

TECHNICAL NOTE 012

Derrick Crane - Stability of King Post Is Crucial, But How To Ensure It?



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Keywords

King post stability, tie-back cables forces, lifting boom operation range, cable anchor levels and stabilising effects, steel base frame movements

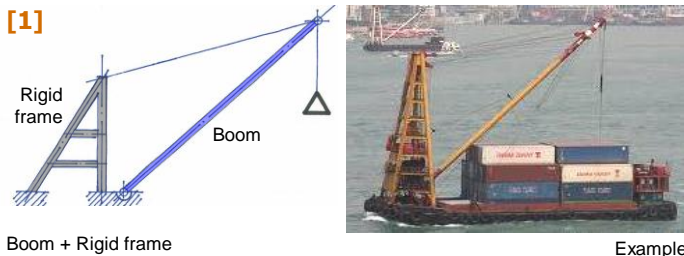
Synopsis

Derrick cranes (referred to as hoisting cranes hereinafter) are commonly assembled at roof top to facilitate activities such as dismantling of tower crane, replacement of chiller plant, etc. Hoisting crane is a stable lifting device. Yet, instability failures are not unheard-of in construction industry. This note explains what it takes to ensure the stability of this lifting device.

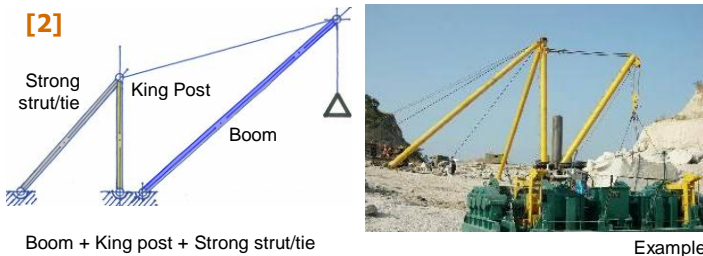
1.0 Introduction

Hoisting cranes come in different configuration as shown indicatively in the figures below.

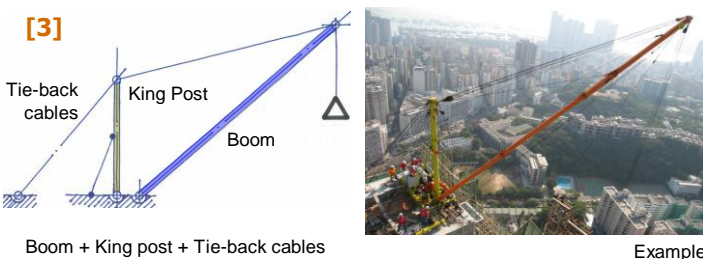
[1]



[2]



[3]



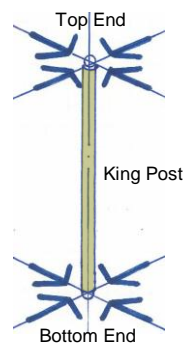
In essence, the hoisting crane comprises a **Boom** at the front for lifting, and a **Rear Supporting Frame**. The pulley system is excluded in this note for clarity. The rear supporting frame could be formed by a rigid frame as that mounted on barges, a strong strut/tie tripod, or a king post with a set of tie-back cables. In terms of stability, configuration [1] is the most stable whereas [3] is the least. Despite it is the least stable, **Configuration [3]** is commonly adopted at the roof top because of the following reasons:

- i) It is difficult to find a big enough flat surface on the roof top to accommodate the rigid (and probably heavy) frame in configuration [1].
- ii) Ditto for the strong strut/tie tripod in configuration [2]. Besides, there are only two strong strut/tie elements (excluding the king post), and hence the forces in these elements and their anchors must be necessarily high, making it restrictive for holding-down design.
- iii) Tie-back cables in configuration [3] are easy to handle in terms of length, providing flexibility in fixing locations. Also, there is usually a set of tie-back cables of 10 to 15 nos (approx) connected to the top of the king post. The cable forces are thus lower after load-sharing, making the cable system more adaptable for holding-down arrangement.

2.0 Stability of King Post

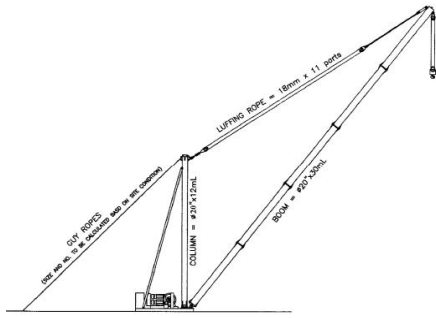
Stability of the king post in configuration [3] is crucial in ensuring the stability of the entire hoisting crane. The king post must be prevented from any undue lateral translation at the top and bottom ends.

At the top end, the king post is connected to a set of tie-back cables. The cables of different lengths are in turn anchored into the surrounding structures, ie, parapet walls and/or dog house walls at roof level.



At the bottom end, the king post is connected to a rectangular steel base frame which is usually placed on top of a set of spreader beams. The steel base frame is required to be restrained from any undue lateral translation by a set of cables which are again anchored into the surrounding structures.

The setting out of the abovementioned cables depends on the height of the king post and the geometry / levels of the surrounding structures. Cable forces are different and have to be analysed case by case.



Hoisting cranes assembled at roof top for dismantling of tower crane.

(Please note the level of the cable anchors in the photo and see Section 3.2 for the respective discussion)

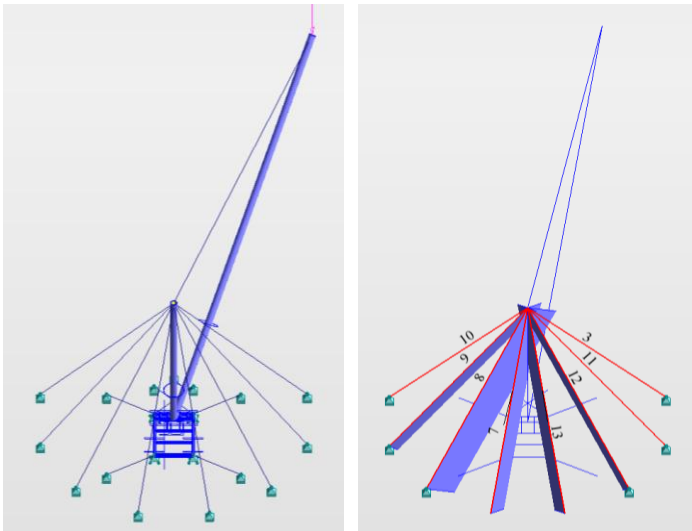


3.0 Potential Causes for King Post Instability

The restraint requirements for king post explained in Section 2.0 above is well known. Yet there are failure cases of hoisting crane in the construction industry from time to time. The potential causes for such failures are explored below.

3.1 Under-Estimation of Cable Forces for Anchor Design

The top end of the king post is held in position by a set of tie-back cables. It was noted in the calculations prepared by some hoisting crane supplier(s) that the main cable force **T** (ie, that holding the lifting boom) had been calculated using a 2D type of analysis, and the main cable force so calculated was then assumed to be shared equally by the nearest 4 tie-back cables, ie each taking **0.25T**, making no particular reference to the different tie-back cable lengths nor angular geometry.

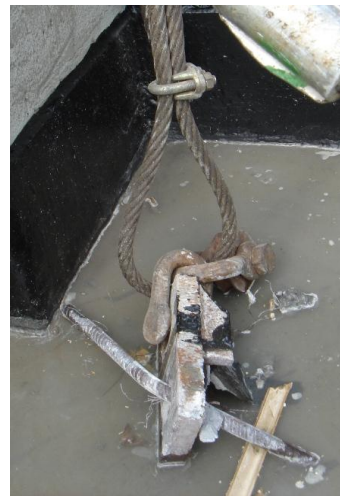


3D computer model for hoisting crane

Varying share of tie-back cable forces

The above crude assumption is of no solid basis and simply unacceptable. As revealed in confirmatory 3D analyses, for the same main cable force **T**, the tensile forces in the tie-back cable can be as high as **0.4T**, which is some **60%** higher than the prediction made using the above assumption.

Whilst such under-estimation might not adversely impact the tie-back cables owing to their usual capacity margin, the anchors might not have been designed with ample buffer for the higher cable forces. Pull-out failures of cable anchors have been seen. The design cable forces should always be analysed using 3D computer model to prevent undue under-estimation.



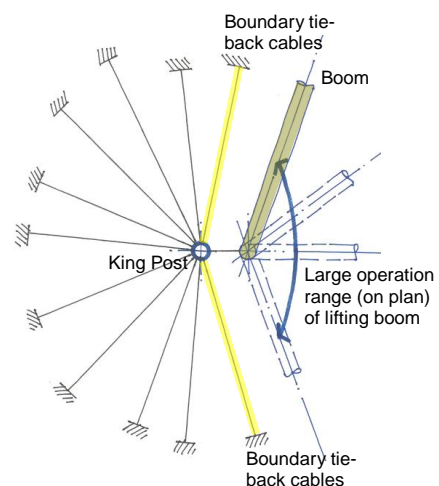
Pull-out failure of cast-in anchor



Shearing of rebars owing to pull-out failure of anchors

3.2 Large Operation Range of Lifting Boom

The lifting boom is normally designed to operate within a narrow angular range on plan. However, in some specific operation requirements, the lifting boom might be required to swing through a plan angle of **120°** or more (see figure below). This being the case, the tie-back cables would have to be set back to create an unobstructed operation zone. It should however be noted that the larger the opening up of the tie-back cables, the more unstable the system will become – If the two boundary tie-back cables (highlighted yellow below) are opened up to **180°** apart, the tie-back cable system will become redundant, and any small disturbance could cause total collapse.





Steel base frame of hoisting crane (blue in colour) on spreader beams



Failed king post (probably initiated by excessive base movement)

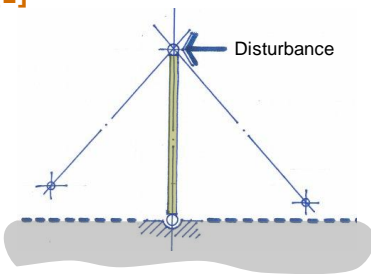


King post top end (with tie-back cables and pulley system for the lifting boom)

To enhance the stability of the king post in the above scenario, the cable anchor levels should be maintained ABOVE the base level of the king post as shown in the figure below.

It can be demonstrated that the cable anchors in arrangement [1] have a beneficial stabilising effect when the king post is subject to lateral load disturbance, whereas in arrangement [2], there is no such beneficial effect.

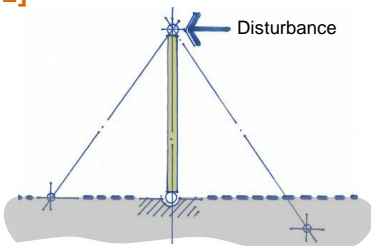
[1]



Cable anchor levels ABOVE the king post base level.

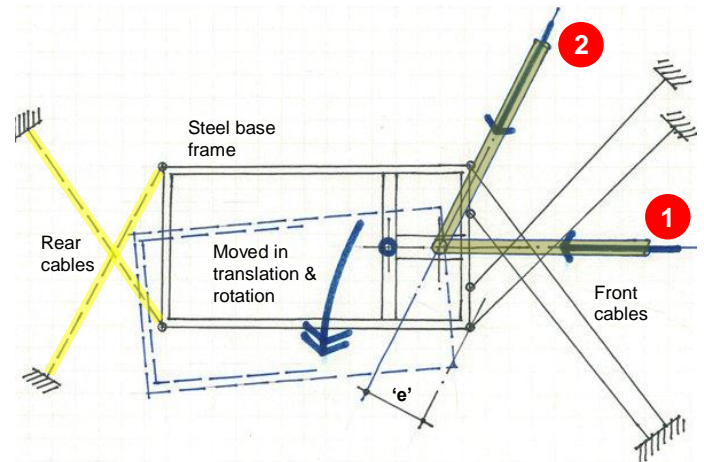
Under disturbance, this arrangement provides beneficial stabilising effect.

[2]



Cable anchor levels AT or BELOW the king post base level.

Under disturbance, this arrangement CANNOT provide stabilising effect.



To mitigate the above movements, a set of REAR cables (highlighted yellow above) must be installed such that there is a complete load path to provide resistance against undue translational and rotational movements.

NB – This technical note covers only the engineering safety aspects of the hoisting cranes. There are other statutory, health and safety, and testing requirements which need to be dealt with sufficiently. Please feel free to discuss with the Technical Department regarding your particular issues regarding the use of the hoisting cranes.

- End -

3.3 Translational Movement of King Post Bottom Support

As mentioned before, the king post is supported at the bottom by a steel base frame. This steel base frame must be held in position by suitable means. Some hoisting frame supplier(s) might provide only a set of FRONT cables to restrain the steel frame as shown in the following figure. As can be seen, all front cables would only be effective when the lifting boom is in **Orientation 1**. If the lifting boom is swung to **Orientation 2**, some cables would become ineffective (ie, in slack). It must be noted that the line of axial forces in the lifting boom does not necessarily coincide with that in the cables, and an eccentricity 'e' is thus created within the system that will force the steel base frame to translate and rotate, impairing substantially the stability of both the steel base frame and the king post.

This technical note is for internal circulation only. For enquiry, please contact

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