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Stability Studies of Water Tower's Vertical Flanges

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Summary:

High reinforced-concrete water towers are commonly used for water storage in the low regions. Water tanks, with big storage capacity, are placed at the top. Middle carrying part has to be stable enough and to secure the overall structural stability. To set the whole area under tank as a carrying element is not economically sound and is ugly from the architectural standpoint. Therefore, thin vertical flanges are radially placed around the central tubular part as buttresses. Designing of such flange-buttress elements is complicated as the problems of their out-of-plane and overall structural stability are coming together.

In order to study this problem simplified model studies of the water tower's middle part. The models were exposed to incrementally increasing vertical loads. Out-of-plane deformations of the flanges were registered and critical buckling forces and forms were determined. Then the sophisticated analytical model of the overall structure has been done. Critical flange's buckling load and buckling forms of the scaled experimental model and that of sophisticated numerical model correlated very well. Model studies gave good sense of the load carrying ability for a full-scale structure. Calibrated numerical models were used to study the influence of various parameters on the flange's and overall structural stability.

Keywords: water tower, vertical flanges, and experimental model, buckling analysis, comparison

1. Introduction and Conclusion

The flange's out-of -plane stability can determine the overall structural stability. Sometimes these elements are from the architectural reasons made with openings. Their numerical analysis without very sophisticated mathematical models presents a problem. This study was undertaken in order to gain insight in the behavior and stability of the vertical flanges and to distinguish among various parameters that influence that stability.

Typical water tower's structural cross section and dimensions, for a particular case, are presented on Fig. 1. The Model 1 has uniform buttress flanges and Model 2 has the same geometry but its flanges had openings at their upper and lower part. Both models have six radially placed flanges around the middle tubular element.

Experimental analysis is performed on a simplified (quasi 3D) scaled structure with the intention of finding the first critical buckling force and form of a flange in system. Analytical models represented the whole system without simplifications. Their results were compared with the experimental ones. Parameters that contribute to the flange carrying ability are than varied in order to distinguish among them.

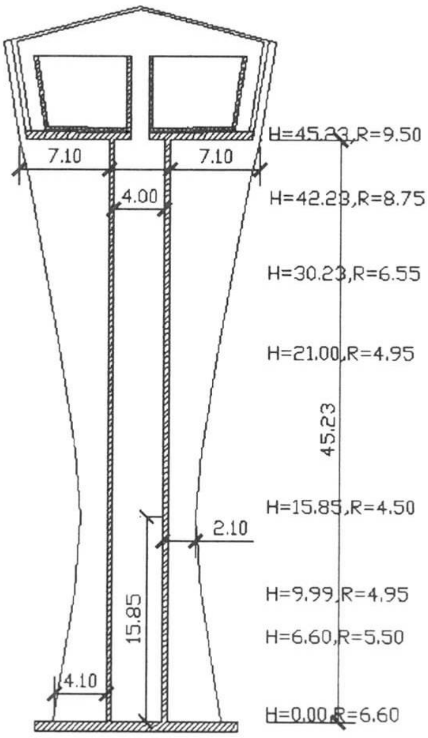

Figure 1Water tower-Model 1

The experimental tests were done on a simplified model in a scale 1:50. By incrementally applying loads and registering the displacements, critical buckling forces and forms for the models were determined. Critical buckling force in Model 2 was 2 times smaller than that in Model 1. Restraining rotation of the flange's edges was found to be very important. Determined forces are directly, through the application of model analysis, applicable to a full-scale structure, and as it turned out represent the lower bound.

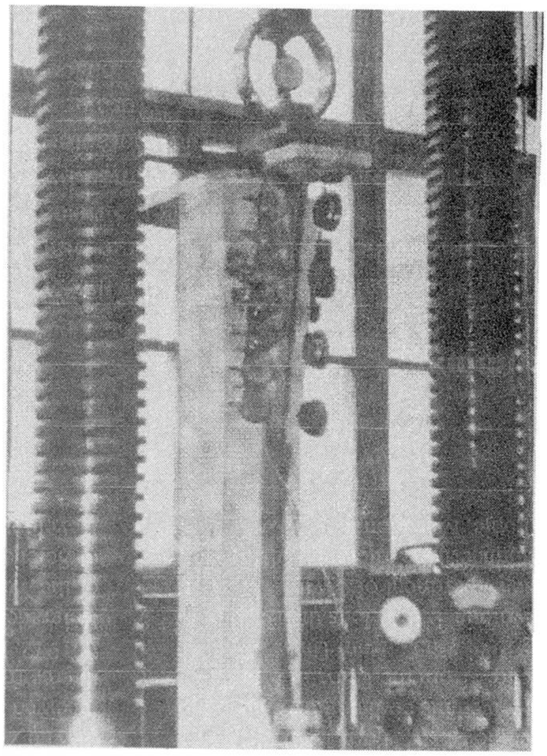

Figure 2 Model test set-up

The analytical models were sophisticated and represented detailed structural models. Critical buckling forces and forms of the scaled experimental model and that of numerical models correlated very well. The Model 1 has additional reserves due to the spatial distribution of flanges, which was not simulated in the experiment. Spatial distribution of the flanges had significant influence on Model 1 and little influence on the Model 2 structural stability. Model 2 fails locally in the flange-opening region. By implementing openings in the flanges, critical buckling force is reduced several times (up to 3 times) and implementing openings in the flanges minimizes spatial reserves of the system. While simplified plane analysis can be approved for structures with such flanges (Model 2); it gives us only a lower bound for a structure with solid flanges. Structures with solid flanges have much greater stability reserves due to the spatial (3D) structural stiffness distribution.

Calibrated numerical models were used to study the influence of various geometric parameters on the flange's and overall stability. From the limited parametric analysis has been observed that for load carrying ability of the vertical flanges the most important factors are its protruding length outside the central tube and the elements' thickness while flange's height plays a minor role.

Conclusions achieved from the simplified experimental models proved to give us good orientation in dealing with very complicated problems. Such problems are local and global stability analysis of buttress flanges encountered in high water tower tanks. Usage of simple models can obviously serve us as a rule of thumb for complicated numerical analysis or as an additional tool to the simple numerical methods.