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EXTENDED ABSTRACT

Stability Analysis of Double Layer Barrel Vaults Equipped with Accordion Force Limiting Device

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1. Introduction

Space structures are the best solution for covering large areas with few or no intermediate supports. These structures have advantages such as light weight, delicate appearance and ease of erection. Despite these advantages, space structures suffer from progressive collapse due to buckling of compression members. In order to prevent the progressive collapse and improve the double layer space structure's response, several mechanisms have been developed including force limiting devices (FLDs). The available FLDs have never been practically applied to space structures due to serious drawbacks. To improve the previous FLD's performance, an innovative type of force limiting device is introduced in this study. This force limiting device which is entitled as Accordion Force Limiting Device (AFLD) is designed based on the idea of buckling restrained braces (BRB). To evaluate the efficiency of this new device, a whole steel accordion force limiting device is designed and constructed to be tested under uniaxial compressive loading. Numerical models are also developed to investigate the effect of applying AFLD on stability of double layer barrel vaults. A parametric study is carried out to study the effect of AFLD, considering Length to span ratio and rise to span ratio in double layer barrel vaults. Results indicated that applying AFLD to critical compression members improves the stability behavior noticeably.

2. Methodology

2.1. Experimental study

AFLD is consisted of core, encasing and Mero joint system. In order to assemble the AFLD, the core which was manufactured by CNC machining was placed inside encasing and Mero joints were bolted to both sides. Test program was consisted of one uniaxial compressive test. A Uniaxial testing machine (UTM) capable of exerting compressive force of 500KN was used to perform the test. The whole AFLD was connected to UTM by means of auxiliary gadget in top and bottom which provided hinge boundary conditions. Test was carried out under displacement control loading. During the test, the relative axial displacement of MERO ball joints (center to center) was monitored. The details of test setup is shown in Fig. 1.

2.2. FE modeling

ABAQUS finite element software was used for the numerical modeling and analysis. In this study, accordion force limiting device was modeled and verified according to the results of experimental test. Then, the double layer grid was modeled and results were compared to Parke's (1984) experimental program. In order to

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investigate the effect of applying AFLDs on space structures, six double layer barrel vaults models were developed.

3. Results and discussion

3.1. Results from experimental test

The experimental results clearly reveal that AFLD could successfully modify the brittle buckling state to elastic-perfect plastic behavior. Despite ordinary members in which the load carrying capacity has a sudden drop referred as brittle buckling, AFLD experienced no sudden drop in its load carrying capacity (as shown in Fig. 1-c) that means no brittle buckling has happened. This notion confirms that AFLD is the perfect device for improving the "brittle buckling" to "elastic-perfect plastic behavior in space structures.

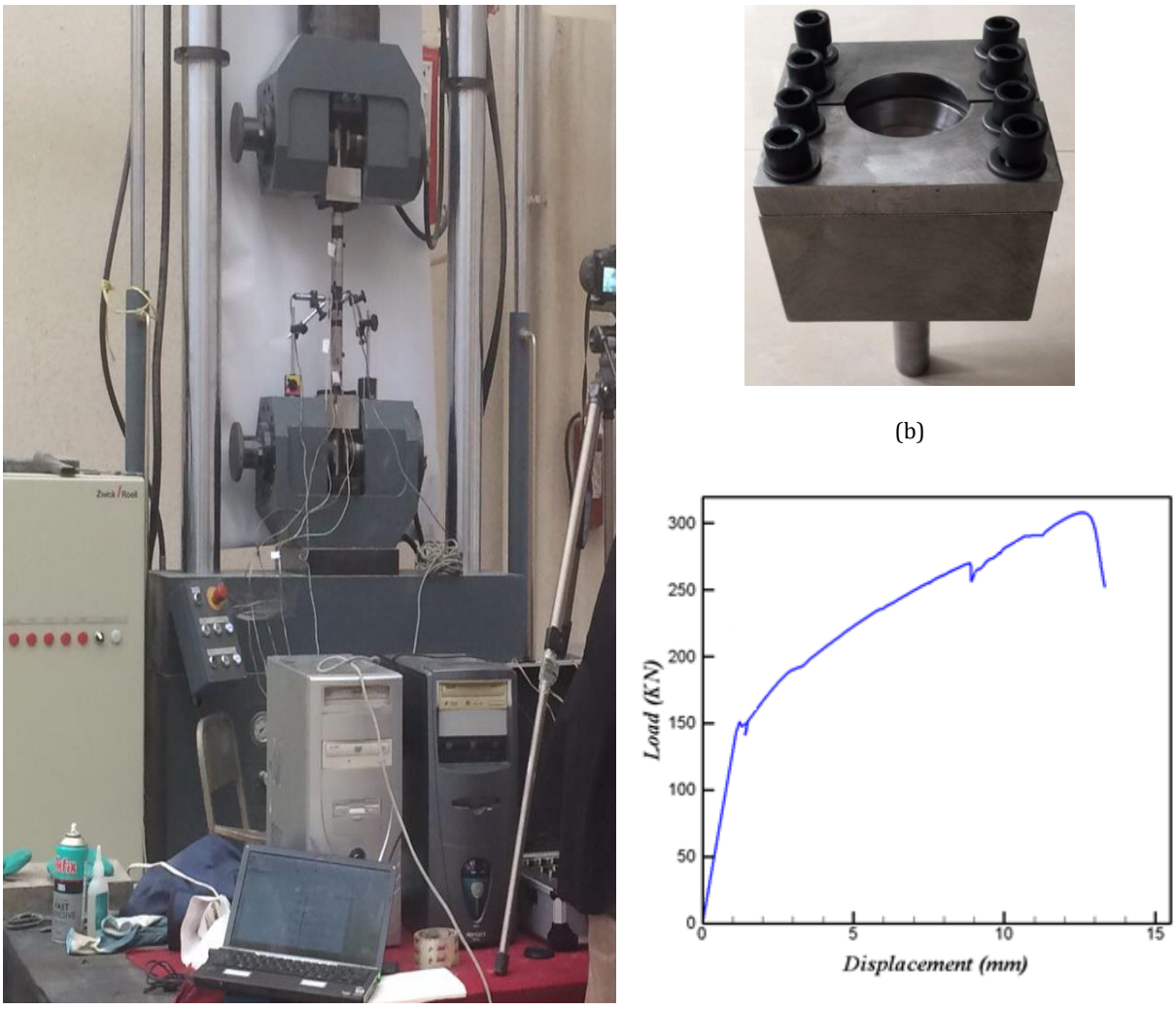

Fig. 1. Test program: a) Universal Testing machine with AFLD, b) auxiliary grip gadget, c) force-displacement behavior of AFLD

3.2. Effect of applying AFLD to double layer barrel vaults

It was found that applying AFLD to critical compression members (in all the models) increased the load carrying capacity and model's stiffness. This notion can be seen in Figure 2, which shows the effect of applying AFLD on one of the mentioned models. Results from parametric study reveal that decreasing length to span ratio and increasing the rise to span ratio, leads to an increase in load carrying capacity. As the length to span ratio decreases, the rate of increase in load carrying capacity accelerates. As the rise to span ratio increases, double layer barrel vault benefits more from applying AFLD.

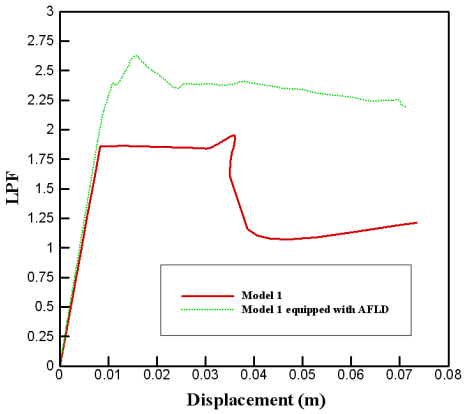

Fig. 2. Effect of applying AFLD on the stability behavior of double layer barrel vault

4. Conclusions

In the present paper, an "all steel accordion force limiting device" is introduced. AFLD is an innovative force limiting device, designed based on the concept of buckling restrained braces. This device is applied to prevent buckling of compression members in space structures. The main objective of the present study was to see if by applying AFLD it is possible to control the buckling of space structures' members. To this end, an all steel AFLD specimens was designed and manufactured to be tested under uniaxial compressive loading. The experimental results obtained from uniaxial compression test reveal that it is indeed possible to alter the brittle post-buckling behavior of normal members to elastic-perfect plastic behavior. Parametric study was conducted to investigate AFLD's effect on double layer barrel vaults behavior considering length to span and rise to span ratio. According to the obtained results, applying AFLD leads to increase in load carrying capacity as well as model stiffness.

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