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In-plane Stiffness of the Prussic Caps

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Summary:

Prussian caps (flat masonry arches) were used very often as a masonry slab structure in living houses on the verge of the century. While transfer of the vertical loads is clear, for the in-plane acting horizontal loads (wind, earthquake, etc.) remain several doubts to be cleared. Floor slab is commonly assumed as an infinitely stiff membrane which performs force transfer and distribution to the vertical bracing elements. In this work, we have tried to analyze: a.)stiffness of the Prussian caps and their ability to withstand the in-plane loading; b.) meaning of the strengthening with an additional thin concrete slab; c.) stiffness and load distribution among the two systems.

Keywords: masonry, Prussian caps, strengthening, stiffness distribution, justification

Analyzed models

Analyzed were slab structures made as Prussian caps (flat masonry arches) with a slab span of 6m and width of 4m. They consist of 4 flat masonry arch fields supported by steel I beams which span over the shorter span. Each span is 1,50m long and its height at its middle is 0,15m (f/l=1/10). Walls were modeled as having a symmetric stiffness distribution (Model S) and non-symmetric stiffness distribution (walls with the openings-MODEL N).

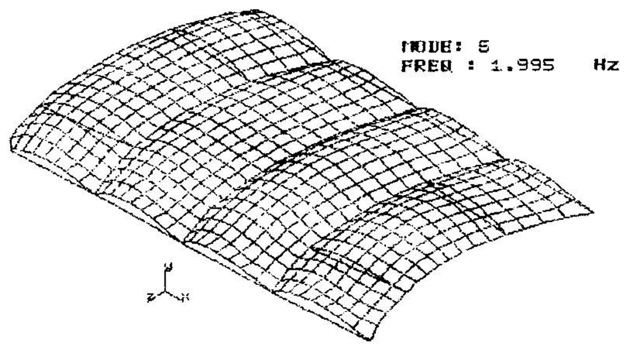


Fig. 1 Modal form of PKS

For both models, several sub-models were defined: (1) MODEL PK where the Prussian caps are the only horizontal diaphragm; (2) MODEL PK-PL are the Prussian caps with the added dead weight load due to the reinforced/concrete slab. Stiffness was not changed; (3)MODEL PL where 6cm reinforced/concrete slab was the only stiff diaphragm and the loading included total load. All models were exposed to the horizontal design earthquake response acceleration in both directions (longitudinal -MODEL-X and transverse MODEL-Z). Contribution of the single modes to overall structural response is estimated with SRSS mode combination method.

Results of analysis

Calculated were natural frequencies, forms and response spectra analysis has been performed for all analyzed models. Mode contribution was analyzed with SRSS combination method.

Fig. 2 SRSS displacements in X direction

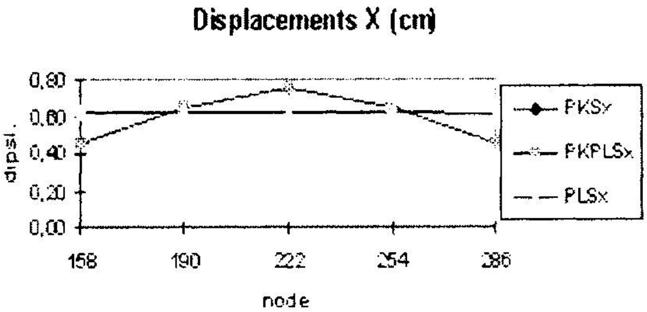
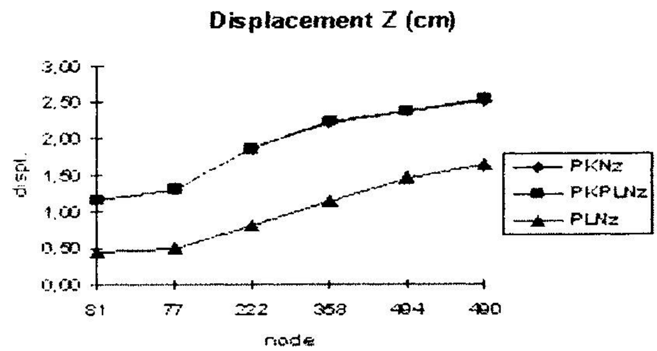


FIG. 3 SRSS displacements in Z direction



The basic slab system, consisting of the flat masonry arches and steel beams (Prussian caps) is not infinitely stiff in comparison with the walls. The buildings made with that system should be, for horizontal loading, analyzed as buildings with a flexible diaphragm.

Additional thin reinforced/concrete slab has contributed to the overall stiffness, while at the same time, its additional dead load did not change basic characteristics of the main system. Average displacements were the same for all models, but their distribution along the span was different (Fig. 2 and 3). Reinforced/concrete slab contributes to the uniform displacement distribution along the span and it has activated the complete bracing system in resisting horizontal loads.

The reinforced/concrete slab, although relatively thin, makes a significant and important contribution to the in-plane stiffness of the basic Prussian cap structure. That seems to be reasonable and justified solution for increase of the in-plane structural stiffness. In that case reinforced concrete slab has to be designed to take over and transfer the complete horizontal loading. Due respect must be paid to the joining details among the new slab, Prussian cap and the walls.

This study is limited and its value is only qualitative. For a quantitative value it should be expanded on the systems having different geometry, thickness, stiffness and mass distribution and excitation models.