

TECHNICAL NOTE 014

Internal Climbing Tower Cranes – Load Effects on Supporting Steel Brackets



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Keywords

Internal climbing tower crane, In-service condition, Out-of-service condition, Climbing condition, One-sided hydraulic jack, Eccentricity of support reactions

Synopsis

Internal climbing tower cranes are used commonly in building construction projects. The climbing procedure from one level to another has been well established. To enable the operation and climbing of the tower crane, three sets of support (usually comprises steel beams + steel brackets) at pre-determined levels are required to be fixed to the nearby structural walls or other suitable elements to support and restrain the mast of the tower crane. During a recent tower crane climbing process, severe cracks were noted in one of the supporting structural walls. As a result, the climbing process was suspended immediately and remedial works introduced. A study of this incident reveals that an additional condition for the design of the tower crane support system should have been considered. Detail is explained in this technical note.

1.0 Introduction

The general arrangement of an internal climbing tower crane (the lower portion) is shown indicatively in the figures below.



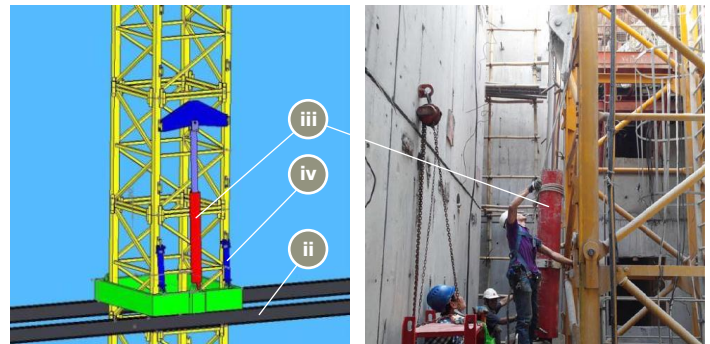
Tower crane mast supported by two sets of support (should be three sets)

(i) Proprietary tower crane collar; and
(ii) non-proprietary steel beam support

As shown in the figures above, the proprietary tower crane collar (i) is supported by a pair of steel beams (ii). The steel beams are in turn supported on the floor plate through openings pre-formed in the vertical walls. More often than not, the steel beams are supported on steel brackets which are bolt-fixed to the nearby structural walls.

2.0 Climbing of Tower Cranes

The mechanism that enables the climbing of the tower crane is shown in the figures below. The mechanism comprises a hydraulic jack (iii) and a pair of interim supports (iv). The hydraulic jack is used for pushing the tower crane upwards. Upon reaching the full stroke length of the jack, two interim supports are inserted to upkeep the tower crane, allowing the hydraulic jack to be retracted for the next push.



NB –

It should be noted that during climbing, all vertical supports to the tower crane are released, and the self-weight of the tower crane rests only on the hydraulic jack which is placed on one side of the tower crane mast. It follows that the self-weight of the entire tower crane is supported only by one steel beam (ii), ie, the one in the near face in the above figure. The load effects under this condition appear to be critical as demonstrated below.

3.0 Load Effects of Tower Crane on Support

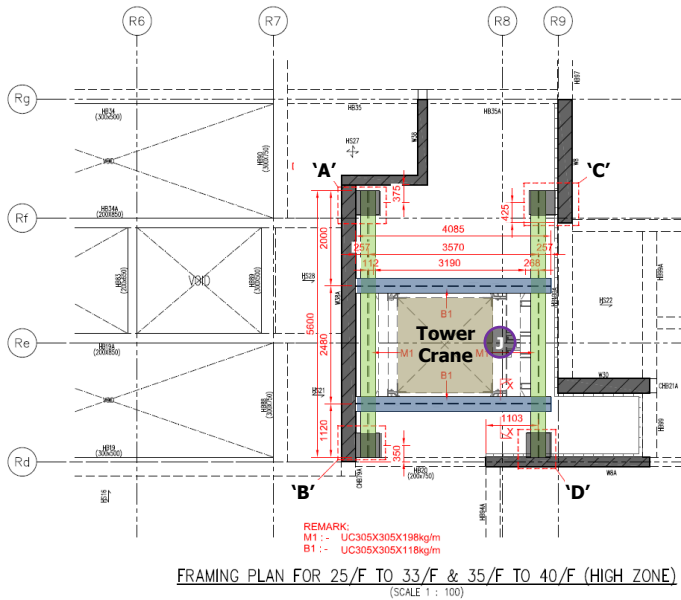
Design reports prepared by various tower crane designers have been reviewed. It is noted in these reports that the load effects of the tower crane are derived from two scenarios, namely the in-service and out-of-service conditions of the tower crane – and this appears to be an industry norm.

In the above two conditions, all four legs of the tower crane mast are properly secured to the support, and therefore the resulting load effects are shared amongst all the supporting steel beams and steel brackets. Whereas in the climbing condition, only one steel beam and the respective steel brackets are loaded. As such, the load effects in these brackets need to be ascertained carefully.

View of tower crane support system
(i) Tower crane mast
(ii) Proprietary tower crane collar
(iii) Steel beams
(iv) Wall-mounted steel bracket



For the particular climbing process in question, the setting out of the tower crane and the respective supports, ie, steel beams + steel brackets 'A' to 'D', are shown in the figure below. Given the height of the tower crane, the jib length (radius) and the tip load, the loading on each steel bracket has been calculated, and is shown in the table further below.



NB – J denotes the position of the hydraulic jack for climbing of the tower crane.

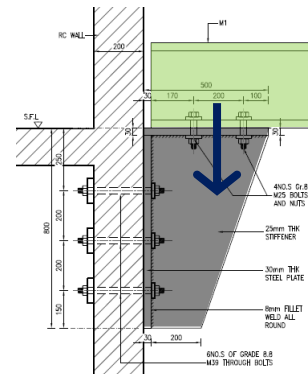
Conditions	Bracket Reactions (kN)			
	'A'	'B'	'C'	'D'
In-Service	314	278	225	318
Out-of-Service	227	201	162	230
Climbing (Static)	33	29	314	445
Climbing (×1.25)	41	36	393	556

The reactions in the table above are all UNFACTORED. During climbing, the reactions in the brackets are due only to the self-weight of the tower crane. However, it must be noted that these reactions will be magnified by the starting / stopping of the hydraulic jack in each push. The dynamic magnification factor could be taken as **1.25** if no information (such as jacking speed) is available for a more accurate assessment.

4.0 Load Effects for Design Checking

As can be seen from the previous table, the reaction in Bracket 'D', **556 kN**, under the climbing condition should have been selected by the tower crane designer for relevant structural design and assessment. Instead, the reaction in Bracket 'D', **318kN**, under the in-service condition was chosen, noting perhaps that the climbing condition was not considered at all.

Apart from the above underestimation, the eccentricity value adopted by the designer was questionable too. According to the detail of Bracket 'D', the eccentricity should be in the order of **300mm**. However, for some reasons, a nominal eccentricity of only **20mm** was assumed in the checking.



The above double-inaccuracies meant that the structural wall (W8A to which Bracket 'D' was fixed) was only checked for an ULS moment of **11.70 kNm**. However, according to this study, the ULS moment could be up to **167 kNm**, depending on the actual scale of the dynamic magnification.

5.0 Moment Capacity of Structural Wall W8A

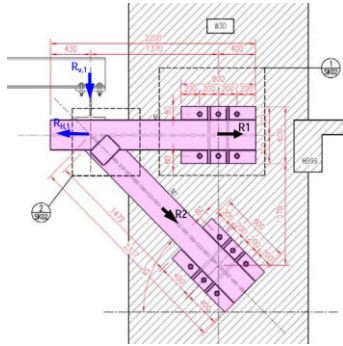
The moment capacities, M_u , of structural wall W8A have been assessed in this review, and are listed below.

$$M_u = 156 \text{ kNm (with material factors)}$$

$$M_u = 169 \text{ kNm (without material factors)}$$

$$M_u = 159 \text{ kNm (as assessed by the designer)}$$

It can be seen that, by factoring in the potential dynamic magnification effect and the correct eccentricity, the structural wall was practically at the point of incipient failure.



Remedial works proposed by the tower crane designer – A pair of steel brackets fixed on structural wall W30.

With the bending moment of 167 kNm in structural wall W8A, the rebars would be stressed locally to around 439 N/mm² in tension, which is way higher than the normal SLS stress level of 280 ~ 300 N/mm², for high-yield rebars. It is almost certain that the concrete within the affected zone would crack and de-bond from these highly stressed rebars.



Structural cracks in wall W8A
(Steel Bracket 'D' on the other face)



Close-up view of the structural cracks

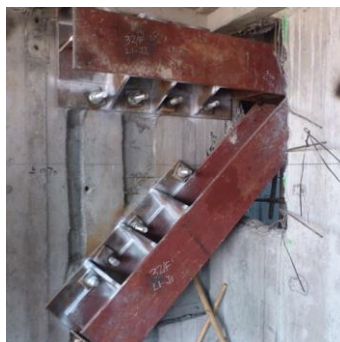
6.0 Remedial Works

In light of the cracks and spalling concrete noted in structural wall W8A, the climbing process of the tower crane was suspended immediately. It was subsequently decided that separate steel brackets had to be installed to replace the defunct Bracket 'D'.

The structural wall (W30) that could be used for fixing the steel brackets was very close to the mast of the tower crane. As a result, the new brackets had to be designed to take up most of the loading from the tower crane. The steel brackets, during and after installation, are shown in the figures below.



Installation of steel bracket member



Completed steel bracket
(with MPI tests for the fillet welds)

7.0 Recommendation

In light of the observation made in this incident, the points below must be enforced strictly:

1. For structural design and assessment in relation to tower crane support systems, the **Designer** must be required to consider, amongst any other potential load effects, those induced during the **climbing process of the tower crane**; and
2. For the structural design of wall-mounted steel brackets and strength assessment of the supporting walls, the eccentric moment from the brackets must be calculated based on a **realistic eccentricity** according to the actual detail, not a nominal eccentricity of mere 20mm.

If project teams came across any uncertainties in this regard, please feel free to contact the Technical Department for assistance.

- End -

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