Strengthening of short span steel jetty exposed to abnormal loads

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ABSTRACT: The steel jetty selected for strengthening is in Baghdad city, over Tigris River, consists of 55 short spans, each of approximately 4 meters and one navigational opening of 12 m. The bridge is 224.85 meters in length and 8 meters wide. The strengthening system was designed to remove over-stresses that occurred when the bridge was subjected to abnormal loads of 380 000 kg. A strengthening system which installed was used, where the main concept is to depend on adding lateral supporting elements which impose reversal forces on the bridge to counteract most of the loads expected from the abnormal heavy loads. Also, depends on modifying the bracing system at navigation opening.

1 INTRODUCTION

Bridges play a vital role in road and railway networks all over the world. They are often subjected to variable load patterns, i.e. increase in axel load and traffic intensity by time, and sometimes harsh environments which might result in the loss of their functionality, Demir (2011). For instance in USA 122 000 bridges out of 615 000 bridges in the country are in need for upgrading. Similar problem exists in Europe where 66 % of the bridges are 50 years or older, Björklund et al. (2007). This indicates that many of existing bridges are not compatible with existing traffic in terms of axel loads and traffic intensity which might give rise to problems such as load carrying capacity and fatigue. When a structure cannot be restored by maintenance and local repair, it must be strengthened or replaced. It is often more advantageous to strengthen a structure due to the fact that strengthening is, in most cases, less expensive than replacement. Strengthening would be especially favorable if the method used is fast, effective, and simple.

Many existing steel bridges in Iraq have insufficient load bearing capacity due to a number of reasons such as corrosion, aging, and deficient structural design. Besides aging, there are several reasons that necessitate strengthening and repair operations such as damage caused by accident, vandalism, increasing service load and intensity, changes in codes/standards or extra safety requirements. The loads applied to many of the bridges have changed during the years. More traffic and heavier vehicles increase the magnitude and the intensity of the applied load. Therefore repair and strengthening works are vital to keep existing bridges in service and also traffic safety.

In Iraq, demands for power plant components are economically justified because of the vast need to the electricity industry due to the huge damage that occurred in the Iraqi power network since the last war of 2003. Accordingly, there has been an increased demand for hauling heavier machinery and industrial components on highways during the past few years, Oukaili et al.

(2016). On land, large and heavy loads required to be moved from inland boarders or Fao seaport to various inland destinations. Because of the absence of inland waterways and the limited capacity of rail network, these loads are transported on the road network. Almost these large loads categorized as abnormal loads which comprise equipment for electric power generation and different production plants.

When large indivisible payloads, together with the combination of vehicles used to transport them, exceed 150 tons, 8 meters in width or 4.8 meters in height they are defined as abnormal loads and are of paramount interest to highway and traffic officials responsible for preserving the road network and infrastructures, European best practice guidelines (2004). Abnormal loads need special roads or routes where the visual restraints are not present. These routes are termed super routes, Nordengen et al. (2002). Assigning such strategic super route and establishing of a super route map, which can be used to display relevant data related to this super route, will have a great importance for highway and traffic officials.

Accordingly, it was necessary to establish the Iraqi super route map that will include relevant information regarding the network of super routes. The first step for creating such map started with the establishment of the working committee, comprising participants from the Iraqi Ministry of electricity, highway and roads authorities, traffic officials and consulting engineers from University of Baghdad, in order to identify the minimum super route network of roads necessary for the purpose. The second step based on considering the position of the major border posts to neighboring countries that may need to import larger and heavier machinery and components. The third step included the inspection process with all the required measurement and determination of obstacles that may face and how to overcome or bypass them. Accordingly, the super loads the super route map was created which based on the basic national road network, Oukaili et al. (2016). On this super route there are many bridges, culverts and roads which require rehabilitation and strengthening. One of these bridges is the 14-July steel jetty (Plate 1), which was constructed in the late 1990's, carries vehicular traffic between Karkh and Rasafa sides of Baghdad city. This bridge has been designed for a load of 65 000 kg which is extremely small compared to the abnormal heavy weights. The bridge passes over Tigris River that makes the strengthening techniques are very difficult due to the inaccessibility to the structural components (Plate 1). No documents, design drawings or technical design data for the structure are available.

The primary objective of this study was the development of strengthening system for 14-July steel jetty to sustain abnormal load of 380 000 kg.

Plate 1. 14-July steel jetty – upon – Tigris.

2 OVERLOAD PERMIT REQUEST

The Iraqi highway and traffic officials received an overload permit application from the Ministry of Electricity to haul 20 Wartsila – Deugro transformers. These transformers each weighing 277 000 kg were to be hauled from the Iraqi-Jordanian borders to Samarra Substation which is located at a distance 170 km to the north of Baghdad. Odeh Naber & Sons Transport Company, (Nabresco), proposed to use four types of Goldhofer tractors to tow the 277 000 kg transformers on single lane 12-line, 14-line, 15-line and 16-line hydraulic trailer units, respectively (Plate 2). The initially proposed gross vehicle mass (GVM) is 380 000 kg. Each axle of the trailer units consisted of 8 tires (8 wheels) and the axles were equally spaced at 1.5m. Five times these trailers will be used to carry these transformers to final destination in Samarra city. These configurations distributed the load, including the counterweight on tractors, over a distance of 29.3 m, 31.4 m, 32.9 m and 34.4 m, respectively. The weight of the transformer was to be equally distributed over all the axles using hydraulic mechanisms. The height of trailers, including transformer, is 7.3 m.

3 BRIDGE DESCRIPTION

The steel jetty is 8 m wide and has 56 short spans supported by a system of steel HEA-beams, where 55 typical spans of approximately 4 m length and one navigational opening of 12 m span. The bridge is continuous with a total length of 224.85 m. Geometrically the bridge is straight on a zero-degree horizontal curve and is not super elevated. At the navigational opening the supporting frames in the transvers direction consist of five steel pipe columns 600x5 mm dimensions and main steel girder of 2HEA290x300. Nine steel girders of 2HEA290x300 are connecting the individual steel frames in the longitudinal direction (Fig. 1). At the 55 typical spans the supporting frames in the transvers direction consists of three steel pipe columns 600x5 mm dimensions and main steel girder of HEA290x300. Three steel girders of 2HEA290x300 are connecting the individual steel frames in the longitudinal direction. For all spans in the longitudinal and transvers directions, channel 140x60 mm used for the cross bracing (Fig. 1). Sumi deck is covering all spans of the bridge and supported on the system of the transverse and longitudinal steel HEA girders. The bridge deck is topped with an asphalt overlay for a riding surface. The bridge has significant deterioration to some structural members. This damage poses a challenge to verifying assumed load distribution and calculating bridge capacity.

Most common defects in 14-July steel jetty can be categorized as corrosion and accident damages. The product of corrosion has greater volume than the parent material and caused pushing stresses in the material.

In 14-July jetty two different types of corrosion could be identified, namely: surface and pitting corrosions. Surface corrosion occurred on the surface of the component and caused damage and reduction of cross section. While, pitting corrosion took place over very small surface. Pitting is evolving extremely inside the steel and resulted in local stress concentration, where the humidity due to Tigris River has an effect as accelerator for pitting corrosion. Corrosion caused a reduction of the cross section, mainly, of the steel pipe columns and in turn led to reduction of stiffness and increase in stresses in the structure.

Accident damage caused by boots could result in buckling, tearing or cracking of some steel pipe columns (Plate 3). Sometime damage on the bridge components do not need to be repaired and left unrepaired depending on how this damage influences the system of load carrying capacity.

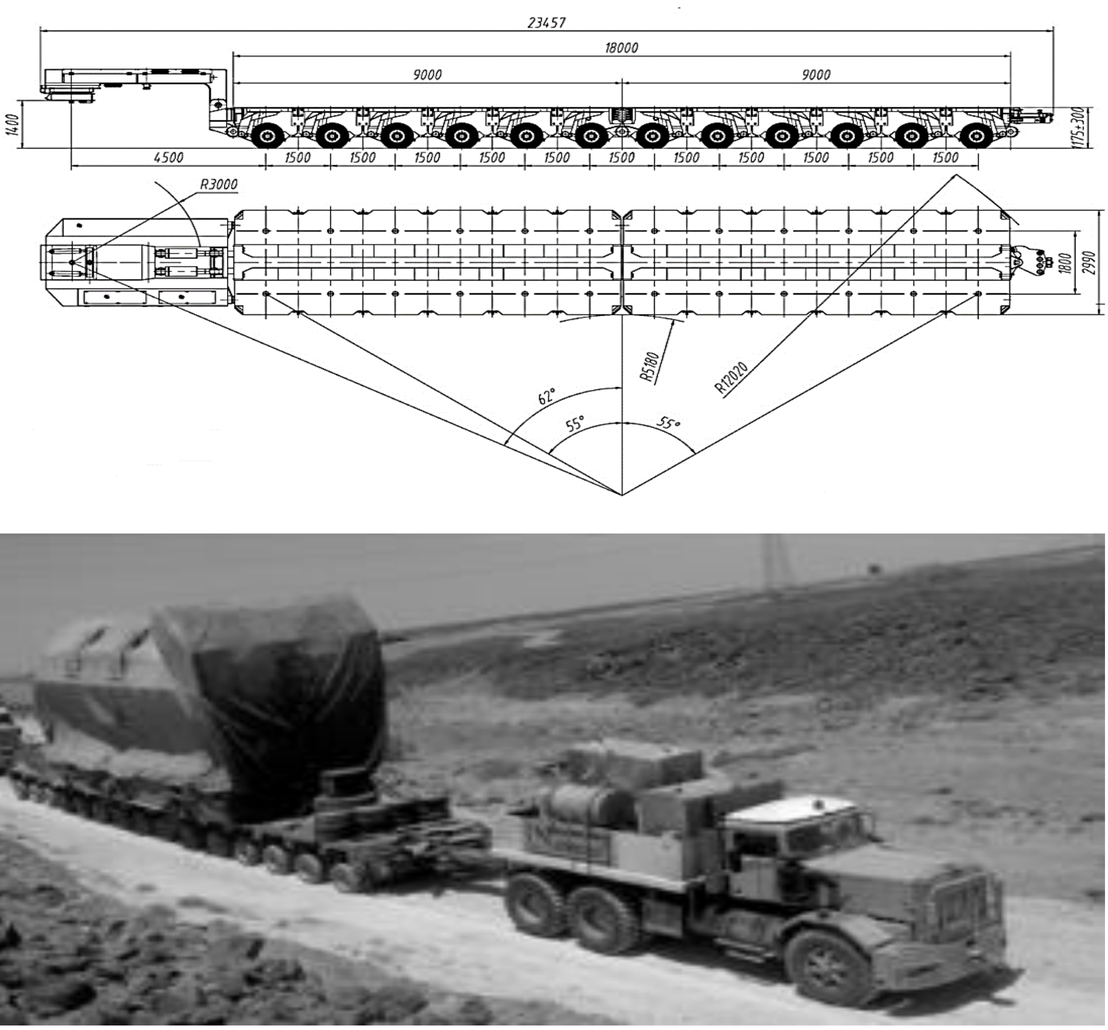

Plate 2. 277 000 kg superload on single lane Goldhofer hydraulic trailer.

4 ANALYSIS PHASE AND PROPOSED STRENGTHENING SCHEME

It is very difficult to accurately assess the strength of the different structural elements of the bridge due to the lack of design drawings and technical design data. During analysis phase, there are some aspects that should be considered since they can influence the strengthening process, Radomski (2002), namely: (a) for which load, the strengthening of the structure or the structural component is performed? For instance dead load and live load or only live load; (b) Type of dominant load in the critical component? Compression, tension, bending or torsion; (c) Effect of strengthening to the structure? E.g. effect of the redistributed internal forces on the structure; and (d) Connections? By welding, bolting or riveting.

As a result, 3D numerical analysis using finite elements approach of ANSYS 12.1, as the main modeling program, was used to analyze the steel jetty. In the creation of this model, it was noted that three factors are the main contributors to the accuracy of the structure model. These factors include the material properties, load distribution and member ends continuity.

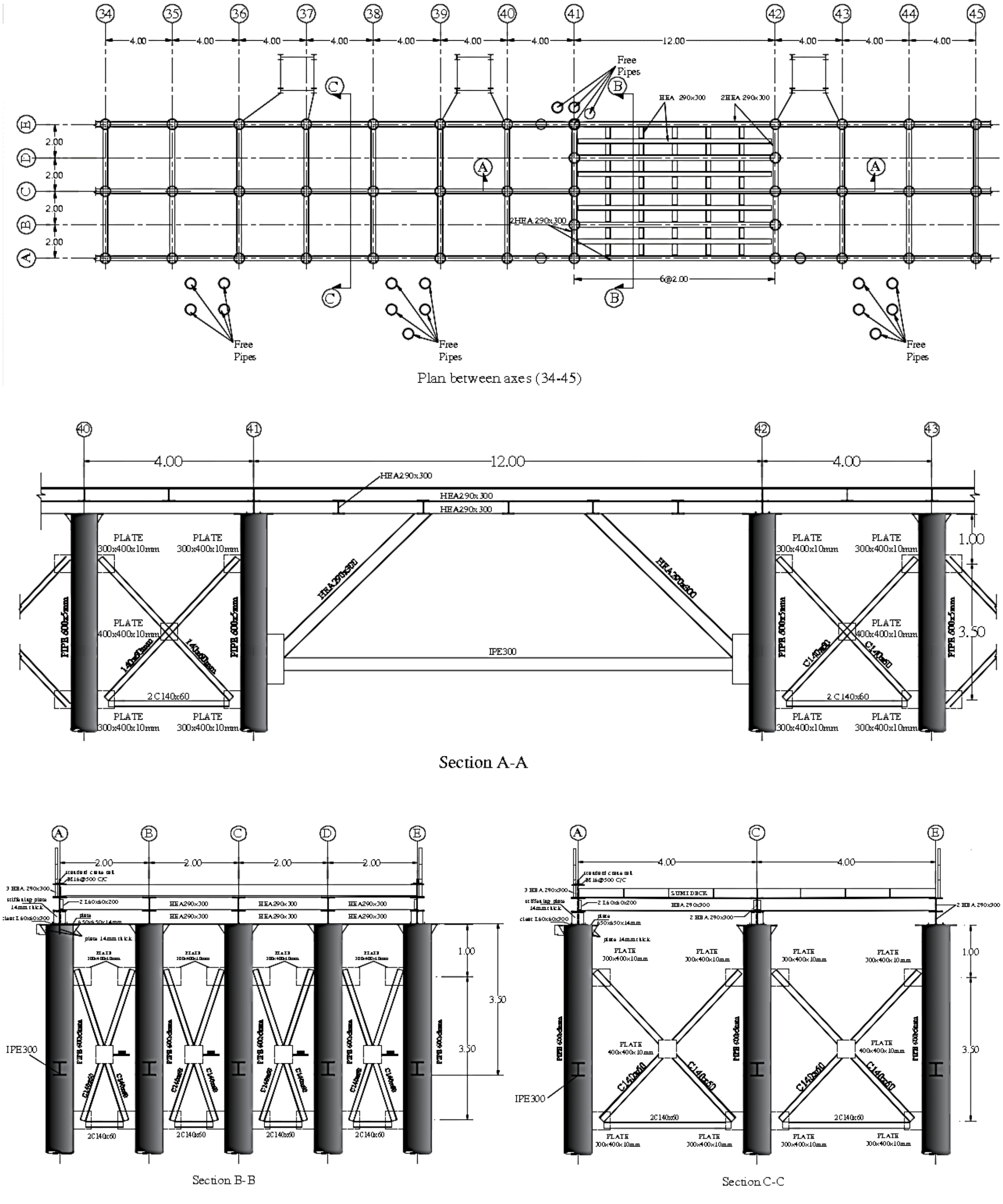

Figure 1. Plan and sections at navigation opening before strengthening.

Plate 3. Corrosion and accident damages of 14-July steel jetty.

Based on these factors, a number of recommendations were proposed to follow for the creation of the model, and they are: (a) For steel members, the gross moment of inertia should be used for non-composite members and the transformed moment of inertia for composite members; (b) Load distribution percentages are based on the number of girder lines, construction materials and span length; (c) Load is distributed longitudinally and transversely and could be modelled as a uniformly distributed load; and (d) The use of nonlinear link elements to control member end continuity in one model is key to develop an accurate bridge model. Accordingly, all elements of the steel jetty were modeled using Link8 element. This element is a 3D spar element and it has two nodes with three degrees of freedom per node (translations in the nodal x, y and z directions).

The bridge passes over Tigris River that makes the conventional supporting techniques are very difficult due to the inaccessibility to the structural components. During the analysis phase, different strengthening schemes were proposed where members at different locations suggested to be added to the steel frame model at the navigation opening and lateral supporting member at other locations using the available free steel pipes (Fig. 1). After that the strengthened structure was analyzed under the abnormal load of 380 000 kg. Many trials were conducted to choice the most economic and safe option between strengthening schemes which achieve the required carrying capacity for the system, fast in installation, effective and simple. Accordingly, a new strengthening technique is decided to be used as a permanent strengthening scheme, (Fig. 2), that mainly depends on: (a) Adding main steel girders HEA290x300 at navigation opening; (b) Providing lateral supporting members to restrain the side-sway of the bridge during the movement of the abnormal load; and (c) Using longitudinal and diagonal bracing members at navigation opening. The main concepts of this technique, which has been developed and verified by author, is to depend on elements, impose reversal forces on the bridge to counteract most of the loads expected from the abnormal heavy loads and restraining the side sway.

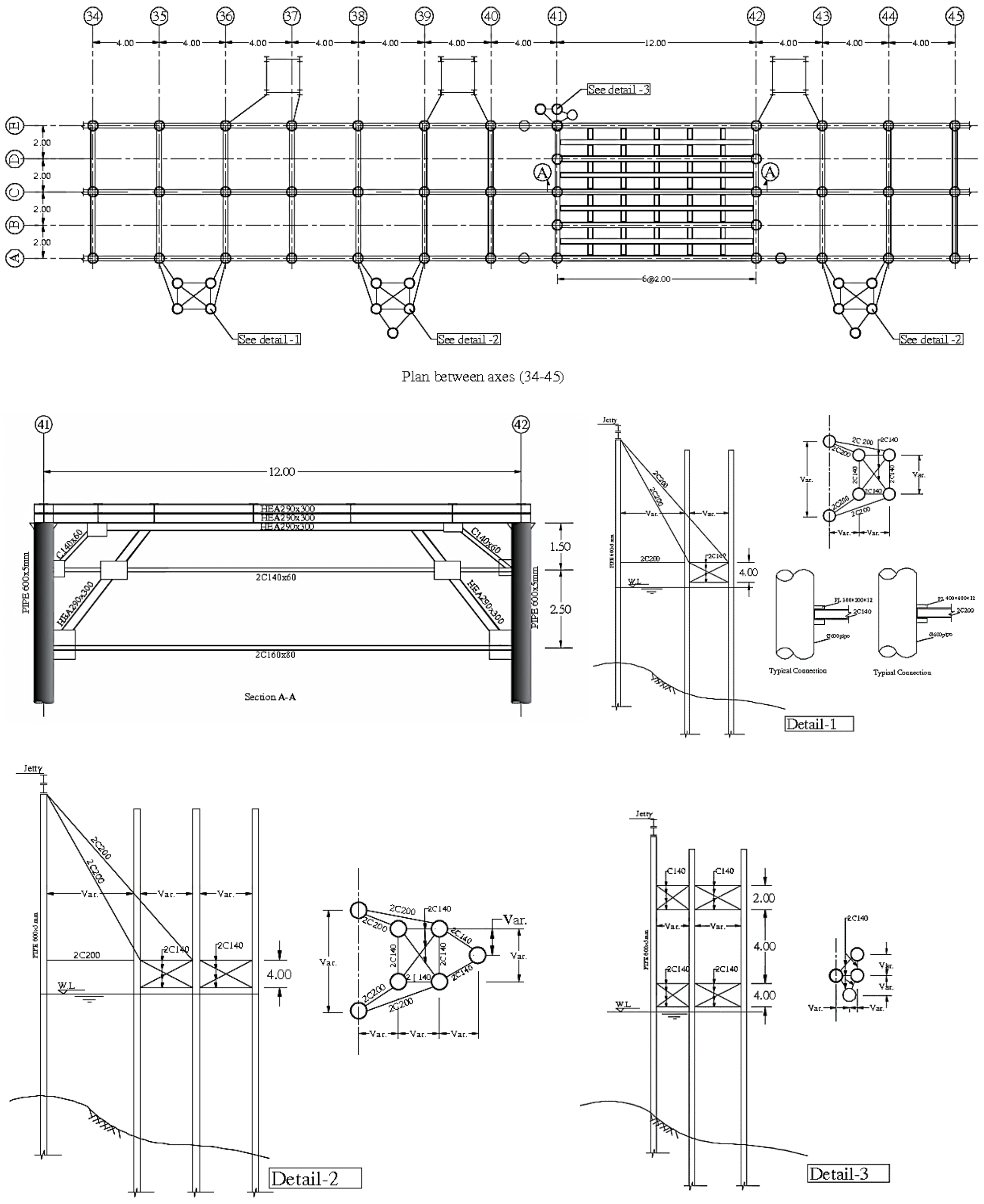

Figure 2. Plan and sections at navigation opening after strengthening.

5 LOAD TEST

Bridge load testing offers a unique opportunity to investigate the behavior of real structures. The main goal of load test will generally be to demonstrate satisfactory performance under an abnormal load. This is usually judged by measurement deflections under this load, which may be sustained for a specified period. Static load test is conducted on bridges and are considered as accepted criteria and useful information concerning testing and deflection measurement. A load-testing program was carried out on 14-July steel jetty after strengthening. The load was applied in multi stages so that timely action, such as stopping the test, can be taken if any untoward distress is observed at any stage. The suggested stages of test load placement are 31%, 62%, 93% and 100%, Oukaili et al. (2016). The next incremental loading was added only after the deflections under the previous load have stabilized and all the stipulated observations are completed. Survey process was carried out for the steel jetty during loading. A maximum deflection of 6 mm was observed at midspan of the navigation opening during the load test. Unloading was carried out also in the same manner. The midspan section rebounded back to its position as the load removed from the bridge.

6 CONCLUSIONS

The following conclusions can be drawn:

1. A new permanent supporting system, which has been developed by the author, is applied to support the existing 14-July steel jetty – upon – Tigris which located at the route required for the transportation of the abnormal heavy package to Samarra power station, Iraq.
2. Analytical model was conducted to determine the necessary dimensions of all the suggested strengthening system components and to approve that the suggested strengthening system can carry the abnormal heavy load safely.
3. The maximum deflection of 6 mm was observed at midspan of the navigation opening during the test under the abnormal load. The midspan section rebounded back to its position as the load removed from the bridge. This indicates the effectiveness of the proposed strengthening system.
4. The details of the new supporting system are illustrated

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