# Strengthening and Load Testing for Short Span Steel Bridge for 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 meters length and 8 meters in width. The strengthening system was designed to remove overstresses that occurred when the bridge was subjected to abnormal loads of 380 tons. A strengthening system which installed in spring 2008 was used where the main concept is to depend on added side supporting elements which impose reversal forces on the bridge to counteract most of the loads expected from the abnormal heavy loads. The bridge was load tested before and after the strengthening system was activated. The load test results indicate that the strengthening system was effective in reducing the overall deformability of the bridge.

## 1 Introduction

It is needs to be noted that in Iraq the use of waterborne transportation is virtually non-existent because there are no navigable rivers or canals for all practical purposes. Also, the rail network is poorly developed compared to Europe with limited access in terms of origin/destination considerations.

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. 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 comprise equipment for electric power generation and different production plants.

## 2 Restrictions for selecting super routes

The National Abnormal Loads Technical Committee recognized a need to identify and monitor a minimum number of strategic routes that need to be preserved for the movement of abnormal loads. Abnormal loads need special roads or routes where the visual restraints are not present. These routes are termed super routes [1]. 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. This route map will be a useful tool for indicating to planning authorities the effect that a particular project such as a new bridge or a cable across a road could have on reducing or improving the capacity and effectiveness of a given super route. It will also be used by the National Abnormal Loads Technical Committee transportation and consulting engineers for preliminary planning of the movement of super loads. To establish such map, the most important consideration is to arrest the increasing constraints, being placed since the last war of 2003, on the existing routes by the encroachment of restrictive features that reduce the effectiveness of the strategic routes.

There are three main restrictions to select the strategic super load route, which will be used for the movement of large equipment for power generation and production plants units that are comprise the following:

1. Height clearance offered by overpasses, overhead cables and road furniture,
2. Roads and bridge capacity and geometrics, involving mass, height, width and length restrictions, and,
3. Strength of bearing structures such as bridges and culverts.

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 [2]. Items associated with abnormal loads are normally huge specialized vehicles such as mobile cranes and piling rigs, transformers, pressure vessels. While the width and length may present practical problems, these problems can usually be overcome by using steerable dollies or multiple axle steerable trailers.

In Iraq, after the edition of the first highway design manual in 1982, the legal height limitation is considered 4600 mm and the maximum allowable gross vehicle mass is 65 tons for vehicles with a maximum overall length of 35 m and the minimum vertical clearance over roads as 5200 mm. The geometric and structural design for the roads facilities were based on some foreign specifications which permitted 4900 mm vertical clearance for bridges over roads since the maximum vehicle height stated in these specification was 4100 mm and the maximum gross load of vehicle was 43 tons. During that time period, a lot of bridges were constructed in the highway network of Iraq. Some of these bridges even belong to an old era which adopted 20 tons truck as a design vehicle load, when this truck load was thought to be monstrous and awesome. Accordingly, it is generally found that vehicles with abnormal loads category, as defined, encounter few restrictions. Recently, due to the dramatic changes in the transporting modes combined with the drastic increase in vehicle axle loadings, the existence of these bridges without improving their load carrying abilities and rehabilitation represents an impediment in the highway network for the road users.

## 3 Proposed Iraqi strategic super route

Route clearance is defined as the process needed to find a given route to transport abnormal loads. This is a time-consuming and expensive process that requires a careful inspection, measurement and fixing of all obstacles that may prevent the transportation of the super loads. All load bearing structures should be inspected and their load bearing capacities determined, taking into consideration their current condition, including cracking formation, deformations, and corrosion. In case of doubt, special supports have to be designed and installed. This, of necessity, is highly specialized and expensive work. Alternatively, the structure maybe by passed, or in exceptional cases, replaced.

It is necessary to establish the Iraqi super route map that will include relevant information regarding the network of super routes. The first step 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 (Fig. 1). 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 (Fig. 1).

## 4 Description of 14-July steel jetty

The jetty has 56 short spans supported by steel HEA-beams, where 55 typical spans of approximately 4 m length and one navigational span of 12 m. The bridge is continuous with a total length of 224 m. Geometrically the bridge is straight on a zero-degree horizontal curve and is not super elevated. At the navigational opening the bridge supporting frames in the transvers direction consist of five steel pipe columns 600x5 mm and main steel girder of 2HEA290x300. Nine steel girders of 2HEA290x300 are connecting the individual steel frames in the longitudinal direction (Fig. 2). At the 55 typical spans the supporting frames in the transvers direction consists of three steel pipe columns 600x5 mm 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. 2). Sumi deck is covering all spans of the bridge. 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.

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. As a result, a new technique that mainly depends on side supports is decided to be used as a permanent supporting system.

The main concept of this technique, which has been developed and verified by authors, is to depend on elements impose reversal forces on the bridge to counteract most of the loads expected from the abnormal heavy loads.

## 5 Description of abnormal loads

In Samarra city which located to the north of Baghdad, at a distance of 170 km, a new power sub-station of 20 Wartsila – Deugro transformers is decided to be built. The highway and traffic officials received an overload permit application from the Iraqi Ministry of Electricity to haul these transformers. The twenty transformers each weighing 277 tons were to be hauled from Iraqi-Jordanian borders to Samarra Sub-Station. Odeh Naber & Sons Transport Company (Nabresco) proposed to use four types of Goldhofer tractors to tow the 277 tons transformers on single lane 12-line, 14-line, 15-line and 16-line hydraulic trailer units, respectively. The initially proposed gross vehicle mass (GVM) is 380 tons. Each axle of the trailer units consisted of 8 tires 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. This configuration distributed the load (including the counterweight on tractors) over a distance of 29.30 m, 31.4, 32.9, and 34.4 m, respectively.

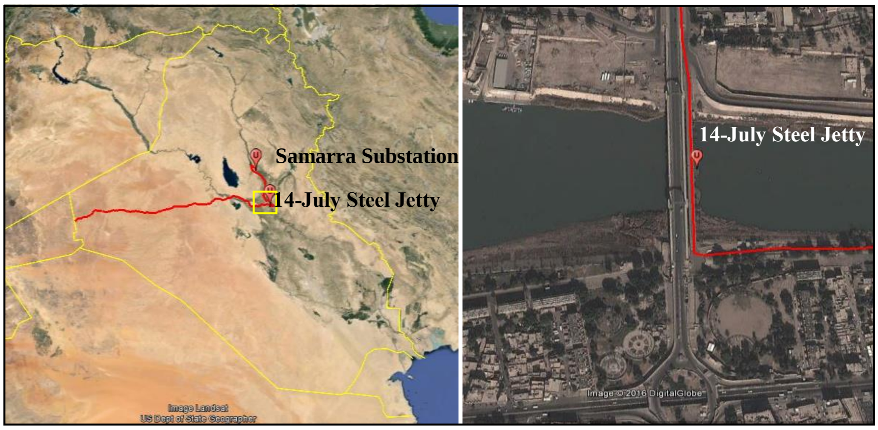


**Fig. 1 Iraqi super route map**

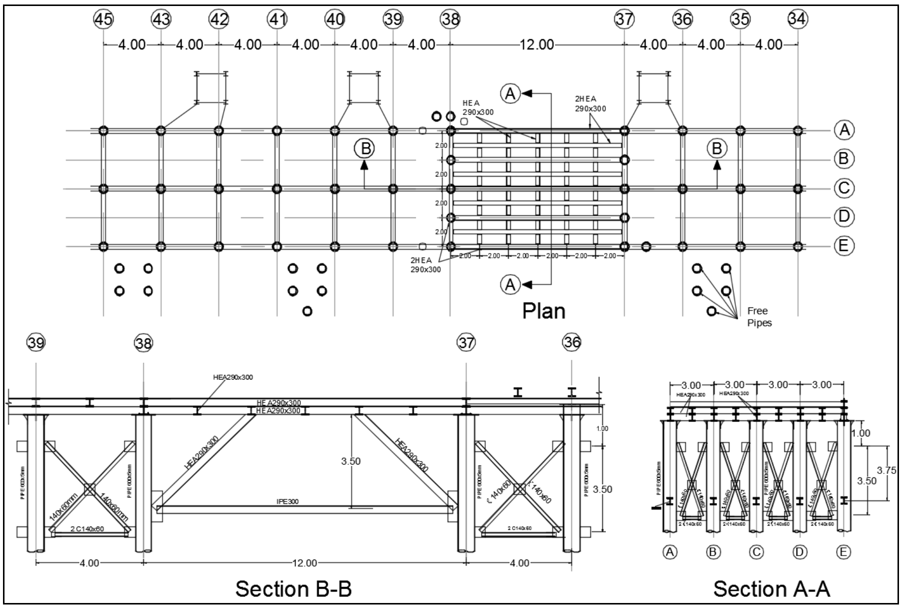


**Fig. 2 Framing plan and sections of 14-July steel jetty before strengthening**

The height of trailers, including transformers, is 7.3 m. The weight of the transformer was to be equally distributed over all the axles using hydraulic mechanisms (Plate 1).

Known locally as the 14-July Jetty, which was constructed in the late 1990's, carries vehicular traffic between Karkh and Rasafa sides of Baghdad city in Iraq will exit on the super route of the passage of the machinery of the above station. This bridge has been designed for a load of 65 tons which is extremely small compared to the abnormal heavy weights of equipment that exceed 277 tons required for Samarra Sub-Station. The bridge passes over Tigris River that makes the conventional temporary supporting techniques are very difficult due to the inaccessibility to the structural components (Fig. 1). No documents or plans for the structure are available and roads which require rehabilitation and strengthening.

## 6 Load testing

Bridge Load test is an inspection process for determining the safe load carrying capacity of structures, determining if specific legal or overweight vehicles can safely cross the structure. The need for load test may also arise from doubts about quality of construction or design, or whether some damage has occurred. Where member strength cannot be adequately determined from the results of in-situ material tests, load testing may be necessary. Traditional evaluations of a bridge behavior are based upon assumptions of material properties, load distributions in the bridge deck, any quantified structural damage from visual inspections, and the accuracy of as-built construction drawings. During and as a result of the inspection, the live load capacity of a structure based on its current condition through analysis and engineering judgment will determine. The main goal of load test will generally be to demonstrate satisfactory performance under an overload above the design working value. 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. Bridge load testing offers a unique opportunity to investigate the behavior of real structures. A diagnostic load test does not seek to evaluate the safety or the load carrying capacity of the structure, but, rather, it is designed to verify its performance under service load conditions. Accordingly, the objective of the load test is to determine and quantify the global deformation of the bridge and its flexural performance and not assess shear performance or ultimate capacity.

A load-testing program was carried out on 14-July steel jetty before and 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% (see Plate 2 and Fig. 3). Unloading was carried also in the same stages. The next incremental loading was added only after the deflections under the previous load have stabilized and all the stipulated observations are completed.

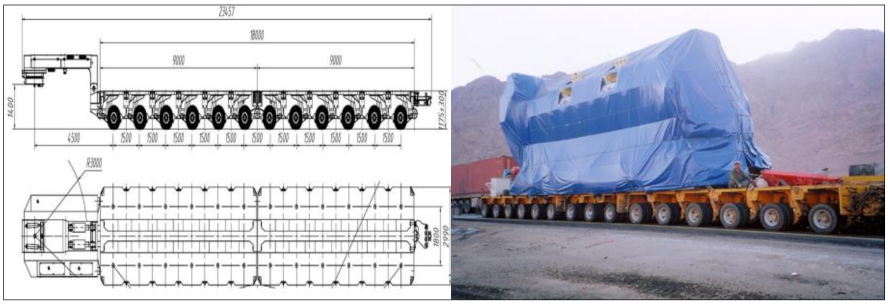

**Plate 1. Goldhofer hydraulic trailer on single lane with transformer of Samarra substation**

**Plate 2. Load test**

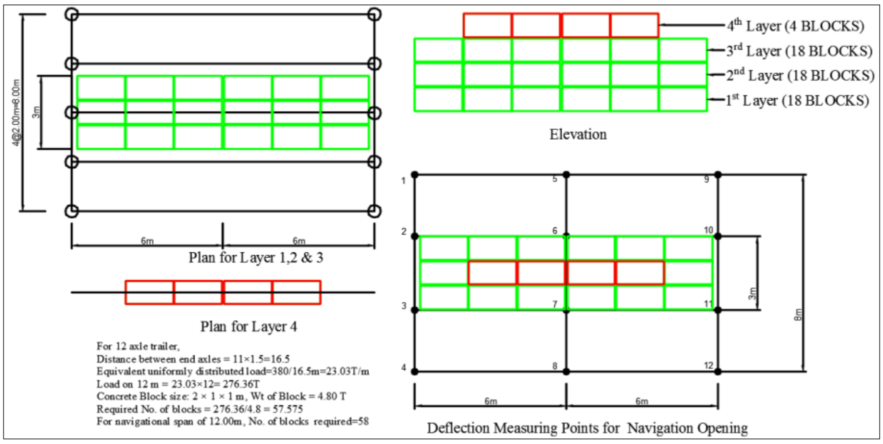


**Fig. 3 Full loading pattern**

## 6 Modeling, analysis and load testing of strengthened jetty

This work set the groundwork for the computer modeling and calibration that is currently part of the study. The goal of this study was to accurately depict the behavior and response of the main structural system of the 14-July short span steel jetty tested. This study focuses on the use of 3D numerical analysis using finite element approach of ANSYS 12.1 as the main modeling program to analyze the steel frame. In the creation of these models, it was noted that three factors are the main contributors to the accuracy of the bridge models. These factors include the material properties, load distribution and member end continuity. Based on these factors, it was proposed a number of recommendations to follow for the creation of the models, and they are as follows:

1. For steel members, the gross moment of inertia should be used for non-composite members and the transformed moment of inertia should be used for composite members. The modulus of elasticity should be set to 200,000 MPa.
2. Load distribution percentages are based on the number of girder lines, construction material and span length.
3. Load is distributed longitudinally and transversely and could be modelled as a uniformly distributed load.
4. The use of nonlinear link elements to control member end continuity in one model is key to developing an accurate bridge model.

All the elements of the steel frame were modeled using Link8 element as shown in Fig. 4. 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).

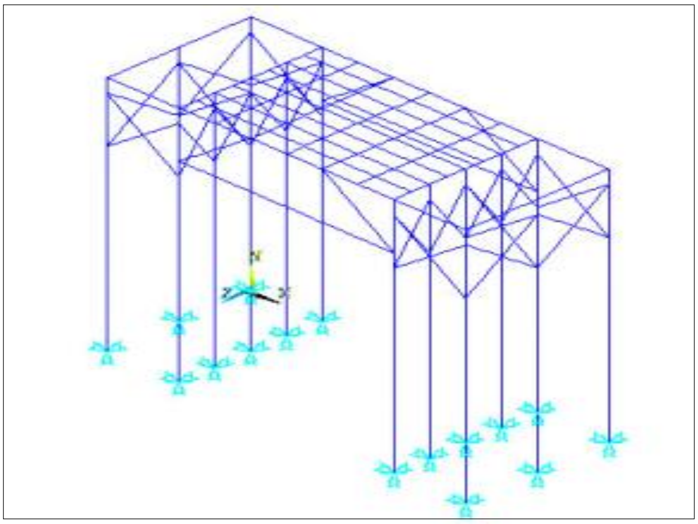

**Fig. 4 Geometric model**

The real constants for each type of frame elements and the material property are given in Table 1. It is assumed to be bilinear isotropic behavior at nonlinear stage. Bilinear isotropic material is based on the Von Mises failure criteria. This model requires the yield stress ($f_y$) as well as the hardening modulus of the steel to be defined.

Load testing for 14-July steel jetty after strengthening was provided. Figure 5 shows the load-deflection response for steel jetty after strengthening. The strengthening scheme for the jetty was shown in Fig. 6. The load-deflection response indicates the effectiveness of the proposed strengthening.

**Table 1. Real constants and material properties**

| Real Constant Set | Element Section | Cross-Sectional area, mm$^2$ | Properties |
|---|---|---|---|
| 1 | Pipe 600 | 9400 | Ex: 200000 MPa |
| 2 | HEA 290x300 | 11000 | Poisson's Ratio: 0.3 |
| 3 | 2HEA 290x300 | 22000 | Yield Stress:252 MPa |
| 4 | C140x60 | 9500 | |
| 5 | 2C140x60 | 19000 | |
| 6 | IPE300 | 5380 | |

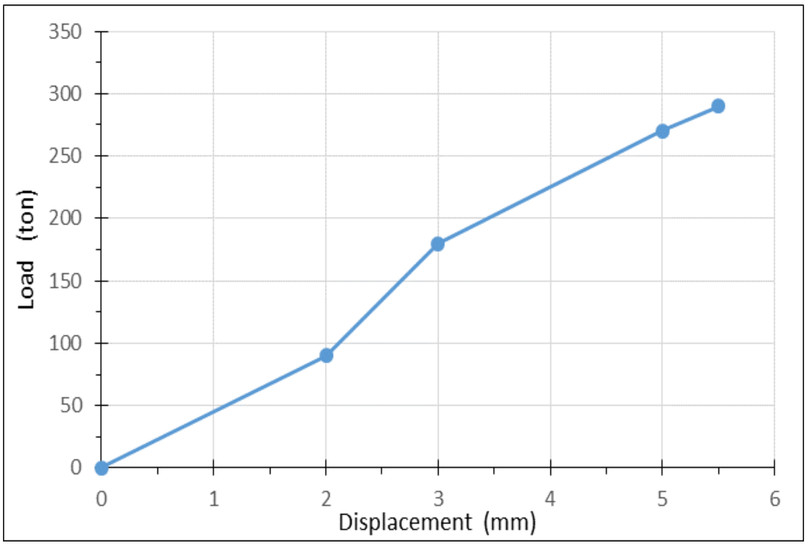


**Fig. 5 Load-deflection response at mid span**

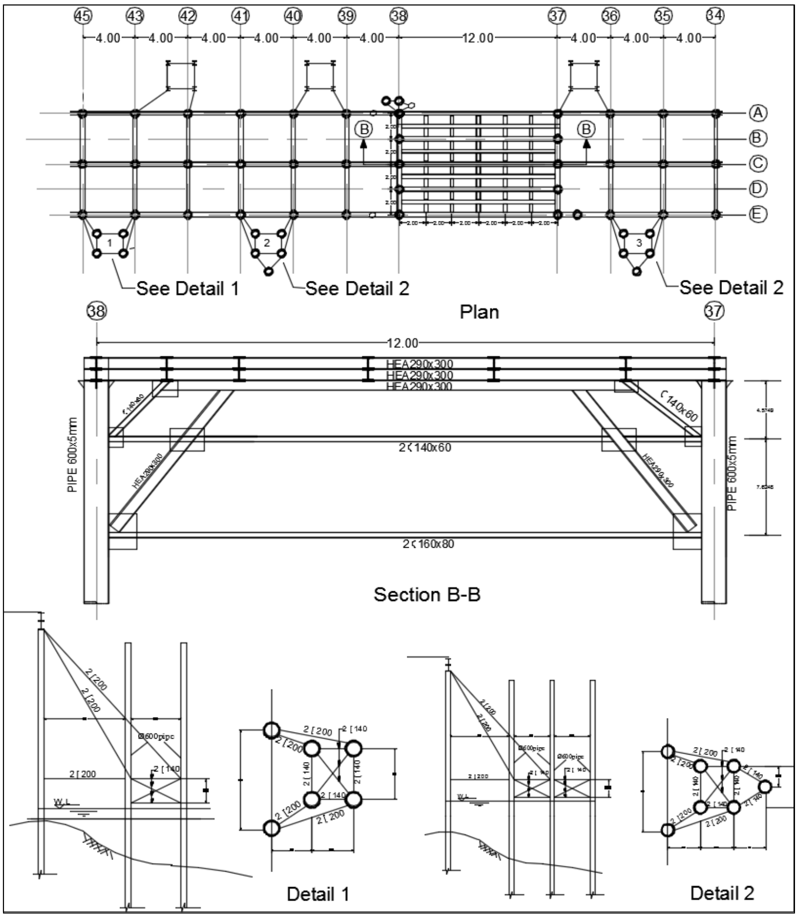


**Fig. 6 Framing plan and sections of 14-July steel jetty after strengthening**

## References


1. Nordengen P. A., Steynberg R. J. and Sallie, I (2002) Abnormal loads super route – A strategic investment for promoting South Africa's economic growth, 21st Annual South African Transport Conference Towards Building Capacity and Accelerating Delivery, South Africa, July 2002.
2. European best practice guidelines for abnormal road transports (2004) European Commission Directorate-General for Energy and Transport: 1-61.