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ELIMINATING HALF OF THE CONSTRUCTIONAL DEFLECTIONS OF SIMPLY SUPPORTED STEEL BRIDGES BY USING TEMPORARY CONTINUITY

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ABSTRACT: When it is required to cast a bridge over a valley, a river or a busy highway, it is difficult to use the required shoring for the concrete casting molds. In such cases, the heavy weight of fresh concrete will be directly subjected to the bridge girders. This situation will apply severe stresses to the bare supporting - normally long span - girders, leading to an un-favorite and uncorrectable permanent deflection. In this research, a simple test was done to simulate the mentioned critical case. It was found that; by constructing temporary joints for both ends of the steel girders of a simply supported bridge panel with its adjacent panels will apply reversal moments to the original panel. By reducing mid span moments due to the weight of fresh concrete of the deck slab during construction, a noticeable reduction-up to Fifty percent-of the expected mid span constructional deflection can be eliminated.

KEYWORDS: Bridge construction, Steel bridges, Bridge deflection control, Constructional bridge deflection, Plate-Girder bridge, Deck slab construction

INTRODUCTION

A normal bridge is a long structure, usually consists of several spans. Each span is also considered as a long structure compared to other types of engineering constructions. Bridges are designed to sustain the safe passing of heavy traffic and pedestrians loading. Heavy loading in addition to long span result in greater stresses leading to the adaption of huge sections. These large scale formations and their extra weight require special precautions during manufacturing, transporting and erecting.

Generally, it is impossible to construct a bridge panel within one stroke. Therefore; design and construction processes will follow suitable procedures to fulfill the required aim of building a safe, durable and nice looking bridge without making any destruction to the site surroundings.

Mainly, bridges are designed to be constructed by the use of reinforced concrete, pre-stressed concrete, steel or their combinations to act in a composite manner. In most cases, each panel consists of a number of equally spaced supporting girders topped by a reinforced concrete deck slab.

During design stages, supporting girders are analyzed and designed to carry its self-weight and the weight of the fresh concrete of the deck slab plus 20% of the bridge live loading to account for the weight of the casing moulds, the construction equipments and the workers. The design is cross checked under the full dead and live loading for composite action of the hardened concrete that will be fully attached by shear connectors to the supporting girders.

In cases where a bridge has to be constructed over a deep valley/river or in a busy city, it is difficult to construct or to attain-for few weeks- for the removal of the required temporary deck slab casting molds and its shoring. In such situation the constructing engineer will face a trouble of supporting his un-shored temporary molds directly over the supporting girders. This will lead to an inevitable expected deflection.

The mentioned extreme loading case is embarrassing during design stages. If the fresh concrete load of the deck slab is considered to be held by the supporting girders alone, it will lead to larger sections, altering the aesthetic appearance of the bridge and certainly it will increase the cost. While, following the standard code procedures without taking construction stresses into consideration will lead to un- favorite deflections. To have a numerical idea regarding the problem; for 10m wide bridge spanning 30m and with a concrete deck slab thickness of 20cm, the total uniformly distributed load due to the weight of the fresh concrete only – without the 20% increment of the live load- will be 156 tons. This load alone is much greater than the design live load recommended by AASHTO standard truck {1} which is suggested to be applied after the completion of the bridge. Normally this temporary construction load is taken by the shoring system, but if there is no shoring a problem will certainly arise.{2} For suspension bridges there is no problem of deflection, because each hanger could be considered as a support transforming the total load to the main cables which directs its tensile force to the bridge towers and *anchors then to the foundation. For Pre-stressed bridges, the problem is automatically solved due to the natural cambering of its girders. The expected constructional deflection will reduce the original cambering resulting in a flat surface under the effect of the total dead load of the bridge. {3} the pre-stressing force is placed eccentrically to counteract the downward deflection of the flexural member caused by gravity loads and service loads. The problem in steel bridges is more difficult, but it can be solved by fabricating an artificial cambering by an elaborate and costly methods. {4} not much has changed over the past thirty years in the general means and methods that a fabricator uses to induce camber in a member.{5} There is no known way to inspect beam camber after the beam is received in the field because of factors that include:*

- *The release of stress in member over time and in varying application.*
- *The effects of the dead weight of the member.*
- *The restraint caused by the end connections in the erected state.*
- *The effects of additional dead load that may ultimately be intended to be applied, if any.*

{5} AASHTO Specifications limits live load deflections to Span/800 for different types of ordinary bridges. But there is no specific limitation for dead load deflections. In the present research a test has been done to highlight the idea of a new suggested method for constructing the reinforced concrete deck slabs of Steel bridges. Temporary clamping of both ends of the supporting girders with adjacent panels girders - before casting the concrete of the reinforced concrete deck slab- can reduce mid span moment and deflection. It is believed that; the mentioned un-costly method can reduce construction deflections to acceptable limits.

TESTING PROGRAM

***Materials**: During all the test stages, the following materials have been used to simulate the following actual bridge components (presented in Table 1.)*

Table 1. Materials used

	Material Properties	Simulation for
1	Four steel rulers. Each ruler has the following properties: □ Cross sectional area of 25x0.5 mm. □ Length of 30cm. □ Weight of 1gm/cm. □ Second moment of Area equals: $(I)=\frac{bh^3}{12}=\frac{25\times0.5^3}{12}=0.26 \quad mm^4$	Bridge girders.
2	A number of 6 gm Plastic blocks having the dimensions of 6x20x40 mm.	The weight of fresh concrete of a Bridge Deck- Slab.
3	Super glue, Cyanoscrylete adhesive.	The role of Shear Connectors to join composite member components.
4	Two Φ4mm bolts.	Temporary End Clamping.
5	Eight, 35mm long, Erasing Rubbers having triangular cross sections.	Bridge Bearings.

***Testing procedure**: Three 32cm steel rulers were temporary jointed by two 4mm diameter bolts and screws. Each joint was done by fastening a single bolt as shown in Figure 1.*

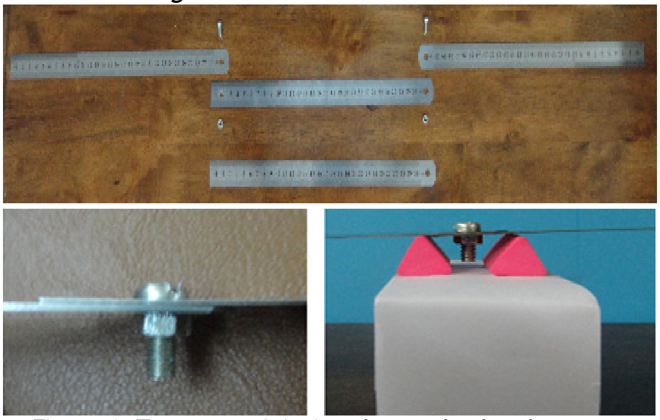


Figure 1. Temporary jointing the steel rulers by screws

The total length of the jointed rulers was 92cm. Three 30 cm c/c supports were used. The intermediate couple of supports were topped by two red rubber erasers 2 cm apart, while the end two supports were topped by a single blue rubber eraser as shown in Figure 2.

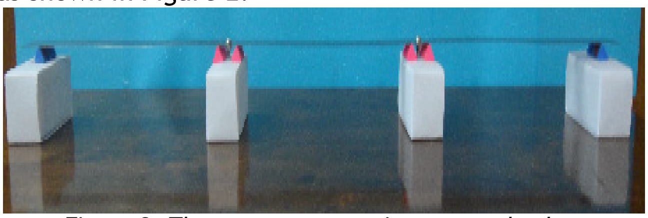


Figure 2. The temporary continuous steel rulers

The system simulates a disassembling continuous beam having three 28cm long spans. For deflection comparison, the forth ruler was simply supported over two additional yellow rubber erasers -28cm apart -resting on the intermediate two supports. Two 6gm plastic prisms were put at the center of the intermediate span of the continuous ruler and at the center of the simply supported ruler. Segmental Loading was continued for the whole rulers' lengths as shown in Figure 3. The central Deflections for both rulers were tabulated in Table 1.

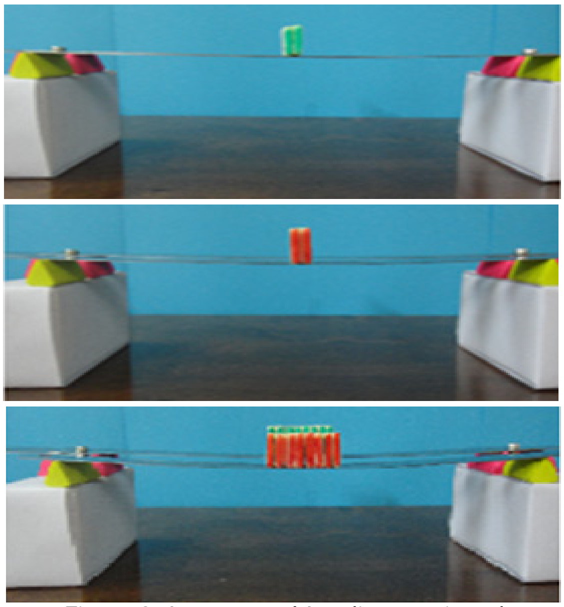


Figure 3. Incremental Loading continued until the ends of spans

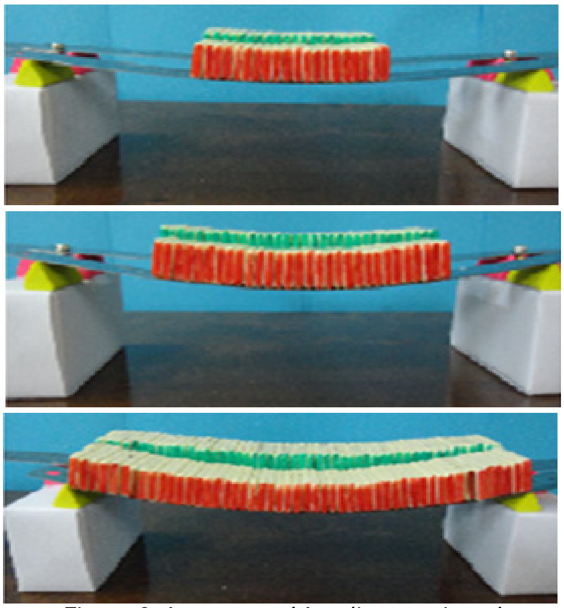


Figure 3. Incremental Loading continued until the ends of spans (continue)

Table 2. Deflection measurements for simply and continuous rulers

Weight (gm)	Simply Def. (mm)	Continuous Def. (mm)
0	0	0
12	0.25	0
24	0.75	0.25
36	1.75	0.75
48	2.50	1.25
60	3.50	1.75
72	4.50	2.50
84	6.00	3.00
96	7.00	3.50
108	8.00	3.75
120	8.75	4.25
132	9.50	4.75
144	11.00	5.25
156	12.00	6.00
168	13.50	7.00
180	15.00	8.00
192	17.50	9.50
204	20.00	11.00
216	22.50	12.50
228	25.00	13.00
240	27.00	14.00
252	28.00	14.50
264	29.00	14.75
276	30.00	15.00

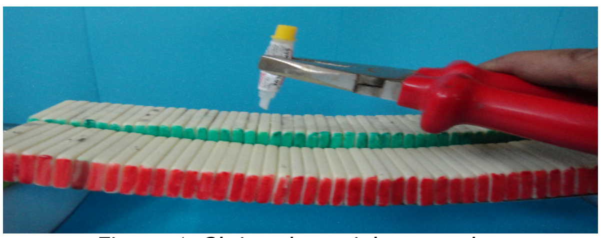


Figure 4. Gluing the weights together and with its continuous ruler

The second stage was gluing the weights together and with its holding continuous ruler as shown in Figure 4. This action was done to simulate the state of a hardened concrete attached to its supporting girders in a real bridge. Gluing also reflects the positive properties of composite structural members, especially its higher moment resisting capacity. Under the same loading, normally a member having a noticeable moment resistance shows less deflection.

For comparison and to simulate the case of casting fresh concrete over simply supporting girders, the simply supported ruler was left without gluing to its loadings.

The third stage of the test was done by unscrewing the bolts to leave the intermediate loaded span of the previously continuous span alone. It was found that the glued ruler had preserved its shape with no further deflection, as shown in the Figure 5.

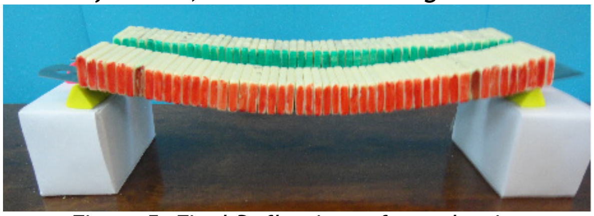
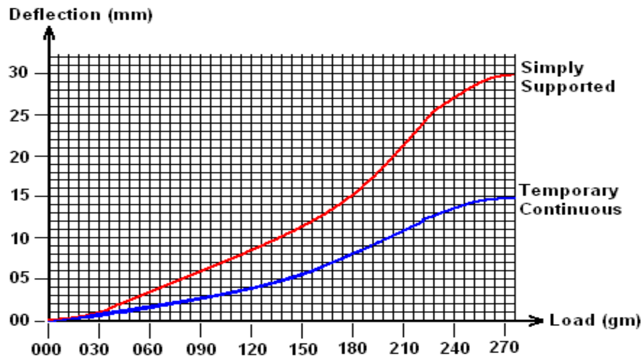


Figure 5. Final Deflections after releasing the continuity clamping

Graph 1 shows the magnitude and the mode of deflection increase with the increase of loading - during all the test stages- for both of the continuous and the simply supported rulers.



Graph 1. Mode of deflection for both of the continuous and the simply supported rulers

DISCUSSION

The simply supported - uniformly loaded - ruler shows the expected excessive deflection of a simply supported bridge girder subjected to the load of fresh concrete during construction. While the - temporary continuous three spans - rulers explain the idea of this research which aims to reduce central constructional deflection.

The reverse moments due to the weights of the adjacent rulers will act as temporary partial two ends fixation. The application of the glue to attach weights segments to each other and to its supporting - temporary continuous- ruler simulates the state of concrete hardening in a real bridge. The hardened concrete in a finished bridge acts compositely with its supporting girders, which means a noticeable increase in its moment resisting capacity. A composite member having higher moment resistance will certainly produce less deflection compared to a similar simply supported bared girder subjected to the same loading. Unscrewing the bolts which connect the three continuous rulers reflect the release of the temporary clamping and the return to the original design of a specified span under a given loading. The final result represents the intended constructional trick to reduce unfavorite deflection in real bridges.

CALCULATIONS

The 28 cm long simply supported ruler was loaded with a uniformly distributed load of 276/28=9.9gm/cm in addition to its self weight of 1gm/cm. Therefore, its mid span maximum moment will be: $M_{s\,max} = \frac{w \times l^2}{8} = \frac{(9.9+1)\times 28^2}{8} = 1068 gm.cm$

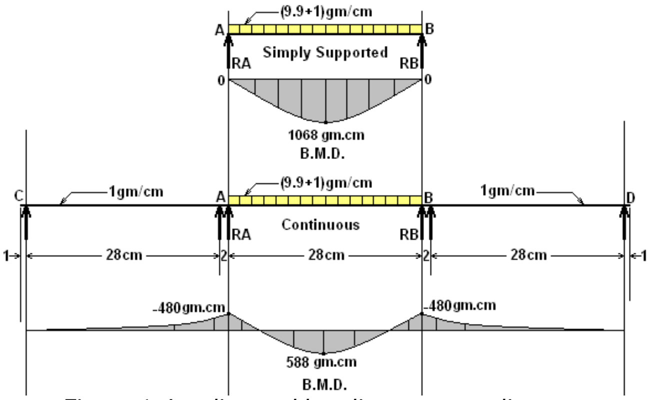


Figure 6. Loading and bending moment diagrams for the simply and the continuous rulers

While for the triple 28cm long spans of the continuous ruler, the negative end moments of the intermediate span ends will be:

$$M_{c\,max} = \frac{1 \times 31 \times 31}{2} = 480 gm.cm$$

Therefore, the positive moment of the middle span will be reduced to be 1068- 480 = 588 gm.cm. Figure 6 shows loading and bending moment diagrams for the simply and the continuous rulers.

To find the Elastic modulus (E) of the rulers, the deflection (Δ) equation {6} for a uniformly loaded (w) simply supported beam AB can be applied to the actual test deflection of 30mm as follows:

$$\Delta = \frac{5w \times l^3}{384 EI} = 30mm = \frac{5 \times 305 \times 280^3}{384 \times E \times 0.26}$$

$$\Rightarrow\Rightarrow\Rightarrow \; E = 10176816 \; gm / mm^2$$

To calculate the central deflection Δ of the continuous triple span ruler, the following formula {6} for a beam-uniformly distributed load and variable end moments will be used:

$$\Delta_x = \frac{wx}{24EI}\left[x^3 - \left(2l + \frac{4M1}{wl} - \frac{4M2}{wl}\right)x^2 + \frac{12M1}{w}x + l^3 - \frac{8M1l}{w} - \frac{4M2l}{w}\right]$$

By substituting the values of w = 1.09 gm/mm, x = 140 mm, E = 10176816 gm/mm^2*, I = 0.26 mm*^{4}*, l = 280 mm, and M1 = M2 = 4800 gm.mm, the central deflection will be:*

$$\Delta_{140} = \frac{1.09 \times 140}{24 \times 10176816 \times 0.26}\left[140^3 - (2 \times 280) \times 140^2 + \frac{12 \times 4800}{1.09} \times 140 + 280^3 - \frac{8 \times 4800 \times 280}{1.09} - \frac{4 \times 4800 \times 280}{1.09}\right] = 15.2mm$$

The above calculation shows that the maximum bending moment was reduced by:

$$\frac{(1068 - 588) \times 280}{1068} = 45\%$$

While the central deflection was reduced by:

$$\frac{(30 - 15.2) \times 100}{30} \approx 50\%$$

Lastly, the test results closely match the theoretical calculations.

SUGGESTED APPLICATION

It is believed that; constructing temporary fixed joints for both ends of a simply supported steel bridge will reduce the expected constructional deflection during casting the concrete of its deck slab. Figure 7 shows the proposed temporary joints. Each joint should be designed to have not less strength than that of the full strength of the two jointed parts. Precautions also should be taken to arrange these joints to be easily taken apart after the completion of the required purpose.

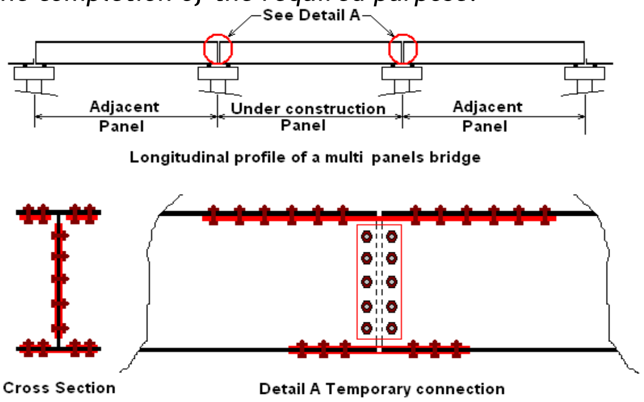


Figure 7. The proposed Temporary Connection

CONCLUSIONS

The following statement has been concluded: Temporary jointing both ends of a simply supported un-shored deck girder steel bridge- during the process of casting its deck slab concrete - can reduce FIFTY Percent of its inevitable and unfavorite mid span Deflection.

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