8.4.2 Portal Frame Loads

8.4.2.1 GENERAL

In addition to the portal frame loads determined in Chapter 4, the portal columns are subjected to axial compression loads, corbel moments and lateral loads due to the crane loading. The frames therefore need to be designed for extra load combinations with crane loads and in-service wind loads.

The crane code considers *out-of-service* and *in-service* wind loads for different load combinations but does not clearly define what these terms mean. Logically out-of-service wind loads are meant to be limit state strength wind loads and are therefore the same as previously calculated in Chapter 4 for the portal frame without a crane. They are not to be taken as coincident with full crane loading.

In-service wind loads are the wind loads which occur during crane operations. The selection of in-service wind speeds for determining crane load combinations and deflection limits for portal frame design has not been straightforward for designers. AS 1418.18 states that in-service wind loads are to be as determined by AS/NZS 1170.2 whereas superseded versions of AS 1418.1 and other references nominate an in-service wind speed of 20 m/s. The 20 m/s speed was really intended for exposed or partially exposed cranes and unfortunately, no in-service wind speed was given in these codes for cranes in enclosed buildings. More detail on the background to the confusion over in-service wind speeds for portal frame buildings supporting cranes is presented in the next section.

8.4.2.2 SERVICEABILITY WIND SPEEDS

Part of the reason for the confusion has been the slow transition for crane design from permissible stress design to limit states design. For example, Reference [5] which was published in 1983 indicates that the in-service *permissible stress design* wind speed to be used in crane load combinations was 20 m/s. It appears that this was meant to apply to internal cranes as well as to external cranes because the wind speed was presented in the context of supporting structure and photographs for both internal and external cranes. The superseded 1986 and 1994 versions of the crane code AS 1418.1 also nominated 20 m/s as the in-service design wind speed for cranes on stationary rails but stated that this wind speed applied to external and partially exposed cranes. This is rational enough because external cranes have operational limits on the wind speed at which they can safely operate. Reference [2] also suggests that the 20 m/s limit applies to cranes inside buildings unless the crane operation cannot be stopped such as for alumina potrooms. However, stopping the operation of an internal crane due to high winds does not seem a realistic procedure.

In any case, it follows from this discussion that the 20 m/s wind speed was meant to be a *site and structure specific wind speed* V_Z rather than a regional wind speed. Whether or not the 20 m/s limit was meant to apply to internal cranes in 1983, the question remains as to whether it is appropriate now to use as the serviceability wind speed for structures supporting internal cranes particularly for satisfying deflection limits?

Another part of the confusion in determining in-service wind speeds lies in the selection of return period to use. Return periods are generally now embodied in the Building Code of Australia for strength design purposes and the only guidance on return period is given in Appendix C of AS/NZS 1170.0 [4] which recommends a 25 year return period. Adopting 25 years as the appropriate return period, the serviceability or in-service wind speeds are then obtained from AS/NZS 1170.2 [11].

The AS/NZS 1170.2 serviceability wind speed for the particular building in the design example is 26.1 m/s. If the building were in Region A with no wind direction multiplier and the same 0.85 shielding multiplier, the serviceability wind speed would also be (coincidentally) 26.1 m/s. If there were no shielding multiplier in Region A, the serviceability wind speed would be 30.7 m/s. Hence, the increase in loading for combinations with crane loads and wind loads by using the 25 year return serviceability wind speed rather than 20 m/s is quite significant for some buildings even though these combinations may not be critical for strength.

In conclusion, using serviceability wind speeds based on a 25 year return period for assessing portal frame deflections when cranes are in-service is a rational approach which will not only be in accordance with AS 1418.18, but will also help overcome the current confusion between the 20 m/s speed and AS/NZS serviceability wind speeds. However the deflection limits which were considered appropriate for a 20 m/s in-service wind speed need to be adjusted to suit the higher wind speeds. This is discussed in the next section.

8.4.3 Portal Frame Deflection Limits

The sway deflection limit proposed for portal frames supporting gantry cranes is ***h*/250** under serviceability wind speeds as presented in Table 4.1. The height *h* should be taken at crane rail level. A stricter limit of ***h*/300** is recommended in Table 4.1 for gantry cranes with a SWL greater than 10 tonnes. As explained in Chapter 4, these limits were proposed following a survey of Australian engineers in 1986 before limit states design was adopted. Fortunately the survey and the limits proposed were based on the current requirement of 25 year return serviceability wind speeds. Nevertheless, AS 1418.18 [1] and other references appear to have more stringent limits and so the following background and calibration are provided in support of the recommended limits.

For buildings with overhead cranes, AS 1418.18 [1] nominates a lateral deflection limit of *h*/500 at the crane rail level using 'the loads at the serviceability level'. It is not clear what combinations of 'the loads at the serviceability level' should be used for the purpose of calculating lateral deflections but it would seem statistically reasonable to consider lateral inertia loads acting **separately** from wind loads. The *h*/500 limit at the crane rail level appears to be significantly more stringent than the *h*/250 recommended in Chapter 4 for light to medium cranes, and the *h*/300 limit for heavy cranes. It is also appears more stringent than the *h*/400 limit in Reference [5]. However the *h*/500 and *h*/400 limits presumably have their origin in the era when the in-service wind speed was taken as 20 m/s [5]. If the AS/NZS 1170.2 serviceability wind speeds are generally between 25 m/s and 30 m/s as shown above, it can be demonstrated that the *h*/250 and *h*/300 limits given in Chapter 4 are reasonably consistent with the limits of *h*/400 to *h*/500 from the previous era.

For example, the *h*/500 limit for a serviceability wind speed of 20 m/s is equivalent to an *h*/294 limit for a Region B serviceability wind speed of 26.1 m/s $[294 = 500\times(20/26.1)^2]$ as in the design example. Hence the *h*/250 limit in Table 4.1 is slightly more liberal in this case. This comparison and two equivalent limits for Region A are presented below.

Region B, TC 3, $h = 8.35$ m, $M_s = 0.85$, $M_d = 0.95$	$V_s = 26.1$	*h*/294
Region A, TC 3, $h = 8.35$ m, $M_s = 0.85$, $M_d = 1.0$	$V_s = 26.1$	*h*/294
Region A, TC 3, $h = 8.35$ m, $M_s = 1.0$, $M_d = 1.0$	$V_s = 30.7$	*h*/212

Similarly the $h/400$ limit for a serviceability wind speed of 20 m/s is equivalent to an $h/235$ limit for a Region B serviceability wind speed of 26.1 m/s [$235 = 400\times(20/26.1)^2$] as in the design example. Hence the $h/250$ limit in Table 4.1 is slightly more conservative in this case. This comparison and the two Region A examples are presented below.

Region B, TC 3, $h = 8.35$ m, $M_s = 0.85$, $M_d = 0.95$	$V_s = 26.1$	$h/235$
Region A, TC 3, $h = 8.35$ m, $M_s = 0.85$, $M_d = 1.0$	$V_s = 26.1$	$h/235$
Region A, TC 3, $h = 8.35$ m, $M_s = 1.0$, $M_d = 1.0$	$V_s = 30.7$	$h/170$

It can be seen that the general $\boldsymbol{h/250}$ limit proposed in Table 4.1 for portal frames supporting gantry cranes falls in the middle of these equivalent limit examples and therefore seem reasonable. The $\boldsymbol{h/300}$ limit proposed in Table 4.1 for frames supporting heavy cranes (those with SWL greater than 10 t say) is more conservative than all three of these examples of equivalent limits.

8.5 DESIGN EXAMPLE – CRANE RUNWAY BEAMS AND SUPPORTING STRUCTURE

8.5.1 General

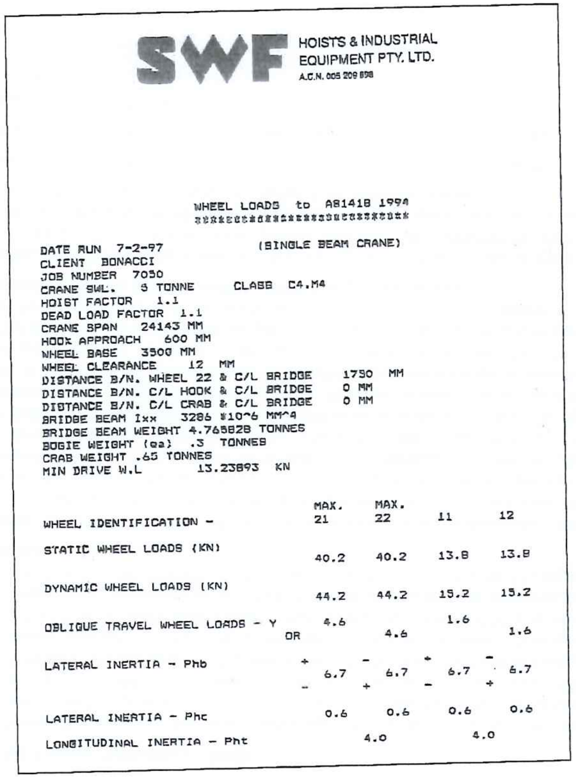
A building with same envelope used for the design example in the previous chapters will now be designed to accommodate a 5 tonne SWL overhead travelling crane with the general arrangement shown in Figure 8.1.

Capacity	5 tonne SWL
Span	24 m approximately
Hook height	5800 mm minimum
Wheel base	3500 mm
Utilisation	U3 (10 lifts per day maximum for 25 years = 91,000 cycles)
State of loading	Q2 – Moderate (rated capacity lifted less than 16% of the time and loads less than 20% capacity lifted half the time)
Structure classification	S3 as determined from U3 and Q2
Crane runway beam type	Single simply supported spans of 9000 mm on corbels
Crane runway beam section	Trial 410UB60 + 300PFC Final 460UB67 + 300PFC
Rail	31 kg rail (although no longer made by OneSteel [12,13])

The design example in this chapter will first deal with the crane runway beams and then the portal frames which support them. The crane itself is designed and supplied by the manufacturer who will provide the dynamically factored vertical and horizontal wheel loads for the design of the crane runway beams.

8.5.2 Load Cases

As the height and plan dimensions of the building have been kept the same with or without the overhead travelling crane, the dead, live and wind loads are the same as in previous chapters. The crane loads as provided by the crane manufacturer are presented in Figure 8.4 and are shown pictorially in Figure 8.5.



SWF HOISTS & INDUSTRIAL EQUIPMENT PTY. LTD.
A.C.N. 005 209 898

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                    WHEEL LOADS  to  AS1418 1994
                    ************************

DATE RUN  7-2-97                    (SINGLE BEAM CRANE)
CLIENT  BONACCI
JOB NUMBER  7030
CRANE SWL.   5 TONNE      CLASS  C4.M4
HOIST FACTOR   1.1
DEAD LOAD FACTOR  1.1
CRANE SPAN   24143 MM
HOOK APPROACH   600 MM
WHEEL BASE   3500 MM
WHEEL CLEARANCE    12  MM
DISTANCE B/N. WHEEL 22 & C/L BRIDGE      1750  MM
DISTANCE B/N. C/L HOOK & C/L BRIDGE      0 MM
DISTANCE B/N. C/L CRAB & C/L BRIDGE      0 MM
BRIDGE BEAM Ixx   3286 *10^6 MM^4
BRIDGE BEAM WEIGHT 4.765828 TONNES
BOGIE WEIGHT (ea)  .3  TONNES
CRAB WEIGHT .65 TONNES
MIN DRIVE W.L       13.23893  KN


                                        MAX.    MAX.
WHEEL IDENTIFICATION -                  21      22      11      12

STATIC WHEEL LOADS (KN)
                                        40.2    40.2    13.8    13.8

DYNAMIC WHEEL LOADS (KN)
                                        44.2    44.2    15.2    15.2

OBLIQUE TRAVEL WHEEL LOADS - Y           4.6            1.6
                                     OR         4.6             1.6

LATERAL INERTIA - Phb                  +       -       +       -
                                         6.7     6.7     6.7     6.7
                                       -       +       -       +

LATERAL INERTIA - Phc                    0.6     0.6     0.6     0.6

LONGITUDINAL INERTIA - Pht                      4.0             4.0
```

Figure 8.4 *One Manufacturer's Crane Loads*