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Site investigation of damages occurred in a steel space truss roof structure due to ponding

Filiz Piroglu [a], Kadir Ozakgul [a,*], Hikmet Iskender [b], Levent Trabzon [c], Ceyhan Kahya [d]

[a] Department of Civil Engineering, Istanbul Technical University, Maslak 34469, Istanbul, Turkey
[b] Department of Chemical Engineering, Istanbul Technical University, Maslak 34469, Istanbul, Turkey
[c] Department of Mechanical Engineering, Istanbul Technical University, Gumussuyu 34439, Istanbul, Turkey
[d] Department of Meteorological Engineering, Istanbul Technical University, Maslak 34469, Istanbul, Turkey

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ABSTRACT

In this study, a steel space truss roof structure which was partially collapsed after a local meteorological event that produced strong winds and heavy rains in Marmara region was investigated. For this purpose, damage reconnaissance studies were conducted and findings observed in the site were interpreted according to the current Turkish steel building design codes based on allowable stress design. For the structural members taken from debris, material tests were conducted. This steel space truss roof structure covering an industrial facility was supported on reinforced concrete columns of 11 m height, sheathed by using fibro panel with membrane, having a slope of 1% to monitor the waterflow to the siphonic roof drainage system and surrounded by the parapets of 15 and 25 cm heights at the roof-edges. As a result of the investigation, it was estimated that during this extreme rainfall event, due to any deficiency or blockage of the roof drainage system in the edge zones with parapets of the roof, rainwater accumulation occurred at these regions of the roof fully and eventually due to the ponding which is a particular loading case for the design of the structures that is however not defined by the Turkish design standards, roof collapse of this industrial hall building occurred partially.

1. Introduction

The roof structures can be generally damaged under the unforeseen extreme meteorological events or in case of poor design or construction under normal load conditions. The roof collapse is a failure case especially for steel structures which can occur worldwide. The causes of such collapse events have been investigated by many researchers [1–8]. In these studies, the structural deficiencies and defects in the damaged or collapsed roof systems have been researched in detail by carrying out experimental tests and computer analysis.

In addition, each of the roof components such as the roof sheathing panel, drainage system and parapet has been individually scrutinized by several researchers. It may be said that the performance and strength of these components may be so important in terms of load-carrying capacity of the roof structures under extreme loads. The wind effects on the various roof covering systems have been estimated by experimental and analytical studies [9–13]. Henderson et al. [14] conducted an experimental study on the performance and failure mechanisms of roof sheathing under fluctuating wind loads. Massarelli et al. [15] performed an experimental study based on dynamic tests in order to determine the seismic characteristics of the steel deck roof diaphragms. Blaauwendraad [16,17] presented numerical methods and models for the analytical solution

* Corresponding author. Tel.: +90 212 2856572; fax: +90 212 2856587.
E-mail address: ozakgulk@itu.edu.tr (K. Ozakgul).

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of rainwater ponding problem on flat or nearly flat one-way and two-way roofs. Mans et al. [18] carried out a study related with wind-induced loads acting on parapets situated on low-rise buildings. In this paper, the wind-induced pressures on parapet surfaces were measured and then, the wind loads on the parapets were obtained by using these measurements. In another study, Suaris and Irwin [19] investigated the effectiveness of different parapet geometries by reducing the extreme suctions on the low-rise building roofs experimentally and analytically. Also the performance of the roof drainage systems has been investigated using numerical models and laboratory tests by several researchers [20–24].

2. Description of the steel space roof structure

The industrial hall building investigated due to the partially collapses of the roof structure in this study consisted of an administration building and six halls with different geometrical sizes and column configurations where an industrial production was made. Plan view of this structure is given in Fig. 1. The load-carrying system for the roof structure of each hall was constructed by using a 2 m high double layer grid steel space truss system which is one of the most commonly used form of space truss systems for more than 25 years in Turkey.

Mero system consisting of a steel sphere with screw thread holes is used as joint assembly at the truss connection joints. Additionally chord and diagonal members having a steel tube sections with different diameters and thicknesses belong to the load bearing members of this Mero system, as shown in Fig. 2. The screwed cone ends of these pipes were connected by the steel sphere joints. These spheres with flat facets and tapped holes for bolts are hot-pressed forging nodes which are constituted as connectors, i.e. assemblies by tightening the bolts by means of hexagonal sleeve and dowel pin arrangement for the straight bearing circular hollow sections of the space truss system without causing any joint-eccentricity. At every node-point the axes of all the joining truss members can pass through the center of these connectors so that only axial forces can develop. Thus tensile forces will be resisted by the space truss members and transmitted along the longitudinal axis of the bolts on their end cone. However there will be no stress on the bolts if they are subjected to compression forces which will be then distributed through the hexagonal sleeves to these connectors. In the design C45 steel material having 38–49 kN/cm^2 yield stresses was chosen and galvanized for these Mero connectors according to the Turkish Standard TS 2525-2 [25] by considering the sphere diameters between 75 mm and 154 mm.

In this investigated industrial hall building, six steel space truss roof structures with different spacings on the individual halls covered totally 30,000 m^2 production area and were separated by the structural expansion joints from each other. This light weight roof system on every hall was rigidly supported in vertical direction on reinforced concrete columns of 11 m height. At the support points spheres were welded on square or circular bearing plates which were mounted on the top of the reinforced concrete columns, as seen in Fig. 3.

As can be seen in Fig. 1, Hall A covered 5244 m^2 area in the south-west region of the industrial building between the A–G and 1–4 axes in plan view. 4567 steel pipe members were used in the space truss roof system which was supported on 28 reinforced concrete columns with different spacings. Hall B in the south-east region covered 1440 m^2 area between the G–I

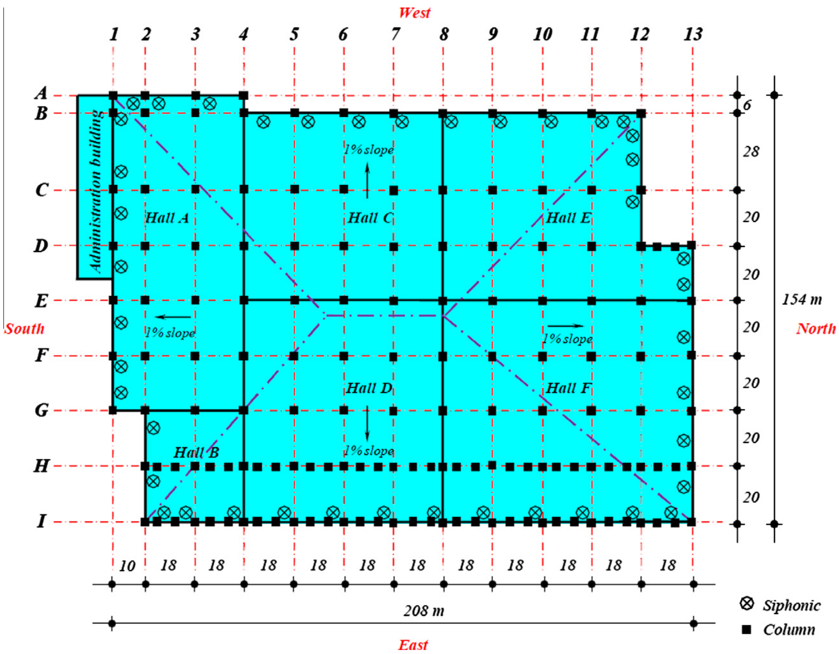

Fig. 1. Scheme of the industrial structure subjected to ponding due to heavy rainfall.