and the U.S. approach. Jim Jirsa at the University of Texas was approached to try and set up a collaborative research project to look at this. Jim got me on board, and I got a few New Zealanders together. I also got the Japanese and some Chinese to become involved. We had a meeting in Monterey, California after the Eighth World Conference on Earthquake Engineering in San Francisco in 1984, then a meeting in Tokyo in 1985, in Christchurch in 1987, and in Hawaii in 1989. Very interesting for researchers, but it didn't really lead to much.[34]

We had a research programme where we designed beam-column joints according to our building codes and we tested them full-scale in the labs. The object was to see who came out best—like a competition. It fell flat on its face, unfortunately. It didn't lead to much, because of the differences in the interpretation of test results, and of acceptance criteria. The U.S. people simply said, "Ours is good enough. We accept the performance in the tests." We said the same thing about ours, and nobody changed their design practise. We agreed to disagree. But it was quite exciting.

Actually, if you want to look at it another way to see how much we did agree, there's a paper written with several Americans along those lines.[35] There are basic differences in theories

32. "Empirical Versus Rational Approach in Structural Engineering—What We Learned From New Zealand in the Trilateral Cooperative Research Program on Beam-Column Joints," *Recent Developments in Lateral Force Transfer in Buildings: Thomas Paulay Symposium*. Edited by Nigel Priestley, Michael Collins, and Frieder Seible, ACI SP-157.

33. The "seismic pedigree" of this academic position extends back to other famous engineers in Japanese earthquake engineering history, beginning with Toshiki Sano, then Kioshi Muto, Hajime Imamura, Hiroyuki Aoyama, Shunsuke Otani, and currently Tetsuo Kubo.

34. Jirsa, James, ed., *Design of Beam-Column Joints for Seismic Resistance*. American Concrete Institute, 1991.

as to how the shear mechanism in a beam-column joint actually works. You're aware of this, are you?

Reitherman: As I understand it, the American approach is to focus on confining the concrete of the joint region, and, if the concrete is properly confined, then it is thought that the shear forces will flow through the concrete. The reinforcing is not assumed to directly transfer shear via the bars themselves—their role is to confine the concrete. Whereas in the New Zealand approach, the joint is visualized so as to isolate the portions of the concrete in that region that act like individual compression struts, with the rebar there to provide the tension members, and thus truss action will occur to keep forces in equilibrium.

Park: Yes, that's right. We both believe that there has to be a diagonal compression strut across the joint to carry most of the shear. The American approach is to confine the concrete with transverse steel, and keep the concrete shear stress below a critical value. The New Zealanders say that if you have confining steel, it also acts as shear reinforcement. You can form little mechanisms where forces are carried through concrete via struts, and the bars maintain equilibrium. Oddly enough, the design outcomes are not that different, but there's certainly a big difference in philosophy. The Japanese more or less sided with the U.S. The Europeans are more like the New Zealanders on this topic. And this is still highly controversial. At the fib Concrete Structures in Seismic Regions Symposium held in Athens in May of this year [2003], I gave a keynote paper on controversial aspects of seismic design in reinforced concrete, and that was one of them.[36] There are many other areas where we are in disagreement, for example with regard to confining steel in columns. In the New Zealand code, we make the amount of confining steel dependent on the axial load level on the column. In the U.S., it's not—it's a constant amount, independent of the axial load.

In beam-column joints, critical actions are associated with shear and bond forces. Horizontal shear forces generated in such a joint are typically four to five times larger than those in the columns above or below the joint. These actions mobilize mechanisms that are entirely different from those applicable to the confinement of compressed concrete. Therefore, the need for transverse reinforcement in columns, including joints, was considered to be controlled by the most severe requirement associated with either the confinement of the concrete, or the provision for shear resistance, or the prevention of premature rebar buckling.

35. Selna, Lawrence, Ignacio Martin, Robert Park, and Loring Wyllie, "Strong and Tough Concrete Columns for Seismic Forces," *Journal of Structural Division, Proceedings of American Society of Civil Engineers*. Vol. 106, no. ST8, August 1980, pp. 1717-1734.

36. Park, Robert, "Some Controversial Aspects of the Seismic Design of Reinforced Concrete Building Structures," *Proceedings of the Concrete Structures in Seismic Regions Symposium*. fib (Fédération Internationale du Béton), Lausanne, Switzerland, May 2003.

Reitherman: Do you think more experimentation will bring about the convergence you seek?

Park: There's been a huge amount of experimentation. It's more a matter of the interpretation of the results and what sort of acceptance criteria you use.

Reitherman: I talked with Jim Jirsa about this a little bit. He said that in the U.S., there is a continual effort, especially on the part of the construction industry, to hold to life safety minimums of the code, and to resist putting anything else in the code because that will cost more money. His view of the New Zealand approach is, if you figure out a better way to do something to enhance performance, and if by putting it in the code it gets implemented, and if it doesn't cost that much more, then why not do it?

Park: That's true. If I may say so, I think the U.S. approach is coming to an end, because of performance-based design. Life safety is not good enough. We need to ensure that important structures can survive an earthquake with minimum, repairable damage and not be in an unacceptable condition. The client rarely knows that the building is not designed to avoid all damage in an earthquake, may be useless afterward, and may even have to be demolished. Performance-based design is looking at how to achieve higher levels of performance for certain earthquake risks. All design is going that way—it's happening in the U.S.

While here in New Zealand, where we have been advocates of capacity design to prevent soft-storey collapse, there is the criticism of the strong column-weak beam philosophy raised by people such as Shunsuke Otani, because Japanese studies of buildings after earthquakes have shown that epoxy repair of cracks at the ends of beams can be extensive. Life safety isn't everything, but it has been the main aim of most codes up to the present time.

U.S. code committees have been significantly influenced by the construction industry to make sure the code requirements are not too ponderous and demanding. The concrete people don't want their material to lose business to the steel industry, and vice versa.

I'd like to think that in New Zealand these pressures are much less. There's no battle between academia and industry about that sort of issue. The industry people don't have a significant influence on the code committees. But we are not totally a "concrete country" by any means. The steel people have very competitive designs to offer.

Reitherman: At least in California, it's probably a fair observation that in each successive earthquake—1971 San Fernando, 1983 Coalinga, 1985 Whittier, 1989 Loma Prieta, 1994 Northridge—the building owners and users expected better performance. Or, at least, the trend is that they have complained and sued more, and the insurance settlements have become larger and more contentious. Finding out what's the matter, and finding someone to blame, are two different things when it comes to advancing the field. The public doesn't know what the building code promises them in an earthquake, or go out of its way ahead of time to articulate a desire for higher seismic protection (and a willingness to pay for it). But afterward, people generally find someone to fault if there is damage.

Park: I believe that's quite right. The building owners are often shocked—they don't have the protection they thought they had, because the aim of the building code has been life safety, not protection from damage.

Comparing Trends in New Zealand and U.S. Universities

Reitherman: In the U.S., you see that much of what is done in earthquake engineering research is based on the goal of involving more and more parts of the country, including regions of low seismicity, and involving new people who are not very familiar with seismic design. Today, this broadening is considered a good thing in and of itself, and it fits with inclusiveness or diversity goals that are popular political beliefs.

However, there is always a negative or two that comes along with a positive. Broadening of the field in the U.S. can be looked at as dilution. Some of the advantages New Zealand has had in making the progress in earthquake engineering that you and Tom have noted are absent in the U.S., or getting scarcer. In the U.S., there are many chefs making soup on a very large scale, with the political mandate to include all the demographic and geographic ingredients in the pantry. The process has become more complex and cumbersome, quite different from what you and Tom have described.

Park: New Zealand does have some advantages with its small size. In the U.S., the National Science Foundation seems to be spreading its funds all over the country with the new NEES (Network for Earthquake Engineering Simulation) labs. How many are there?

Reitherman: Fifteen, located in ten different states.

Park: And some departments are rising, like University of California at San Diego, for example, competing with Berkeley. Even Caltrans, which in the past has always favoured Berkeley, has funded a lot of work at San Diego. People like Nigel Priestley and Frieder Seible are the reason for that development. Austin isn't a seismic part of the U.S., but the University of Texas has done a lot of earthquake engineering work, perhaps because of Jim Jirsa's influence, and there's an emphasis on reinforced concrete seismic research there that probably is the legacy of Phil Ferguson. And now they also have Sharon Wood, who is very good in that area.

Reitherman: There are also some differences among U.S. universities as to how the laboratories are run. From what I have seen, a common American university approach to experimental research relies more on graduate, or sometimes undergraduate, student labor than professional technicians. U.C. San Diego has more skilled technicians on staff, one reason for its higher through-put, but is perhaps an exception. I've heard the theory that if you make the students chip away grout, sweep up the mess, install the instruments, they'll learn from the ground up. However, a result is that you can see facilities that cost a lot of taxpayer money being used only at a leisurely pace, with a small number of specimen tests per year. From what I understand, the New Zealand approach, at least at Canterbury, is quite different. Is it true you have roughly one professional lab technician for each faculty researcher?

Park: Yes. That has been the ratio, and those technicians are funded twelve months of the year. They're not on soft money dependent on each new research grant, and they have a career grade and can get significant promotions. They become very familiar with the instrumentation and so on. I wonder if our students appreciate how fortunate Canterbury is and how much help they've received from these technicians. It's a big strength of our department, the backbone of our experimental research. Each faculty supervisor puts forth a research plan, including estimated technician time. A planning committee then works out the scheduling. We have a large full-scale precast diaphragm test project in the lab now that needs four full-time technicians.

Reitherman: Is that an English tradition? Or something common only to New Zealand?

Park: In England, the technical staff/faculty researcher ratio isn't 1:1; it might be 0.5 to 1. I've never seen a place equipped with better and more technicians than Canterbury—though I don't often say it publicly because we might lose this resource if we start bragging about it. It was really due to Harry Hopkins, who was able to build up the technical staff and knew the value of it. For years, he was able to extract one new technician position for the department out of the system every year. The university administration listened to him because the research output of the department increased proportionally year after year. When I was head of the department, one of the things I was always pleased about was that I never lost any of those positions, even though at that time the university was trying to eliminate positions as they became vacant before they were refilled.

Reitherman: How many full-time technicians in the Civil Engineering Department were there?

Park: Twenty-four.

Reitherman: Wow! How many just for Structures?

Park: We had half a dozen at least, plus access to a pool of technicians who worked as needed on projects in the various engineering labs.

Reitherman: Is that one of the reasons why Canterbury has been so successful in attracting excellent graduate students to do research here?

Park: I think so. The technicians do a huge amount of work. At times you wonder who should be getting the Ph.D.!

Reitherman: You mentioned instrumentation. Have the instruments used for measuring strain, for example, changed much since when you were a Ph.D. student?

Park: In the early days, mechanical strain gauges would be installed by gluing a couple of studs to the concrete specimen, and strain was measured between the studs by a demountable mechanical strain gauge. It would take several minutes to properly take one reading from one such gauge during a test. Now, electrical resistance strain gauges and linear potentiometers have taken over the process, and data loggers are capable of absorbing batches of strain measurements, including dynamic strains, very quickly.

You can take a lot more readings a lot quicker, and the computer reduces it all down much more quickly to nice graphs.

Reitherman: Most non-engineers would probably assume that engineers in a structures laboratory are preoccupied with forces and stresses. Obviously, several types of quantities are measured in tests or calculated, but would you say that strain and displacements are actually the most central parameters of interest and the ones that require the most attention, rather than stresses and forces?

Park: Yes, strain and displacements. In New Zealand, displacements have always been a very important part of design. We've always kept a strict check on drift limitations and how much drift is expected. In fact, in the U.S. the sort of design we do here in New Zealand would be called displacement-based design—there's so much emphasis here on limiting displacements. As in the U.S., force-based design is the common method, where you calculate accelerations and apply them to the masses of the structure. You check drifts, but with the force-based method you don't design to a target maximum drift of the structure, as you do in displacement-based design. The profession is changing very slowly in that direction in the U.S. and New Zealand, because the old force-based method is so engrained.

Reitherman: In the CUREE-Caltech Woodframe Project, André Filiatrault and a Canadian visiting researcher, Bryan Folz, did research developing a displacement-based seismic design method for wood structures—something of a high-tech analytical method for what is still a rather low-tech design and construction field in the U.S. It won the 2002 ASCE Moisseiff Award, which I see from your curriculum vitae you won in 1978, merely one award among many on your list.

Making Prestressed Concrete a Seismically Acceptable Material

Reitherman: Let's talk about one or two specific examples of where academic research here in New Zealand was aimed at dealing with practical problems faced by your engineering and construction fields. How about precast prestressed concrete?

Park: There were a few individuals who set up a firm called Stresscrete. It's a small country, so when a firm sets up branches throughout the country, they can push it hard. Sandy Comack,whom I regard as "Mr. Concrete New Zealand," was behind this. Precast concrete has always been widely manufactured. But when it comes to seismic experience, such as in the 1976 Tangshan earthquake in China or in some other earthquakes, there have been some failures with this kind of material. But our capacity design philosophy here was ideally suited to this form of construction—to ensure that we can make yielding occur where we want it to occur—in areas where we can make the structure ductile. In a lot of ordinary design in other countries, yielding can occur almost at random.

In New Zealand, precast concrete was being pushed hard by the consulting profession, and to some extent, they got ahead of the codes. I got worried about this, about precast concrete being used to resist earthquake forces, but outside the code. So I set up a meeting in Christchurch, and we established a study group that wrote guidelines. Those guidelines summarized the best practises and test results.[37]

Before the great share market [stock market] crash in New Zealand in 1987, there was a big building boom. It was "big" on the scale of our wee country—we're still only four million people. Ordinary cast-in-place concrete was a bit slow to use during a boom. Precast concrete was being pushed because of its reduced labour costs, speed of construction, and good finishes. It required a lot of cranes but they were available. If you look at the floors of buildings in New Zealand from the 50s and 60s onward, they are almost all of precast concrete, either reinforced or prestressed concrete. If you look at building frames now, they are invariably of precast concrete. Quite a few of the walls are also precast reinforced concrete.

Reitherman: Does this have to do with the competition between material costs—how dear steel is compared to concrete—or labor costs associated with one construction method or another?

Park: A bit of both, both giving precast concrete an edge.

Reitherman: At the same time you and others in New Zealand were investigating how to make precast concrete work as a part of the seismic-resisting system, most people elsewhere, at least in the U.S., were treating the material as a liability—the precast units were mass that increased load, but they were brittle and couldn't be used as part of the lateral force resisting system. Except for perhaps tilt-up walls in one or two-story buildings, and for precast floor or roof systems that then had a layer of reinforced concrete topping applied to make a traditional diaphragm, engineers in the U.S. seemed to be looking at precast concrete quite differently. There are some engineers in the U.S. now actively designing precast elements into their seismic systems, but it's still novel.

Park: In California, because of certain engrained views by a few people, innovation and the precast industry were held down. Now there are some innovations breaking through, like the Paramount building in San Francisco, 39 stories tall I think, using the PRESSS technology.[38] Bob Engelkirk, the design engineer, has been a champion of the use of precast concrete, and he hasn't always been looked on with favor in this respect by his colleagues.

Reitherman: What about the early influential buildings in New Zealand that motivated design and research efforts with precast concrete? It seems that the Students Association Building at the University of Canterbury, designed by Lyall Holmes, was the first. Then

37. Park was a member of the Precast Concrete Study Group of the New Zealand Concrete Society, 1988-1999, which published *Guidelines for the Use of Structural Precast Concrete in Buildings: Report of a Study Group of the New Zealand Concrete Society and the New Zealand National Society for Earthquake Engineering*. University of Canterbury, 1991. Park has published a number of works on seismic aspects of precast and prestressed concrete (both wall systems and frame systems). To cite but two: An early paper was "A Review of the Seismic Resistance of Prestressed Concrete," *Bulletin of the New Zealand Society for Earthquake Engineering*. Vol. 3, no. 1, March 1970, pp. 3-23 co-authored with Roger W.G. Blakeley and Robin Shepherd. Blakeley did the full-scale tests of the University of Canterbury Students Association building beam-column tests in his Ph.D. work. A later work by Park was "Seismic Design and Construction of Precast Concrete Buildings in New Zealand," *Journal of the Precast/Prestressed Concrete Institute*. Vol. 47, no. 5, September-October 2002, pp. 60-75.

there was a similar campus building at the University of Auckland.

Park: The building at the University of Canterbury was under construction in 1968. It had pretensioned columns set into foundation sockets in the ground. The precast, pretensioned beams were set in between the columns, and then they were post-tensioned together, through the beams. The post-tensioning was grouted. It went beyond the code. One of my doctoral students did some studies on it, and it turned out okay.

Reitherman: In the U.S., the first earthquake that put precast concrete on the map—and in a very negative way—was the 1964 Alaska earthquake, with collapses of tilt-ups, prestressed concrete roof systems, and the complete collapse of the six-story Four Seasons apartment building with its prestressed floors. That may have been the largest building to have collapsed in a U.S. earthquake up to that time, a record since eclipsed by some parking garages in the 1994 Northridge, California earthquake.

Park: The reaction to the Alaska earthquake was also quite negative in New Zealand concerning all the damage to precast structures. Certainly, the collapse of the Four Seasons apartment building slowed everything down in New Zealand as well. The 1982 code here was very unkeen on unbonded tendons, but more recently we've allowed them—provided the anchorages are shown to be okay under cyclic load testing. The trouble with unbonded tendons is that you get very little energy dissipation in the structure, so that the load-deflection loops are very narrow. But the advantage is that you get full deflection recovery after the earthquake. And if you're looking for damage control design, you need a way to bring the structure back to its zero position. Ordinary post-tensioned, prestressed concrete that is grouted also has that advantage: cracks will close, and the structure will tend to come back to its zero position. The Japanese use grouted post-tensioned building construction a lot.

Reitherman: How has precast prestressed concrete been used in New Zealand to form moment-resisting frames?

Park: The whole column was precast, maybe as much as four stories in height. The precast beams were placed between the columns, and then the beams were post-tensioned longitudinally, with the tendons extending through the columns, anchored in a stub on the outer side of the column. That was the first application of precast concrete in frames here in New Zealand.

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38. PRESSS stands for Precast Seismic Structural Systems, a multi-year research effort funded by the National Science Foundation, the Prestressed Concrete Institute, and the Precast/Prestressed Concrete Manufacturers Association of California. See Stefano Pampanin, M. J. Nigel Priestley, S. Sritharan, "Analytical Modeling of the Seismic Behaviour of Precast Concrete Frames Designed Without Ductile Connections," *Journal of Earthquake Engineering*, vol. 5, no. 3, 2001, pp. 329-367. An overview of PRESSS is provided in: Nakaki, Suzanne, John Stanton, and S. Sritharan, "An Overview of the PRESS Five-Story Precast Test Building," *PCI Journal*. March-April, 1999.

It was looked on with suspicion in the early days. Of course, we have had no major earthquakes to provide the real tests, but I'm confident the Students Association Building, built in 1968 and the first of the type, will go through okay.

Reitherman: Have you had a campus-wide review of the buildings on the Ilam campus, since the oldest buildings were designed and constructed in the 1950s and early 60s?

Park: Oh, yes. A lot have had to be retrofitted, even some of the 1970s buildings. It's amazing how recent good seismic design is. If you look at the Kobe earthquake, those buildings designed in Japan to the new 1981 Japanese building code survived the earthquake very well, on the whole. The older buildings designed to the previous regulations often suffered bad damage. Same for the bridges. Good seismic design in reinforced concrete is a new technology—it's really only a bit more than twenty years old, which surprises a lot of people.

Reitherman: I'm unfamiliar with a term I see used here in New Zealand: "shell beam."

Park: It's simply a precast concrete beam of a U-shaped section. Basically, you place that shell between the columns, and then you fill it with reinforced concrete to form a single, composite member. The shell-beam is strong enough to act as formwork to hold itself up and carry the weight of the reinforcing and concrete placed in it. On-site labour is greatly reduced, and quality of finish is improved.

This concept has been used here for years and years, but there were some doubts about it for seismic application because of the possibility of de-bonding of the cast-in-place concrete from the shell. Also, what happens at the end? The precast beam just stops. The cast-in-place concrete, of course, continues with its reinforcing, but there is a discontinuity introduced where the shell stops. Some people felt that this caused an undesirable concentration of plastic hinging. Des Bull tested a number of shell-beams for his master's degree, using beam-column joints as found in construction here. And we found them to behave very well indeed. There was a wee bit of de-bonding, but it helped the plastic hinging along the member. So, they have been widely used here in New Zealand.

Exterior Versus Interior Moment-Resisting Frames

Reitherman: I'm vaguely aware of another seismic design philosophy tenet here in New Zealand that differs from practice elsewhere. Tell me a little bit about how you approach the design of the exterior moment-resisting frames of a building as compared to the interior ones.

Park: We tend to have a rather stiff perimeter frame around the structure—almost like a tube—and the interior framing is rather more slender. When you look at the amount of seismic force taken by the perimeter frame, you find that it is taking almost all the horizontal forces. The interior frame is primarily gravity-load-carrying. Almost all of our structures are designed that way. Sometimes, parts of the exterior frames are replaced by structural walls. Of course, I've oversimplified it a bit because the interior frame will take some lateral force based on the relative stiffness of its members to those of the outside frame.

One advantage of this is that, for the perimeter frame, the depth of the beam is not so much of a problem as it is in the interior, where deeper beams mean increasing the floor-to-floor height to achieve the necessary ceiling height. Moreover, shorter beam spans can be used in perimeter frames, thereby increasing both the lateral stiffness and strength of such frames, while relevant gravity loads lead to correspondingly reduced strength demands on the members. Also, detailing of a significant number of two-way joints is eliminated.

Reitherman: Does this also give you a torsional resistance advantage?

Park: Yes, very much so.

New Zealand Society for Earthquake Engineering

Reitherman: What was the role of the committees (I believe they're called study groups[39]), which brought the efforts of you and other researchers into collaboration with practicing engineers?

Park: The study groups of our earthquake society, the New Zealand Society for Earthquake Engineering, were comprised of structural designers, industry people, academics, and other research people. We all got together concerning a technical topic that needed to be sorted out. We talked it through and wrote design recommendations and published them as guidance reports. They formed the basis of codes of practise. Very useful, a huge success in New Zealand. We did that for buildings; we did that for bridges as well. Unfortunately, this work has slowed down a bit because, in these more commercial times, designers aren't prepared to give their time freely, as they used to. It's difficult to find the people who can find the time to do it.

Reitherman: Once things were settled at the level of the study group, then it was easy for that recommendation to become a standard throughout New Zealand?

Park: Very easy. Because all the best people worked on it. Well, we are a small country, and it has advantages sometimes. You can get a hand-picked group of a dozen or so people in one room who are the best people in the country on that topic—design engineers, researchers, industry people, and so on. The study group reports were not really challenged. The 1982 New Zealand reinforced concrete code, which was seen as a pioneering code, was actually based on the reports of these study groups. I chaired the committee on ductile frame design that prepared some of those reports. It was a wonderful time, very innovative. I think Tom would agree it was the most exciting time, because it was bringing in the research that was going on in the university and developing it and getting consensus from the profession as to what was sensible and what wasn't. There were some very good people in the profession at that time like John Hollings, Keith Williamson, Latham Andrews, and others. Yes, a very productive time.

39. The first study group of the New Zealand Society for Earthquake Engineering was established in the same year the organization was founded, 1968, and was on the subject of the seismic resistance of prestressed concrete. See "Leading Article," *Bulletin of the New Zealand Society for Earthquake Engineering*. Vol. 1, no. 1, June-July 1968.

Efficiently Developing and Implementing Codes

Park: You have huge resources in the U.S. for research, of course. A little country like New Zealand really can't compete on that field. We've got where we are mainly by having a small cluster of highly informed professional engineers and some good academics who have pushed things along. That's been our secret, actually. Smallness has been a help, in a way, even though resources have been lacking here.

Reitherman: Has the Ministry of Works declined as a funding source?

Park: It's gone. There was a time when the consulting engineers were peeved that the Ministry of Works was getting the major engineering jobs in New Zealand—all the public buildings and bridges. After a lot of pressuring, and with Rogernomics,[40] the Ministry was virtually put to sleep. A bit of it still survives, it's called Opus. It's been sold to Malaysia, and Kevin Thompson, a Ph.D. student of mine, is the current chief of Opus New Zealand.

There was a time when they were absolutely dominant, writing the codes for public buildings, both national and local, but now it's just a shadow of its former self. For other buildings, Standards New Zealand developed the regulations, but the Ministry of Works was very influential in that process.

I take my hat off to a fellow called Otto Glogau, the Ministry's chief structural engineer. He died in the London airport in 1980 after the Seventh World Conference on Earthquake Engineering in Istanbul. He was a great thinking man. Although there was not a lot of money available, he gave us what he could, and he was a follower of developments. He was the guy who wrote, pretty much single-handedly, the 1976 New Zealand loadings code, which had some very forward-looking ideas.

Reitherman: I see from your résumé that you were awarded the Otto Glogau Award from the New Zealand National Society for Earthquake Engineering in 1983 and 1988 for the best publication of the year.

Park: He was not a bureaucrat. He sat at his desk and read and thought a lot.

Study Group on Ductile Concrete Frames

Reitherman: Of the study groups I've read about, a prominent one seems to have been the New Zealand National Society for Earthquake Engineering Discussion Group on Seismic Design of Ductile Moment-Resisting Reinforced Concrete Frames, 1976-1977.

Park: Yes, I chaired that. A "discussion group" is the same as a "study group."

Reitherman: And then there was the influential *Seismic Design of Bridges*. Did that come from a study group?

Park: Yes. It was chaired by Hans Huizing of the Ministry of Works.

Reitherman: And then the *Recommendations for the Design and Detailing of Ductile Prestressed Concrete Frames for Seismic Loading.*

40. The Labour Party came to power in 1984. Roger Douglas, the Finance Minister, led New Zealand's economic deregulation policy.

Park: That was written by about four people, Gavin Cormack and a couple of other people, including myself.

Reitherman: And then *Use of Structural Precast Concrete in Buildings*—another study group product?

Park: Yes. That involved the Earthquake Engineering Society and also the New Zealand Concrete Society. That group was chaired by David Hopkins.

Reitherman: Concerning the 1982 NZS 3101 ("three-one-o-one"), the New Zealand Standard for the design of concrete structures, or what in the U.S. would be called a national model building code: you and Tom were key members of the committee whose purview was the seismic design part of the code, which dominated the design provisions. And I know from Tom Paulay that there were over 40 meetings—with homework assigned of course.

Park: Once our group completed its work in 1976 and 1977, there was very little discussion needed after that to implement it. It was done by a very good group of respected people who carried the day. Gordon McKenzie of the Ministry of Works was the chairman of the small group that drafted this landmark 1982 concrete code. Because of illness, I missed a number of meetings.

Reitherman: It's regarded as a historic, forward-looking development in seismic design worldwide.

Park: It's pioneering. But I must say it is based a lot on ACI—load factors and strength design procedures are based on ACI. Where it varied mainly was in the seismic provisions.

Reitherman: Besides input from the New Zealand concrete industry—the New Zealand Concrete Society, which broadened out from its original scope as New Zealand's prestressed concrete institute—has the steel industry been involved in code development?

Park: There's a Heavy Engineering Research Association, HERA, funded by the steel industry in New Zealand, which provides input to many of the steel standards.

Reitherman: How does a study group's final set of recommendations become a legal standard?

Park: A standards committee is set up and ratified by the Standards Council of New Zealand. A draft standard is written, taking into account available information. A public draft is released for comment. Input is taken. The Standards Council can then pronounce it as a standard. There's also a Building Industry Authority, BIA,[41] which ratifies the appropriate standards for design.

However, at the present time, study groups are not common in New Zealand because of the work commitments of people.

Origins of the Ruaumoko Symbol of the NZSEE and the IAEE

Reitherman: Tell me about the origin of the use of a symbol of the Maori god Ruaumoko by the New Zealand Society for Earthquake Engineering and the International Association of Earthquake Engineering.

Park: The carving itself, about two feet high, of the Maori god of volcanoes and earthquakes,

41. The BIA was subsumed into the Department of Building and Housing in 2004.

New Zealand Society for Earthquake Engineering Inc

http://www.nzsee.org.nz

The inaugural meeting of the New Zealand Society for Earthquake Engineering under the chairmanship of Latham Andrews and following activity by an interim committee of Wilf Edwards, Doug Mackenzie and Robin Shepherd, was held in rooms of the NZIE, the New Zealand Institution of Engineers (now the Institution of Professional Engineers New Zealand, IPENZ) at 8 p.m. on 8 April 1968. It attracted an audience of 40, most of whom were prominent in the science of earthquake engineering even then. Several were later to become Presidents of the Society—Andrews, Butcher, Glogau, Mackenzie, Shepherd, and others who now feature in Life Membership and Fellowship lists—also assisted in the fledgling Society's considerations. They adopted Rules and elected a Management Committee. At its first meeting, held immediately afterwards, Wilf Edwards was elected the first Chairman.

The Society's formation, its necessity, and objectives originated from the Third World Conference on Earthquake Engineering; it was promoted by an earthquake group of the Consulting Engineers' Division of NZIE, supported by the Royal Society of New Zealand. The Earthquake & War Damage Commission made the first of its grants at this time. The Management Committee introduced the *Bulletin* and set the first subscription.

The year 1971 was a landmark one for the growing Society. The first National Conference on Earthquake Engineering was held in Wellington with guest speakers Professor George Housner, President IAEE, and Professor Emilio Rosenblueth, Coordinator of Research at the National University of Mexico. The registration fee was $35. Registrations totaled 130 (including a number from overseas) and 24 papers were presented. The Earthquake & War Damage Commission (now the Earthquake Commission), assisted in sponsoring the attendance of these speakers and was then again called on to assist when a meeting in October with NZIE showed a substantial deficit.

Those early days set the pattern for the future Society: gradually increasing membership; a quarterly magazine with a deserved worldwide reputation put together by a succession of dedicated and able editors; continuing support from IPENZ and the Earthquake & War Damage Commission in financial and other fields; one or two further financial crises which hopefully are now a thing of the past; a hard working and innovative Management Committee, prepared to donate time and energy to the Society, and conveners and other members of study and related groups, giving the same; a number of successful international conferences; and, providing leadership and guidance, a series of top class Presidents.* The Society changed its name when it became incorporated at the beginning of 1999, and "National" was dropped from the name of the journal beginning with the March, 1999, vol. 32, no. 1 issue.

* Adapted from the version originally published in the June 1998 Membership List of the New Zealand National Society of Earthquake Engineering.

is in the University of Canterbury engineering library. It's very valuable, actually. It was carved by a very high-class Maori carver, Charles Tuarau. It was given to Karl Steinbrugge. You've met him of course?

Reitherman: Yes, he was the professor I studied under at Berkeley who was most responsible for my going into the earthquake engineering field, though a number of other faculty in architecture and engineering there were also inspirations. He features Ruaumoko prominently in his book, *Earthquakes, Volcanoes, and Tsunamis: An Anatomy of Hazards*[42] and has a photo of the carving right at the beginning of it. Was it when Karl was the President of the International Association of Earthquake Engineering that his interest in Ruaumoko led to it becoming a worldwide earthquake engineering symbol?

Park: Exactly. It was when the World Conference on Earthquake Engineering was held in New Zealand in 1965.[43] Karl saw this carving of Ruaumoko in the national museum in Wellington, and he got the carver to carve a replica, which he held for years. He wrote to me in 1991, a decade before he died in 2001. He said he wished it to come back to New Zealand, and would I accept it on his behalf. So, it's now on display in our engineering library at the university. I'm its keeper actually, its guardian. And I've been taking it to world earthquake engineering conferences for some years now. It was Karl who made it the logo of the International Association.

Reitherman: I remember at the Twelfth World Conference in Auckland in 2000 that the carving of Ruaumoko was featured at the opening ceremony. You presented it almost as a person, an honored person.

42. Skandia, New York, 1982.

43. This was the Third World Conference on Earthquake Engineering (3WCEE), held in Auckland and Wellington. The first was held in Berkeley in 1956, though not called the "First" at that time. The Second was in Tokyo and Kyoto, Japan in 1960.

Chapter 7

Lessons Earthquakes Teach Us

When you go out and study all these earthquakes over the years, you wonder, what's next? Or who's next?

Park: The New Zealand Society for Earthquake Engineering has in recent years sent reconnaissance teams with a mixture of disciplines to most of the major world earthquakes to write a report and learn what we can. Immensely valuable. Of course, the Earthquake Engineering Research Institute (EERI) does this all the time. David Hopkins has looked after that scheme for our Society, and currently Andrew King is in charge of it. In some earthquakes, the construction is so badly designed and constructed that we can't learn much. In other earthquakes, the lessons are more applicable to our types of construction.

Earthquakes in Chile, 1960 and 1985

Reitherman: You mentioned the 1964 Alaska earthquake previously. Let me ask you what impact some other earthquakes have had on the development of earthquake engineering. What about the huge 1960 Chile earthquake, one of the biggest earthquakes documented by modern seismology and associated with extensive damage, and also the smaller, but still very large and damaging, 1985 Chile earthquake?

Park: Soil-structure interaction is a key part of the reason many Chilean buildings have performed so well. Their seismic design philosophy is to include extensive walls. They can rock and dissipate energy at the point of contact with the ground rather than within the structure itself.

Reitherman: I called up Loring Wyllie to get some background for the interviews with you and Tom prior to coming to Christchurch, and I asked him about something I had heard him say about the 1985 earthquake and design practice in Chile. He had remarked at an EERI annual meeting that Chilean buildings had such ample amounts of shear wall—thick and long shear walls, continuous from bottom to top of the structure, providing a stiff and strong box structure. Loring had asked Rodrigo Flores once when he was in Chile how the Chilean engineers had managed to be able to use such large amounts of solid wall, when normally architects insist on minimal wall areas to have more open plans. And Flores said, "We have domesticated our architects." So, in New Zealand, have you domesticated your architects?

Park: Flores is the grand old man of earthquake engineering in Chile, and there's no doubt he has personally pushed the trend toward extensive walls and has got away with it, because they have had very good experience with that approach. Here, in New Zealand, the architect is still the king. If engineers try too hard to influence the architects and point out the problems of irregularities or lack of walls, the architect will simply go to someone else. This is why there is a limit as to how far the structural designer can go. In the architectural schools here, now there is a fair amount of earthquake engineering taught. Structural behaviour and the influence of symmetry are emphasized. Of course, the architects make up their own minds, but when you look at New Zealand buildings, on the whole, they are fairly regular, there aren't many discontinuities. But there is an unfortunate trend now back to less regular buildings.

Reitherman: This seems to be a worldwide situation. When you refer to the architect, that means the individual or collective team that has to be concerned about the overall budget, the usable floor area, fire regulations, where you're going to put the parking, and all that. So I think there are some valid reasons sometimes for apparently irrational structural arrangements. But frankly, in the U.S. in the last three or so decades with the post-modern style being in vogue, there have been some arbitrary and rather outlandish structural configurations that architectural fashion has required the structure of the building to accommodate, simply to be stylish.

Park: It happens in all countries. There are buildings in New Zealand where you can see weaknesses and the potential that they will behave badly in an earthquake.

1967 Caracas Earthquake

Reitherman: What about the 1967 Caracas earthquake—complete collapses of ten-story concrete frame buildings. That seems likely to have had an impact on design and research in New Zealand.

Park: Huge impact. Ivan Skinner was the New Zealander who went there and reported on it—very thorough report.

Reitherman: I just talked with Ivan recently to get some more background for these interviews with you and Tom. Quite a fellow—key roles in developing strong motion instruments, seismic isolation, an electrical rather than civil engineer, but I never knew he had studied the Caracas earthquake.

Park: The Macuto Sheraton was an instructive case—you know that building?

Reitherman: I read about it years after the event, that's all. I recall it was a badly damaged seaside resort.

Park: Yes. It was a tall building with walls in the upper part, but they were supported on columns at the lower levels. They were huge three-meter diameter columns, but it had very bad soft-storey damage there. I believe the building was repaired and retrofitted and is still in use. It also had a lot of nonstructural damage to concrete cladding panels. There were a number of dangerous panel failures in the 1985 Mexico City earthquake as well.

1968 Tokachi-Oki Earthquake

Reitherman: What about the 1968 Tokachi-Oki earthquake in Japan, where reinforced concrete frames with just the opposite of capacity design's strong column-weak beam design had numerous failures? They had many cases of short columns created by deep spandrels that led to this disproportion of column-beam strengths, especially in school buildings. In fact, that earthquake is usually cited as one of the more significant in calling attention to the problem of the weaker column-stronger beam condition.

Park: Yes, that damage was widely discussed in New Zealand.

1968 Inangahua Earthquake

Reitherman: The 1968 Inangahua earthquake in New Zealand was large in magnitude, a magnitude 7. What influence did it have?

Park: Not much. There were only a couple of deaths. There were some landslides and some damage to bridge bearings. But, because it occurred in such a remote area on the west coast in the South Island, it didn't really affect any significant buildings or bridges. Robin Shepherd was very much involved in writing up a report on that earthquake.

Reitherman: Robin Shepherd told me the Society was preceded by activities by a key group of New Zealanders who carried on from the momentum of the 1965 World Conference on Earthquake Engineering held in Auckland and Wellington, so I realize the Society wasn't an instant side effect of the Inangahua earthquake. In fact, I noticed recently that the Society had just barely had time to get its first *Bulletin* published before the earthquake came along, so it's Volume 2 that reports on the Inangahua earthquake. That was in the days when the journal had a buff color, before switching to green. Robin also mentioned, a few years ago at a symposium in honor of George Housner, that George played a key role in encouraging the planning committee to select New Zealand for the Third World Conference and helping to find funding. Housner was one of the first overseas members of the Society.[44]

44. Robin Shepherd made these comments as chair of the session on "Looking to the Future," at the CUREe Symposium in Honor of George Housner, October 27 and 28, 1995, Pasadena, California.

Park: The major fault line in New Zealand is the Alpine fault, going off on average about every 200 years. It's now long overdue.[45] It would affect some of the relatively small towns on that side of the island, but over on this side where there is more development, it's rather far away, a couple of hundred kilometers. But there are some other significant fault lines closer to Christchurch.

1971 San Fernando Earthquake

Reitherman: What was the first earthquake you studied in person, immediately afterward, to observe the damage or the cases of good performance?

Park: The 1971 San Fernando, California earthquake. Paul Jennings of Caltech took me around to look at the San Fernando earthquake damage. I learned a lot.

Reitherman: Penzien noted in his EERI oral history[46] that the 1940 El Centro record had some pulse in it, but it wasn't recognized at the time. It seems to be the 1971 San Fernando earthquake that brought out the near-fault, large-displacement motion phenomenon.

Park: For years and years, we primarily used the 1940 El Centro record in our research. It had a peak ground acceleration of one-third g. Then the Pacoima Dam record from 1971 appeared, with a peak over 1g. That was horrendous. That level of motion wasn't imagined in the early days.

Reitherman: In the reports on the earthquake, although there was so much severe damage to witness in the northeastern portion of the San Fernando Valley where that record was obtained—Olive View Hospital, the VA Hospital, tilt-up buildings, highway bridges—there was still a reluctance as of that time to accept that the ground motion could be so severe. For example, one judgment at the time was that the peak ground acceleration in these hard hit areas was only 40 percent g.[47] They were calibrating against the 0.33g peak value of the El Centro record as if that were near the maximum.

45. The M_w 7.2 Fiordland earthquake occurred a month after this particular interview session, on August 21, 2003.

46. *Connections, The EERI Oral History Series: Joseph Penzien*, Stanley Scott and Robert Reitherman interviewers. Earthquake Engineering Research Institute, Oakland, California, 2004.

47. "The maximum horizontal ground acceleration at this site [Sylmar Industrial Tract] is estimated at approximately 40 percent of gravity." Subcommittee on Buildings, NOAA/EERI Earthquake Investigation Committee, in *San Fernando, California, Earthquake of February 9, 1971*, National Oceanic and Atmospheric Administration, 1973, vol. I-A, p. 44. An early milestone indicating that it took most of a century for earthquake experts to realize that peak ground accelerations could reach or exceed the 1g level is Fusakichi Omori's statement about the 1906 San Francisco earthquake—in San Francisco, the peak ground acceleration was less than 1/4g and the peak ground displacement two inches. ("Preliminary Note on the Cause of the San Francisco earthquake of April 18, 1906," *Bulletin of the Imperial Earthquake Investigation Committee*, January 1907.) With many more strong motion instruments deployed in seismic regions today than a few decades ago, it is unusual, but no longer surprising or hard to believe, when maximum ground accelerations of 1g are recorded.

1976 Tangshan Earthquake

Reitherman: What about the 1976 Tangshan earthquake?

Park: I went to Tianjin University as a guest professor in 1982, and Tangshan must have been about 100 kilometers away. They took me to Tangshan, and even after half a dozen years, there was still huge damage on show. To my mind, one of the sad things is that they reckoned that the death toll was approaching a million people. But the government has claimed that it was only about a quarter of a million.

Very poor design and construction. Some examples of poor precast frames.

1985 Mexico City Earthquake

Reitherman: Were there any lessons from the 1985 Mexico City earthquake, especially with regard to concrete frames?

Park: A lot of beam-column joint failures. And there were some well-designed frames that did well. Newmark's steel frame, the Latino Americana Tower, of course rode through very well.[48]

Reitherman: You've written a couple of papers with Mario Rodriguez on the subject of bridge retrofit.[49] Did the work arise because of the lessons and motivation provided by the 1985 Mexico City earthquake?

Park: To a great degree. Mario is actually a Peruvian by origin, though now he lives in Mexico City. He came here to Canterbury on leave. We looked at an example of 1940s bridge design here in New Zealand with rather poor detailing. We looked at concrete jacketing of the concrete columns, which had been done to a lot of buildings in Mexico City after the 1985 earthquake. Now, a lot of people prefer to use steel jackets or epoxy resin, or other types of fiber jackets to reduce the cost. A large amount of research was done by the University of California at San Diego. The Japanese use a lot of carbon fiber for this kind of jacketing.

1989 Loma Prieta Earthquake

Reitherman: Did you visit the San Francisco Bay area to see the effects of the 1989 Loma Prieta earthquake?

Park: I did. The two-level Cypress Viaduct collapse in Oakland was so devastating. And on the other side of the Bay in San Francisco, the similar two-level elevated Embarcadero freeway was very close to collapsing. The beam-column joints were very badly damaged with diagonal cracking. That was a lucky escape. A bit more duration of shaking and it would have started to collapse.

Reitherman: Were there any lessons learned from the Loma Prieta earthquake with regard to these reinforced concrete failures, or by that

48. Nathan Newmark (1910-1981) was the earthquake engineering consultant on this forty-four-story office building, Torre Latinoamericana, for which Leonardo Zeevaert and Eduardo Espinoza were lead design engineers and Augusto Alvarez the architect. The first earthquake test it passed was the July 28, 1957 Mexico City earthquake, shortly after the building was completed in 1956.

49. Rodriguez, Mario and Robert Park, "Seismic Load Tests of Reinforced Concrete Columns Strengthened by Jacketing," *Proceedings of Technical Conference of the New Zealand Concrete Society*. Wairakei, September, 1990, pp. 72-83.

time was reinforced concrete design mature enough to predict these problems?

Park: Well, it wasn't ho-hum, but mostly a repetition of what had happened in other earthquakes. The Cypress Viaduct was constructed in the 1950s, when earthquake engineering was in its infancy. It had some very poor details—the way the reinforcing steel was anchored, for example. Caltrans stated that they had identified the Cypress Viaduct as vulnerable prior to the earthquake, but had yet to receive enough funding to tackle such a large retrofit project. I was contacted by some people who wished to have me testify in court against Caltrans about that Cypress failure. I was offered a big fee, too! I refused. This is one reason why innovation with precast concrete and prestressed concrete has gone ahead in New Zealand, and not in the U.S. The prevalence of lawsuits in the U.S. scares the engineers off from innovation.

1999 Turkey Earthquake

Reitherman: The 1999 Turkey earthquake again showcased, in a negative way, reinforced concrete building collapses. Were there new lessons learned in that regard, or was the damage due to causes that could have been foreseen?

Park: Mostly poor workmanship and design, with both frames and walls. Turkey has some very good engineers, but they have difficulty putting into practise their design concepts because of construction quality.

1995 Kobe Earthquake

Reitherman: From which earthquake have you learned the most?

Park: The 1995 Kobe, or Great Hanshin, earthquake. I led a New Zealand reconnaissance team of thirteen people.[50] Quite an earthquake: the difference in performance between the buildings designed to the old and new codes that I mentioned previously, the ground motions, the liquefaction, the faulting running underneath the longest suspension bridge in the world that made the towers end up farther apart.

Reitherman: A clever way to add a meter to the span record for your bridge, but a difficult method for others to duplicate. You were in charge of the New Zealand team for all aspects, not just reinforced concrete, isn't that right?

Park: Yes, we had experts in all the various areas. An earthquake like that has all kinds of effects, and in this case the problems with disaster response, as well as the engineering failures, were important. We had steel people, concrete people, and so on. For example, we had André Filiatrault for timber.

Reitherman: I talked to André about that experience. He said that when he joined up with your team, he was given a set of maps and a packet of already compiled data from various sources. He was very impressed. He said, "If you want to know how to investigate an earthquake, ask Bob Park and the New Zealanders."

50. Park, Robert, et al., "The Hyogo-ken Nanbu Earthquake (The Great Hanshin Earthquake) of 17 January 1995. Report of the NZNSEE Reconnaissance Team," *Bulletin of the New Zealand National Society for Earthquake Engineering*. Vol. 28, no. 1, March 1995, pp. 1-98.

Park: We came back with engineering lessons. We also emphasized the need for better emergency planning and response. This responsibility has now been given high priority by a government ministry in New Zealand. One of my former master's students, John Norton, is now in charge of emergency response.

What's Next? Or *Who's* Next?

Park: When you go out and study all these earthquakes over the years, you wonder, what's next? Or *who's* next? If you look at Hong Kong, you see that it is at least moderately seismic, but they don't design for earthquakes. They design for huge wind forces, which can be significant for the taller structures, but there are a large number of middle-height and lower buildings that should have seismic design.

Reitherman: Do the design wind forces give the buildings strength but not ductility?

Park: Exactly. And also, wind design doesn't concentrate on good structural concepts, such as avoiding soft stories. Soft stories are very common in Hong Kong. That's okay for wind forces, where you can get by with strength, but not for seismic.

Reitherman: Almost the inverse of capacity design—accidentally designing the failure to occur exactly where you do not want it.

Park: It's repeated in earthquake after earthquake—soft storey failures of columns leading to collapse of the building.

Chapter 8

Current Work, Future Hopes

Unification is my dream, sorting out the world's codes and making them consistent.

Reitherman: Tell me about your current work with "fib" (Fédération Internationale du Béton), also called the International Federation for Structural Concrete.

Park: For the fib, I've just finished chairing a committee that has produced a report on the use of precast concrete in buildings designed for seismic resistance, with over 30 contributors from eight different countries.[51] A bit of a handful to chair. I'm sure it will set an international standard. Also, the Eurocode 8 has a very good section on the use of precast concrete.

We set up fib task groups to look at various things, and one I am chairing is a critical comparison of major seismic codes for concrete buildings. We meet about twice a year. It has people from the U.S. like S.K. Ghosh, Jack Moehle, and Joe Maffei on it. We're going to do a critical comparison of the major international seismic codes. We'll compare codes from the U.S., Canada, New Zealand, Japan, Eurocode 8, and Central and South America, and we'll compare them down the line.

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51. "Seismic Design of Precast Concrete Building Structures: State-of-the-Art Report." fib, Lausanne, Switzerland. Bulletin 27, 2003.

On the demand side, there are loadings and drift, and on the capacity side there is strength of sections and ductility and so on. There are some glaring differences between codes still. We're going to try to see where the major differences lie. It's a very ambitious project.

Reitherman: Do you think that from this comparison will come unification?

Park: Unification is my dream, sorting out the world's codes and making them consistent. It's very hard to budge code committees. You know how entrenched people get. Obviously, there will be some criticism of current codes in the results. Hopefully, some unification may result. The New Zealand code has already had some influence on the Europeans, more so than in the U.S. EC8, the seismic code of the European Commission, has a lot of New Zealand material in it. It has embraced capacity design, for example. This comparison will be quite helpful.

Reitherman: Any more comments on current developments?

Park: The big change that is coming in seismic design is the adoption of displacement-based design. This will require a change in mindset away from force-based design. Displacement-based design will mean designing for a chosen interstorey drift. This will permit performance-based design to be more easily introduced, so that designers will be able to limit damage to acceptable levels for various degrees of earthquake intensity and the importance of the structure.

Photographs

Bob Park, 1991.

Bob Park's paternal grandfather, the Crown Prosecutor for Westland, South Island, New Zealand.

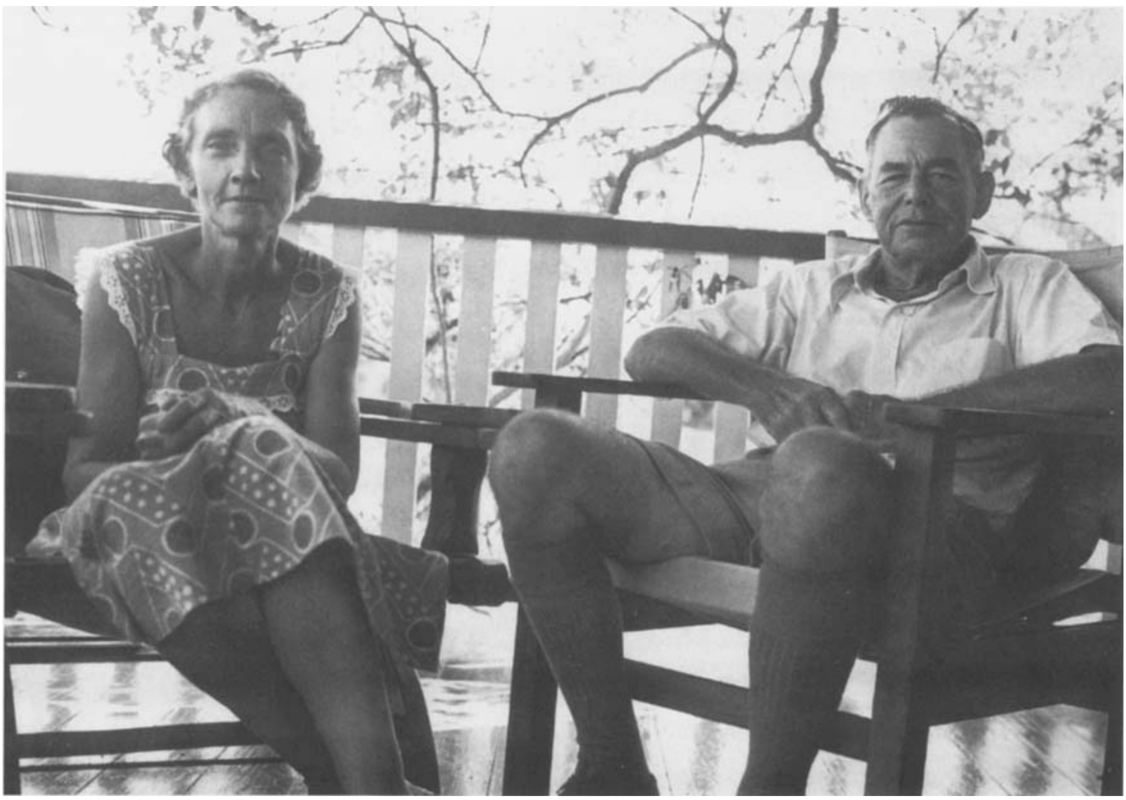
Bob Park's father, James Stobie McIntyre Park, in military uniform during the First World War.

Bob Park as a young child in Fiji.

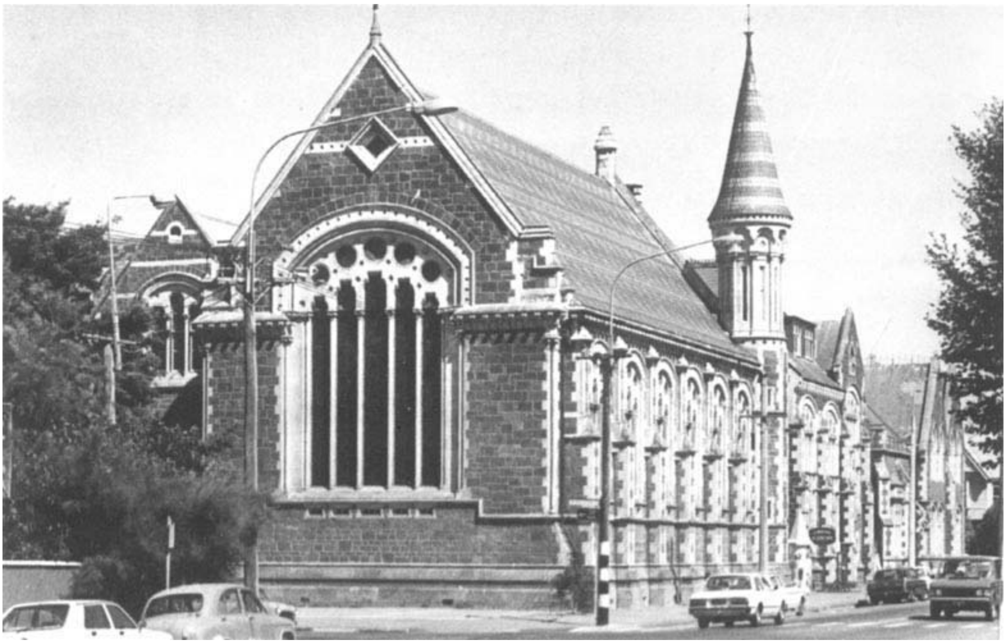
Above: The Park family home in Nadi, Fiji.

Left: Bob Park as a young child with his father in Fiji.

Below: Bob Park's mother and father, Loma and James, on the veranda of the family home in Nadi, Fiji.



Bob Park studying as an undergraduate student in the 1950s. A slide rule is next to his right arm.



The Great Hall at the University of Canterbury's former site, now part of the Arts Centre.

A scene today at the Arts Centre of a building formerly used by the University of Canterbury for engineering classes. Harry Hopkins occupied the office with the oriel window in the upper story,

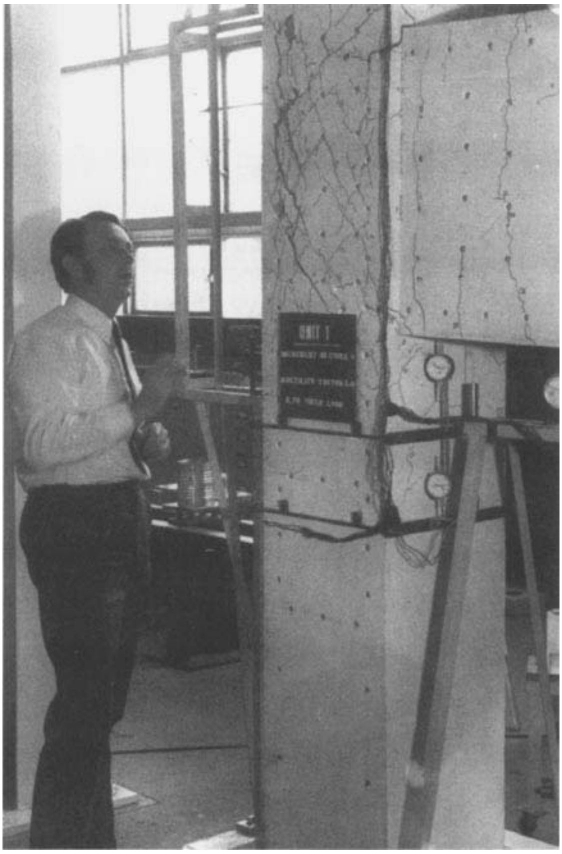
The view today across the courtyard of the Arts Centre to the Great Hall, from the office formerly occupied by Harry Hopkins.

A 1959 view of the Structures Laboratory on the former University of Canterbury site, which was housed in a pre-fabricated hut of Second World War origin.

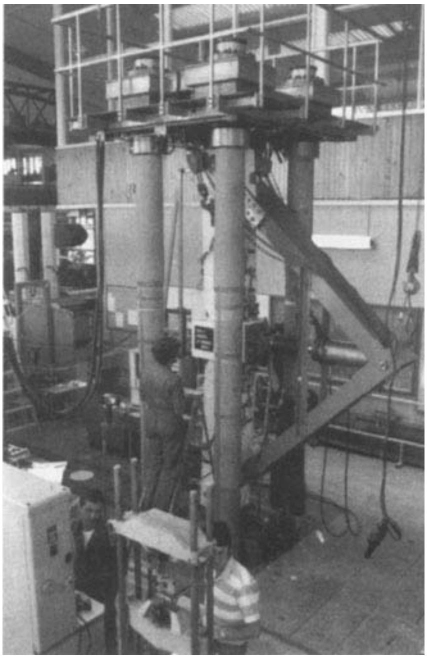
A view today of some of the engineering buildings at the University of Canterbury at Ilam.

Portrait of Harry Hopkins by William Sutton, which hangs in the engineering school at the University of Canterbury, with Bob Park left and David Hopkins, son of Harry, at right. The Pont du Gard in the portrait reflects Hopkins' love of the structural engineering principles that can be learned from a study of bridges, which he documented in his book, A Span of Bridges. *The water tower that Hopkins designed for the hydraulics laboratory at the Ilam campus is a symbol of his role as head of the Civil Engineering Department at the university when it began its ascendancy.*

Professor Harry Hopkins.

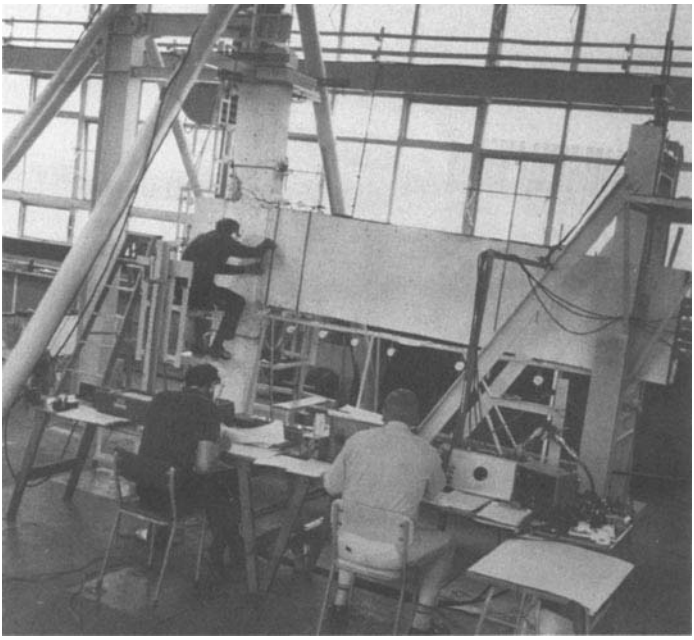


Bob Park with a beam-to-exterior-column joint after seismic load testing at Ilam.



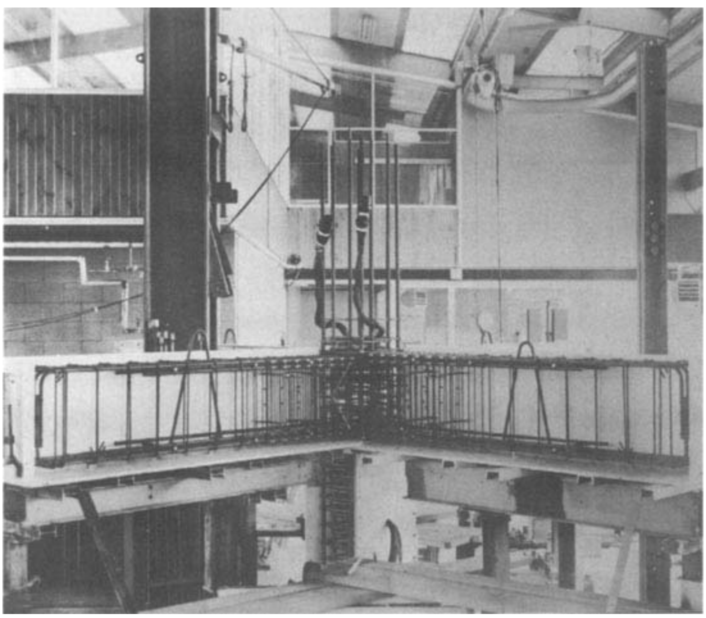
Reinforced concrete column under seismic load testing using the Dartec machine at Ilam.

Full-scale test at Ilam in the late 1960s of a precast, prestressed concrete beam-column joint with the beam post-tensioned to make the connections to the columns. This was a specimen representative of the Students Association Building, University of Canterbury. From left to right: Jim Sheard, technician; Roger Blakeley, Ph.D. student; Ken Marion, technician.



A current view of the Students Association Building, University of Canterbury.

Expression of prestressing anchorage in a frame of the Students Association Building, University of Canterbury.



A reinforced concrete column and beams being constructed in the laboratory at the University of Canterbury in the 1960s so they can be subjected to two-way simulated seismic loading.

Test set-up for full-scale seismic loading of a precast concrete, hollow core diaphragm and its related concrete structural components at the University of Canterbury, 2003.

Ruaumoko, the Maori god of volcanoes and earthquakes, is the logo of the International Association for Earthquake Engineering and the New Zealand Society for Earthquake Engineering. The Ruaumoko carving is signed on the bottom by Charles Tuarau, Chief Maori Carver, Dominion Museum, Wellington, May 22, 1970.

The carving of Ruaumoko was introduced by Bob Park at the opening ceremony of the Thirteenth World Conference on Earthquake Engineering in 2004 in Vancouver, Canada. From left to right are Sheldon Cherry, Luis Esteva, Bob Park, and Tsuneo Katayama.

Bob Park sailing on Lake Travis, in Austin, Texas on a visit to the University of Texas.

Bob Park and his family in front of a portrait of Queen Elizabeth at Government House, Wellington, in 1995 when he became an Officer of the Civil Division of the Most Excellent Order of the British Empire (OBE). Left to right: Shirley, wife of son Brendon, who is holding their daughter, Sandra; Kathy and Bob Park; son Robert with his wife Jacky. Not pictured are the Parks' other grandchildren, Moira, Jacky, and Tony.

Bob Park with his second wife, Pauline, in the summer of 2004.

CONNECTIONS

Thomas Paulay

Chapter 1

Growing up in Hungary

I was born in my grandmother's house in Sopron, a small town in Hungary. The house was about 400 years old. I always used to tease my grandmother that the plumbing was of that age also.

Reitherman: Tom Paulay and I are at his home in Christchurch, New Zealand in July 2003, a few days before the Paulay and Park Symposium.[52] I know that your early years in Hungary will figure prominently in this oral history, so correct me if I'm wrong in noting for the record that your last name is properly pronounced "Pole'–ay" and the Hungarian spelling of your first name was Tamás. Now, let's begin with when and where you were born.

Family Home in Sopron, Hungary

Paulay: I was born on May 26 in 1923 in Hungary, only about five miles from the Hungarian-Austrian border. This

52. Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park. University of Canterbury, Christchurch, New Zealand, July 11, 2003.

region of Hungary was for over 400 years an integral part of the Austro-Hungarian Empire. Even though the Austro-Hungarian Empire was dissolved in the Paris treaties after 1918, five years before I was born, I was a product of it. Because the town where I was born and grew up, Sopron, was so close to Austria, the Austrian influence, and the use of the German language, were prominent. The farther you went to the east in Hungary, the less people spoke German. Sopron was established over 2,000 years ago by the Romans, and a few remnants of Roman construction are still there.

Reitherman: Have you ever been back to Sopron?

Paulay: Yes. I was forced to escape from communist Hungary in the time of Joseph Stalin, in 1948. I had some interesting moments avoiding capture while passing through Sopron. Then, mainly because of the Iron Curtain, I could not return for twenty years. But that's another story. In 1968, when I was able to return to visit my mother, it was a very emotional experience. I had left behind my widowed mother, and I was her only child.

Reitherman: When you were able to return to Hungary, did you go to the house where you grew up? Was it still there?

Paulay: Yes. Taking the train from Vienna, we crossed into Hungary. The border, where the train stopped, was fenced off with barbed wire. The guards came and stood on the steps of each of the carriages. I had obtained special permission to visit my mother, and I was temporarily "forgiven" for having escaped from the glorious Communist People's Republic.

In 1947, after the war, the family villa was confiscated by the communists, and it was converted into a school of music. When I visited Sopron years after I had escaped Hungary, I went sometimes to the family house. I remember the caretaker appointed by the party saying, "What are you doing here?" I replied that I was just looking at this nice old building. "What do you want?" I don't want anything, I just want to look at this old family house, I said. "You wouldn't be by any chance one of those who used to live here?" I said yes, and he had an embarrassed look on his face. The years after World War II were difficult ones for Hungary.

Reitherman: Were you actually born in your family's house, or in a hospital?

Paulay: I was born in my paternal grandmother's house in Sopron. The house was about 400 years old. I always used to tease my grandmother that the plumbing was of that age also.

On an old map of Sopron, one can see the pattern of the medieval wall around the town centre. The family garden was next to a part of the old wall. We were very proud of it. We kept about 40 yards of the old town wall preserved.

Reitherman: What were your father's and mother's names?

Paulay: My mother's maiden name was Margaret, or Margit in Hungarian, Scholz. My father was named George (György) Paulay. He was a lovely man. I adored him. He was a rather handsome man. If you look over there, you'll see him in that portrait painting on the wall.

Reitherman: The man in uniform, with a sword?

Paulay: Continuing the old traditions of the Austro-Hungarian Empire, all officers carried a sword, for ornamental purposes. The way you can tell he was in the cavalry is those three silver stars with the gold background on his collar, showing his rank as colonel, behind which is a little bit of light blue, the colour of the cavalry.

My father's father was a German who was born near Frankfurt on the River Main. He was in partnership in a firm that made leather goods. He did quite well. My paternal grandfather had to travel around in Germany and elsewhere in Europe and show his products, so he often went to Vienna to sell these leather goods. In Vienna was a little haberdashery, owned by the family of the woman who was to be my paternal grandmother. That's where my grandmother worked and where they got to know each other, and so they married. My grandmother was Viennese.

They settled down near Frankfurt, where the factory was, and had three children. He had first two boys. My paternal grandfather badly wanted also a girl. When the girl was born, they rushed to report to him—it is a girl! And he was so excited that he died on the spot. A few days later, from the hospital where my grandmother was still recovering from delivering the baby, the baby who is my much-loved aunt, she watched the hearse pass by, taking her deceased husband to the cemetery.

Reitherman: What a tragedy! Such sadness!

Paulay: She decided to leave and return to her family in Vienna. The partner bought out the business. My grandmother had with her three little children: seven years old, five years old, and two or three months old.

Reitherman: And one of those three children was your father?

Paulay: Yes, the oldest. A few years later, my paternal grandmother met another man and married him. That man was Hungarian, a captain of the infantry. That's where the Hungarian influence started and those children, including my father, grew up being able to speak also Hungarian. At that point, there was no Hungarian blood per se in my parents' families. The two sons, my father and his younger brother, had military training and both became officers, one in the cavalry, one in the artillery, where at least half the regiment were pure Hungarian.

When World War I came to an end, the victorious powers decided to abolish the old Empire; the Austro-Hungarian Empire was gone. Hungary became an independent country, a kingdom. However, it could not find a king.

By that time, my father was so attached to the regiment that was dominated by Hungarians that he and his younger brother decided to settle down in Hungary. They were both accepted in the new Hungarian Army. My father was posted in about 1920 to a small town—Sopron—where he got to know a local girl. In 1922, they married, and I was born in due course.

Reitherman: And you were their only child?

Paulay: Yes.

Reitherman: What do you remember very early on? Can you remember your very first schooling, when you were perhaps four or five years old.

Paulay: Well, Hungary was in a bad shape, but so was the rest of Europe—it was recovering from World War I. Especially when you recover in a country that has lost a war. With the disappearance of the 400 years of Empire, it was tough. The Hungarians didn't know much about democracy. It was a benevolent kingdom, guided by a regent, an admiral of the former empire, without any experience in politics. Hungary was a bankrupt country run according to the peace treaty of World War I, a country that had a small army. The pay was pretty miserable for my father. But if your father was an officer in the Hungarian Army, or a merchant, or in business, you belonged to the middle class of society, as opposed to being a small farmer or the laboring class of society, who had it much more difficult. Nothing shows it better than the fact that when I went to a primary school that was run by the state, in the summer, half the boys came to school barefoot. It wasn't that they didn't have any shoes, but shoes were expensive, and they had to be saved for the winter when in the snow you must wear your shoes.

I had four years in the primary school there. It was interesting that the city and the western part of Hungary still kept some traditions of the Empire. The Austro-Hungarian Empire had seven major nationalities bound within it, and the German-speaking Austrians were the influential group. German, as a compulsory second language, was introduced from the first day in primary school.

Reitherman: At age eleven you started military school. Was that when you realized you wanted to have a military career?

Setting Out to be a Cavalry Officer

Paulay: Already at a very young age, about five or six, I knew I wanted to be a soldier. I had my father as a model. He was a wonderful man, and I was his only son, he loved me dearly and I felt it, and we had a lot of time together. Of course, since he was in the army, his housing accommodation, a fairly nice apartment, was in the military quarters. I grew up, most of the time, in the military barracks of the cavalry. I saw the horses, I saw the band every now and then, a military band, the change of the guards, the parades, and, you know, for a young boy, this was all wonderful.

I knew I wanted to be a cavalry officer like my father, and he said, "Well my boy, it's rather difficult for you to be in the cavalry." "Why?" I asked. "Well, you are too skinny—they won't take you. And I know why you're skinny—because you tell your mother you don't like spinach. If you want to be big and strong, do like Popeye." I just enjoyed listening to him. He had spent the entire four years, from 1914 to 1918, fighting the Russians. He was very good at describing the human features of the war, what a dreadful thing war is, dreadful that people shoot each other. But when World War I started, it still appeared to be a "gentleman's war." The Emperor of the Austro-Hungarian Empire, Franz Joseph, entered the war without really an emotional call to hate the other side.

Reitherman: I know the years you spent as an officer in the Hungarian cavalry in World War II are a significant and interesting part of your life, so let me ask some more details now about your father and the military. What was your father's rank?

Paulay: He started off in World War I as a second lieutenant, and by 1918 he was promoted to a captain. He was wounded, but luckily he survived. As you can see in his portrait, there are medals for bravery and what in the United States is called a Purple Heart. He died at age fifty-one a few weeks before his planned retirement as a general.

Learning to Ride

Reitherman: So you rode a cavalry horse at a very early age. Do you remember about how old you were when you first rode?

Paulay: I was exactly seven years old. My father said in a military way, "The time has come, my boy, to get on a horse." And he was a perfectionist. He said, "I'm going to teach my boy *proper* horse riding." He trained me slowly, with great patience. My father shouted for the horse to canter, and, no matter what I did, the horse cantered. The horse taught me. And oh, I remember, I was very excited and enjoyed it, and I can still see from a long distance a seven-year-old boy sitting on a fully grown cavalry horse. The ground, where I would occasionally fall, seemed so far below me. I never learned on a pony. I was pretty good at running around and jumping over the little hurdles. Eighteen months after my father put me on one of the cavalry horses and started to train me to ride, he said, "From tomorrow, you are allowed to use stirrups. You're not doing too badly, you might even make it in the cavalry."

Reitherman: You learned to ride without stirrups?

Paulay: For the first year and a half. You have got to get your balance. An added influence in my training to ride horses was my father's younger brother, Hartmann, who was two years younger, who became for several years Hungarian champion at jumping. When he left Hungary and immigrated in 1947 to the United States, he was quickly accepted in the U.S. equestrian Olympic team and competed in the 1952 Helsinki Olympics. His last performance was at the age of about seventy.

Reitherman: The next step after primary school was what might be called intermediate or middle school through high school. Tell me about that.

Paulay: After the war, around 1920, there were two schools in the country established by the defence ministry for boys who were orphans, boys whose fathers were killed in action in World War I. It was a very nice conception of the Hungarian government, based partly on traditions. The government gave them the same education as in any other state or private school—mathematics, physics, languages—but it was in a military environment, a boarding school, funded entirely by the state, providing food, clothing, and so on. The premise was that after eight years of this education, the country should have some dedicated young men willing to become officers in the military.

I wasn't an orphan. By the time I was eleven, they had run out of orphans from World War I. It was because my father was a decorated officer, that I, like most of my classmates, was admitted in 1933. I spent the next eight years in such a school in Sopron, boarding with children from all over the country, about 300 of us. At the end of each year, we had to sit our examinations as in any other school, examinations specified by the ministry of education. Physics, mathematics, chemistry, geometry, German, French or Italian, with extensive sport—even though if you were going to be in the cavalry you might think you only need a stable behind! I benefited considerably from the science-oriented syllabus later, when I embarked on my engineering studies, though unfortunately, English was not taught.

There was half a cavalry regiment there in Sopron where my father served, and the army was pretty tolerant and let him serve there for sixteen years, in the town where his wife was from, where his son was going to school.

Going to Military School

Reitherman: What was your schooling like, in your years from eleven to eighteen?

Paulay: I had good preparation for science-oriented university studies. A major feature of that school, which clearly remains in my memory, was the relationships and the friendships which develop among classmates. We knew that we lived in a very difficult period of history. Europe was building up for another war. We realized that with the emergency of having Mussolini and Hitler in our immediate neighborhood, we, little poor Hungary, could be swallowed up in a major cataclysm. At the end of World War I, and after the Austro-Hungarian Empire was broken up, Hungary lost two-thirds of its territories, and one-third of its population. Hungarians sometimes were the minority in some parts of a country, even though they had lived there for a thousand years. France and Britain did not worry about the Austro-Hungarian Empire breaking up. I think history showed it was a mistake: Hitler might never have come to dominating Europe. We went to school as boys, knowing we would get involved in a war.

Of my classmates from the cadet school, a fourth were later killed in action in World War II. The survivors of my class are scattered around the world. About five or six of those I started with in that school more than seventy years ago live in Hungary now. They meet every third Thursday in a small restaurant in Budapest, and on each occasion, after a glass of beer, they send me a post card.

Reitherman: Every month—seventy years later!

Paulay: Every month! I would like to attend, but I can't be there bodily. When special anniversary reunions are held in Budapest, I send them a little money, and I want a place to be set for me, with my name. I was rather touched by the card they sent me after the fortieth anniversary celebration of our graduation at that school. It told me that I would be surprised to learn that during the dinner, with my name displayed, I was "seated" at the head of the table.

Royal Hungarian Military Academy

Paulay: If you qualified on your examinations, at eighteen you were admitted to the Royal Hungarian Military Academy in Budapest, where in four years of college you were trained to be a commissioned officer. It was still called the Royal Academy, even though, as I mentioned earlier, there was no king at that time. The Academy is similar to West Point in the United States. In 1941, when I was eighteen, I finished my high school, and three months later I reported to the Military Academy.

Reitherman: Because World War II was already underway in Europe, your class at the Royal Hungarian Military Academy was called up early?

Paulay: Yes. The war started in 1939, when Germany invaded Poland. In 1941, Hitler decided to attack the Soviet Union after earlier attacks on France, Britain, and a number of smaller countries in Western Europe. I don't like to bring up that name, Hitler. Unfortunately, the government of Hungary decided in 1941 to join Germany in the war against the Soviet Union. As I see it now, this was a fatal mistake. However, a decision to remain neutral, leading almost certainly to an early occupation of Hungary by Germany, would most probably have resulted in an equally dramatic, if not even greater, catastrophe. When our boundaries were redrawn after 1918, there were about five and a half million Hungarians living as minorities in the neighboring countries. Many of them were treated as second-class citizens. Between the two wars, Hungary was striving to reunite those people with the mother country. Benito Mussolini was sympathetic and also influenced Hitler. Their message perceived by us was: join us now and after our total victory your boundaries will be radically changed and will then include your former citizens. Patriotic emotions of an uninformed society, including those young ones determined to serve their country within the army, fueled the support of the majority at that time for this tragic decision.

Chapter 2

In the Army During the Second World War

So I found myself, at the age of twenty-one, in charge of 283 men and 308 horses. It dawned on me later that I was still a kid.

Paulay: So, Hungary went to war. I graduated from the Royal Hungarian Military Academy in 1943, and on that day, August 20, I was a second lieutenant in the army.

Reitherman: How old were you at that point?

Paulay: Just past twenty. I became a grown-up boy, in a serious military uniform, and with a serious military job. One year later, in June 1944, twenty-four thousand men, and fourteen thousand horses of the Hungarian cavalry division were sent to fight on the Russian front. I was in the war, with my squadron, which had six officers: a captain in charge, and four other officers beside myself, all older men called up on reserve. I was second in command. I was the third cavalry officer from the Academy since World War I to graduate with distinction. But that was a school, and this was a war. My perceived reputation far exceeded my abilities.

A few weeks later, we went into battle and my captain and two other officers out of the original six, along with dozens of our men, were killed, and I was suddenly in command. I had some small-sized shrapnel penetrate to my lungs. But I was surrounded by the Russians, so they couldn't take me away to a hospital. I was found by a German tank. A German had a look at the holes, and put some plaster on me. It was a miracle that I was not infected. You know, normally when shrapnel goes through dirty clothes and penetrates you, it introduces germs. My men put me in a little hand-drawn cart and carted me into the bush for cover. Three weeks later, my wounds had healed.

So I found myself, at the age of twenty-one, in charge of 283 men and 308 horses. It dawned on me later that I was still a kid. Perhaps a few soldiers were eighteen and nineteen, but by and large, I was the youngest. But this young kid—me—was the boss. I would order a sergeant to go up a hill and see where the Russians were, and as he went it occurred to me that he had three little kids at home.

Reitherman: You were in the same cavalry regiment as your father had been, is that correct?

Paulay: Yes. It saddened me that he had died suddenly in 1942 and did not see the commissioning of his only son. I was in the same regiment, Number Three, named after an old cavalry regiment of the seventeenth century. That gave me extra strength, the tradition. A lot of my fellow officers felt the same way. Their fathers had been in that regiment, or an uncle had been there, or another uncle died in a battle. It was a bunch of superb gentlemen. You would laugh now at the regimental commander. He would say: "Tom, I'm sorry to bother you, but there's a bit of a problem in this area. Would you be kind enough to deal with those Russian tanks? And Tom, please watch out that you don't get blown to bits." I found such orders five times more binding than if he had spoken in strict compliance with military specifications.

Fighting in the Hungarian Cavalry

Reitherman: How did your cavalry, a branch of the military going back to ancient times, fight in the Second World War?

Paulay: Now don't mix it up with those movies showing the old times with people in very smart, colourful uniforms, charging around on their horses and swinging their sabers. The plain truth is that our cavalry in World War II was mounted infantry. The horse was a means of transport. You don't actually fight on horseback against tanks and machine guns.

Reitherman: Where were you fighting?

Paulay: We were ordered to the Pripet Marshes, the largest swamp region of Europe. The Pripet is a tributary to the Dnieper River. It's a huge, boggy, wooded area, now in Belarus and the Ukraine, about 600 kilometers east-west, and about 250 north-south, that had one single road in the middle going east-west and another going north-south. Twelve-inch-wide wooden planks, placed on the top of a loose sand embankment, enabled the road to be used by motorized vehicles.

The job of our regiment was to guard a major highway at the northern edge of this swamp, where the Russians were sending their tanks. The tanks had to pretty much stick to the highway because of the soft ground elsewhere. At most, about six of them could line up abreast to face us. If a tank went off onto the soft ground, half an hour later there would just be bubbles.

We would quickly go in and blow up bridges, which slowed their progress. By that time, it was a general retreat from the battle of Stalingrad in 1942, so our job was really to cover the retreat of the German Army in that region. We would move quickly on horseback, dismount somewhere among the little hills. The horses were hidden in the forest while we could fire on the Russians and their tanks with anti-tank guns. We couldn't stop them completely, but by the time they could move around our flanks, we would sound the whistle, call up on the radio, get the horses out of the forest. The horses that were being kept two miles behind us were brought up. Hop on the horses and disappear. Ride twenty-four hours back, find another river, blow up the bridge, dig in again, hide the horses. Stop the advancement of the Soviet troops on the sole highway in this region, hold out till they found our unprotected flanks, then call up the horses and quickly retreat again.

One-quarter of our men did nothing else but hold horses. It was quite a job, you know. A man would sit on his horse, and he had two on his right, and one on his left. And when our little radio message said "Come on squadron number one to this point, squadron two go here or there," these men would be pretty busy in the bog, leading their own horses, and keeping control over the others.

Reitherman: Handling four horses must have been a challenge.

Paulay: Everyone was busy tending to their jobs. And then coming out of the sky, were two small Soviet fighter planes. The horses were totally defenceless. By that time, the German air force had lost its superiority. I radioed for my 300 horses, and I was told that we had lost 100 of them—aircraft had machine-gunned them. So we had to walk. By about three months' time, many of my men were marching.

Reitherman: Did you usually have one particular horse assigned to you?

Paulay: Yes. As an officer I had my own personal horse. All officers had their own horses. You had the privilege to go around the regiment, look at the horses, and you could pick one you liked. It goes to my heart to think of that horse, a wonderful, wonderful horse. You know that horses, when they are together, act like a herd. Now this horse of mine, seven years old, got on so well with me that he behaved more like a pet dog than a horse. I walked around my men and horses when we had regrouped in the woods to check everything, and, while all the other horses kept together, my horse followed me wherever I went. Whenever I needed him, I could just reach for him. If I slept under a tree, he slept next to me on the ground. He would wake me up. He would start to lick me. He was saying, "Oh, hello there, good morning, now get up and let's get going." He was lightly wounded several times.

Reitherman: What kind of horses did you have, and what was your horse's name?

Paulay: My horse's name was Leader. The Hungarian name for him was Vezér. I told you my uncle was a famous horse rider. He won many international competitions. Here's one of his trophies, a statuette of an Arab thoroughbred [taking a silver statuette of a horse off a shelf in his living room]. It's a beautiful piece of work. That symbolizes my past and my affinity with horses. It was originally on a wooden pedestal, which disintegrated, and I attached it to the new greenstone base, from New Zealand. Greenstone, or jade, is very hard—not as hard as diamond but very hard. I had to drill holes for screws in the veins of the softer part of the rock. We're still talking about horses! You can see at this rate, we'll be here another two weeks!

Reitherman: Okay, we'll continue with your experiences in the war and move on to your rise to prominence in the earthquake engineering field after the war, but readers will be interested in these details of your personal life.

Wounded a Second Time

Paulay: My next injury was when I was ordered to the defence of the capital city of Poland, Warsaw. Most of Warsaw is on the western side of the Wisla, or Wistula, or Vistula River, and a much smaller part is on the other side. This district was called Praga. With one German division on either side of the Hungarian cavalry division, a bridgehead around Praga was formed. Because I spoke German, the divisional commander said, "Tom, you will be on the left flank, and make sure there is effective communication with the German troops."

The Germans took me for an informative walk of about a mile in those trenches. I counted about 250 Russian tanks in front of them, already destroyed. I was informed that the Russians would not take prisoners—they would kill you. The Hungarian army was fighting according to the recognized rules of warfare. There was not a single event in my brief service in the Second World War for which I today should be ashamed. I lost some of my own men because I ordered them to retrieve under fire some of the Russian wounded. They became exhausted, and in the process of saving Russian lives, they were killed.

At the end of August 1944, my squadron was dug in, some eight miles from downtown Warsaw on the other side of the River Vistula, in extremely well prepared trenches with shelters. Moreover, it was also protected by thousands of touch mines and some 500 anti-tank mines. For some two hours in the morning, about 150 pieces of German artillery would bombard, over our positions, the Soviet troops facing us. Then they would turn the guns around 180 degrees to shell for two hours downtown Warsaw. At the beginning of August, the Poles staged their heroic uprising in the capital city against the Germans. This was in the hope that the fast-approaching Soviet troops would liberate Warsaw within days. There is overwhelming evidence now that Stalin decided to allow the German troops to crush the Polish uprising before advancing to the city. Recently, Polish people all over the world, including New Zealand, commemorated the sixtieth anniversary of this tragic event in which 250,000 Poles lost their lives in the city.

For us Hungarians, this presented an extraordinary situation. For hundreds of years there was an empathy between the people of Poland and Hungary, stronger than to any other of our neighbors. The preservation of these mutual feelings during those days of conflict is part of my memories. After sunset, I often encountered nearby leaders of the Polish underground forces. They visited me, always bringing a bottle of strong drink, and we would discuss for hours the looming tragedy of Poland. The underground fought the Germans fiercely, yet many realized that after a Russian victory, Stalin would eliminate those dreaming of a free Poland that could embrace a western-style democracy.

I was in the bridgehead at Warsaw about two weeks when the Russians broke through. In a counter-attack, I was wounded. It was in September of 1944. It was a very light gunshot injury, but it came close to killing me on the spot. I conducted the counter-attack of my men. Their spirit was not very good and I needed to personally lead them into battle. I more or less did the stupid thing. Hanging from my neck I carried a plastic bag in which I kept my map. For the Russians, this was a sunlit target. A 20-mm (three-quarter-inch diameter) high-velocity explosive bullet, fired from a rather long heavy rifle, took a bit of flesh from near my left shoulder. Because it missed hitting bone by five millimeters, it passed right through and exploded fifteen yards behind me when it hit the earth.

Reitherman: This was the second time you were wounded in the war. Then what happened?

Paulay: They picked me up and took me to a little military hospital in Poland. I had an experience there where I was totally embarrassed. I was a shy young man. And I was given a bath…by a beautiful, smashing blonde nurse. She kept telling me to relax. Washing my hair, she also told me that I had lice.

Two or three days later they packed me into a train and I was sent back to Hungary, and then eventually back to Sopron where several schools had been converted into hospitals. I was able to see my mother there, who worked voluntarily for military hospitals. I spent close to three months there to get recovered. The witnessing of MASH-type surgery performed on much more seriously wounded Hungarian soldiers haunted me during my subsequent involvement in the field.

Then, I was out of the hospital in November 1944, and I volunteered immediately and was back in action again. It's part of the old cavalry spirit—I wanted to rejoin my regiment. Not because I thought we would win the war—we wouldn't. But I realized that it was not my decision whether to stop fighting or not. I perceived a sincere obligation and desire to join my buddies in the trenches, in the mud, for a totally lost cause.

Wounded a Third Time

Paulay: When I was released from the hospital, it was the very end of 1944. By that time of the war, more than half of Hungary was occupied by the Russian Army. I was given a relatively small unit, 192 men, six officers. After seventeen days of battles, I was the only officer alive, and sixteen men were left. I was dug in, using a little farm building as a place from which to fire our machine gun. And then it was hit by an artillery shell, and the whole thing collapsed. Luckily, I only got a squeeze of the chest and a back injury when the building collapsed on me, and I wasn't blown up. I had some paralysis of my legs for some time, but I recovered. Some deafness from the blast has stayed with me to this day. So now I was back in the hospital for another three months. Eventually, I ended up back at the same hospital in Sopron, and they said, "So Tom, you want your old bed back again, do you?" The bright side of being wounded another time was to see the many kind nurses again!

Reitherman: We're now up to the end of 1944, and the war will end in Europe in a few months. You've been wounded three times. You've also left Sopron several times, but have come back to it by various unpredictable events of fate or chance. Was that the end of the war for you?

Paulay: In March, 1945, I was released from the hospital at a time when eighty percent of Hungary was occupied by the Russians. I was attached to a group of invalids and other soldiers released from the hospital who couldn't go home anymore. I received orders to get together this group of cripples, avoid Russian capture, and keep moving west. Becoming a Russian prisoner of war was a dreadful thought. Once we moved west into German-speaking Austria, I did all the talking with the local authorities, such as finding the mayor of a town to obtain food for the people and for the horses drawing our carts. Other Hungarians were fleeing, fearful of the Russians—rape, death, being sent to Siberian camps. We were a pitiful little unit of army veterans from hospitals to start with, but we also ended up with some thirty women and children refugees without any transport who asked to join us.

We crossed the Enns River in Austria in May of 1945, and a few days later, on May 8, the war in Europe ended. I didn't know it then, but the Russians and the Americans agreed that the Russians would occupy Austria from the east up to the Enns River, and the Americans would occupy up to the Enns River from the west. So, by chance, we ended up on the American side. I had never seen an American soldier before. I remember seeing one leaning casually against a wall chewing gum, very relaxed—the war was over.

The American army officer communicated to me to come into the small town and to try to find lodging for our group. At that point, I didn't speak a word of English. I realized the relative importance of the Hungarian military effort in the overall scale of World War II when, using an interpreter, the American captain wanted to know on which side I had fought.

I went around from house to house in search for some accommodation, particularly for women with children. In the process I met a lovely lady who offered her help. She turned out to be the mother of my future wife. Herta, tell Bob what happened.

Herta Paulay: This soldier, Tom, arrived there at our house and asked my mother if she could possibly offer accommodations for some Hungarians. I listened as my mother eventually said that if he gave his word they were good people, she would help. My mother told me to show him to some houses in the neighborhood where he might look for some space, so I went out and pointed out some likely houses.

When I came back into the house, I did something really very unlike me. I said to my mother, "You know, I think I could marry a man like that." It was his manners, his character. Later on, we met again, and I lent him some books in German. Our little valley went from a population of about 5,000 to at least double that with the refugees.

Reitherman: What was the name of this town in Austria?

Herta Paulay: The town, which was about two kilometers from our house, was Windischgarsten.

The World Was Upside Down

Paulay: After five months, I had the feeling that I had to move on. The war was over, life has to go on, so I went back to Hungary with a horse-drawn cart. It was a difficult time, and I didn't know what the future held for me.

Herta Paulay: All around us the world was upside down.

Paulay: But I made one big mistake when I left—I never kissed Herta good-bye.

Herta Paulay: I wouldn't say it was mistake; there was no invitation extended! [Laughter]

Reitherman: Then after that you two corresponded?

Herta Paulay: Yes, though the mail was erratic then.

Paulay: Over the next three years, we got to know each other very well through that correspondence when I was back in Hungary. Then in 1948, I was forced to run for my life. But that is another story.

Chapter 3

After the War

It was late at night, and eventually the guard with the machine gun began to doze off.

Reitherman: To this point in your life, you led a military career, were wounded three times in World War II, had returned to Hungary, and not yet begun the engineering studies that would eventually lead to your prominence in the earthquake engineering field.

Paulay: My life's preparation, my career, was to be a soldier, an officer, perhaps to become a general. Then it was all gone. Because I had spent five months in an American-occupied area in Austria, I was not trusted by the Russians, who were setting up a new communist-oriented Hungarian government and army. Though they briefly drafted me, I was soon dismissed after an investigation of my background by the security arm of the Red Army.

I knew I had to have a new career, so, after months of explorations of possibilities, I decided to be an architect.

Reitherman: Architect? Not engineer?

Paulay: I went to the Technical University of Budapest in 1946 to visit the Dean of the School of Architecture, and he said, "We have a problem with enrollments in architecture now, admitting only about one out of eight applicants." I said, just tell me what the examinations are and I'll take my chances—if I am good enough to get in, I get in, and if I'm not, I won't.

But the Dean told me, "Even if you finish first out of hundreds, you will not get in." To the communist way of thinking, my family was too prominent, my father had been a colonel in the Hungarian army, my mother descended from a long line of "capitalists," and I had a military record fighting against the Soviets, who now had control over things, with files on people. He advised me to go into civil engineering instead, because that department had no special restrictions on entry, and thus wasn't subjected to political scrutiny as the architects were. He suggested that, once I was admitted to the university and past the initial communist screening, I could, say a year later, quietly transfer to the faculty of architecture. So, I enrolled in civil engineering.

Reitherman: What was the physical condition of the Technical University of Budapest?

Paulay: A beautiful old university, views of the Danube, lovely site, handsome buildings mostly built in the nineteenth century.[53] But there was a siege by the Russians of the city in World War II, with the city defended by German and Hungarian army units—fifty-two days long, a "mini-Stalingrad." The artillery damage to the university was severe.

The first thing that struck me about the campus was the graves. In 1946, there were shallow graves of soldiers all around the campus—a little wooden post with a Hungarian helmet here, another over there with a German or Russian helmet, and so on marking these graves.

For some subjects, such as mathematics, they put all the mechanical and all the civil engineering students, seven hundred in all, in the largest auditorium hall, with a glass dome over it, which as a result of the bombardments, had about fifty percent of it missing, letting the snow fall through. There were only seats for 600, so others stood or were sitting on the stairs. There was an overflow of enrollment from all the young men with disrupted educational plans returning from the war. I remember one of my professors whose home had been bombed out, Professor Egerváry, teaching us mathematics at the blackboard, with the auditorium about minus five degrees centigrade. Of course, the heating system wasn't functional then. He had no winter coat, so he wore two layers of raincoats or other clothes he had. He would have to put the chalk down and put on gloves to warm his hands for five minutes every so often, as did we students. He was brilliant, lecturing for a couple of hours, always without any notes.

My parents had a Roman Catholic background. Our local parish priest had just become a bishop, replacing the bishop who was shot by the Russians as he attempted to prevent Soviet soldiers from entering his building, where he was sheltering a great number of women from

53. The antecedent to the present university, which is now named the Budapest University of Technology and Economics, began in 1635 in another city in Hungary, Nagyszombat, then moved to Buda during a Turkish invasion. Engineering was established as the Institutum Geometricum within the University of Buda by Emperor Joseph II in 1782 and was the first in Europe to grant engineering degrees in surveying, river control, and road construction. Its modern era dates from 1872, when it began granting engineering and architecture degrees to students after five years of study. (http://www.bme.hu/en/hrs/history)

them. The new bishop, an old friend of the family, helped me with being admitted to one of the student hostels, which was administered by the church and located very close to the university. It was a four-storey building, but the top storey wasn't used because it had been bombed out. No central heating, most of the windows were missing. I covered up the gaps by pinning my drawings over them. And the plumbing didn't usually work. A pipe broke and the water froze on my floor, so I put a plank down to walk from the door to my bed until I could chip away all the ice. But you know, Bob, if you have only one piece of bread and you share half of it with a friend, you share hardship and it elevates you. The everlasting memories of those human encounters have overridden those associated with hunger and icy temperatures.

I learned there about the relationship of theory and reality, using mathematics and equations to solve engineering problems, translating the mathematics into a graphic description and sketches that traced where the forces come from and where they go. Even today, I do not begin to attack any structural engineering problem with mathematics before sketching the perceived situation. The professors forgot about the cold when they started their lectures—and they worked us so hard! I'm very grateful to them for those times. In a few short years the communists were to completely take over. At the beginning of the second year of my studies, the Dean of Architecture sent me a note to the effect that he was following my progress and that he would be pleased to admit me to the School of Architecture. By then I realized that civil engineering was much more in line with my interests, and possibly abilities, and hence I gratefully declined his offer.

Escaping From Communist Hungary

Reitherman: Tell me the details of how you managed to escape from Hungary once the communists had taken over. As I understand it, you and some fellow students were targeted for arrest.

Paulay: Details? I cannot oblige! A detailed recounting of the events would take a few hours. May I just gloss over a few events?

The average citizen could not visualize then the descent of the Iron Curtain and the eventual imprisonment by Moscow of the countries of central and eastern Europe. The gradual dominance of the Moscow-controlled communist party in Hungary led to an awakening by the idealistic student body. Politics had no appeal, but the freedom of the nation and that of academic life were clearly endangered. We were naïve and optimistic. The secret political police responded with an increased number of arrests. Permanent disappearance of fellow students became increasingly evident. The outspoken cardinal of Hungary was arrested and given a death sentence that was later changed to life in prison.

In our Catholic hostel near the university, students had been regularly arrested. Students had enjoyed the right to elect representatives, but now that right was being taken away and there were protests. One day, I discovered my name posted on the wall, nominated to be a candidate in opposition to the communist system. My friends and I realized we could now be in trouble, and we talked about what to do if we had to go into hiding.

Friend Arrested

Paulay: I mentioned that there weren't enough seats in the large auditorium for all the engineering students. A few friends and I organized ourselves to have one of us go in a half hour early in the morning and occupy about five seats with coats and so on to save them for us. One day, it was the turn of my friend Steven to save the seats. But when we showed up, there was no sign of Steven. After the lecture we went home, but he still didn't show up.

We had pooled our money to buy two tickets to the subscription to opera house performances. That night, it was the turn of myself and my friend and classmate Andy to go. I remember it was the *The Barber of Seville.* We were on the tram going there, but we decided to instead look up an aunt of an old friend of Steven's who lived in Budapest to see if she knew anything about where he was. When the door opened, there she was, pale and afraid. A few hours earlier, the secret police had taken Steven away and the house had been searched. As it turned out, over two dozen others had been arrested.

As you can imagine, I didn't see the *The Barber of Seville* that night. We went back to our room, quickly packed, and went to a cousin of Andy's that night. We devised a plan to split up: Andy home to his farm town and me back to Sopron, to hide and see if this was a false alarm and we could perhaps return to our studies. Perhaps we should have stayed together, because it turned out that splitting up complicated our tactics for eventually crossing the border to escape, with fatal consequences for Andy. He was caught, and as a slave labourer, together with many of my friends, spent over four years in a communist-controlled Hungarian punishment camp, now preserved as a historic monument, where fifteen percent of the inmates died.

I was given shelter in Sopron a few miles from the Austrian border by a childhood friend. Everyone told me how hard it would be to cross the border at the nearby lake, which was now patrolled with anti-aircraft searchlights that went back and forth across the water. The whole place was loaded with guards.

The best suggestion was to be smuggled out on the train that went through Sopron. Trains left Hungary loaded with sugar beets, and one of the guards was known to be a possible helper. At this point, my mother received a coded message via telegram that my room back in Budapest had been searched. I sent a pre-arranged coded telegram to my friend Andy saying we had to try to separately escape.

Friends told my mother later that the house of the railway man, who was willing to help me escape by burying me in sugar beets in a rail car, had been surrounded by police, waiting to capture me. Not trying that escape option saved me. In fact, it took several such miracles to allow me to escape.

Steven, meanwhile, had been taken to the secret police headquarters in Budapest, kept in a basement cell, beaten for several days, interrogated, and not allowed to sleep. After the collapse of the communist empire, the headquarters of the political police was converted into a museum to preserve evidence for thousands of visitors to Budapest of the horrors imposed on society for decades. Then they took him to a police station out in the country. Steven thought, "This is the end of me" as he was held there with a policeman watching him, while the political police were rounding up other suspects in this "plot" against the state to try to get him to incriminate them.

It was late at night, and eventually the guard with the machine gun began to doze off. Behind the guard on the wall of the police office in that small, local police station, there were a number of keys, one of which was probably the one for the locked front door. He reached for one, the guard started to wake up but dozed off, and with that one key in hand he quietly went to the front door of the police station and tried it. It worked: another miracle.

At two o'clock in the morning he was running down the unfamiliar streets to try to find the one family he had once met in that town, miraculously found the residence, knocked on the door, and explained he was running for his life. They were Jewish, had been very lucky to get passports and permission to leave Hungary for the United States after a long wait, and were going to leave in one week. If the authorities found out they had sheltered him, it would ruin their lives, but they let him hide there anyway. Steven figured that Andy and I would have fled by now, if we had not already been captured, and took the risk of taking a taxi cab sixty-five kilometers to my hometown of Sopron. A taxi was a luxury in those days. The police weren't expecting a penniless escapee to use one, but he convinced the driver to take him to Sopron and looked up my mother.

She had him hide in the bushes at the back of our garden and got a message to me. I showed up after dark at the back garden gate, and after a few whispers in the night, Steven appeared. We were together again.

An Alternate Escape Plan

Paulay: I had prepared another plan to escape by train, but not by taking it straight out of Hungary as the authorities would expect, but by taking it another direction. At the railway station of my hometown, Sopron, two policemen, one standing at each side of a narrow door leading to the platform, visually scrutinized each passenger intending to board the train at five o'clock in the morning. We got through. Some twenty-five miles away we jumped off the train and walked across farmland and forests to a small village near the border with Austria, where an old family friend lived. He knew how Hungarian pork was being smuggled out of the country into Austria, where there were people who were starving, and he put me in touch with the smugglers.

At this time, the Iron Curtain was guarded, but it was not a completely fortified line yet. In some areas, there was no barbed wire, just cleared strips in the forest with guards posted at intervals of about two hundred yards. The smugglers knew that the guards smoked, so they marked the location of the guards in the darkness by where the cigarettes glowed. The border itself was a little creek. The smugglers preferred that location because the creek made a little sound and helped to mask their noise. We crept down to the creek between two cigarette markers and made it into Austria.

I'm sorry to tell you, Bob, that this isn't the end of the story! And we haven't mentioned earthquake engineering yet.

Reitherman: Please go on with the details. I know the readers of this volume will find these facts fascinating.

Paulay: Austria was divided into French, British, American, and Russian occupied zones after World War II. Adjacent to Hungary was the Soviet sector, so that's where we were, and there were Soviet procedures in this part of Austria to catch people like us. We walked for about fifteen miles to a farmhouse where the smugglers had a place, carrying heavy bags of ham of course.

Captured on the Train

Paulay: We needed to get to Vienna. How to take the train to Vienna and not get caught by the police that frequently checked each passenger's personal identification? Each railway carriage was a separate compartment from the next one, old carriages dating back to World War I. The detectives walked through one carriage while it was moving, then got out and entered the next carriage when the train stopped at a station. An Austrian farmer who wanted to help us accompanied us on the train. He could tell who the plainclothes detectives were. When the train stopped at another small village, he signaled to us that the man who climbed up in our carriage was a detective of the Austrian police. Some of them were compelled to work for the Russian security system. However, most of them were very sympathetic to the plight of Hungary. We quickly jumped out at the far end of the carriage, walked back to the next one, and climbed aboard. We were safe till the next stop. Eventually, we ended up in the last carriage, which happened to be empty. There the detective surprised Steven. While Steven pretended to search for his non-existent Austrian identification papers, I jumped out of the train and hid under the carriage till the train started to move again. Steven was led away to the first carriage of the train. I climbed back into the last carriage.

On the way to Vienna this local train crossed Hungary at Sopron, a rail junction used by Austria ever since the break-up of the old Empire. No passengers were allowed to disembark or to board there during the brief halt and no checking of the Austrian train by Hungarian police was allowed. Just before the train entered Hungary, I was caught.

I, too, was led away, the train left, and there in the border police station was Steven. When they found we were just students, they told us to run for our lives before the Russian military police arrived, saying, "Good luck, and go!"

Of course that was good news to be free to go—but go where? Another miracle to allow us to make good our escape: the detective took us to a house and asked the farmer to put us up for the night and to give us some food. We asked the detective if he could help us get on the train the next morning, and he agreed. We got on the train, but a uniformed Austrian border police officer found we had no proper papers, took us to the same police office, and there the same detective was sitting. He said he would take charge of us, and he later got us on the train to the British-occupied sector of Vienna. A widow of a former Hungarian ambassador let us stay at her house.

Reaching Freedom in West Germany

Paulay: To get to West Germany, our next destination, we needed to pass through Russian-occupied territory. We were equipped with false papers, courtesy of the architecture students of the University of Vienna. They matched by hand the dark blue stamp on top of my photograph in the Austrian identification booklet, recording personal data in four languages, lent to me by a Viennese student with physical features similar to mine. Those architecture students did a great job! We made it to Germany. Of course Steven and I were like brothers, and a few years later made our next big trip in life together, to New Zealand.

I remember giving a talk to a club of elderly ladies here in New Zealand a few years ago about my escape from communist Hungary, decades after that event, when the chair had to interrupt me politely to let the afternoon tea service be brought in. At that point in the storey, the audience knew I was fleeing the police and Steven was captured and being held under armed guard. One of the ladies was so worked up at having to wait till after tea to hear the rest of the story that she blurted out, "To hell with the tea! Tell me now! Did you get away? Did you get out?" Since I was standing there in New Zealand, I apparently had got out, but the story had quite an effect on her.

Reitherman: Your oral history forms quite a story—a story that connects the reader of this account to major historical events that they may not have lived through. Did you ever publish this story in New Zealand or elsewhere?

Paulay: No, I didn't, and for a long time I couldn't. If details of such an account would have reached the old system in Hungary, the authorities would have probably prohibited me from entering the country. As long as my mother lived, I could not risk my chance to visit her. After the communist system collapsed, I responded to a number of invitations and have given brief talks on the subject.

Reitherman: So you reached West Germany and wanted to continue your university education. This is before you eventually made it back to Windischgarsten in Austria to find Herta again and marry her.

Paulay: Shortly after I left Vienna, I arrived in West Germany, in Munich, which was badly bombed out in the War. The Technical University of Munich admitted me. The university in Munich had been damaged far worse than the university in Budapest.

American army trucks would come to the campus and serve a rich soup, and I ate half of it for lunch and kept the other half for dinner. The U.S. Army provided a hot lunch to students, from kindergarten up through the university—and sometimes a block of chocolate too! But, eventually, with no money, I had to give up studies.

Returning to Austria to Marry Herta

Reitherman: Herta, do you remember when Tom arrived in Windischgarsten again?

Herta Paulay: It was the twenty-seventh of November, 1948, and I was playing the piano, when I heard some voices outside, and my mother came in with a strange look on her face.

She said, "You will be so surprised who is here." I came out into the living room, and there was Tom standing there, and then he threw his arms around me for the first time. And that was it!

Paulay: And one year later, in 1949, we got married. We had a daughter Dorothy—

Herta Paulay: —born nine months and ten days after we were married.

Paulay: Our second daughter, Esther, lives here in New Zealand. Our two-days-old third daughter, Rosemary, died. Our son, Gregory, born five years later, lives now in Australia.

Herta Paulay: It was a difficult life, with the young children, it was a lot of work. I had to make the pennies go around. We recently had the pleasure of celebrating our fifty-fifth wedding anniversary.

Chapter 4

Coming to New Zealand

I developed an appreciation for the relative value and relative cost of the components of the construction, structural and otherwise.

Paulay: As I mentioned, after leaving Hungary in 1948, I was in West Germany for three years, soon marrying Herta. I worked for a charitable organization for a living and couldn't continue my studies. I was a stateless refugee there, along with thirteen million other refugees, about eight million of whom were German, mostly expelled from East Germany.

Receiving a Scholarship to Immigrate to New Zealand

Reitherman: How did you emigrate from Germany and end up in New Zealand?

Paulay: How I came to New Zealand was another extraordinary instance of good fortune in my life. There were some Catholic students at Victoria University in Wellington. They thought about those refugees in Germany, which was so badly bombed out, while New Zealand had no war damage. They thought, "We could help one refugee, which isn't much, but is a lot more than nothing." They were thinking of someone young, high-school age, to support them for four years while they learned English and went through university.

At the time I was married, with one daughter, and I was twenty-seven. I knew about the scholarship opportunity, but it seemed hopeless. I nevertheless applied. Four weeks later came a telegram from New Zealand, asking, "Would you accept?" I said, of course, but I had Steven to think about. We did not want to be separated, after all we had been through. So I asked them whether they could persuade the relevant authorities to grant a landing permit to Steven, who would then look after his own needs. This was speedily approved and a few months later, with the aid of the International Refugee Organization, we were shipped to New Zealand. Twenty-five years after that, Herta and I went up to Wellington with Steven, where we invited for dinner those former students who conceived the scholarship. It was then that I could ask them, "How the hell did you pick me?"

They said they had a large number of applications from people in hard circumstances, but "Tom, by a long shot, you were the hardest case." Just another little miracle in my life, for which I am so very grateful.

After six weeks sailing, Herta, our little daughter Dorothy, and I arrived in Wellington. I got a job in a small town in the South Island, Oamaru, south of Christchurch, with New Zealand Railways, as a maintenance labourer. I started on September 11, 1951. Fifty years later, Herta and I, along with Steven and his wife, made a sentimental journey back there. We stopped at the police station to say how much we appreciated the friendly police officer who helped us when we first arrived there. This sentimental return visit was on September 11, 2001, and of course it was marred by the television pictures of the twin towers collapsing in New York.

My job as a labourer was a wonderful educational experience. Though I was already learning English, this was where I was first exposed to the rich Kiwi vocabulary of His Majesty's English as practised by the railway labourers.

Schooling Resumes at the University of Canterbury

Paulay: After some correspondence with the University of Canterbury, the Civil Engineering Department agreed to admit me as a third year student. I ended up in a class two years ahead of Bob Park. That was at the old campus in downtwn Christchurch, now the Arts Centre. This was 1952, and the key man was Professor Harry Hopkins, who had just arrived. Harry was a wonderful man, a rough diamond from western Australia. His son, David, later became a brilliant student of ours. Structural engineering, and particularly design, interested me most during my studies. The engineering profession in New Zealand expected schools of engineering to give solid grounding in structural design to students. The fact that the very last examination, involving the design of a garage for the city buses, without any interior columns, lasted fourteen days, demonstrated perhaps the then-perceived importance of the subject. I think Harry Hopkins noted that for this examination project I chose to design a reinforced concrete shell roof. This subject was then not covered in the syllabus for civil engineering.

First Engineering Job

Paulay: Harry saw something in me because he helped me get my first engineering job in 1954 after my undergraduate degree. My employer, Don Bruce-Smith, was a good friend of Harry's, and Harry would visit him once in a while and also see me occasionally. Bruce-Smith was then building up the staff for his newly established consulting engineering practise. There were three other young Canterbury-educated engineers in the firm when I joined. Soon, there were eight of us.

I worked for Don for eight years. The wide experience of designing a variety of buildings and industrial structures, using a variety of materials, had profound effects on my subsequent academic career. Bruce-Smith insisted on the highest ethics and standards of quality. He also encouraged us to help rectify the mistakes and identify the issues that arise at the construction site, to help out the owner, the architect, and the contractor. To make the project a success, everyone has to cooperate. It was a positive attitude.

I didn't know what to expect within a new profession in a new country. I was very fortunate that Don had been an academic at Canterbury before he opened his consulting practise. Nearly all of our clients were architects. The engineer assigned by Don to the job worked closely with the architectural counterpart. Many of these engineer-architect relationships turned into long-lasting friendships.

My first job was the design of a brewery, with a steel frame supporting brewing vessels and with concrete structures for the large coal hoppers, a chimney, foundations, and so on. I worked and worked, but Bruce-Smith didn't check my calculations, didn't look over my shoulder. I was disappointed and asked him if he wasn't interested in the progress, and he said he would wait till I had made all my drawings and then he would review them—looking at key aspects of the design and detailing of the structure—and only then would he look at the calculations if necessary at all. I tried to anticipate how my structures would behave over the years, not just how they would be on opening day. I recall one design for a facility on poor soil in which I incorporated into the basement something like the chambers for adding and removing ballast that they have on a ship, so that weight could be shifted over the years to counteract differential settlement. I also learned a great deal about detailing a structure to be easy rather than difficult to build.

I remember my first multi-storey building—eight stories was a big job in New Zealand in those days! I included a specification that required how the concrete was to be placed and compacted by vibrators. The contractor asked, "Would you mind showing us exactly how to do it the way you want it?" I quickly realized that you can't push a three-inch diameter vibrator through reinforcing steel bars that are an inch and a half apart, as shown on my drawings. My failed demonstration, however embarrassing, was one of many invaluable experiences I learned on construction sites.

I recall walking along a narrow steel beam, four stories up, to go to a corner to look at a weld detail the foreman wanted to show me. The structural detail was just fine, and the workmen enjoyed watching the worried and wobbly design engineer pressed to perform as a steeplejack. This was just part of the fun, which I tremendously enjoyed during my very cordial relationships with construction workers on building sites.

I developed an appreciation for the relative value and relative cost of the components of the construction, structural and otherwise. After working to try to get an efficient way to size and reinforce a column, I would realize that the cost of the formwork with twelve edges, to accommodate visually attractive terra cotta tiles, put my frugality to shame.

Chapter 5

The University of Canterbury

When I first taught in New Zealand, I told my class that I would deliver all my lectures in Hungarian—but for their benefit, I would do it with a strong English accent.

Paulay: In 1961, I was considering starting my own consulting engineering design practise, or entering into partnership with Don Bruce-Smith, when Harry Hopkins enticed me to return to Canterbury. He suggested I might like to apply for a tenured position with a specialty in teaching structural design, because of my background in practice. I followed up, was offered the position, which was as a Lecturer, comparable to your Assistant Professor, and accepted. It was the least remunerative of my alternatives, requiring a thirty-five percent drop in income. However, with the skillful management of the family finances by Herta, the five of us survived without any ill effects. At thirty-seven I was older than most of those embarking on an academic track. My decision was largely based on my desire to teach structural designers—I had not yet given much thought to research.

At that time, structural engineering was a big part of a university civil engineering department. Environmental engineering, traffic engineering, construction management, and so on, were not yet well established.

When I first taught in New Zealand, I told my class that I would deliver all my lectures in Hungarian—but for their benefit, I would do it with a strong English accent.

By the time students graduated, they were expected by the New Zealand practicing engineers to be quite competent, so we had to prepare them. In those days, much greater emphasis was placed on structural design skills.

Teaching Structural Design

Reitherman: I called up Richard Fenwick[54] to get some background on you for this interview, and he said, "Students knew they were going to spend three times more hours of work in Tom's classes, but they loved it."

Paulay: So did I. I worked hard, and I loved it. Each design project was an individual effort incorporating a number of unpredictable decisions by the designer. In my evaluation of the quality of work, I needed to follow the train of thought of each individual and provide constructive comments relevant to alternatives and possible improvements. It was emphasized that structural design was in part an art. Servile obedience to codes, seldom referred to during the course, was discouraged.

54. Richard Fenwick, Paulay's first Ph.D. student, gave the talk summarizing the career of Tom Paulay at the Paulay and Park Symposium: "The Contribution of Tom Paulay to Structural Engineering," *Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park.* University of Canterbury, Christchurch, New Zealand, July 11, 2003, pp. 127-137.

Reitherman: In talking with Nigel Priestley over the phone before traveling here to interview you, he also mentioned, and I think it's okay to quote him verbatim from my notes, because he's also said it in print,[55] "Tom worked us like slaves." Blunt, but very much a compliment coming from Nigel. How did you teach your students? What were your methods?

Paulay: Apart from my work in the army, I did not have any teaching experience. So, at least in the first two years, I did not have a teaching method. My teaching was fueled by enthusiasm and a search for a simple rationale to underpin creative concepts. Officially, my design class was two to five p.m., twice a week. I would start off with an hour or hour and a half lecture. After that, students would sit down at a drawing board with drawing tools and a slide rule. I would walk around and get involved in discussions. It was a lovely atmosphere. As I said, officially it ended at five o'clock, but rarely did the class end till six or six-thirty.

Once the informal atmosphere was established in the drawing room with seventy to one hundred students, they opened up with a flood of questions. These related to the transformation of design decisions to construction on the

55. Priestley, Nigel, "Myths and Fallacies in Earthquake Engineering—Conflicts Between Design and Reality," *Recent Developments in Lateral Force Transfer in Buildings: Thomas Paulay Symposium.* Edited by Nigel Priestley, Michael Collins, and Frieder Seible, ACI SP-157, 1993, p. 230. The Symposium was held in La Jolla, California when celebrating Paulay's seventieth birthday and was sponsored by EERI, ACI, and the University of California at San Diego.

building site, issues of professional ethics with respect to both fellow engineers and clients, and (of course) financial rewards in design. These topics were not then part of the civil engineering syllabus. In my first two years, I received invaluable assistance from Graham Powell, then finishing his Ph.D. at Canterbury. Later he became a well-known professor at the University of California at Berkeley.

Reitherman: And, according to Nigel Priestley, you had Saturday classes as well?

Paulay: No. That's not quite true. Those were not formal classes. Design projects, keeping students busy for several weeks, had to be handed in for my assessment of the efforts. That was usually on a Monday. So, over the preceding weekends, the drawing room was usually quite full as a result of inevitable last minute attempts for improvements and completion. On such weekends, I often called in to see the students, knowing that many would have a few last minute questions. No lectures were given, only answers were provided.

I wanted to challenge the brightest student. I said, "I am offering you a bucket. In the weeks allotted, you can fill it with ideas, backed up by equations, and solutions recorded on drawings." I believed that the best measure of the student's progress was in the work they did over the year, not in the final exam. Yes, I was a bloody slave driver. However, my exams were a walk-over. I said, "You are here to learn. I want to pass on to you as much as I can, which you can take with you and use for the rest of your life. To hell with the examination!" My final-year class for the students was elective. Typically, eighty to eighty-five percent would decide to take it—knowing fully that I was a slave driver.

It was a demanding class. Occasionally, I had to write "Impossible!" or "Both you and your bridge will probably fail!" on their work, to motivate them. It was a design class. It involved a trial and error process. Preliminary concepts needed to be formulated and subsequently reviewed with respect to the viability of the chosen structural system. Students had to be weaned off textbook approaches that relied on immediate analysis of structural members. Equations don't tell you where the forces originate and the path they take to get down to the foundation.

My class harmonized with Bob Park's courses. Bob would teach the theory and analysis of concrete structures. Then, six months later in my design classes, the students would try to apply what they had learned to reasonably realistic situations.

Reitherman: I asked Richard Sharpe, a former student of yours, how you taught your classes. He said you would write and draw all over the blackboards until they were covered. At that point, when you had more to explain, you went back and wrote, drew, and added calculations into the empty spaces left over from before.

Paulay: I don't think I ever went over my fifty-minute lecture time by more than a minute. But I started exactly on the hour, and fired away. I had some rough notes that I prepared, but then seldom used them. That was sometimes a mistake, because I was often provoked by the class to spontaneously talk about issues that were not planned for the particular session. However, with passage of time I learned about budgeting for lecture time.

I would start with a problem: we're going to design a covered swimming pool—so long, so wide, so deep. People would like to watch the sporting events there, so we need a seating area, and they can't sit on air, so we need to make something to hold them up. For all-year-round activities, we need a roof. You can't put a column in the middle of the water in the way of the swimmers. We then had to address the nuisance caused by wind effects. I tried to guide them to a structural system that would best meet functional requirements. Earthquake phenomena affecting design were introduced then only in the last year of the undergraduate studies.

Former Students

Reitherman: Here's a list of former Ph.D. and master's students of yours. And, by the way, Richard Fenwick has come up with the figure for all the graduate students whom you have taught, from 1961 to 1989, along with the undergraduates. The total is over 2,500. Any comments on that?

Paulay: Well, the list of Ph.D. students of mine is much shorter than Bob Park's. My career in academia started late, after eight years or so of war and aftermath, and eight years of design practice. As for all the many students over the years, I hope they put some useful things in their "buckets." It was a great joy when during subsequent years they spotted me at odd places in various countries. Of course, I have forgotten most of the names. After a while the aged faces become less recognizable. Then I could usually recall their handwriting, which I had followed so critically over hundreds of pages of their explanations and calculations.

Reitherman: Richard Fenwick was your first Ph.D. student?

Paulay: It took a few years in my academic role before I thought about research. At the beginning, I was concentrating on my teaching. Yes, Richard was my first Ph.D. student. Richard's interest was related to a body of work relevant to shear mechanisms in concrete, then addressed with great vigor in Germany, so partly I functioned as a translator, discussing with Richard the German research and what he thought about it. Richard impressed me greatly. Irrespective of the authority of the source, he critically scrutinized every aspect of published research findings. One renowned professor visiting the department warned our acting head that, because of his heretical and disrespectful views, Richard and his academic advisor should be watched. Richard reminded the great professor during his well-attended lecture that some of his postulates appeared to violate established elementary principles. Richard's dissertation, published in the form of a departmental research report, was subsequently in such a demand from overseas that it had to be reprinted. He recently retired from the University of Auckland and joined those of us in retirement at Canterbury with continued indulgence in earthquake engineering hobbies.

Doctoral Students of Thomas Paulay*

Ph.D. Student	*Years*	*Topic*	*Co-Supervisor*
Fenwick, R.C.	1966	Shear in reinforced concrete beams	
O'Leary, A.	1971	Shear and axial tension in reinforced concrete beams	
Santhakumar, A.R.	1974	Coupled walls	
Taylor, R.G.	1977	Dynamic response of ductile walls and slab coupling between walls (analytical and experimental)	Athol Carr
Beckingsale, C.W.	1978	Beam column joints	Robert Park
Spurr, D.D.	1979	Frame-wall structures (analytical and experimental)	
Ang, B.G.	1984	Rectangular columns under biaxial loading (experimental)	Robert Park
Goodsir, W.J.	1985	Structural frames and stability of walls against buckling	Athol Carr
Ogawa, S.	1987	Assessing probability of seismic failure of reinforced concrete frame buildings	David Elms
Wong, Y. L.	1990	Circular columns under biaxial loading (experimental)	Nigel Priestley
Cheung, P.C.	1990	Beam-column joints	Robert Park
Yanez, F.W.	1993	Openings in structural walls	Robert Park
Castillo, R.	2003	Torsion in buildings shake table tests, and analytical	Athol Carr
Sommer, A.†	2000	Seismic torsion and ductility demands in buildings	Hugo Bachmann
Dazio, A.†	2000	Design and detailing of wall systems for seismic actions	Hugo Bachmann

† Doctor of Technical Sciences, Swiss Federal Institute of Technology, Zürich.

* Fenwick, Richard, "The Contributions of Tom Paulay to Structural Engineering" *Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park.* University of Canterbury, Christchurch, New Zealand.

Master's Degree Students of Thomas Paulay

ME Student	*Years*	*Topic*	*Co-Supervisor*
Loeber, P.J.	1969	Aggregate interlock	
Beekhuis, W.J.	1971	Squat walls	Robert Park
Renton, R.N.	1972	Exterior beam-column joints	Robert Park
Phillips, M.H.	1972	Construction joints subjected to shear	Robert Park
Patton, R.N.	1972	Exterior beam-column joints with anchor block	Robert Park
Smith, B.J.	1972	Exterior beam-column joint	Robert Park
Row, D.G.	1973	Design of columns including bi-axial section analysis (analytical)	
Binney, J.R.	1973	Coupling beams with diagonal reinforcing	
Kelly, T.E.	1974	Multi-storey concrete frames (analytical)	
Hitchings, A.J.	1975	Horizontal construction joints	Robert Park
Lindup, G.H.	1975	Moment demands on columns (analytical)	Athol Carr
Bull, I.N.	1977	Shear in plastic hinges	
Birss, G.R.	1977	Elastic beam column joints	Robert Park
Jury, R.D.	1977	Moment demands on columns (analytical)	Athol Carr
Synge, A.J.	1979	Squat walls	Nigel Priestley
Zanza, T.M.	1980	Lap splices in columns	
Scarpas, T.	1980	External beam-column joints	
Carter, B.H.P.	1980	Frame-wall structures	Athol Carr
Tompkins, D.M.	1980	Multi-storey frames (analytical)	Athol Carr
Goodsir, W.J.	1982	Frame-wall systems (analytical)	Athol Carr
Smith, D.B.M.	1985	Coupled walls (analytical)	Athol Carr
Mestyanek, J.M.	1986	Squat structural walls	
Mullaly, K.W.	1986	Gravity dominated frames (analytical)	Athol Carr
Papakyriacou, M.D.	1986	Coupled shear walls (analytical	Athol Carr
Beyer, K.†	2001	Re-examination of the seismic behaviour of ductile coupled walls	Athol Carr and Hugo Bachmann
Smith, D.B.M.	1985	Coupled walls (analytical)	Athol Carr

† Diploma Project, Swiss Federal Institute of Technology, Zürich.

In one of the Master of Engineering projects, with R.N. Patton, we set out to design specimens to test what would happen with the existing buildings that were designed with strong beams and weak columns, rather than with the then-newer concept that was based on a strategy of precisely locating desirable regions that would behave in a ductile manner. So we had four specimens with varied column and beam reinforcing. We were expecting column failures. In the first test, the joint failed, not the beam or column. So, what do you do? We had no time to re-make specimens. We simply renamed the project—it was then a "beam-column joint research project," not a "strong beam-weak column research project." It was a topic that kept Bob and myself busy for the next thirty years.

Teaching in Other Countries

Reitherman: You've been a visiting professor in other countries: the University of Stuttgart, University of British Colombia, University of Tokyo, McMaster University, and the Swiss Federal Institute of Technology (ETH) in Zürich, Switzerland. You seemed to have developed a very close connection to ETH and Professor Hugo Bachmann there. How did that come about?

Paulay: The system at Canterbury allowed us to take a year off every seven years for a sabbatical study. Because of our isolation in New Zealand, it was of great benefit to be exposed to other academic, research, or applied engineering environments. Most of my colleagues visited the United Kingdom or the United States. I felt that experiences gained during a stay in Germany would complement those gained by my colleagues. I spent most of 1968 at the Technical Universities of Stuttgart and Munich with Fritz Leonhardt and Hubert Rusch, informally referred to as the two ruling German concrete popes. I used a major part of my time in Stuttgart to write up my Ph.D. thesis. As I'll explain, I was pursuing my doctoral degree at the same time I was on the faculty. To this end I carried an extremely heavy suitcase with all the records of my experimental work that I had gathered at Canterbury over the previous three years. At one railway station in Austria, the porter refused to handle it because its weight exceeded the limit specified by the porters' union.

I did a great deal of writing also while I sailed with my wife and three children six weeks each way to Europe. A generous grant enabled me to visit several other universities in West Germany. A significant event in my personal life during that year was when the communist Hungarian authorities forgave me for the crime I committed by my escape and permitted me to visit, the first time after twenty years, my widowed mother, as I mentioned earlier.

During my later sabbatical leaves, I offered graduate courses at a number of Canadian universities. While stationed in Toronto, I also gave regular graduate courses nearby at McMaster University in Hamilton, Ontario. My friends there asked why I do not spend my next study leave there. I explained that sometimes I have to be in New Zealand. They invited me for a three-month period after my retirement. I happily agreed. After twelve years, I received a short note from them, "Tom, according to our records, your time is up!" So my next visit to them became a most enjoyable post-retirement sabbatical leave.

A fellowship from the Japan Society for the Promotion of Science enabled me to visit a number of universities and research institutes in Japan. My principal host was Hiro Aoyama at the University of Tokyo. This visit enabled me to develop numerous friendships and professional contacts that led to a large number of subsequent visits to Japan.

During 1968, while stationed in Stuttgart, I visited the renowned Swiss Federal Institute of Technology in Zürich, Eidgenössische Technische Hochschule, or ETH, an envied tertiary educational model all over Europe. It was there that I met Hugo Bachmann. His major interests were concrete structures and structural dynamics.

In 1976, after the Friuli, Italy earthquake's ground motions crossed the border from Italy into Switzerland and revealed the seismic vulnerability of some parts of the latter, Hugo plunged into frantic work over the next three decades to become the father of the current Swiss seismic code. He invited me to participate in the relevant research work. In the ten years following my nominal retirement in 1989, I was an annual visitor at the ETH. Hugo asked me to act as the "devil's advocate" during our annual "Paulay Week" debating sessions with his very talented research group. He established the leading earthquake engineering centre in the German-speaking world, where research is now continuing with undiminished vigor under the guidance of our young colleague, Professor Alessandro Dazio.

Getting a Ph.D.

Reitherman: You did your Ph.D. work at the University of Canterbury from 1964 to 1969 on the seismic aspects of the coupling of shear walls.[56] That was the beginning of your work in earthquake engineering research. The Mt. McKinley Building and 1200 L Street Building, twin fourteen-story buildings in Anchorage that were damaged in the 1964 Alaska earthquake, are well known in the literature as examples of coupled shear walls. Did you start on your thesis before the earthquake produced those object lessons?

Paulay: When I was teaching structural design at the university, toward the third year I was there, I talked to Harry Hopkins and asked him what he thought of my work because he had never commented to me about it. Harry said, "Don't assume I don't know what you're doing. If I had a suggestion to improve your work, I would have said so." Harry was a very reserved man, and it took a long time for me to realize just how fond he was of me. He told me, "Tom, you work bloody hard. You should do something for yourself. Put some jam and butter on your sandwich." I asked, what do you mean? He suggested I do some research and get a Ph.D., which I could do in four years while still working on the staff at the same time. I ended up getting my Ph.D. late in life, at age forty-five, because of the war and my years in design practice.

Then I had to select a subject, so I did a bit of reading. I came across the topic of coupling

56. "The Coupling of Shear Walls." Vol. I and II, Ph.D. thesis. University of Canterbury, Department of Civil Engineering, 1969, 460 pp.

beams, which is so common in structural design. You lay out the building and you have these short beams over windows or doors, between elevator core walls. Coupled walls were then an architectural accident, not part of a seismic design strategy. There is negligible gravity load on such a beam. Its sole purpose, whether it knows it or not, is to wait patiently until an earthquake occurs. I looked at how such beams were being analyzed, as conventional beams using flexural theory, and said, "This is a different kind of animal. You can't analyze them like that." A beam with a span-to-depth ratio of 3, 4, 5, 10—we know how those work. But when the span is about the same as the depth, what is the flow of the inner forces and how do we get ductility out of that system?

I decided to have a look at coupled walls. I experimented with beams of different proportions and reinforcing, with different applied rotations. I have always thought it was important to convey an engineering message in graphic form. I had so many illustrations in my thesis that I realized it would be inconvenient to flip through a large number of pages to find the right figure. Therefore, I put all the illustrations in volume II, and all the text in volume I, so you could have both open at the same time.

Then came the earthquake in Alaska in March of 1964—one of those little things that have fallen into place in my life. Here were actual observations of what I had been suspecting.

Capacity design thinking had initially led me to try to provide shear reinforcement sufficient to prevent a diagonal tension failure. But, conventional stirrups, even though they remained elastic, didn't do the job. This I wouldn't have discovered without testing. When the top and bottom flexural bars yield, as the cycles continue, and because of elongation of the bars, the major crack is reluctant to close. There is a gap between the face of the wall and the beam. I was clever enough to realize that the shear strength of air is very low indeed.

After two or three cycles, the damage was very bad. It is referred to as dowel action. I concluded that one cannot construct a sufficiently ductile reinforced concrete link beam between the walls in a conventional manner, no matter how much stirrup reinforcing there is. These stirrups do not cross a potential vertical failure section, where sliding due to shear is expected. Subsequently, we abandoned this traditional construction practice and introduced instead intersecting diagonal reinforcing bars.[57] These enable the transmission of all earthquake-induced coupling beam actions to be resisted by steel, with negligible contribution of the strength by concrete. This arrangement resulted in superb ductile response of test specimens. Once this technique became better known, many friends used to greet me, from a distance, for example during ACI conventions, by crossing their arms over their heads.

Then I had a Ph.D. student, A.R. Santhakumar, who built a one-quarter-scale, seven-storey, coupled wall specimen, conventionally reinforced, and another specimen with the diagonal reinforcement. I was already convinced of what the results would be, but I knew that one couldn't convince the world without

57. Paulay, Thomas, "The Coupling of Reinforced Concrete Shear Walls," *Proceedings of the Fourth World Conference on Earthquake Engineering.* Santiago, Chile. Vol. B-2, 1969, pp. 75-90.

this comparison. The tests confirmed what I have just explained to you.

Bob Park told Santhakumar, when he arrived from India to begin his studies, that his name was hard for him to pronounce, so he would call him Santha. Then when I met him, I said, your name is hard for me to pronounce so I will call you Kumar. Thereafter, when he walked down the hall, Bob would say, "Good morning Santha," and I would say "Good morning Kumar." I visited him in India years later, staying with his family in Madras. He retired recently as a professor of civil engineering. It just shows you that I am getting rather old.

To test the coupled wall specimens upright, we would have needed a large reaction wall, but we didn't have one. The nearest possibility was the physics building, two hundred feet away, but I didn't think the physicists would have liked that! So we tested the model on its side. This necessitated the introduction of simulated gravity effects in a horizontal direction.

When we were done, we stood the specimen upright, which is the way it is seen in reality. It was convenient to erect it in this position as an exhibit in 1983 during the centennial celebration of the School of Engineering at Canterbury. One day, after it had been standing in the lab for over a year, Harry Hopkins said, "You know Tom, that large thing of yours that's still in the lab? It's been there quite a while." I said, "Yes, it's a nice centennial display." Harry replied, "Which centennial? The last one or the next one?"

Reinforcement of Coupling Beams

Paulay: The first application of our work on coupling of walls was on a fairly large scale, namely "The Beehive"—the circular Parliament Building in Wellington—which was then in design. The chief design engineer, Otto Glogau—whom we knew as an innovative leader at the Ministry of Works, and for whom our New Zealand Society for Earthquake Engineering has named its award—saw our results and had the reinforcing changed for all the coupling beams; there were many of them all around the structure because of the pattern of the windows. It was encouraging to see the research put into practice so quickly.

Another application was in a twenty-eight-storey building in Honolulu by an American consulting engineer. He said, "You know, Tom, all those coupling beams with your diagonal reinforcement will add a bit of cost, even though each one is rather lightly loaded, and we can use much less steel than in your Parliament Building design." Thus, it was decided to use diagonal reinforcement only in fourteen beams, with extremely lightly reinforced beams in between as dummies. It's cheaper to build one beam with twice as much reinforcement than it is to use two beams, each with half the reinforcement.

Reitherman: At the Pacific Conference on Earthquake Engineering in Christchurch earlier this year [2003], we were standing there at the University of Canterbury talking with Chris Poland about the addition to the Sutter-Stockton parking garage in San Francisco, where Degenkolb Engineers used the diagonally reinforced coupling beam concept on a large scale, with story-high depths to the beams. As I understood it, a multi-story parking garage adjacent to the old part of the garage had been acquired, but it was a problem to join up the old and new portions.

Paulay: Yes. At the time they did that project, Degenkolb Engineers was kind enough to send me many photographic slides, which I used extensively in my lectures. They needed to punch very large holes through what had been solid walls to allow cars to pass between the old and new portions. That created the problem that was solved by constructing, in each of the principal directions, a massive new centrally positioned coupled wall with beams, diagonally reinforced with some forty-foot-long bars. These walls provided close to the total required seismic resistance. Those were the biggest coupling beams I had seen used anywhere in the world.

Reitherman: You also did similar work on diagonal reinforcement, for use in shear walls?

"Shear" Walls

Paulay: Yes. It can prevent shear failure under large cyclic displacements, though often it's not needed. Usually, the diagonal reinforcement was designed to take a proportion of the earthquake-induced shear, and the rest was assigned to the conventional non-yielding shear reinforcement. Some walls need it. But we should get our terminology straight. Why is it called a shear wall? Look at a continuous frame that resists lateral forces. It resists moments, shears, and axial forces. We don't call it a shear frame. Now Bob, tell me: why do you call a shear wall a shear wall?

Reitherman: I've been taught that it was so named because the wall has to carry the horizontal shear forces from one story to the next.

Paulay: But a multi-storey frame made up of columns and beams has to carry shears from one storey to another also. But do we call it a "shear frame"? Doesn't every structure have to transfer interstorey shear forces?

Reitherman: Yes.

Paulay: I notice another American custom, which we in New Zealand have been reluctant to replicate: a moment-resisting frame. As I stated earlier, a frame, comprising beams, floor slabs, columns, and joints, must also resist axial and shear forces, as well as moments. Why should we place the emphasis on "moments"? I suspect that these usages have a historical background.

Beams in early frames were pin-connected to columns. Hence, such frames required independent diagonal bracing to sustain lateral forces acting on the building. In continuous frames, moments could be effectively transmitted from beams to columns, eliminating the compelling need for bracing. Hence, "moment-frames."

I think early on in the twentieth century, the walls of that era usually failed in shear when they went through an earthquake. Early walls, poorly designed and constructed, had the habit of failing in shear during earthquakes. This was manifested by very visible, large, diagonal cracks. Thus, shear became a focal point. It was perhaps perceived that the principal role of these walls was to resist shear. In practice, the major difficulty with "shear" walls is to provide foundations capable of resisting large overturning moments without excessive base rotations. If you look at the early California seismic regulations, you will see a big penalty for use of structural walls—twice the design seismic forces as for frames. But, if we don't like a shear mode of failure in the wall, then we must tell the wall what to do, so we use capacity design to make the wall have a shear capacity that is in excess of its flexural capacity.

A few years ago, I received a letter from a young German woman who was then a student at the Swiss Federal Technical Institute, where Hugo Bachmann is. A requirement of the degree was a final project, for the equivalent of a master's degree, which she asked to do in New Zealand with me. Katrin Beyer, a very bright student, came to New Zealand. I told her I had done some work on coupled walls many years ago, but now we have new ideas relevant to displacement-controlled design and damage control strategies. Would she like to look at coupled walls in a new light?

She did some very nice work, got the university's prize in Switzerland for best project of the year, then joined Ove Arup, and now is about to do a Ph.D. Inspired by her results in Pavia at the ROSE School, I became motivated to go on a bit further with that line of research and did some new work in that area, almost forty years after my Ph.D. work.[58]

58. Paulay, Thomas, "The Displacement Capacity of Reinforced Concrete Coupled Walls," *Engineering Structures, The Journal of Earthquake, Wind and Ocean Engineering.* Vol. 24, 2002, pp. 1165-1175; Paulay, Thomas, "Seismic Displacement Capacity of Ductile Reinforced Concrete Building Systems," *Bulletin of the New Zealand Society for Earthquake Engineering.* Vol. 36, no. 1, 2003, pp. 47-65.

Chapter 6

Philosophy of Seismic Design

You can't control the earthquake, but you can control the structure.

Reitherman: Here's a quote from the 1993 symposium in your honor held at the University of California at San Diego, from the paper by Nigel Priestley. "It appears, however, that the enormous approximations involved in seismic design are perhaps becoming less appreciated rather than more, as sophisticated analytical techniques become specified by codes and accepted into common design practice. In the United States, I suspect elsewhere too, this has resulted in a tendency for the functions of analysis and design to be separated."[59] He doesn't gainsay the advantages provided by modern computers, but he points out how an increased reliance on computers has led to a decreased reliance on thinking.

Paulay: The computer is a wonderful device. It informs the designer with a high degree of precision about many quantities resulting from simulated earthquake actions in the structural model that has been conceived. But it doesn't tell the

59. Priestley, Nigel, "Myths and Fallacies in Earthquake Engineering—Conflicts Between Design and Reality," *Recent Developments in Lateral Force Transfer in Buildings: Thomas Paulay Symposium.* ACI SP-157, 1993.

structure what it should do. Structural engineers are in the habit of asking what the structure can do. The designer must *tell* the structure what it must do. One must also understand the practical aspects of how the structure must fit with the architectural and other functional requirements. You must have a common sense design to start with. When the computer subjects the structure to a number of earthquake records, the only certainty is that none of those motions will be exactly the same as what your structure will actually experience. You can't control the earthquake, but you can control the structure.

With all due respect to the power of computers, we should not lull ourselves into the conviction that the precision they can deliver will compensate for inevitable errors attached to the range of assumptions that must be made in seismic design.

Originating Capacity Design

Reitherman: In your books, co-authored with Bob Park and Nigel Priestley,[60] the concepts of capacity design were given prominent roles. How did this strategy evolve in New Zealand, and what was your part in it?

Paulay: It was suggested by some of our particularly gifted consulting engineers that in order to protect some elements against inelastic deformation demands, they should be made somewhat stronger than adjacent elements selected for energy dissipation in the inelastic range of the system's response. Subsequently, we proposed that in the design of structures for ductile seismic response, energy dissipating regions of mechanisms should be chosen and suitably detailed, and other structural elements be provided with sufficient reserve strength capacity, to ensure that the chosen energy dissipating mechanisms are maintained at near their full strength throughout the deformation that may occur.

Committees and workshops were set up by the New Zealand Society for Earthquake Engineering to examine thoroughly aspects of seismic design of reinforced concrete structures, and to make recommendations which design practitioners may consider till the incorporation of such recommendations into relevant local codes becomes possible. I was assigned first the job of studying aspects and consequences of a desired hierarchy between the strengths of ductile beams and adjacent columns of multi-storey frames.

By that time, the potentially dangerous performance of frames, comprising weak column-strong beam strength hierarchies, was widely recognized. In advocating the use of strong column-weak beam frame systems, the first important question emerging was, "How much stronger should a column be than the beam that frames into it?"

The study led eventually to the identification of strengths recognized by an earthquake rather than those complying with a particular code. The overriding criterion to be satisfied was that the simultaneous formation of plastic hinges at the top and bottom ends of all columns in any storey should be prevented. New

60. Paulay, Thomas and Nigel Priestley, *Seismic Design of Reinforced Concrete and Masonry Buildings*. Wiley and Sons, New York, 1992; Park, Robert and Thomas Paulay, *Reinforced Concrete Structures*. Wiley and Sons, New York, 1975.

Zealand designers went a stage further by asking whether it would be possible to provide affordable reserve strength to columns in the upper stories, which would ensure their essentially elastic behaviour during seismic excitations. The inevitable cost increase was felt to be compensated for by simplifications in the detailing and construction of columns. Simplifications were eventually introduced in terms of the reduction of the confining and shear reinforcement in columns, and the waiving of restrictions on the locations of lap splices of column bars. The anchorage of beam bars in beam-column joints was also made easier by this practice. It has been used for some twenty-five years in New Zealand.

The application of capacity design was subsequently extended to include building systems—in which seismic resistance was to be provided by structural walls, such as cantilevers or coupled walls—and to dual systems. The strategy was universally accepted in New Zealand as a prerequisite for ductile systems relying on viable energy dissipation. The protection of elements intended to remain essentially elastic during the ductile response of the system, necessitated also the introduction of allowances for increased strength demands arising in certain regions of elements as a result of higher mode dynamic effects.

An example I have widely used is a weak, but very ductile, link of a chain, which determines the overall chain's strength and deformation capacity. It is connected to stronger adjacent links that need not be ductile.

Mallet-Milne Lecture: Simplicity and Confidence in Seismic Design

Reitherman: The earthquake engineering field has become increasingly sophisticated in the past few decades. We're a long ways from the early years of earthquake engineering, when Robert Mallet in the mid-1850s and John Milne[61] a little later began to develop the modern engineering and seismological aspects of the field, respectively. Hundreds of papers are now published each month in our field in dozens of journals on new analytical and experimental research results or design applications. The *Proceedings of the Thirteenth World Conference on Earthquake Engineering* contains 2,300 papers—much more content than any single person can comprehend, for example. Yet your Mallet Lecture was on the subject of simplicity, not complexity, in seismic design.[62] Has our

61. Robert Mallet (1810-1881), a British engineer, has been credited by such experts as Bruce Bolt, John Freeman, Donald Hudson, and Karl Steinbrugge as the first to put the engineering study of earthquakes on the modern path. In addition to authoring one of the most complete earthquake catalogs of the day, he produced the first earthquake reconnaissance report, of the modern factual type, on the 1857 Neapolitan earthquake in Italy. John Milne (1850-1913), one of the first British professors to move to Japan and help build up the study of earthquakes there, at what was to become the University of Tokyo in the late 1800s, is commonly credited as being the most influential of the early seismologists, and was the inventor of one of the most common seismographs of the first few decades of the twentieth century. He was a founder of the Seismological Society of Japan.

earthquake engineering field become too sophisticated and complex for its own good?

Paulay: A major motivating aspect of my work in earthquake engineering was the speedy transfer of viable results of research to the design practitioner. It may sound obvious, but improvements in seismic performance of engineering structures are achieved only after structures are constructed that embody improved seismic design knowledge. This is the challenging task for the designer. A prerequisite of promising solutions is that the designer must truly understand how newly developed concepts can be translated into better structural performance. Therefore, the message must be not only rational, but it must also be simple. Structural designers will have little time to comprehend solutions that are, in terms of the designers' knowledge, sophisticated. The conviction gained from rationality, when combined with the simplicity of application, will then confer the confidence in improved performance to be achieved in the design process.

Further developments in earthquake engineering will be inevitably associated with increased sophistication. Who are the people who can extract the essentials, perhaps at the expense of some loss of precision, and simplify solutions in order to make them palatable to the everyday designer? Michael Collins, the distinguished professor at the University of Toronto (in spite of the fact that he was a student of mine), had a relevant message, "If you have a sophisticated solution, ask a white-haired engineer to check it with a slide rule."

Reitherman: The phrase "deceptively simple" comes to mind. It applies quite well to your Mallet-Milne Lecture, which right there on the first page, concisely and simply lays out the essence of seismic design in a way that the less knowledgeable might think was easy to do. I say "deceptively" because each straightforward sentence contains great meaning, and is based on your very large amount of experience. For example, you speak of the goal of designing a structure to have "*tolerance* with respect to the inevitable crudeness of predicting earthquake-imposed displacements." A person with less experience might be more likely to jump to the conclusion that the designer's main goal is to calculate expected earthquake ground motions and resulting response for the purpose of achieving great *precision* in the design of the structure, to achieve more decimal places, if you will.

Paulay: Simplicity implies that, once the designer has explored the parameters affecting seismic response, often based on previous experience, he or she can readily envisage critical features of the expected response. By simple inspection, a viable mode of behaviour can be chosen. All that remains to be done is to ensure that the structure cannot respond in any other manner than that intended by the designer. I exclude here features of elastic seismic response, which are seldom critical.

62. Paulay, Thomas, *Simplicity and Confidence in Seismic Design: The Fourth Mallet-Milne Lecture.* Wiley and Sons, New York, 1993. The Mallet-Milne Lecture series is sponsored by Britain's Society of Earthquake and Civil Engineering Dynamics. The first of these lectures was presented by George Housner.

The second stage of the designer's mental process should be to choose a kinematically admissible plastic mechanism, suitable for efficient energy dissipation and providing for the system the desired displacement capacity. This, then, leads to an acceptable nominal strength level.

A further consideration, to be exploited without the use of analysis, is an experience-based study of the potential inelastic regions of the system. This involves intuitive estimates of deformations that the chosen design earthquake may impose on these regions. This is the stage when changes, when deemed desirable or necessary, may be made in the choice of the ductile mechanism of the structure. The purpose of this contemplative exercise is to eliminate regions where excess deformations may occur, and to pinpoint localities where the detailing (commensurate with the local deformation capacity), may present construction difficulties or economic penalties.

The designer may then proceed with the assignment of strengths to elements or components chosen to deliver energy dissipation. In accordance with the principles of capacity design, all other elements can be assigned sufficient excess strength.

These steps then allow routine calculations to be carried out to satisfy perceived performance criteria in terms of the required strength of the system.

The crudeness I referred to in several of my presentations is mainly associated with the estimation of seismic displacement demands likely to be imposed on a structure at a given site. The actual demand imposed may be well in excess of the specified displacement capacity of the system. I believe that it is easy, and far from being economically prohibitive, to provide a higher quality of detailing in plastic regions of the structure, whereby its displacement capacity can be significantly increased. Of course, it must be appreciated that increased displacements are commensurate with increased damage. However, such measures should prevent collapse and consequent loss of life. This enhancement of displacement capacity of a system manifests for me the very desirable structural property of tolerance with respect to our inability to predict, with a sufficient degree of accuracy, imposed seismic displacement demands.

Analytical techniques are now readily available to check out the model of the structural system having properties compatible with all details of the construction. Scenarios associated with earthquake records of differing severity can then be readily studied.

Weakest Link, Most Ductile Link

Reitherman: Here's another deceptively simple sentence from your Mallet-Milne Lecture, one that explains why two buildings designed to the same base shear levels prescribed in a building code, and subjected to the same shaking, may behave very differently, "In some structures, the global ductility that can be relied on for reducing seismic response will be limited by the ductility capacity of the most critical ductile link in the system."[63] Your example of a chain being only as strong as its weakest link seems obvious. But if that obvious

63. Paulay, Thomas, *Simplicity and Confidence in Seismic Design: The Fourth Mallet-Milne Lecture.* Wiley and Sons, New York, 1993, p. 8.

design principle were always followed, would there have been so many soft-story collapses, buckling failures of braces, pull-out of anchored bars, or tension failures of diagonal rods?

Paulay: Earlier application of these rational and simple principles would have prevented the type of failures you quote from occurring. I feel that the relationship between global displacement ductility and those of the ductile links of the system has not received the attention it deserves. The acceptable displacement capacity of the system should depend on the displacement capacity of its critical element. Comparable elements of a multi-storey building, made up of similar rigid-jointed ductile frames, will have very similar displacement capacities. Therefore, these will be representative of the displacement capacity of the system. However, in a building where seismic resistance has been provided by a set of structural walls with different dimensions, the elements controlling the displacement capacity of the system will be the walls with the largest length. All walls may be detailed so as to be able to deliver the same displacement ductility capacity, but the displacement capacities they provide will be very different. The displacement capacity of the walls with smaller lengths will not be able to be utilized. Hence, the displacement ductility capacity of a system may be considerably less than that of its constituent elements. Therefore, the global or system displacement ductility capacity should not be a vague and subjective judgment-based quantity. It should be made dependent on the displacement capacity of its critical element, requiring a larger degree of protection than any other element. These features are easily identified and quantified during the contemplative stage of the design exercise.

My simplistic example of a chain illustrates the relationship between the strength of the chain and those of its links. The elongation capacity of this chain is clearly controlled by that of the ductile link.

In our early approaches to seismic design, the assignment of element strength relied on the properties of an elastic structure. We had little interest in the strength of elements as built, provided that the requirements for the total strength of the system were not violated. The violation of strength hierarchy that may result, may thus lead to a mechanism for which the structure was not properly designed.

Reitherman: Given the large uncertainty in predicting the ground motion that will shake your structure, you emphasize the need for simplicity, including simplicity, or regularity, in the structure, and warn about "building forms that invite disaster." You wrote about "the importance of choosing a reasonably regular structural system, the response of which can be predicted by simple inspection at the conceptual stage…."[64] Are there any particular architectural styles fashionable today that create "building forms that invite disaster"?

Paulay: A well-conceived and judiciously detailed structure should not need subsequent detailed analyses unless gross irregularities in its layout are present. And, for these irregularities, the best solution is to avoid them. The essence of my intended message was that once a kinematically admissible and appealing mech-

64. Ibid., p. 15.

anism is conceived and the regions assigned for energy dissipation have been adequately detailed, we should have a tolerant structure. Therefore, some lack of precision in analyses should not affect significantly the structure's ability to accommodate earthquake-induced displacements, even if they are at variance with those expected.

Seismic design needs to be based on a thorough understanding of, and good feel for, the behaviour of the entire structure, as well as every part of it. The instantaneous utilization of this understanding of situations that may arise during a major earthquake, combined with innovations that have rational bases (often nothing more than astute avoidance rather than a sophisticated solution of a cumbersome problem), are ingredients of what we might consider art in seismic design.

Reitherman: Structural design can be thought of as stating a logical thesis; that thesis is then defended, or revised, by structural analysis. The design thesis argues that the columns, beams, walls, floors, foundations, and other components of construction will behave in a particular way, and that they are logically configured in a preliminary design. Those decisions can then be verified by analysis. In your Mallet-Milne Lecture, you put this decision-making role of structural design in context with the computer-oriented role of structural analysis, "The causes of the majority of failures in earthquakes can be attributed to neglect in detailing for ductility and flawed structural concepts, rather than to lack of precision in analysis."[65]

Paulay: In simple terms, a mediocre solution of a recognized problem is nowhere as serious as the absence of the problem's recognition. Flawed structural concepts are often associated with the latter.

Reitherman: In your Mallet-Milne Lecture, you point out that "predictions of the probable characteristics of large earthquake-generated ground motions are crude" and that "errors arising from crude estimations of the characteristics of ground motions will manifest themselves only in erroneous predictions of earthquake-imposed displacements, that is ductility demands…."[66] There are two sides to the generic seismic design equation: demand and capacity. Are you saying that, even though the seismic demand is uncertain, the structural designer must take responsibility for building into the structure enough capacity?

Paulay: Yes. I believe that designers should take responsibility, as part of their professional integrity, for precautions addressing possible demands in excess of those envisaged in building codes. I specifically refer here to displacement demands that may be in excess of the stipulated code capacity, usually expressed in terms of the displacement ductility capacity of the system. Enhanced quality of the detailing of critical regions, based on thorough understanding of the flow of internal forces, imparts this highly desirable property, tolerance, to a ductile system.

65. Ibid., p. 47.

66. Ibid., p. 64.

Presentation for the Housner Symposium

Reitherman: The first time I met you was in Pasadena, California, in 1995 when you gave a lecture for the CUREE-Caltech Symposium in Honor of George Housner.

Paulay: If I may correct you, Bob, nothing was further from my thoughts than to give a lecture to the distinguished audience during that extremely pleasant and for me a very memorable occasion. It was merely a presentation.

Reitherman: Okay, presentation. There was this tall, distinguished gentleman at the rostrum, the famous Professor Paulay, and you proceeded to begin a very serious presentation.[67] You emphasized your points with a few slides that listed important principles and formulas, leading up to a major seismic design breakthrough you said had just been achieved—the Seismocup. Then, you continued in a serious manner as you showed an outlandish cartoon sketch of a tall building with a hemispherical base, which could rock around like a toy, though at that point your eyes were twinkling enough to reveal how much fun you were having as the audience caught on.

Hugo Bachmann did a good job of summarizing the solidity of your character at your Paulay and Park Symposium banquet: "...With Tom Paulay, the inner values are decisive and form a firm foundation for his great achievements and success," values that Hugo cited such as maintaining strong and stable relationships, unselfishness, ethics.[68] But, along with those characteristics, another trait we need to touch on in this interview is your wonderful sense of humor. Your former students have all mentioned it. Your colleagues have all mentioned it. In his banquet speech for you at the 2003 Paulay and Park Symposium, Hugo said that you "always radiated warmth and humour toward other people."

Let me cite a statement of Harry Hopkins from the time you were doing your Ph.D., a quote that his son David quoted in his 2002 Hopkins Lecture[69]: "I have no doubt that the engineers of the future, like the engineers of the past, will find that engineering is fun, providing that they take their subject and not themselves seriously."[70]

Paulay: I attribute my appreciation in life for a little bit of humour in my upbringing. It was in the family. Moreover, Hungarians were always attracted to cheeky humour, particularly when, in gloomy times, its expression was at the expense of oppressive state control of everyday life.

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67. *Proceedings of the October 27 & 28, 1995 CUREe Symposium in Honor of George Housner.* Consortium of Universities for Research in Earthquake Engineering, Richmond, California, 1995.

68. Bachmann, Hugo, "Professor Thomas Paulay, An Outstanding Person: International Tribute to Professor Thomas Paulay on the Occasion of His Eightieth Birthday," *Symposium To Celebrate the Lifetime Contributions of Tom Paulay and Bob Park.* University of Canterbury, Christchurch, New Zealand, 2003.

69. Hopkins, David C., "Consulting Engineering—Serious Fun," Hopkins Lecture. University of Canterbury, Christchurch, New Zealand, 2002.

70. Hopkins, Harry J. "Engineering is Fun," *NZ Engineering*, March, 1964.

I fully subscribed to Harry Hopkins's sentiments. Seldom did I give a lecture where some humour would not have been hidden behind sketches and equations. Fortunately, I did not need to plan for these. The humour emerged spontaneously. I remember an occasion when I noticed a student, sitting in the first row right in front of me, fast asleep during a part of the lecture. When he awoke, giving me an embarrassed look, I remarked, "Sorry, was I too loud?"

My brief presentation on the occasion of honouring George Housner was based on the assumption that, among the many laudatory and serious addresses, there may be room for a less serious topic. It also intended to remind the audience that George, all during his illustrious career, seldom missed an opportunity to trigger a hearty laughter in the audience. My address included the highlight of a previous longer storey, which I presented in Switzerland on the occasion of Hugo Bachmann's sixtieth birthday, celebrated by a symposium.

A presentation of a small gift at the end of the year to Professor Hugo Bachmann, the leader of the earthquake engineering research group in the Department of Building Construction at the Swiss Federal Institute of Technology (ETH), Zürich, Switzerland, has been a custom for many years. A recent gift was a plastic cup, familiar to all who have cared for infants. A concentrated mass, placed at its hemispherical bottom, enables this cup to regain always its upright position. It has been suggested that this feature manifests an unexplored concept with promising applications in the control of earthquake-induced damage in buildings. For this reason, it was named "the Seismocup."

A figure shows this seismocup alongside the model of a twelve-storey building, which I used in my lecture there to demonstrate its dynamic properties and its ability to let its occupants literally explore new visions.[71] The roles of the mass of the superstructure and the hemispherical base were illustrated. It was pointed out that the funding of the project by the Swiss cement industry will be swift once the need for a very large concrete mass at the base is translated into business benefits. The appeal to the real estate industry was also pointed out. In the absence of torsional resistance at the base, the building will rotate. This means that each earthquake will offer the occupants a new view of the surrounds. Hugo was also presented with a watercolour painting of such a building when exposed to 100 MPH wind effects on the hills of the capital city of New Zealand. I was also delighted by the effusive compliments of a prominent attendant of the symposium, who seriously asked about the numbers of such buildings already constructed in New Zealand.

Honors for Contributions in Seismic Design

Reitherman: You have received a number of honors for your contributions in seismic design. Some of them are tabulated here. Do you want to comment on any that were particularly memorable?

71. Paulay, Thomas, "The Seismocup Building System," *Journal of the Structural Engineering Society of New Zealand.* Vol. 8 no. 2, 1995. pp. 9-15.

Selected Honors and Leadership Positions of Thomas Paulay

President of New Zealand Society for Earthquake Engineering

Membership on many ACI and ASCE committees

Membership on many New Zealand Standards Association committees, 1974-1996

Freyssinet Award of New Zealand Institution of Engineers, 1974 and 1977

Gzowsky Gold Medal of the Engineering Institute of Canada, 1975

Co-recipient of Inaugural Award of the New Zealand National Society for Earthquake Engineering, 1978

Fellowship of the Japan Society for the Promotion of Science, 1982

Raymond Reese Structural Research Award of American Concrete Institute, 1982 and 1983

Fellow of the Royal Society of New Zealand, 1983

Professional Commitment Award of the Institution of Professional Engineers of New Zealand, 1985

Fellow and Life Member of the New Zealand Society for Earthquake Engineering, 1985

Officer of the Order of the British Empire (O.B.E.), 1986

Honorary Member of the American Concrete Institute, 1987

Otto Glogau Award of the New Zealand National Society for Earthquake Engineering, 1989

Honorary Doctor of Technical Sciences, Swiss Federal Institute of Technology, Zürich, Switzerland, 1988

Professor Emeritus, University of Canterbury, 1989

Honorary Doctor, Technical University of Budapest, 1990

President of the International Association of Earthquake Engineering, 1992-1996

Mallet-Milne Lecture, Institution of Civil Engineers, 1993

Order of Merit of the Republic of Hungary, 1996

Honorary Member of the International Association for Earthquake Engineering, 1996

Honorary Doctor, Technical University of Bucharest, 1996

EERI Distinguished Lecturer, 1997

Structural Award of the Institution of Professional Engineers New Zealand, 1998

Distinguished Fellow of the Institution of Professional Engineers New Zealand, 1998

Honorary Doctor, National University of Cuyo, Mendoza, Argentina, 1999

Award of the Structural Engineering Society New Zealand for Structural Engineering Excellence, 2000

Outstanding Paper Award, International Association for Bridge and Structural Engineering, 2001

Honorary Member of the Chamber of Engineering of Hungary, 2003

Paulay: I suspect that several of the awards I received resulted from the well-intentioned efforts of friends and colleagues who generously inflated my efforts.

My work over some twenty years with the Standards Association of New Zealand gave me particular satisfaction. I was very pleased to be a part of a small team, comprising dedicated colleagues, including Bob Park, with whom we attempted to modernize our seismic design practise for reinforced concrete structures.

Intimate dialogues with many members of the structural design profession, our opportunities for introducing new earthquake engineering principles to our undergraduate teaching activity, and endeavors to translate our research efforts into simple, viable design recommendations that were friendly to users, were ingredients of this very satisfying activity. These achievements would not have been possible without the New Zealand Society for Earthquake Engineering sponsoring a number of workshops, where the needs of the designers, the potential use of recent research findings, both in New Zealand and other countries, were amiably hammered out. Our approaches also influenced the drafting of similar provisions for the European Community (Eurocodes).

EERI Distinguished Lecture

Reitherman: You state in your EERI Distinguished Lecture, "The ever-increasing relevant technical literature does not appear to pay much attention to the conceptual choice of structural systems with a potential for possessing desirable seismic properties."[72] Are you referring to the very first step of conceiving a seismic design, before any computer analyses are run?

Paulay: Yes! Indeed! Important and sometimes fatal decisions are made in the preliminary, previously referred to as the contemplative, stage of the design process. An ill-conceived system places the subsequent design activity, including computer analysis, into a straightjacket. Therefore, I often returned to my personal view that it is much more effective to avoid problems originating from conceptual flaws, than to solve them with the aid of sophisticated analyses. I suspect that relevant issues did not receive worldwide the attention they deserve. Designers should be more aware of the messages sent out by Chris Arnold, for example, your friend in the U.S., architect and former president of EERI, about the importance of fundamentals in seismic design decision-making.

Reitherman: A famous quote from Mies van der Rohe regarding architecture is "God is in the details." In the same passage I quoted above from your EERI paper, you say, "Detailing, particularly of reinforced concrete structures, which is very often considered a subordinate, depreciated drafting activity with apparent lack of intellectual appeal, deserves at least as much attention as the analytical effort to estimate design actions." Why is that so?

Paulay: As implied in my previously expressed views, I believe that, apart from the avoidance of gross misconceptions in seismic

72. Paulay, Thomas, "EERI Distinguished Lecture 1997: Professional Commitments to Earthquake Engineering," *Earthquake Spectra.* Vol. 14, no. 4, November 1998, p. 652.

design, the fate of our product, in terms of both damage control and collapse prevention, will be dependent on the quality of the performance of the weak links in the chain of resistance. These are the regions where the largest local repeated and reversible deformation demands will arise. Therefore, the transformation of such symbolic links, be it in steel, concrete, masonry, or composite materials, by means of judicious detailing assumes paramount importance. Not surprisingly, earthquakes have consistent habits of tracking down poorly conceived and executed details of critical regions of structures.

Reitherman: In your EERI Distinguished Lecture, you call on the earthquake engineering field to "engage in active and generous support of technology transfer in an attempt to alleviate the overwhelming and immediate needs of societies in developing countries."[73] Simultaneously, there is an increase in earthquake engineering know-how in the poorer countries, along with an increase in their risk exposure because of their rapid growth. Do you think the implementation of earthquake engineering around the world will keep pace with the growth of the risk exposure?

Paulay: In spite of the increase of know-how in earthquake engineering, the risk exposure, in my view, is likely to increase. This is particularly applicable to developing countries where, in spite of the awareness of its vital role, the improved quality of construction is not likely to keep pace with the increase of risk. Developed countries could, and should, more actively contribute to the transfer of relevant technology.

73. Ibid., p. 651.

Numerous recent reports of reconnaissance teams have established that the major sources of the lack in progress towards better seismic protection are: irrational adherence to outdated traditions, unconscious or deliberate ignorance of compliance with building regulations, and insufficient attention of governments to relevant needs of the society of poorer countries while condoning undiminished corruption.

Reitherman: It is evident that during the past sixteen years of retirement from the University of Canterbury faculty you have still been quite active in pursuing a number of seismic design issues. What have been the major topics that have attracted your interest during your "retirement"?

Inaugural John A. Blume Distinguished Lecture

Paulay: With the emergence of the need for clearer definitions of seismic performance criteria, I became interested in those associated with earthquake-induced displacements. The dominance of inelastic displacements suggested that adherence to traditional principles of elastic behaviour, still widely used, is no longer necessary. Often, I was greatly inspired by the work of Nigel Priestley while he progressed with his propositions for a direct displacement-based seismic design procedure. The playing with relevant thoughts made me aware that adoption of simpler modeling, and redefinitions of some established concepts, would lead also to significant simplification in the execution of the design exercise.

For example, it emerged that strength need not be assigned to elements in proportion to their stiffness. Instead, stiffness may be more appropriately defined as a function of strength assigned by the designer. This freedom of the designer, when astutely exploited, can lead to the avoidance of commonly encountered mischievous structural problems. Moreover, it can inspire the designer to create, with extensive use of identical elements, more economical construction solutions. The realization that the displacement capacity of a ductile system is only negligibly affected by its strength, eventually to be chosen by the designer, means that very important decisions with respect to promising seismic response can already be made during the preliminary studies of the project.

Some features of a displacement-focused seismic design strategy were presented during the John A. Blume Distinguished Lecture, entitled "Compatibility Criteria Relevant to Displacement Ductility." I was honoured by Stanford University when I was given the opportunity to deliver the inaugural lecture in that series, named after the late John Blume.[74]

The use of these concepts encouraged propositions to be made for a better control of seismic torsional phenomena. The early evaluation of the displacement capacity of elements enables a better utilization of their ductility capacity, while controlled twist of the system is admitted. Dialogues over many years with distinguished members of the "international torsion Mafia," such as W.K. (Dick) Tso in Canada and Victor Rutenberg in Israel, both experts in this area, helped greatly to clear my aging mind.

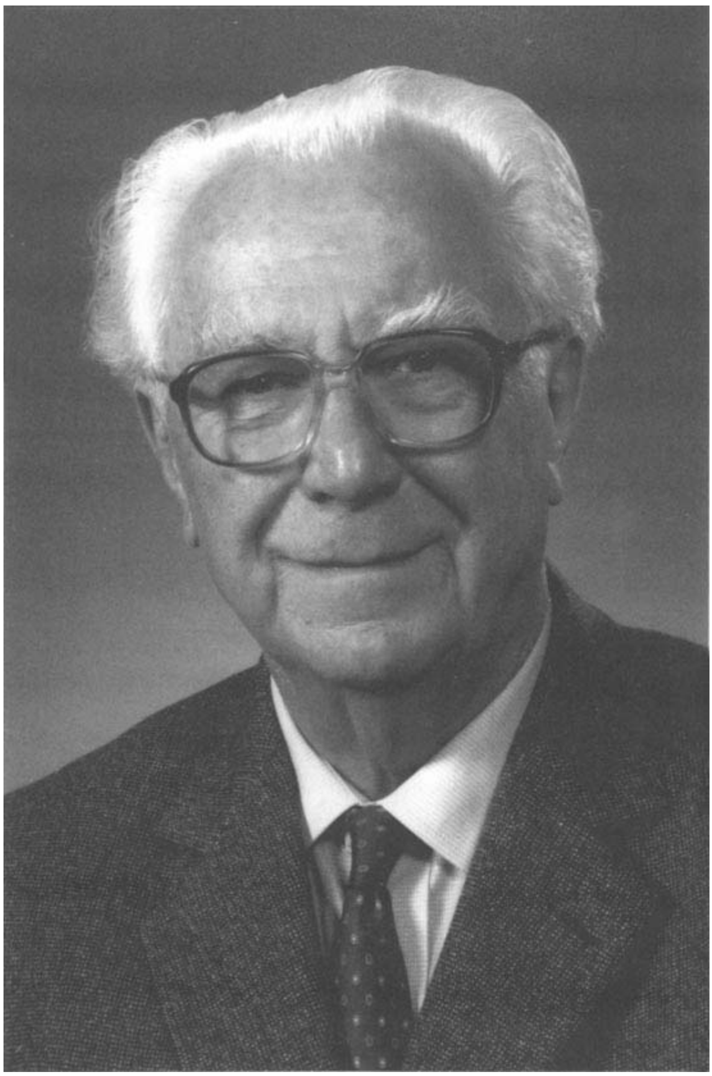
These concepts can be equally used by designers adhering to force-based design strategies. They bring to the fore the need to address displacement capacities of systems, an aspect presently crudely handled by strength-controlled design procedures.

Next Generation of Structural Design and Designers

Paulay: I am not very confident with respect to the appeal to the younger generation of designers of the use of these unconventional, yet simple, engineering features I have advocated. Challenges in the development of ever more powerful software, relevant to analyses and promising greater accuracy and resolution of complexities, seem to magnetize the younger generation more than global aspects of design strategies. To quote Nietzsche, "Science is science, that is the mastery of knowledge only to the extent to which, besides techniques, it is also philosophy."

74. John A. Blume Earthquake Engineering Center, Stanford University, October 25, 2000.

Photographs

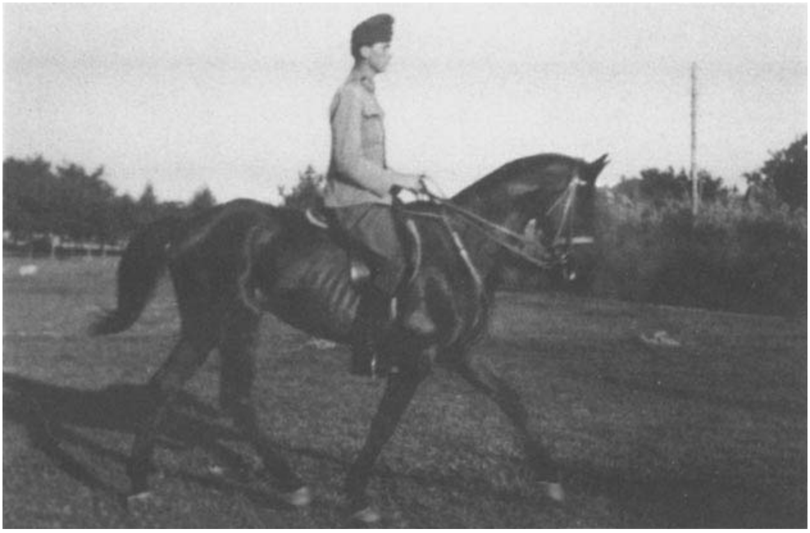


Tom Paulay, 2003.

Tom Paulay's father, György Paulay.

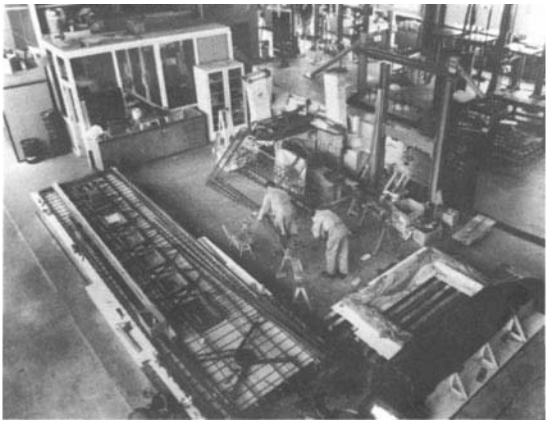
Tom, three years old, with his mother, Margit.

Tom, age 17, with his father's two favorite horses.

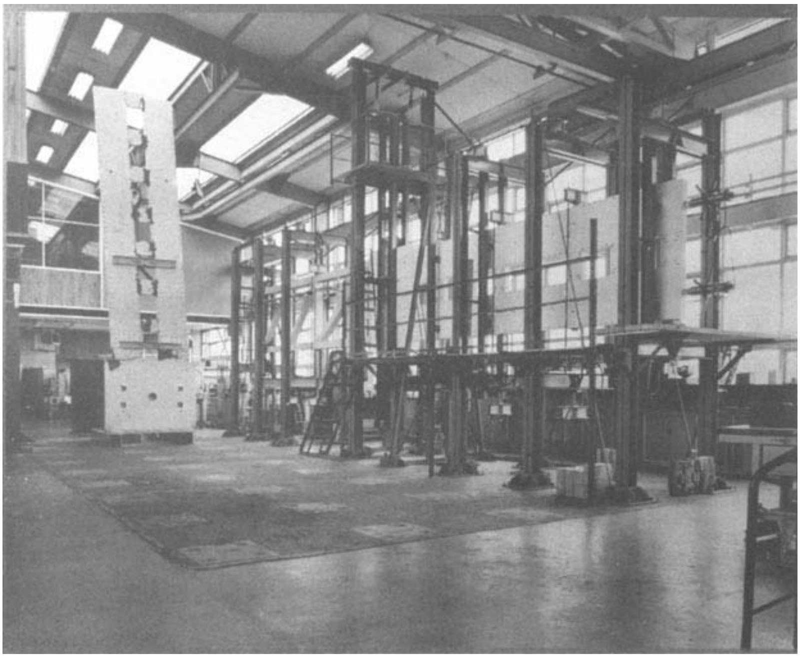


Tom in 1943, at the Royal Hungarian Military Academy.

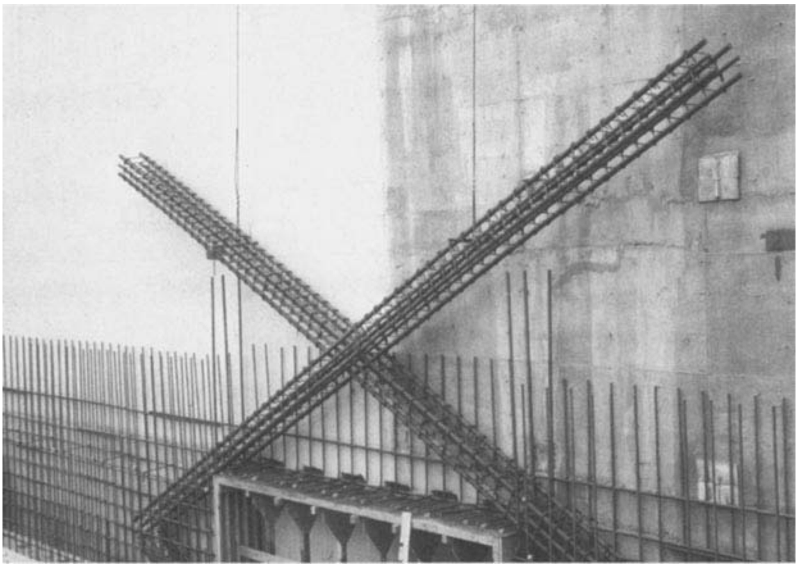
Graduating with a Bachelor of Engineering degree from Canterbury.



Construction of a quarter-scale, six-story specimen with coupled walls in the Structures Laboratory at the University of Canterbury, circa 1970. This specimen, part of the Ph.D. research of Paulay's Ph.D. student A.R. Santhakumar, had diagonal reinforcement, as developed earlier by Paulay, and performed much better than a twin specimen with conventional stirrup shear reinforcement in the beams.

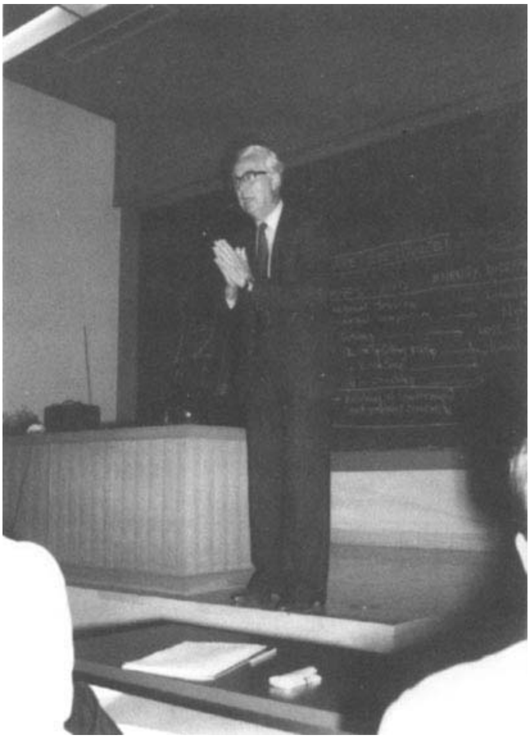


Coupled wall model in the University of Canterbury Structures Laboratory, erected in its upright position after it had been tested in a horizontal position.



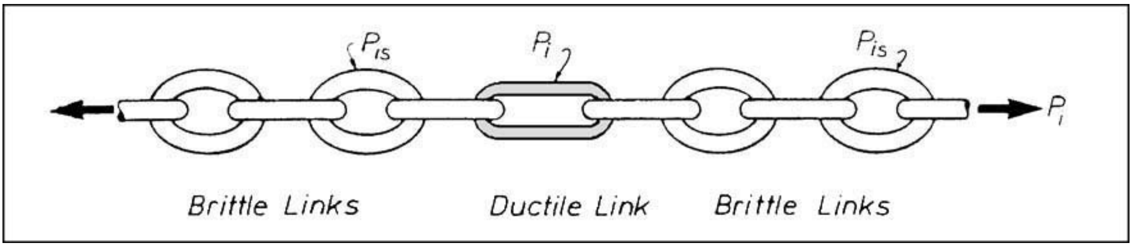
Diagonal reinforcement in a story-high coupling beam at the Sutter-Stockton Garage, San Francisco, following the innovation introduced by Tom Paulay. (Photo by Degenkolb Engineers)

Professor Hiroyuki Aoyama and his family with Tom Paulay in Tokyo.



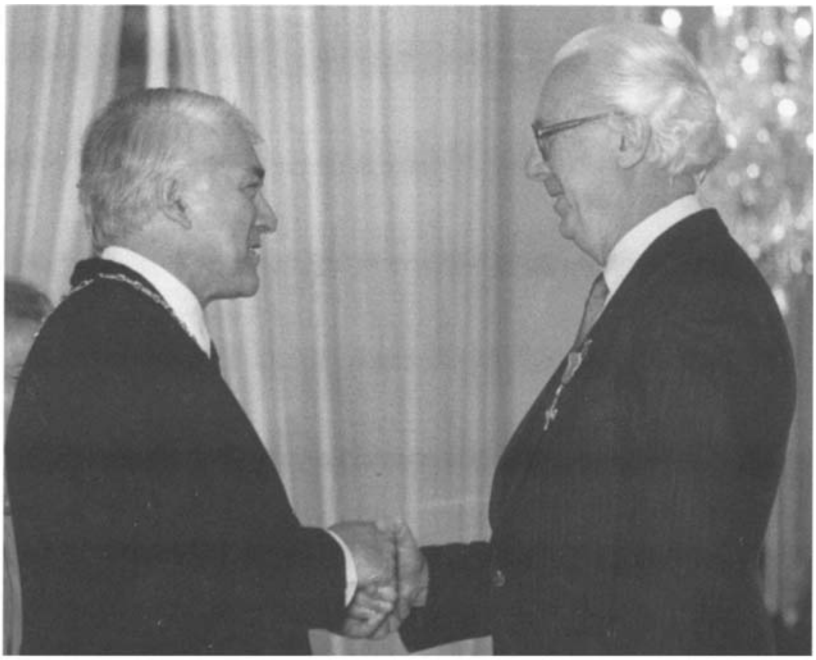
Tom Paulay concluding a lecture in Tokyo with a prayer for Japanese buildings.
(Photo by Shunsuke Otani)

Left to right: Hugo Bachmann, Osamu Joh of Hokaido University, and Tom Paulay.



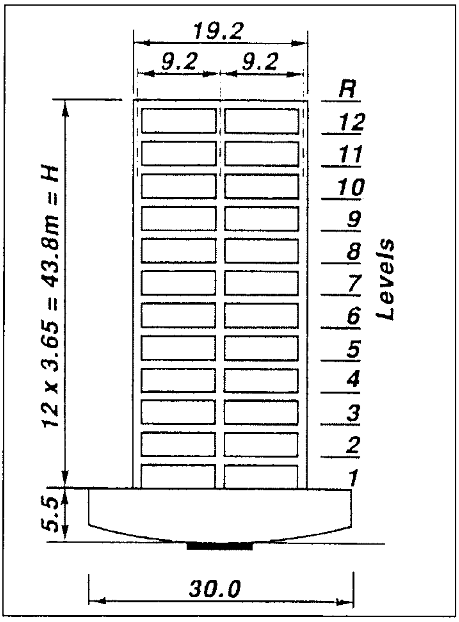
The capacity design analogy of a chain with one of its links weaker and more ductile than the others.

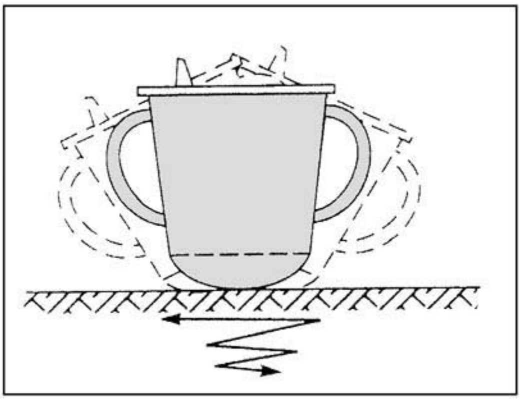
Left to right: Tom Paulay, Herta Paulay, and Hugo Bachmann at Schiers in the Swiss Alps, with the Salginatobel Bridge designed by Robert Maillart in the background, 1992.



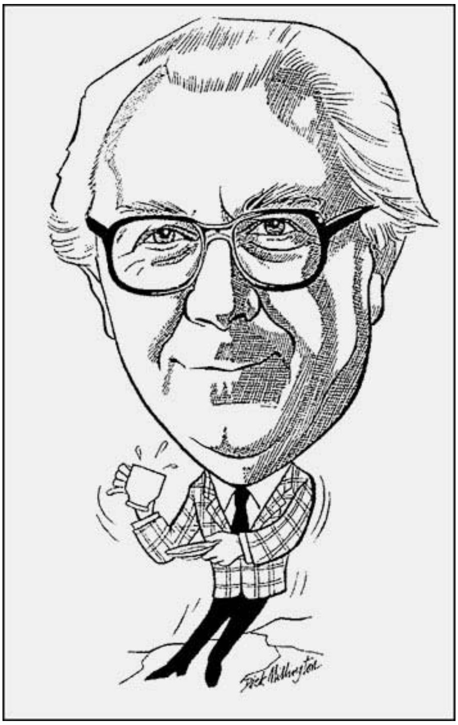
The Governor General of New Zealand, the Most Reverend Sir Paul Reeves, at the installation of Tom Paulay as an Officer of the Order of the British Empire in 1986.

Tom Paulay receives the honor of Distinguished Fellow of the Institution of Professional Engineers New Zealand in 1998 from the Institution's President, John Blakeley.





The spoof "Seismocup" seismic design of a tall building originated in a talk given by Paulay at the sixtieth birthday of Professor Hugo Bachmann of the Swiss Federal Institute of Technology in Zürich, pictured with Tom Paulay in 1995. The infant's cup, which rocks but does not tip over because of its rounded and weighted base, was extrapolated into a full-scale, realistic-looking building design—realistic enough in appearance and in its technical description by Professor Paulay to fool more than one member of an audience when this lecture was delivered.



Nigel Priestley with Tom Paulay in New Zealand, 2005.

Caricature of Tom Paulay from the May 28, 1993, New Civil Engineer *magazine.*

Herta and Tom Paulay at the banquet of the 2003 Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park. (Photo by Fumio Watanabe)

A Conversation with Robert Park and Thomas Paulay

Reitherman: Perhaps we could start off this conversation here at Bob Park's house in Christchurch, New Zealand by having you two explain how you first met your mutual colleague and mentor, Harry Hopkins. There are many things that have connected your careers, and I gather from your individual interviews that Hopkins was one of the most important.

Meeting Harry Hopkins

Park: I met Harry when I was a student, doing a Bachelor of Engineering (B.E.) Civil. He taught mechanics and was also head of the Civil Engineering Department. I took an instant liking to him. He was a natural leader. A rather gruff man, he liked his own way, a man's man. He had great enthusiasm for history and for concrete. He treated me like a close family member.

Paulay: I met Harry Hopkins perhaps a little earlier than Bob did. Harry came to the University of Canterbury in 1951 from Australia. Harry was the first man I had to negotiate with to be admitted to the university and continue my interrupted civil engineering studies. The dean, a mechanical engineering faculty member, was inclined to give me only one year of credit for my previous work, and I was a bit disappointed. But Harry let me enroll in the second professional year, the third undergraduate year, giving me two years credit for my studies in Europe. Later on, when my wife Herta was ill at home, out of the blue there was a knock on the door. There was Harry Hopkins, who had heard of her illness and thought he should call on us. It was a lifelong relationship—with him, his wife, his son David, and being at all of the weddings of Harry's five children.

Reitherman: Hopkins wasn't an earthquake engineer. So why did both of you end up in that field?

Park: When I was in Bristol, England, on the staff there and getting my Ph.D., I was quite interested in inelastic behaviour, ultimate strength theory. When I came back to New Zealand, I thought a natural application of that approach was seismic design. Then there was the case of the thirty-four-storey Bank of New Zealand Building early in my career, in the 1960s, when Tom and I went to Wellington to consult with the structural designers. We concluded that the structure couldn't be reliably designed in reinforced concrete to withstand earthquakes—we simply didn't know enough. That was a call to action.

Paulay: My eight years in consulting engineering practice made me aware of the importance of the earthquake issues and the serious shortcomings in the understanding of many relevant features in New Zealand. After joining the University of Canterbury, I discovered the golden opportunity for delving into seismic aspects of structural design.

Reitherman: There seem to be three main subjects in the earthquake engineering field when it comes to designing structures: inelasticity, dynamics, and probability. In your career, Bob, and also in yours, Tom, it seems to be the theme of inelasticity that was at the core of your interests. From dynamics and probability, you obtained an understanding of the demand side of the equation, but you seemed to concentrate on the properties of the structure and how it could be designed with confidence to behave inelastically—the capacity side.

Paulay: In the 1950s, engineers designed for earthquakes as if the lateral forces originated from some kind of glorified wind, using elastic, working stress design assumptions. There was no thought for inelastic behaviour of the structure. The same thinking was applied to other loads at the time. Bob started teaching seminars for practicing engineers to convert them, to get them to look at the ultimate limit state. From then on, we became more and more aware of a basic earthquake problem: what if the earthquake is a little larger than you have budgeted for? There are the dynamic response and probabilistic aspects, as you say, but we thought there were enough problems to be solved just dealing with how this composite material would respond with particular detailing to ensure ductile behaviour. And you had to test and verify your ideas, and there were always a few surprises. The professionals came back with probing questions.

Park: The professionals were crying out for answers. It was a huge incentive to get on with it. Seismic design was the outstanding problem for them in New Zealand at the time. We were inspired by the work of others, such as the Blume, Newmark, and Corning book,[70] and

70. Blume, John A., Nathan Newmark, and Leo Corning, *Design of Multistory Reinforced Concrete Buildings for Earthquake Motions*. Portland Cement Association, 1961; re-published in 1992.

the work of people like Mete Sozen and Vitelmo Bertero. I thought we should pick that up and do more. Major earthquakes overseas were a big push as well. I was interested in the actual behaviour of real structures.

Reitherman: I know you both value clear and complete drawings, along with photographs and other illustrations, of your experiments, your analyses, your engineering ideas. In dynamics, the illustrations often resemble stick figures that look like simple playground structures, lollipops and so on, but the pictures don't look like real buildings or bridges. Once the simplifying assumptions are made, the powerful analytical techniques of dynamics produce voluminous and precise results, but I sense that you two saw that your contributions would lie elsewhere, with the findings that could be illustrated with drawings of rebar, diagrams of areas of concrete that acted like struts, pictures of cracking patterns that represented different failure modes.

Paulay: Bob and I thought that after the dynamic analysis was done, or a dynamic simulation conducted on the shake table, the structural designer still needed to choose the mechanisms that would start to form, and invent schemes to prevent others from forming. Dynamic analyses addressed, then, mainly modal effects associated with the vibrations of elastic systems. Little attention was given to similar features affecting inelastic systems. There was much work to do in that regard. What will happen if the earthquake happens to impose actions that are beyond our expectations? You need to put your finger on the weak link.

Park: You can learn a great deal from what is now called the pushover analysis—what will yield and what will not. In the 1975 reinforced concrete book,[71] you'll see the pushover analysis concept.

Paulay: We decided to identify the critical regions where ductility was needed, and we could do this because we *chose* them. Instead of relying on probability for the estimation of the reliability in the prediction of critical seismic actions in many potential regions of a structure, in terms of the development of possible plastic mechanisms, we tended cautiously toward exploring a deterministic design strategy. This is how the essential features of capacity design procedures emerged. If disaster strikes, if the displacements are large, what form does that disaster take in the building? That is what is up to the designer.

Park: Then we had to test to make sure that those areas that did yield could tolerate the amount of inelastic deformation imposed on them.

Paulay: Moreover, you have cases where the region that will behave inelastically may not be ideal. In frames, we wanted strong columns and weak beams. However, it is almost inevitable at the foundation level that the foundation structure will not be weaker than the column. We were worried about columns at the base of a twenty-storey building being subjected to displacements larger than those envisaged by the code. After all, an earthquake would not read the code. We needed to do the research to

71. Park, Robert and Thomas Paulay, *Reinforced Concrete Structures*. Wiley and Sons, New York, 1975.

ensure that a capacity design strategy would work for real buildings.

Park: And this is being re-invented, so many people are now hopping on the bandwagon.

Reitherman: Is it true that in the 1960s, engineers were focused on forces and stresses, not displacements and strains?

Paulay: In the 1960s, we studied the SEAOC provisions[72] and other design guides that focused on the question: how strong, in terms of earthquake-induced forces, should the structure be? That question somewhat distracted engineers from looking at the limits of displacements that the structure could tolerate under serviceability and ultimate limit states. The design concern of Hollings and other engineers initiated a study over several years addressing the viability of a procedure that would enable a rational and acceptable design practice, quantifying the appropriate strength hierarchy of elements of a ductile system. [73]

Park: The strong column-weak beam concept is now accepted worldwide, but there is still controversy over how strong. It's not easy to talk about the same thing: there are many different factors and definitions for what the strength is, with overstrength and so on. The ACI uses twenty percent, the European code thirty percent, to define how much stronger the column should be, but it depends on the material values you use. This comparison is the mission of the task group I chair now for the fib, Fédération Internationale du Béton, the International Federation for Structural Concrete, a critical comparison of codes around the world. The members of the task group are key people, like S.K. Ghosh, Jack Moehle, and Joe Maffei, who represent U.S. practise, along with people from Latin America, Europe, Japan. Perhaps we'll attain more consistency. But the U.S. is very hard to budge!

Reitherman: It does seem a noble and worthwhile goal: reinforced concrete is basically the same material in different countries, so it doesn't seem rational to have big national differences in building codes.

Paulay: Your valid observation reminds me of the thought that crossed my mind every time I crossed a border when traveling around Europe. While my passport was being checked, this signaled to me the fact that I was about to enter a place that had different limits on maximum permissible shear stresses in concrete.

Ten Theories Why New Zealand Excels in Earthquake Engineering

Reitherman: In a recent article on both of you, journalist Alistair MacKenzie observed, "Little wonder that New Zealand engineers have long concerned themselves with the seismic resistance of their structures. What *is* remarkable is the scale of the contribution New Zealand engineers have made to seismic engi-

72. *Recommended Lateral Force Requirements and Commentary*, Structural Engineers Association of California (SEAOC), Sacramento. Originally published without Commentary in 1959; the first complete edition with Commentary was published in 1960 and in succeeding editions at intervals through 1999.

73. Hollings, John P., "Reinforced Concrete Seismic Design," *Bulletin of the New Zealand National Society for Earthquake Engineering*. Vol. 2, no. 3, 1969, pp. 217-250.

neering, given their low numbers."[74] New Zealand has accounted for a large amount of the progress in earthquake engineering in the last half-century—a large amount of achievement in earthquake engineering, from a small country. That means a big output per capita. How come? Let me ask you that open-ended question and get your viewpoints, and then have you react to ten different theories on that question.

Park: Teamwork, for a start. Interaction between the researchers and the profession as a whole. Good technicians in the laboratory. Funding wasn't bad. Very good consulting engineers, thinking, questioning engineers. Of course, most of them are Canterbury graduates, so I'm biased! The practicing engineers would grab our theses from the university and apply them before anyone had a chance to publish any papers. The study groups of the New Zealand Society for Earthquake Engineering were a great advantage. They brought the best people together, willing to explore solutions for the big problems.

Paulay: The idea of influencing other countries or converting the world never entered my mind. It was just attention to the needs of this small country, responding to the needs of the practicing engineers. A wonderful Civil Engineering Department at Canterbury, good facilities, thanks to Harry Hopkins. The same number of technicians in the laboratory as there was faculty. And very good career technicians who would say to the new Ph.D. student, "I don't know what you are trying to prove, but I can tell you that five years ago we tried that and it didn't work."

74. MacKenzie, Alistair, "On Shaky Ground," *e.nz*. Institution of Professional Engineers New Zealand, Inc. Vol. 4/4, July-August, 2003, p. 18.

Reitherman: Hiroyuki Aoyama said in his paper in the 1993 Paulay Symposium[75] that what accounts for the fact that the New Zealanders come at seismic design problems from a different direction and arrive at different innovations is the Coriolis Effect, which is opposite from Southern to Northern Hemispheres. In the Northern Hemisphere, something set in motion, such as the atmosphere, exhibits a relative turn to the right, clockwise looking down on it. In the Southern Hemisphere, this turning tendency is opposite. He was being humorous, but it is interesting how many aspects of New Zealand earthquake engineering are different than in other countries.

Meeting the Needs of Professional Engineers and the Construction Industry

Reitherman: Nigel Priestley suggested that practical applications were actively requested from the researcher. For example, in the case of the New Zealand precast and prestressed concrete industries. Researchers did not simply seek research funding from research agencies and later on write up a chapter at the end on possible applications, did they?

75. "Empirical Versus Rational Approach in Structural Engineering—What We learned From New Zealand in the Trilateral Cooperative Research on Beam-Column Joints," *Recent Developments in Lateral Force Transfer in Buildings: Thomas Paulay Symposium*. Edited by Nigel Priestley, Michael Collins, and Frieder Seible. ACI SP-157, 1993.

Paulay: For our potential users, the credibility of our research results and proposals were in direct proportion to the extent to which they could be understood by engineers and the construction industry. While theoretical and experimental research work at Canterbury progressed hand in hand, the emphasis, perhaps unconsciously, was on the question "why things happen," not "how they happened." We knew we had to explain to the designers why a structure would behave a particular way. That was a stronger motive for us than gathering a wealth of data suitable for statistical evaluations. Bob has talked about the way the development of seismic-resistant precast concrete elements were developed to respond to a practical need here in New Zealand. He was largely responsible for initiating research to fill that need. Prefabrication of concrete elements promised significant economic advantages, but the postwar system of that type had not been developed with earthquakes in mind.

Word Getting Around

Reitherman: Another impact on the engineering world was the way students and visiting faculty came from a number of countries to Christchurch and returned home with new ideas.

Park: We have given short courses in China, Indonesia, Japan, Latin America, Asia, North America, and Europe. Not just papers and conferences, but short courses, and that has helped to get the New Zealand word around. The books have helped too.

Reitherman: The Park and Paulay text was published in 1975[76] and the Paulay and Priestley text in 1992.[77] The books have been extremely influential, almost revered. I heard a story from Joe Maffei about that. Working in an engineering office on a concrete structure, the partner said, "Get that authoritative New Zealand book off the shelf," and Joe replied, "Which one do you want? Old Testament or New Testament?"

By the way, I noticed from the university's scrapbook of visiting faculty that Paul Jennings came here twice.

Park: It was the fishing! Actually, he liked New Zealand, and sharing ideas with us.

Paulay: Paul was immensely helpful to me while patiently listening and talking to me for hours when we met later in India. The philosophy of capacity design was the subject of our conversation. Some of my concerns at that time were the possible effects of the dynamic response of ductile systems on the hierarchy of element strengths. Bringing in people from outside New Zealand was good for us, to talk to people with different ideas, posing new questions that we may not have thought of. We benefited greatly from people coming here.

Park: It might sound crazy, but having coffee or tea has something to do with our success as well. We would all sit down and have coffee or tea mid-morning and mid-afternoon at the same

76. Park, Robert and Thomas Paulay, *Reinforced Concrete Structures*. Wiley and Sons, New York, 1975.

77. Paulay, Thomas and Nigel Priestley, *Seismic Design of Reinforced Concrete and Masonry Buildings*. Wiley and Sons, New York, 1992.

time and talk to each other in the department, rather than having a cup alone somewhere.[78]

Dedication to Experimental Work, Professional Technicians

Reitherman: The one-to-one ratio of faculty to technicians was also a great advantage?

Paulay: The ratio was even higher when you factor in the faculty who didn't use the laboratory in their research.

Park: The technicians are a career grade. They also help plan how to do experiments.

Reitherman: There were also the graphics technicians. Your reports going back decades to the fifties and sixties are still models of clear presentation. The second volume of Tom's thesis, for example, is filled with wonderful illustrations, as if out of a book.

78. According to another New Zealander, William Robinson, a significant seismic innovation stemmed from the staff conversing over tea. "I was employed as a materials scientist at the Physics and Engineering Lab, DSIR, Lower Hutt, when Ivan Skinner at morning tea told me of his work on seismic isolation. After hearing the problems he was having with steel dampers, I went back to my office and carefully examined the periodic table. I concluded that there was only one metal, lead, which could satisfy all the requirements I felt necessary for absorbing the energy of an earthquake. This period of about two hours was one of the most productive periods of my life. I had invented the lead extrusion damper. After four years more work, I invented the lead rubber bearing, in 1974." Personal communication, William Robinson, 2004.

Paulay: I did them in pencil, and a very able lady did them in ink and did the final lettering. This was while I spent my first sabbatical leave with Fritz Leonhardt at the University of Stuttgart, Germany.

Park: You were lucky! I had to do my own figures at Bristol.

Paulay: We are both extremely indebted to Valerie Grey, who later on did nearly all the illustrations for our books. The fact that her files for the two of us were more extensive than those for the remainder of the department illustrates our preference for communicating with the aid of sketches. Over a period of two years, Valerie and I embarked on intermittent research work exploring the production of colour slides with the use of our primitive facilities. I recall that after one of my presentations overseas, the session chairman allowed one more question from the audience. It was, "How do you produce your beautiful slides?" Valerie was pleased when I reported to her after my return.

Reitherman: When I was young, I did some ink lettering with a technical pen (like the Rapidograph brand of pen) and a stencil, and had to scribe each letter. It was an incredibly laborious process, and if you got to the end of the line and ran out of space, or you made a blotch of ink, you started over. Today, those who have only known computer word processing and computer software for page layout, math, and drawing, have no idea how difficult it was.

Park: Today's students don't know what a slide rule is. It took some skill to guess where the decimal point was.

Paulay: You had to keep mentally awake and think about what the approximate value would be. The slide rule, although primitive compared to the computer, had an advantage. It made you develop also a feel for the anticipated magnitude of quantities.

Reitherman: It was about the mid-1970s that the hand-held calculator with trigonometric functions, exponents, roots, and the ability to store a value or two came down in cost to about U.S. $350. The actual computers of that day were centralized, refrigerator-sized and very expensive machines, because it wasn't until the early 1980s that you could have a computer on your desk, a desktop.

Park: The first computers used at Canterbury campus in 1961 had punch cards for the program and the data. And if you dropped the deck of cards you were in big trouble!

While queuing up for getting our cards punched, I had to concentrate on charming the lady who did it alone for the entire faculty of engineering.

Lack of Liability Impediments to Innovation

Reitherman: Let me put another possible theory on the table as to why there has been so much seismic innovation in New Zealand: not very many lawyers and lawsuits.

Park: Quite true. Liability for making an honest mistake is not the big deterrent to trying something new here that it is in some other places.

Paulay: I witnessed another type of impediment to progress. During my visit to a renowned European university, the professor in charge of concrete design tried to convince me that it is not appropriate to mention anything to students which is not laid down in codes.

Lack of Political and Bureaucratic Impediments to Innovation

Reitherman: Another explanation I have heard is that New Zealanders have managed to cut through the bureaucratic red tape, or that there is much less of it in the first place.

Park: In our code committees, we keep the industrial participation to a reasonable minimum and avoid the tendency to protect individual interests. The central government was not bureaucratic from our viewpoint. People like Otto Glogau at the Ministry of Works were great allies. Our academic research got into the code for the design and construction of public buildings very quickly.

Paulay: As I noted earlier, the speedy publication in the *Bulletins* of the New Zealand National Society for Earthquake Engineering, or later called the New Zealand Society for Earthquake Engineering, of the conclusions of workshops sponsored by the Society were widely studied and in many cases applied immediately. In one case, the local authority that issued building permits advised a designer that a particular clause of the code could be ignored provided that the recommendations spelled out in the *Bulletins* were followed. It is a nice example of how common sense made the red tape in New Zealand so much thinner.

Nationwide Extent of the Seismic Problem

Reitherman: How about the national extent of the seismic problem in New Zealand? In the U.S., the most seismically active regions of the country account for ten percent or so of the country's densely developed area and population. Our largest city, New York City, and our capital, Washington, have a low level of seismicity by comparison with the West Coast, though New York has in recent years begun to adopt some earthquake code regulations and seismically evaluate large bridges.

Park: The whole of New Zealand is thought to be seismic. Christchurch is only medium risk, but people still expect an earthquake to strike here. Wellington, our capital, has much higher risk.

Paulay: We believe that we should use seismic details throughout New Zealand just in case you get an earthquake where you didn't expect one or an earthquake larger than what is currently expected. These details, somewhat simplified in low seismic risk regions, are usually very inexpensive—much less expensive than the floor covering, the door hardware, the marble veneer on the wall.

Park: These days, a structure only costs twenty percent or so of the total building cost, so a little extra expense on the structure doesn't change the overall budget much.

Advantage of Being a Small Country

Reitherman: Others have suggested that because of the relatively small population of New Zealand, about four million, there is less volume for the innovation to spread through, so it's like a gas diffusing more rapidly throughout a smaller, rather than larger, chamber. Research developed here in Christchurch and in Auckland can diffuse through the society rapidly.

Park: Having only two universities teaching our structural engineers, Canterbury and Auckland, which are both regionally strong, has been a strength. We don't turn out any weak graduates.

Paulay: Whoever mattered in this country, you knew them by first name. Practitioners never hesitated to talk to the academic who had done the research. We also found an effective way to enter the design offices through their back door. We introduced our most recent ideas, developed while doing research, into our undergraduate teaching. After graduation our former students were brave enough to tell the bosses who hired them that what they were doing was out of date. The bosses were remarkably flexible in adopting non-codified approaches, provided that they could be convinced of their rationale and advantages.

Collaboration Among Universities, Practitioners, Industry, Government

Reitherman: I'm now down to number eight on the list of theories for why New Zealand has accounted for so much in the earthquake engineering world. Collaboration here is both broad and efficient. It consists of collaboration among four basic elements: universities, e.g., the University of Canterbury; practicing engineers, represented, for example, by the Institution of Professional Engineers New Zealand (IPENZ); industry, such as the concrete industry; and government, e.g., the Ministry of Works.

Park: That's a fair description of the four basic aspects of the collaboration. You should also emphasize the importance of the societies, such as the Concrete Society, which bring people together at an annual conference, with long talks at the bar in the early hours of the morning. We had a bit of competition among people as to what organization would represent the earthquake engineering field here in New Zealand. The Third World Conference on Earthquake Engineering, held in Auckland and Wellington in 1965, was a big help in forcing the collaboration. The New Zealand Society for Earthquake Engineering has been a great help.

Geographic Remoteness

Reitherman: Another theory is based on an obvious geographic fact: New Zealand is remote, it has been forced to be on its own. And New Zealand is a Commonwealth nation that inherited British engineering practice. During those middle years of the twentieth century, and still today by comparison with highly seismic nations, that design and construction tradition from Britain has relatively little earthquake engineering in it. New Zealand is remote in terms of distance from countries such as Japan, the U.S., Italy, where there is a strong tradition in earthquake engineering. Your neighbor, Australia, is relatively low in seismicity and earthquake engineering concerns. So you had to innovate, had to be open to new ideas, had to depart from conventional approaches.

Park: The early steel code, concrete, and so on, were direct imports from England. And the 1931 Hawke's Bay earthquake demonstrated their inadequacy. Early on, New Zealanders realized they had to develop their own engineering solutions to their own problems.

Paulay: My work was especially affected by SEAOC, the Structural Engineers Association of California. Their Blue Book,[79] the approach of the practitioner to the earthquake problem, impressed me. So we started to learn from relevant California recommendations.

Park: The early Ministry of Works codes were very much based on SEAOC provisions.

Reitherman: But unlike some countries in Latin America, for example, which imported the SEAOC provisions essentially in one piece and incorporated them into their building codes, New Zealand learned from that approach, but followed a different path at times.

Park: We tried to rationalize the answers, so we didn't always agree. The U.S. has had a huge influence everywhere. If you go to Latin America, you'll see a battle going on now between European practise and ACI practise in concrete design. ACI has prevailed to date, but it hasn't been easy. In Argentina, they are keen on German practise.

Paulay: Our departures from provisions of other countries with advanced developments in earthquake engineering were often initiated by the needs identified by our design practitioners and their persuasive request to researchers to address specific concerns. The frequent success we did have in convincing some of our colleagues in other countries was due to our ability to convert most of our academic visitors. Dur-

79. *Recommended Lateral Force Requirements and Commentary*. Structural Engineers Association of California (SEAOC), Sacramento. It was nicknamed the "Blue Book" because of its light blue cover.

ing their stay for longer periods at Canterbury, at the expense of long and penetrating—yet very enjoyable and exciting—discussions, we could not only cover the finer points, but also dispel justified reservations. As an example, Joe Maffei is one of our valued friends who has persistently waved our earthquake flag in California.

Self-Reliance, Industriousness, Independence

Reitherman: Now, here's number ten on the list of theories, one suggested by José Restrepo: that New Zealanders have the individual character traits of self-reliance, industriousness, independence. It's also something suggested by University of California at Berkeley professor James Kelly. I heard him tell the story of a New Zealand Ph.D. student of his, Ian Aiken. Kelly drove to Aiken's rented home soon after his arrival to see how he was doing. Kelly found Aiken in the front yard—literally in it—up to his waist in a hole he was digging. When Professor Kelly asked him what the heck he was doing, Ian explained matter-of-factly that there was a problem with the pipe, he had located the problem, and he was fixing it.

Park: New Zealanders tend to be very hands-on people, building their own homes, doing it yourself, solving their own problems.

Paulay: New Zealand is a young country, and I feel that the pioneering spirit has lasted longer here than in older, more sophisticated societies. Plumbing, fuse box, gear box of a car—the attitude is, "I'll fix it."

Park: And probably with number eight fencing wire.

Reitherman: That is obviously an inside New Zealand joke. What's number eight fencing wire?

Park: It's a gauge of wire used in fencing, such as on the sheep ranches, and it has taken on many other uses as well as the need arises. We have little weight of history upon us. Japan, by contrast, has trouble changing from what the older people are used to. For example, even today it is hard to depart from working stress design there.

Paulay: I remember giving a talk in China where a graduate student met me and said he wanted to hear my lecture but he had not been allowed to join his elders. When I have tried to convince practicing engineers in New Zealand to use my theory, my research, they feel quite free to say, without any respect for their elders getting in the way, "Sorry, Tom, I don't understand why this is rational." They rely on their own thinking. If I can convince them that a solution is rational and makes sense, then they adopt it.

Park: We get the pick of the bunch in bringing new students into civil engineering. We've been very fortunate.

Changes in Civil Engineering Departments

Reitherman: I would generalize that your experience is quite different than in the U.S. It is a common lament among civil engineering faculty, especially the structural and geotechnical engineering professors, that their enrollments are down, there hasn't been a civil engineering professor filling the position of Dean of the School of Engineering for some time, that the big money after graduation goes to the genetics, computer science, or business graduates, not to civil engineers.[80]

Paulay: Too many people think the civil engineer is a person who drives the bulldozer. With my wife Herta, with her European background, this is a delicate point. She thinks it is disappointing that I have a title that sounds like I fix engines. In fact, it comes from the Latin meaning inventor, genius.

Sometimes, when I was annoyed by the ignorance of people asking what civil engineers do, I replied, "Madam, amongst many things they do, they attend to your personal needs after you pull the chain." To alleviate these misconceptions in New Zealand, the term "professional engineer" is used.

Reitherman: Most people have a fairly good idea of what doctors or lawyers do, but a poor notion of what civil engineers do. This is something else engineers in the U.S. complain about, in addition to the relative decline of the status of civil engineering departments.

Park: Canterbury's Civil Engineering Department is still holding its own, and we find our graduates are in great demand in the profession. But I can't predict the future.

80. In the U.S., civil engineering bachelor's degrees declined by thirteen percent from 1994 to 2003, while computer science degrees went up 238 percent. Brighton, John, *Status of the Science and Engineering Workforce*. National Science Foundation, July 15, 2004.

The Three Ps: Park, Paulay, Priestley

Reitherman: Let me mention Nigel Priestley again. Both of you have mentioned that this symposium in your honor this week [July 2003] for the "two Ps," Paulay and Park, should have been for the "three Ps," Paulay, Park, and Priestley.

Park: The next one will be—when he turns seventy! Nigel is so ingenious. He is so talented. He worked originally on bridges, but of course now he's so wide, he's done work on so many things.

Reitherman: I've heard from Joe Maffei that when strain gauges were manually read, with four digits called off from each instrument for another person to write down, Nigel could remember previous readings and spot errors in the lab notebook.

Paulay: I can only endorse the statement that he is a genius. When he was here at Canterbury, he realized that we were both in concrete, so he picked up a new material to him, masonry, which is used all over the world. But from a researcher's point of view, it is a lousy material. It is very difficult to make a mathematical model of a masonry structure. But Nigel took it up and made a success of it.

Reitherman: Tom, in your textbook with Nigel, *Seismic Design of Reinforced Concrete and Masonry Buildings*,[81] did Nigel write most of the material on masonry?

Paulay: No. He wrote *all* of that material.

81. Wiley and Sons, New York, 1992.

Park: Gil Hegemier was the one at the University of California at San Diego who enticed Nigel away in 1986, to help Frieder Seible set up the big testing laboratory there. We had hopes of getting him back here, but I think we've permanently lost him. He spends much of his time now in Italy at the ROSE school in Pavia.[82]

Paulay: I remember Bob telling me during the years after Nigel's departure, that whenever he wrote to San Diego, he reminded them that Nigel was on loan to them! The Department of Civil Engineering lost him, but as a friend and colleague, we did not. After all, Nigel spends about half the year in Christchurch, and when he is here he likes to discuss many interesting research issues which arise in the ROSE school. Some Ph.D. students there contact me from time to time, perhaps with some encouragement from Nigel, in the hope that I can deliver some enlightenment.

Future of Earthquake Engineering

Reitherman: The 1960s, the 1970s, the 1980s were the decades that really put the University of Canterbury on the map as a place that someone in the earthquake engineering field had to know about. So now, here we are at 2003. What is the future of earthquake engineering, with respect to the University of Canterbury, or New Zealand, or perhaps globally?

Park: I hope Canterbury will continue to prosper. It's up to people like John Mander, who heads up the structural engineering here now. So much depends on the right people being here. The opportunities in our day were huge. Now, the progress is in increments, not in huge steps. So it's not so easy to match the huge steps of the early years.

Reitherman: Tom, do you have an opinion about the future?

Paulay: I don't really like to talk about it, because I am somewhat disappointed by the trends over the last twenty years on the university side. My views are a bit gloomy, perhaps because I cherish those golden earlier years, the utter freedom that brought out the best in each of us. Because it was a joy, because it was meaningful. There was very little administrative burden. Harry Hopkins told me, "You might think I'm a bit of a bossy fellow. I sit up there and make all the decisions. But I do it so you fellows can do all the teaching and research. I do all the boring paperwork for you." Now, today, when you look at the universities, it's different. Bureaucracy is sapping the energy better devoted to research.

Park: It's almost immoral for good people to waste their time on administrative paperwork. You need to delegate and have good people around you. But no matter what, there is more paperwork today. There's a lot of time spent on strategic planning today. We didn't spend a lot of time on that. We almost intuitively knew what needed to be done.

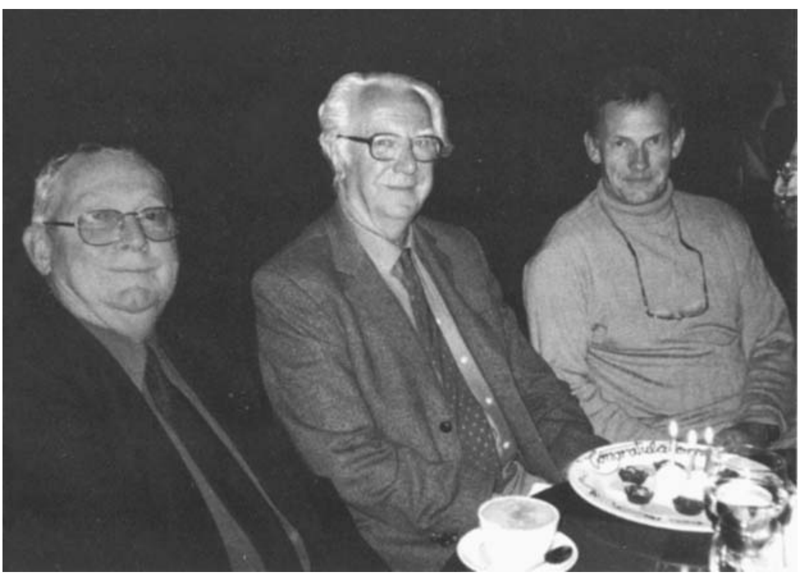
82. European School for Advanced Studies in Reduction of Seismic Risk, University of Pavia, Italy.

Photographs

Bob Park and Tom Paulay at the University of California at San Diego on the occasion of Tom's seventieth birthday in 1993.

Speakers and honorees at the 2003 Symposium to Celebrate the Lifetime Contributions of Tom Paulay and Bob Park. Left to right: David Brunsdon, Rob Jury, Des Bull, David Hopkins, Richard Fenwick, Len McSaveney, Thomas Paulay, Robert Park, Max Irvine, Trevor Kelly, Richard Sharpe, Barry Davidson (kneeling), Kevin Thompson, John Mander, Nigel Priestley, Graham Powell, Michael Collins.

Tom Paulay, left, the portrait artist Sally Hope, and Bob Park at right, on the occasion of the unveiling of their University of Canterbury portraits, October 2004.



Bob Park, Tom Paulay, and Nigel Priestly celebrate their collective 200th birthday.

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