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June 4, 2010

Mr. M. Scott Ratliff
Travelers Insurance Company
P.O. Box 662
Richmond, VA 23113

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| RE: | Structural Investigation- Roof Collapse<br>Blacksburg High School Gymnasium |
| INSURED: | Virginia Association of Counties/Montgomery County School Board |
| CLAIM #: | DMF3428 |
| FORCON CASE #: | V10155 |

Dear Mr. Ratliff:

Per your request, FORCON traveled to the Insured's property located at 520 Patrick Henry Drive in Blacksburg, Virginia, to investigate the origin and cause of the roof collapse. We also investigated the structural integrity of the gymnasium floor and first floor supporting walls that remained under the collapsed roof structure. The date of our site visits were March 1, May 10, and May 19, 2010. The following report provides our general observations and final conclusions.

This portion of the high school includes the Gymnasium, Auditorium, and Commons Area. The construction of this portion was completed in 1974. Our investigation is limited to the Gymnasium and the area immediately to the North damaged by the Gymnasium Roof Collapse. The Gymnasium Roof collapsed on Saturday, February 13, 2010. One of the school's coaches reported concrete masonry (CMU) falling from high up on the South wall early in the morning. An engineer from OVPR Architects and Engineers, was on site when the collapse occurred, performing an investigation at the request of Montgomery County Schools. Photographs made immediately before and right after the collapse are included in the observations below. All of these Photographs are from the OVPR website, taken by others. For clarity, our observations are grouped by date of site visit.

From the As-Built Drawings, the building is 152 feet wide by 106 feet deep. There are two main steel trusses that were supported on steel columns at each end (North and South). The main trusses are located at 31 feet 2 inches from the left and right sides of the building. Steel trusses spaced at 13 feet 1 inch span between the left and right exterior walls and the main trusses. The roof between the main trusses is supported by steel trusses spaced at 13 feet 1 inch apart and spanning 46 feet 8 inches. For clarity, the main truss at the left side is described as the west truss, and the main truss at the right side is described as the east truss. The Auditorium is located to the North.

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OBSERVATIONS

A. The following Photographs were taken by others on February 13, 2010:
   - Photographs # 1, # 2, and # 3 show the front, right, and left side of the Gymnasium after the roof collapsed. Firemen on the scene observed that there was eight inches of snow and ice on the roof. The roof drains were clear of snow and ice.
   - Photograph # 4 shows the south end of the west roof truss, just before the roof collapse. CMU has fallen away from the truss top chord seat area. The masonry pilaster surrounding the steel column supporting the truss has numerous vertical cracks, larger near the top than at the bottom.
   - Photograph # 5, taken just after Photograph # 4, shows that the top chord has rolled to the left, creating additional movement of the CMU.
   - Photograph # 6 shows the south end of the west roof truss, just after the roof collapse. Note that the top chord web has been bent upward, with a notch.
   - Photograph # 7 shows the column that supported the north end of the west roof truss. The bottom chord of the truss bent the column and damaged the surrounding CMU walls.
   - At the Gymnasium Floor level, Photograph # 8 shows the south end of the east roof truss. Note the top chord web has been bent upward.
   - Photograph # 9 shows the south end of the east roof truss. Note that the bottom chord has bent upward, beginning at the first web member intersection.
   - Photograph # 10 shows the roof near the south end of the east roof truss. The roof deck split parallel with and to the right of the truss. There is approximately eight inches of snow on the roof.
   - Photograph # 11 shows the roof trusses to the right of the east roof truss. The truss bottom chords have broken free of the main truss.
   - Photograph # 12 shows the north end of the west roof truss. The truss bottom chords have broken free of the main truss.
   - Photograph # 13 shows the north end of the east roof truss. The bottom chord has bent upward.

B. The following observations were made during our March 1 inspection:
   - The gymnasium roof was collapsed onto the concrete gymnasium floor.
   - The Auditorium roof was intact.
   - Based on eyewitness descriptions, the roof collapse started at the Southwest column with the main truss rolling to the right, pulling the Southeast end of the East main truss from its column, then pulling the Northwest and Northeast ends from the columns.
   - Photograph # 14 shows the left side of the collapsed roof, as well as, the South-west column. Note the column is straight. Also, note that the roof surface appears to be unbroken directly over the main (West) roof truss.

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- Photograph # 15 shows the center section of the collapsed roof.
- Photograph # 16 shows the right side of the collapsed roof, as well as the Southeast roof column.
- Photographs # 17, # 18, # 19, # 20, and #21 show the top of the Southwest column. The bottom portion of the truss seat remains attached to the top of the column. The web is bent to the right, with several notches.
- On the Gymnasium floor level, Photographs # 22, # 23, and # 24 show the South end of the West main truss. The web of the truss seat has several horizontal tears. The lowest tear is below the horizontal weld that originally joined the upper and lower halves of the truss seats. The masonry surrounding the Southwest column has been broken away.
- On the Ground floor, Photograph # 25 shows the masonry pilaster that surrounds the lower portion of the Southwest column.
- Photograph # 26 shows top of the Northwest and Northeast columns. Both columns are bent at the location where the truss bottom chord connected, so that the top of the columns are bent toward the South.
- Photographs # 27 and # 28 show the top of the Northwest column. The truss seat remains attached to the top of the column and is bent to the right. The CMU wall that extended to the Gymnasium roof is also shown- there is no reinforcement visible. This CMU wall fell away from the Gymnasium.
- On the Mezzanine level, Photographs # 29 and # 30 show a bend in the Northwest column. Photograph # 31 shows shoring posts added below the roof beam because the CMU wall was pulled outward by the column movement.
- Photographs # 32, # 33, and # 34 show the top of the Northeast column. The truss seat remains attached to the top of the column, and is bent to the left. The CMU wall that extended to the Gymnasium roof fell into the Gymnasium.
- On the Gymnasium floor Level, Photographs # 35 and # 36 shows the North end of the East main truss. The top chord is jammed against the column, and holding the end of the truss above the Gymnasium floor.
- Photograph # 37 shows the right side of the Gymnasium. The roof trusses are resting on the bleachers.
- Photographs # 38, # 39, # 40 show the upper portion of the Southeast Column. The bottom of the truss seat measures 12 inches wide by 12 inches deep. The web is bent to the left. Photograph # 41 shows the roof debris at this column.
- On the Gymnasium Floor Level, Photographs # 42 and # 43 show South end of the East main roof truss. The bottom chord is bent upward from the first truss panel point. The first truss panel point is located approximately 12 feet from the Southeast column. The first vertical web member is bent. Directly below this panel point, there is a hole punched through the concrete Gymnasium floor (Photographs # 44 and # 45). On the Ground Floor, at the JV Team Room door, Photographs # 46 and # 47 show damage to the CMU bearing wall below. Photograph # 48 shows cracking in the CMU pilaster surrounding the Southeast column.

- On the Ground Level, at the front of the building, a concrete canopy extends between masonry stair towers (Photograph # 49). The canopy extends 48 feet across and is 10 feet 6 inches wide. Photograph # 50 shows that the 12 inch wide by 40 inch deep beam that supports the front edge of the canopy has broken.
- Photographs # 51, # 52, and # 53 show cracks in the Left stair tower Ground Level walls. These cracks have been previously caulked and painted. There are no new cracks in these walls.

C. The following observations were made during our May 10 inspection:
- Demolition contractor was mobilized on site. Temporary shoring had been installed.
- Photographs # 54, # 55, and # 56 show the left side of the building before demolition.
- There is an existing crack monitor located in the Girl's Locker Room (Photograph # 57), on the opposite side of the wall from Photographs # 51, # 52, and # 53. Photograph # 58 shows permanent shoring installed previously to support the Gymnasium floor above.
- To monitor additional movements of the Gymnasium floor and supporting walls during demolition, seven crack monitors were installed at various locations across existing cracks in Gymnasium floor concrete beams and joists, as well as cracks in the existing CMU walls (Photograph # 59).
- Photographs # 60 and # 61 show the South end of the West main truss. This is to be transported to a metallurgical laboratory.
- Photograph # 62 shows the Southwest column as well as the South end of the West main roof truss.
- Photograph # 63 shows the Gymnasium Floor opening at the Southwest column- there is no apparent damage to the concrete.
- Photographs # 64 and # 65 show the North end of the west main truss at the Northwest column. The truss is jammed into the existing column and held 4 feet above the Gymnasium Floor.
- Photograph # 66 shows the south end of the East main truss being cut off. Photographs # 67 and # 68 show the truss after the end has been cut off.
- Photograph # 69 shows the Gymnasium Floor opening at the Southeast column- there is no apparent damage to the concrete.
- Photographs # 70 and # 71 show the shoring installed below the Gymnasium Floor framing near the Southeast column. The floor joist has broken away from the concrete turndown beam that spans between the CMU load-bearing walls. A crack monitor was installed on the beam at this location.
- Photograph # 72 shows shoring installed beneath a cracked concrete beam in Electrical Distribution Room A-47 located on the East side of the East Corridor. Beyond the cracked CMU wall shown, the structural system changes from a concrete pan-joist system to a one-way slab spanning between concrete beams.

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D. The following observations were made during our May 19 inspection:
- The steel roof structure as well as all other debris has been removed from the Gymnasium Floor. The wooden and rubber floor systems have been removed from the Gymnasium Floor.
- The Southwest column is twisted and out of plumb (Photographs # 73 and #74). During demolition, the contractor hit the column with his construction equipment, and damaged the column.
- Photographs # 75 and # 76 show an overall view of the Gymnasium Floor as seen from the rear (North). At the right and left sides (for the bleachers) the floor steps up two feet above the Gymnasium Floor level.
- Photograph # 77 shows the Northwest column bent outward with steel beam attached at the mezzanine roof level, shifting the beam outward. See Photograph # 78. Photograph # 79 shows water damage to the press box roof. Photograph # 80 shows the press box area with walls and roof removed.
- The main portion of the Gymnasium Floor has numerous areas where the surface has delaminated to a depth of 1/2 inch or less (Photograph # 81). This condition occurs on approximately 20 percent of the slab at this level.
- Photograph # 82 shows a six inch diameter hole through the right, raised area 20 feet from the front edge. Photograph # 83 shows this hole is punched through the slab, between the concrete joists.
- Photograph # 84 shows the hole that was punched through the slab and joists by the bottom chord and vertical web of the East main truss (directly below Photographs # 42 and # 43). Photograph # 85 shows the joist broken away from the concrete turndown beam- there is no reinforcement visible in the turndown beam. Photograph # 86 shows the underside of this area- there has been no movement in the crack monitor.
- On the right raised area, there are two hairline cracks in the slab that extend from the left to the right sides (Photographs #87 and # 88). They are located approximately 35 and 70 feet from the front of the building.
- On the left raised area, there are two hairline cracks in the slab that extend from the left to the right sides, located approximately 35 and 70 feet from the front of the building. Photographs # 89, # 90, and # 91 show the crack located at 35 feet, viewed from the underside (Ground Level Ceiling) - the crack extends through the joists, with no reinforcement visible. Photographs # 92 and # 93 show the crack located at 70 feet.
- Photograph #94 shows a crack monitor installed over a vertical CMU crack where a partition intersects the wall at the left side of the West Corridor. There has been no movement.
- On the right side of the West corridor, approximately 20 feet from the front of the building, Photographs # 95 and # 96 show a crack in the CMU wall , concrete joist, and concrete beam turndown (similar location to Photograph # 84).

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- On the Ground Floor Level, the masonry pilaster surrounding the Southwest column base was removed. Photograph # 97 shows the concrete slab at the column- there were no visible cracks.
- On the Ground Floor Level, the masonry pilaster surrounding the Southeast column base was removed. Photograph # 98 shows the concrete slab at the column- there were no visible cracks.

DISCUSSION:

The Gymnasium has a Ground Floor Level, Gymnasium floor Level and Roof Level. The Roof Level is 32 feet above the Gymnasium Floor Level. The roof is a built-up roof with gravel surface, installed in 1999 on wood fiber deck. The demolition process has removed the steel structure and roof from the site. The exterior masonry walls at the left and right sides of the building, supporting the ends of the roof trusses, were not reinforced.

As-built Drawings and Specifications do not include information as to the Design Live Loads used for the building design. The Building Code Live Load required at the time of original construction is 35 pounds per square foot. Based on a maximum snow density of 35 pounds per cubic foot (ASCE Standard 7), the eight inches of snow on the roof would have weighed 23 pounds. During the 36 years since the Gymnasium was constructed, there have been significantly greater snow accumulations on this roof, without collapse. Based on this above, we can rule out excessive live load as the cause of the collapse.

The Building Code Wind Load required at the time of original construction is 20 pounds per square foot. On the day of collapse, the wind velocity was very low, thus exerting minimal wind loads on the Gymnasium. Information from National Weather Service records indicates that on February 10, the average wind speed was 15.9 miles per hour (mph) with gusts of 46 mph from the Northwest. The peak would have exerted approximately 6 pounds per square foot of pressure on the building. The maximum wind load on the days preceding the collapse is less than 30 percent of the required Building Code design requirement. Based on this, we can rule out excessive wind load as the cause for the Gymnasium Roof collapse.

The cracking of the concrete slab and pan joists was caused by the overload that resulted when the roof structure dropped onto the floor slab, causing the concrete to go into tension before the load transferred to the steel reinforcement. All the cracks observed were hairline width, with no reinforcement exposed. This indicates that the joists have not failed.

The Gymnasium Floor is a reinforced concrete pan-joist system supported by 12 inch thick load-bearing CMU walls that are supported on concrete spread footings. The Gymnasium Floor is in good condition overall, except for the following:

1. Two foot diameter hole located 12 feet from the Southeast column. The corrective repair at this location involves the installation of temporary false work, then removing the slab

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and turned down concrete beam, leaving the existing reinforcement intact. Then, installing beam reinforcement in the turned down beam and placing new concrete.

2. Six inch diameter hole through right raised portion of slab. The corrective measure here involves the installation of a plywood form at underside of the slab, chipping out concrete to expose adjacent reinforcement, then re-pouring the concrete slab.
3. Concrete spalling on the main level. This can be repaired using a latex-modified concrete topping.
4. Concrete cracking in the bottom of the concrete joist and turned-down beam (Photograph # 96). The CMU walls adjacent to this location are also cracked (Photograph # 95). The repair involves installing a steel beam with plate beneath the concrete turned-down beam that spans from each CMU Load-bearing wall, then fire-rating the beam by installing fire code gypsum wall board, wrapping it.
5. Cracking of concrete slab and pan joist at various locations. The repair of these involves routing out the cracks, then installing a good quality, siliconized caulk.
6. Cracking of the Ground Level CMU Load-bearing walls. This can be repaired by routing out the joints and re-pointing with mortar, then repainting the area.
7. Cracking at the vertical CMU control joints at different locations on the Ground Level. These joints should be cleaned out, and then re-caulked.

There are no vertical movements that would indicate foundation issues due to the localized over-loading caused by the roof collapse.

The collapse began at the top of the Southwest Column with the West Main roof truss rotating down and to the right. The truss seat was constructed by welding a WT 12 x 60 piece (upside down) to the WT 12 x 60 top chord of the truss using a full penetration weld. The lower portion that remained attached to the top of the Southwest column had torn horizontally below this weld. The exposed edge had an irregular, notched tear, with what appears to be small areas of delamination. The ends of each main truss were cut off using a reciprocating saw, to allow the ends to be analyzed in a laboratory. The laboratory analysis will provide additional information that will be used to determine the cause of the steel truss seat failure at the Southwest column. We plan to issue a separate report to outline and summarize these findings.

CONCLUSION:

Based upon our discussions and observations to date it is our preliminary professional opinion that the Gymnasium Roof collapse was caused by a failure of the Southwest Truss Seat due to something other than an overload condition. We are awaiting final results of laboratory metallurgical analysis to identify what issues within the truss seat caused the failure and subsequent building collapse. An additional report will be forthcoming.

In our opinion, the Gymnasium Floor and supporting walls are in serviceable condition and can remain in place- provided repairs noted above are made.

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If further information is required, please contact our office.

We appreciate the opportunity to assist you.

Sincerely,

Henry W Moncure

Henry W. Moncure, P.E.
Structural Engineer
Enclosure