Engineering Failure Analysis 78 (2017) 1–14

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Capacity analysis, investigations and retrofitting of a long span steel grid hangar

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ARTICLE INFO

Article history:
Received 26 November 2015
Received in revised form 24 August 2016
Accepted 27 February 2017
Available online 01 March 2017

Keywords:
Hangar
Deflection
Load capacity
Reticulated steel roof
Retrofits

ABSTRACT

In this study, a reticulated long space steel hangar that does not meet the allowable maximum deflection limits was investigated. The purpose was to assess, test and reinforce the structure so as to improve its capacity and prevent excessive deformation. Upon site investigations, some members had corroded, bolts are partially tightened onto node ball, mechanical air duct are suspended on the members rather than on joints. The support joint previously designed as a flexible joint translating in the y-dir is partially fixed, and some members experienced bending near support joint. The configuration of crane load path, assumptions of column stiffness effects and errors in designing and construction of joint support configuration contributed to an increment in deflection, internal member forces and bending/rotation on members near to support joints. The structure was incrementally loaded at specified points on the grid to test and evaluate deformation and its loading capacity, and an extensive analysis was carried out before and after retrofitting. Apart from servicing the hangar, other recommended strategies are retrofitting mechanism of welding new steel tubes to existing ones and reinforcing the bolt joints was agreed upon since the hangar was observed to be elastic. The hangar member loading capacity was observed to have improved significantly after the retrofitting. This study urges the stakeholders to be keen on discussed items and on roof erection process. A schedule for monitoring the behavior of the hangar is underway.

1. Introduction

There are many case studies conducted expressing various issues and solutions relating to long span hangars. Unfortunately, accidents and roof hangar failures and collapses occur worldwide in existing and newly constructed facilities [1,2]. Pinto, Varum [3] presents two cases for technological failure and defects relating to the roof system where the failures were as a result of lifting process of the roof. Karamanos and Karamanos [4] observe that supports should be carefully examined, for the rigid support systems are stiffer in comparison to the whole reticulated grid system thus leading to high self-strained forces. Roof system failures and collapses affect the normal operations that may lead to putting people in danger and unforeseen costs. To reduce and mitigate on these effects, regular inspection, repair and monitoring are necessary.

The examined case study project is a long span hangar, located in Jakarta, Indonesia, which is meant for servicing planes and covers an area approximately 50,000 m^2. The structure is fully constructed and needs to open for utilization. The project owners observed an unsightly vertical deformation and after investigations it measured 30.6 cm at the middle of all the hangar bays.

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http://dx.doi.org/10.1016/j.engfailanal.2017.02.012

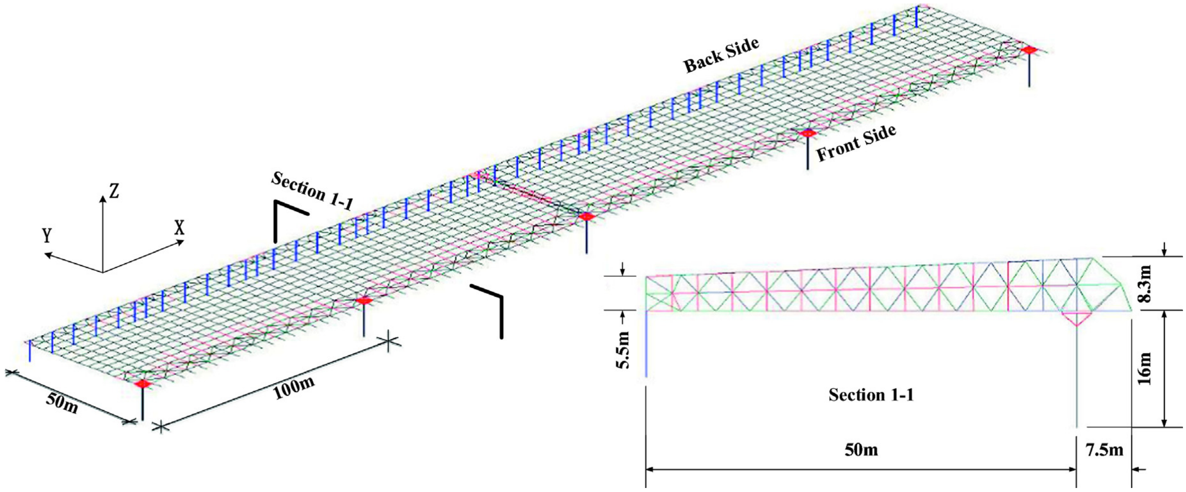

Fig. 1. Orthographic and transverse section view of reticulated roof structure.

However, this could not meet the allowable requirements thus the owner established an expertise team to assess the project and evaluate on loading capacity and deflection. The structure did not have any observable breakdown or failure, however for safety reasons an extensive analysis was scheduled, and retrofitting strategies developed to ensure that it meets capacity, and it is safe for use. The main goal for this study is to present site investigation issues observed in the field, investigate the causes of extra deformation, testing and strengthening mechanisms for this long span hangar to improve members load carrying capacity.

1.1. Description of the long span hangar

The structure consists of two-mirrored general service area with the central part having offices, sanitary area and cafes. The hangar spans 100 m center to center with front elevation having five (5 No.) 5.0 × 5.0 m columns head support with a 3.0 × 3.0 m hollow. On the backside, it consists of forty-eight (48 No.) 0.9 × 0.9 m solid reinforced concrete columns. In the transverse direction the roof spans 50 m column to column. A floor to roof base height of 16 m is specified. A structural thickness of the space frame at the front elevation is restricted to 8.3 m, and on backside a depth of 5.5 m and 7.5 m verge (Fig. 1). Tubular section members of different diameters, thickness and length make the structural grid. The roof structure consists of two layers of diagonal and tie members and three layers of chords members that carries either tension or compression loads (Fig. 2) taking an elegant and impressive design covering a large span. In each part of the hangar, there are 3821 nodes and 17,048 members in total. All tubular members have designs with cross sections made from steel tube and connected with node ball, sleeves, and bolts having been established from SAP2000 [5]. The reanalysis of the hangar was done by combining SAP2000 [6] and STCAD [7] to establish the internal forces, support reactions, displacements and stresses. All analysis are based on two codes: Eurocode 3 and Indonesian National Standard (SNI) and type of steel used in the construction is SS400, and the value of the limit stresses in the project is 210 MPa. Considering the space of this paper and huge amount of members, it is hard to give all details of members. The extracted sections for the structure are as shown in Table 1 and all loads in the original model are shown in Table 2.

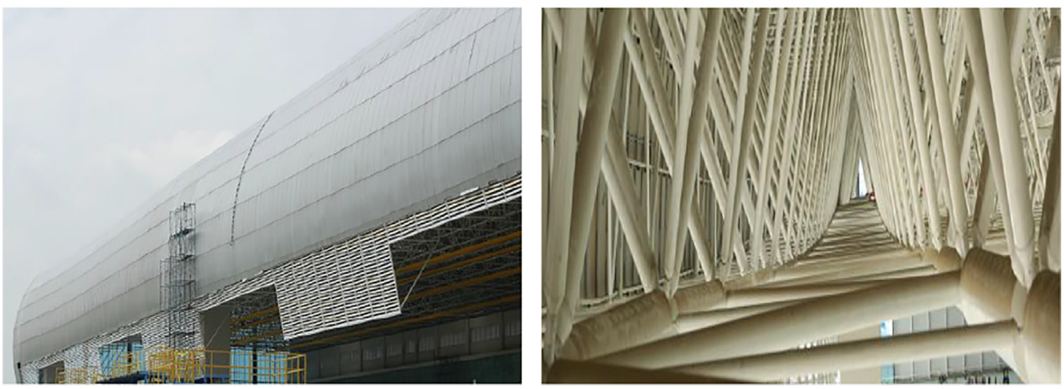

Fig. 2. Part of the structure under investigation.