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Parametric Study of Failure Load of Persian Brick Masonry Domes Stiffened by FRP Strips under Concentrated Monotonic Loads

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1-Introduction

Architecture in Iran has a history of thousands of years. The dome is an element of Persian architecture that is important from the viewpoint of its structural performance. Persian domes have various shapes and are built in different buildings such as palaces, mosques and bazaars. Despite the importance of the dome, adequate studies about the structural behavior of Persian domes have not been done to date.

2- Methodology

In this research study, three types of semi-circular, four-centred and pointed domes have been studied in order to investigate the structural behaviour of Persian brick masonry domes. For four-centred and pointed domes, the three types of drop, ordinary and raised domes have been considered (Fig. 1). The dimensional characteristics of the studied domes including the span and thickness at the base have been selected based on the dimensions of existing domes in Iran. The spans are 12 m, 15 m and 18 m. In order to determine the thickness at the apex, the optimum apex thickness to base thickness ratios reported in the literature has been used. Domes have been subjected to monotonic concentrated loads up to local failure. Vulnerable zones have been stiffened by FRP strips and the stiffened domes have been again subjected to monotonic loads. FRP strips with different dimensions and patterns have been studied. The location of FRP strips has been once at the one-third and once at the two-third of the dome's height. The value of failure load, the effect of dimensions and patters of FRP strips, and the effect of the shape and span of the dome on the failure load have been studied. The Willam-Warnke failure criterion and the Tsai-Wu stress theory have been used for brick masonry and FRP, respectively. The non-linear three-dimensional finite element method using the ANSYS code has been used.

For patterns, FRP strips have been categorised into three groups of FRP strips: 1) at the bottom and top of the steel plate (horizontally), 2) at the left and right of the steel plate (vertically), and 3) all around the steel plate. In Fig. 2 only the first group is shown.

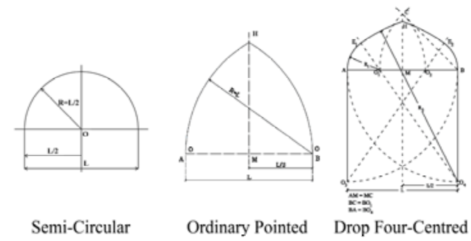

Fig. 1 Sections of three types of studied domes

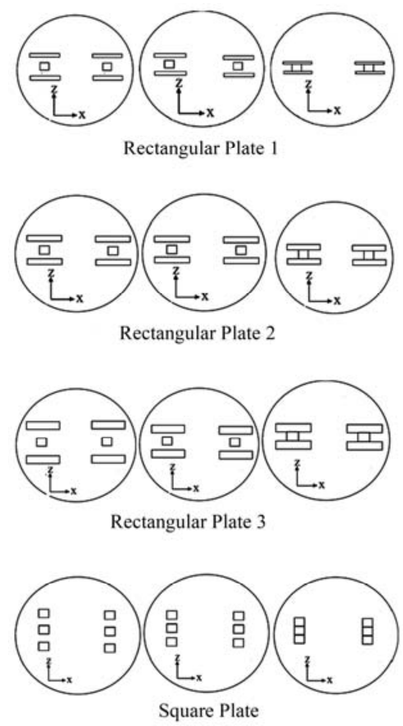

Fig. 2 Top view of the first pattern of FRP strips at the bottom and top of the steel plate with a distance of : a) 0 cm, b) 10 cm, c) 20 cm from the steel plate

3- Finite Element Analysis

Because of the vast application of four-centred domes in Persian architecture, the diagrams of the variations of the failure load against FRP strip pattern for three types of drop, ordinary and raised domes for load applied to the two-third of the dome's height have been depicted in Fig. 3. P, H, V and A stand for without FRP strips, with horizontal, vertical and all around FRP strips, respectively. The value of the failure load for a raised four-centred dome is less than that of a drop or an ordinary one. The drop and

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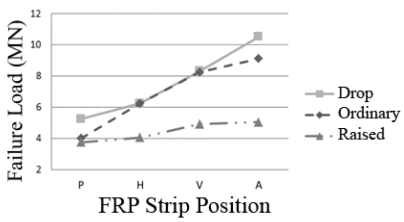
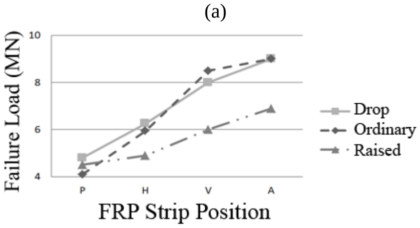
ordinary domes have an indistinctive situation. They have close failure load for spans of 12 m and 15 m, whereas the failure load of the ordinary ones is considerably more than that of the drop one.

Similar diagrams for load applied to the one-third of the dome's height have been shown in Fig. 4. The value of failure load for the raised four-centred dome is larger than that of drop and ordinary domes, which is contrary to the load applied to the two-thirds height case. The minimum failure load belongs to the drop type.



(a)



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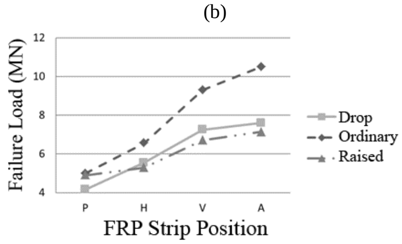
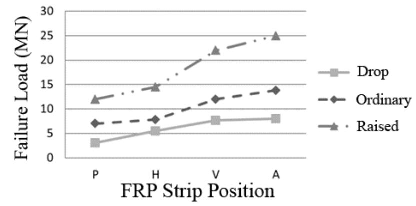


(c)

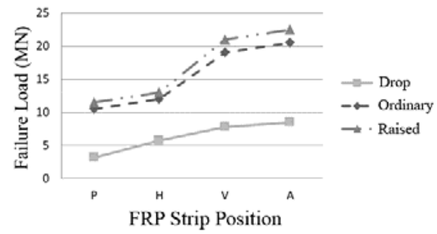
Fig. 3 Diagrams of the varations of the failure load against FRP strip pattern for loads applied to the two-thirds of a four-centred dome height for spans of: a) 12m, b) 15 m, c) 18 m

5- Conclusions

1. The use of FRP strips increases the failure load of the dome. The failure load increases by decreasing the distance between the FRP strip and the steel plate under the concentrated load. The best dimensions for FRP strips is a width equal to the steel plate width and a length three times the steel plate length.



(a)



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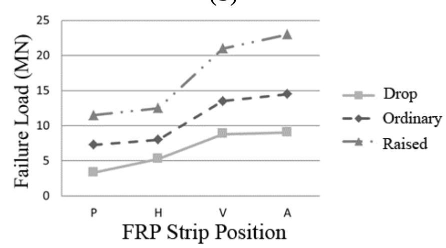

(c)

Fig. 4 Diagrams of the varations of failure load against FRP strip pattern for load applied to the one-third of the four-centred dome height for spans of: a) 12m, b) 15 m, c) 18 m

2. The best pattern of the FRP strip is when it is all around the steel plate without a distance. In most cases, the failure load for horizontal FRP strips is more than that of the vertical ones.

3. In semi-circular and drop four-centred domes the failure load increases with the decrease of the span. For other domes, there is no distinctive rules. When the load is applied to the two-thirds of the dome's height and FRP strip is all around the steel plate, the maximum and minimum failure loads belong to a semi-circular dome of 12 m span (12.5 MN) and a drop pointed dome of 18 m span (2.35 MN), respectively. These values, when the load is applied to the one-third of the dome's height, belong to a raised pointed dome of 12 m span (27.5 MN) and a semi-circular dome of 18 m span (5.4 MN), respectively.

4. When applied to the one-third of the dome's height, the failure load in all domes except semi-circular and drop four-centred domes is larger than when the load is applied to the two-thirds of the dome's height.