ARTICLE IN PRESS
Journal of King Saud University – Engineering Sciences (2016) xxx, xxx–xxx

King Saud University
Journal of King Saud University – Engineering Sciences
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ORIGINAL ARTICLES

Effect of floor openings on the capacity of composite space trusses

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Received 21 January 2016; accepted 16 March 2016

KEYWORDS
Composite space truss;
Openings;
Finite element modelling;
Steel structures;
Numerical analysis

Abstract Presenting the composite deck, which consists of concrete slab with profiled steel sheets fixed to the top layer of Double Layer Grid (DLG), proved its great efficiency in increasing the load carrying capacity for this type of structures. Earlier studies concluded that the application of the prescribed composite action had solved many problems facing the spread of DLG structures such as their prone to collapse in a progressive manner besides their suitability to be used only as roof covering structures. In addition, the application of the composite action introduced an economical solution due to considerable savings in steel material used in building the top layer of the DLG structures. However, openings in the deck are needed for architectural purposes such as passing service ducts, day-lighting panels or passing shear walls or continuous structural elements. Adding such openings in the deck affects the efficiency of the composite deck in carrying the assigned loads especially if the openings are being added after the construction is completed. The current research introduced experimental tests along with numerical investigation using ABAQUS software for composite deck space trusses with common cases of support patterns and different deck opening locations. The study shows the obvious effect of the existence of openings and their locations on the load carrying capacity and ductility of DLG space structures.

1. Introduction

Double Layer Grid (DLG) space truss is the most common application of space structures. It can be defined as a three-dimensional structural system assembled of linear elements and arranged to ensure a three-dimensional force transfer from the load application points to the supports (Makawski, 1981; BSI, 2001). DLG can have many configurations, see Fig. 1. Earlier studies on DLG showed obviously that the common cases of space truss collapses emerged from the buckling of one or more critical top chord members, spreading rapidly to

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksues.2016.03.002
1018-3639

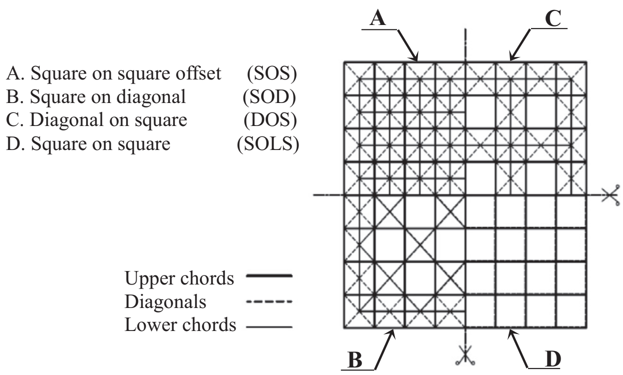

Figure 1 Common configurations of flat DLG space frames.

other members and causing the overall progressive collapse (Martin and Delatte, 2001; Smith and Epstein, 1980). Many techniques were introduced to improve the prone of such type of structures to progressive collapse. Some of those techniques were over design of top chord members and under design of lower chord members to increase the ductility of the structure at failure (Schmidt et al., 1976, 1980), pre-stressing by lack of fit for some specific members (Hanaor and Levy, 1985), diagonal removal technique (Tabatabaei and Marsh, 1993), the use of force limiting device (Schmidt and Hanaor, 1979; El-Sheikh, 1999) and eccentric diagonal technique (Marsh and Fard, 1984). The most effective technique was introduced using a top continuum such as concrete slab, or timber plates or ferrocement slabs connected to the top joints of the DLG to achieve a composite action. Intensive research was introduced to prove the efficiency of such technique under static loads besides the introduction of various techniques to achieve such interaction between the top continuum and the top layer of the DLG (Castillo, 1967; Al-Bazzaz, 1976; Chu, 1984; Kuleib, 1989; El-Sheikh and McConnel, 1993; El-Sheikh and Shaaban, 1999; Shaaban, 1997; Aboul-Anen et al., 2009). Fig. 2 presents samples of techniques used to achieve the composite action between the top continuum and the top chord layer in DLG structures. Experiments showed that using any of these techniques increased obviously the load carrying capacity of DLG as can be seen in Fig. 3 (El-Sheikh and McConnel, 1993). An intensive experimental study conducted at the University of Dundee (Elabd, 2010) concluded the high efficiency of applying the composite action technique in increasing the resistance of DLG to dynamic loads such as those produced by earthquakes. A more recent study concluded that using a top plate of ferrocement slab on top of DLG remarkably reduced the deformations of DLG to earthquake loads (Bakr, 2013). Research and innovations in DLG space trusses witness continuous changes. New trends for using composite materials Fibre Reinforced Plastic (FRP) and Carbon Fiber Reinforced (CFRP) polymers are introduced to be used in the design of DLG space structures for large varieties in practical applications such as bridges, sandwich panel or even bridge deck (Dong et al., 2012; Awad et al., 2012; Soudki et al., 2012; Zhu et al., 2015). Novel techniques are also developed for joint assembly for all composite space structures (Bai and Yang, 2013). Prestressing composite space trusses are also one of the latest developed techniques to increase the load carrying capacity of DLG space trusses (Liu and Li, 2014).

The current study aims to investigate the behaviour of composite DLG under the presence of structural openings. In addition, it investigates the best locations for these openings leading to a minimum effect on the structural efficiency of this type of structures.

2. Materials and methods

2.1. Experimental programme

To achieve the goals of this research the research group at Dammam University developed a specially designed test facility that consisted of a 3.0 m × 3.0 m model DLG space truss, testing box/frame and a high accuracy data acquisition system.

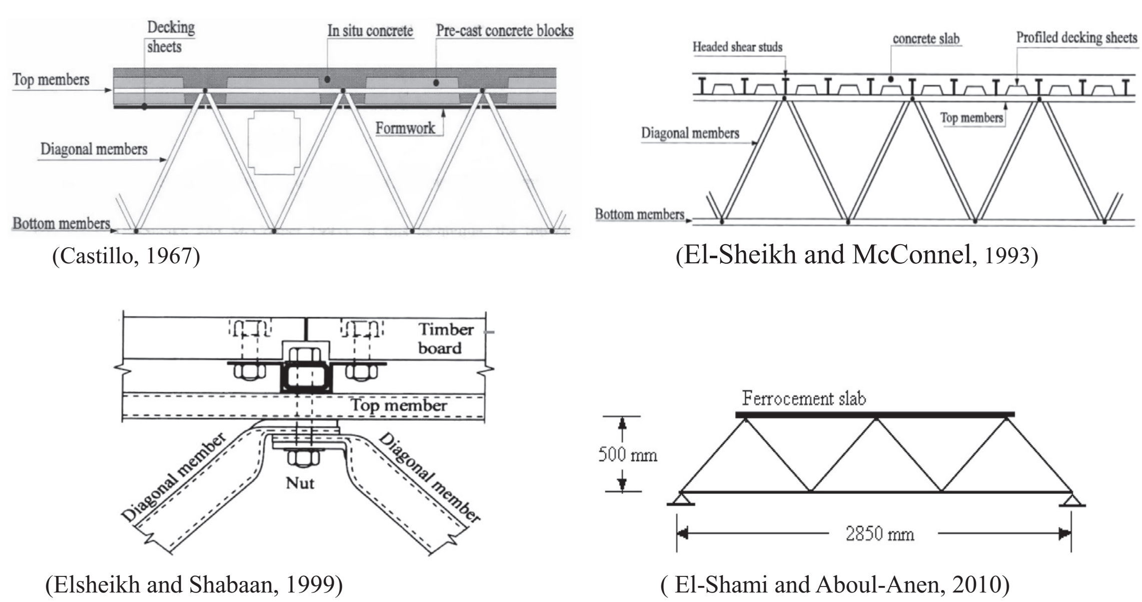

Figure 2 Different techniques used to achieve the composite action.