AN INNOVATIVE ERECTION TECHNIQUE FOR REDUCING TWO- THIRD OF CONSTRUCTIONAL BRIDGE DEFLECTIONS

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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. 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; segmental casting of a bridge deck slab can reduce its final deflection. The method was done by casting the intermediate portion of the bridge, then after attaining its hardening another deck slab portion can be casted. The repetition of this process until reaching both ends of the bridge can provide it with extra strength due to the positive properties of the composite action of the hardened concrete.

The result of the suggested method is a reduction of two- third of the un- favorite constructional bridge mid span deflection.

Keywords: Bridge deflection, bridge construction, segmental bridge casting, bridge deflection control

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. Fig 1 shows a visible construction deflection at the intermediate panel of a real reinforced concrete railway bridge. This bridge is structurally complying with the required loading and design standards but it lacked the construction experience, therefore it lost its aesthetic appearance. 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.

Fig 1 Visible mid span Deflection of the Intermediate Panel

{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 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 amount of cambering is dependent upon several factors: the tendon profile, the pre-stressing magnitude, the span, the section properties, and the elastic modulus of the concrete. 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.

Finally, for reinforced concrete bridges the problem is much greater especially when it is constructed without a temporary shoring during the process of casting the deck slab concrete. {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 reinforced concrete deck slabs. It is believed that; the mentioned un-costly method can reduce construction deflections to acceptable limits.

Testing Program

Materials: The following materials and properties have been used during all the test stages:

- Three 30 Cm long steel rulers. Each ruler has a cross section of 25 x 0.5 mm and a second moment of Area equals; (I) $=\frac{bh^3}{12}=\frac{25\times0.5^3}{12}=0.26\ mm^4$.
- A number of 6 gm Plastic blocks having the dimensions of 6 x 20 x 40 mm.
- Super glue, Cyanoscrylete adhesive.

Testing procedure

Two similar straight steel rulers were simply supported horizontally at a height of 90mm, as shown in Fig 2.

Fig 2 Horizontal Steel Rulers Simulating Supporting Girders

Two plastic prisms were put at the centre of each ruler, as shown in Fig 2. The rear ruler, which will be recognized as RA was glued to the added plastic prisms as shown in Fig.3

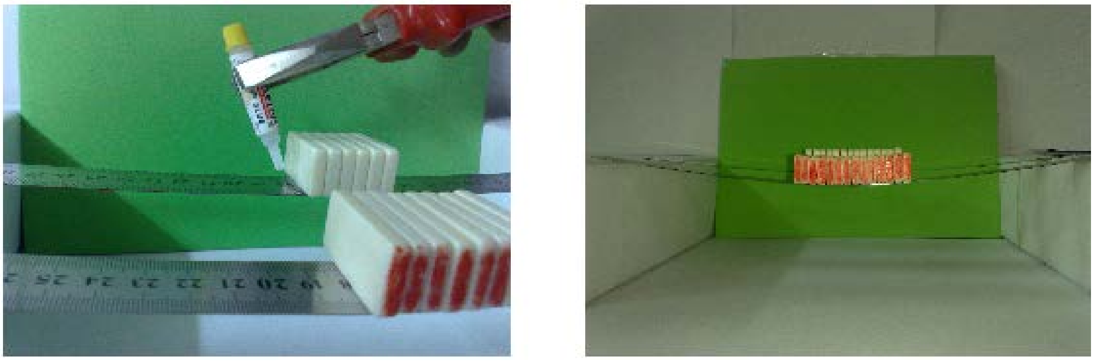

Fig 3 Gluing Plastic Prisms to the Rear Ruler RA

While the front ruler which will be mentioned as RB was left without glue. Then an additional two prisms were glued to RA, one to the left and the second to the right of the first couple of prisms, while the additional two prisms to RB were left unglued. The procedure was continued for whole the rulers' lengths, as shown in Fig 4.

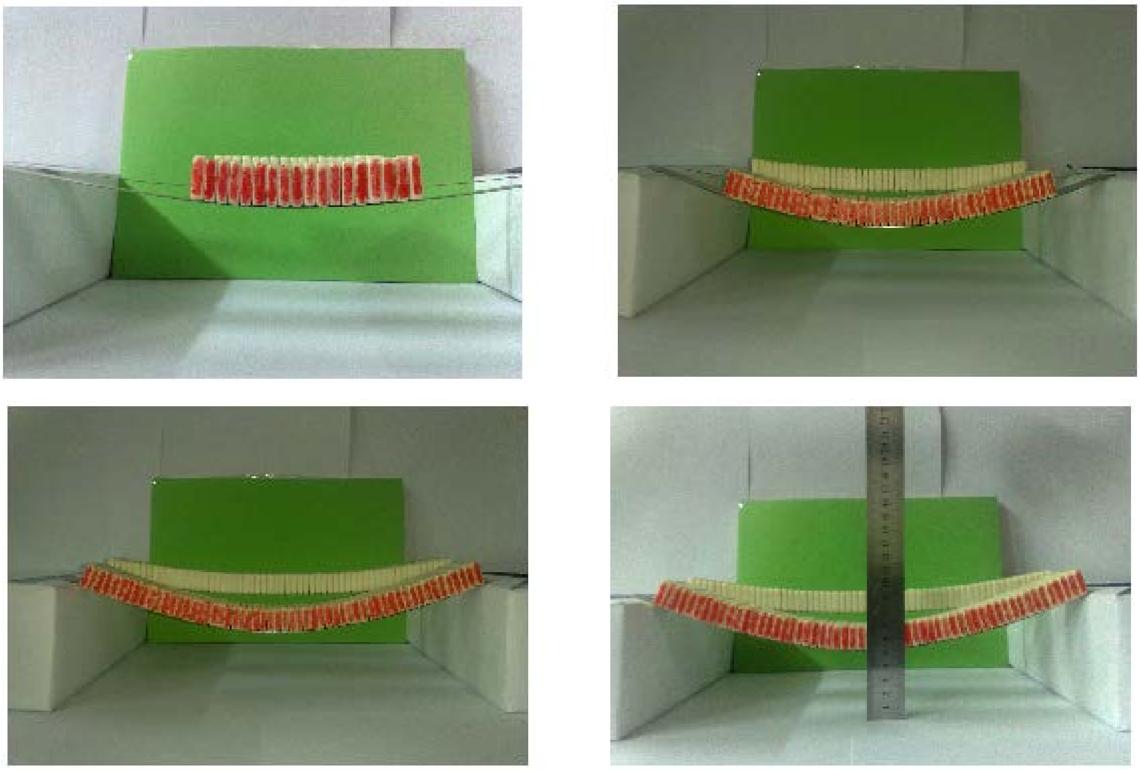

Fig 4 Deflection increase with each Loading increment

Central deflections for both rulers were listed in Table1 for each additional two prisms.

Table 1 Load- Deflection measurements*

Load (gm)	Untreated Beam (mm)	Modified Beam (mm)	Load (gm)	Untreated Beam (mm)	Modified Beam (mm)
12	0.5	0.5	168	25.0	13.0
24	1.0	1.0	180	26.5	13.0
36	2.5	2.0	192	28.5	13.5
48	3.5	3.0	204	31.0	13.5
60	4.5	3.5	216	33.0	13.5
72	6.5	4.5	228	35.0	14.0
84	8.5	6.0	240	36.5	14.0
96	11.5	7.5	252	37.5	14.5
108	14.0	8.5	264	38.0	14.5
120	16.0	10.0	276	39.0	14.5
132	18.0	11.0	288	39.5	15.0
144	20.5	12.0	300	**40.0**	**15.0**
156	23.0	12.5			

*Digits are approximated to the nearest 0.5mm.

Calculation & Results

To find the Elastic modulus (E) of each of the similar 300 mm long rulers, the deflection (Δ) equation for a uniformly loaded (w) simply supported beam RB can be applied to the actual test deflection of 40mm as follows:

$$\Delta = \frac{5w\times l^3}{384EI} = 40\ mm = \frac{5\times300\times300^3}{384\times E\times0.26} \Rightarrow\Rightarrow\Rightarrow E = 10141226\ gm/\text{mm}^2$$

$$\text{Total free deflection} = \frac{Rl^3}{3EI} = \frac{150\times150^3}{3\times13521635\times0.26} = 48mm$$

This theoretical 48mm deflection for the untreated beam RB is close to the actual deflection of 40mm which was recorded during the test.

To calculate the theoretical deflection of the modified beam RA, Fig 5 shows a simply supported 300mm long beam. In actual test (w) was the incrementally increased uniformly distributed load, while LS and RS were the reactions of the left and right sides respectfully. For calculation purposes w was considered as a rigid part of the beam (simulating composite part), while the right side of the beam (l =150-x) was considered as a free cantilever subjected to a hypothetical concentrated load of reaction RS. Increasing the length of x by adding more weights, the length of the free cantilever will be shorter.

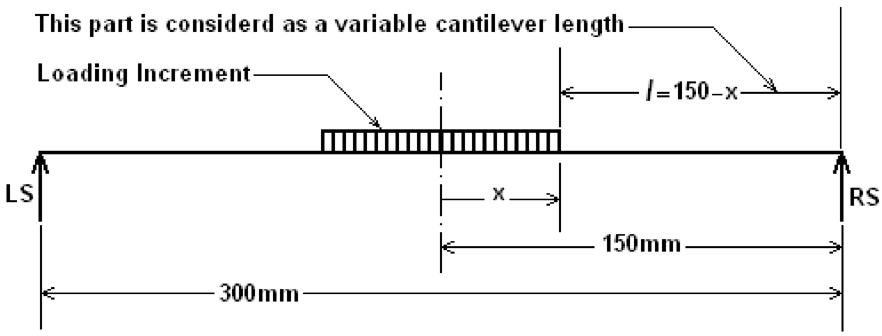

Fig 5 Calculation related Figure

The total upwards deflection ($\Sigma\Delta$) of the extreme right side can now be calculated by integrating all the deflections due to all the load increments as follows:

$$Total\ deflection\ at\ Right\ support\ (RS) = \Sigma\Delta = \frac{1}{3EI}\int_{150}^{1}(150-x)^3\,dx$$

$$= \frac{1}{3EI}\int_{150}^{1}(3375000 - 67500x + 450x^2 - x^3)\ dx$$

$$= \frac{1}{3EI}\left[\sum_{150}^{1} 3375000x - 33750x^2 + 150x^3 - 0.25x^4\right]$$

$$= \frac{1}{3EI}\{23375000 - 33750 + 150 - 3375000(150) + 33750(150^2) \quad - 150(150)^3 + 0.25(150)^4\}$$

$$= \frac{1}{3EI}\{23341400 - 506250000 + 759375000 - 506250000 + 126562500\}$$

$$= \frac{1}{3 \times 10141226 \times 0.26}\{-103221100\} = -13mm$$

This theoretical 13mm upwards end deflection is also close to the actual mid-span downwards deflection of the modified beam RA which was recorded as 15mm. The difference of 2mm between the theoretical and the actual deflections is probably because of the ignorance of the deflection of the rigid (composite) part of the beam.

Disscussion

Continuously casting a simply supported un-shored bridge span concrete deck slab will definitely result in an excessive deflection. Such deflected bridge can serve its structural purpose, but its distorted aesthetic unacceptable appearance cannot be corrected.

In this research, it was found that; fresh concrete apply a considerable weight to the bare girders leading to a noticeable deflection. The Simulation of this case was done by using steel rulers as girders, incremental plastic weights as fresh concrete and glue as shear connectors. The glue managed to combine the weights to its supporting rulers to provide the whole system with the required properties of a segmental composite member, especially its high ability to resist moments.

It was found that; the un favorite deflection can be reduced by: $\frac{(40-15)\times 100}{40} = 62.5\%$. The explanation of such considerable reduction is due to the glue which prevents the plastic weights from sliding horizontally and fixing them to the steel ruler. This action is a simulation of the case of reaching the state of a hardened concrete in a real bridge. For the untreated beam RB, an excessive deflection was occurred during the test due to the weak bond between the weights and the ruler (Simulating the case of fresh concrete which allows for horizontal movement), See Fig 6. In addition to the considerable limitation of deflection and improving the shape of the bridge gained by adapting the suggested method, an important reduction of stresses subjected to the construction materials can be achieved which might be positively reflected upon its durability.

Fig 6 also shows how a deflected bridge slides at its ends and how it will affect its bearing supports and joints.

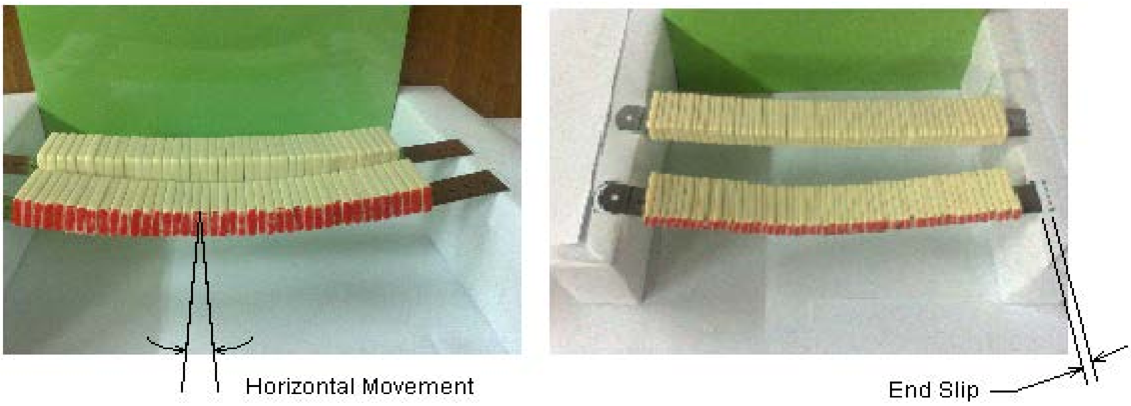

Fig 6 Horizontal Movement and End Slip in Specimen RB

Suggested Application

It is believed that a segmental concrete casting process for an un-shored bridge deck slab can considerably reduce the expected bridge deflection.

Fig 7 shows the proposed schedule of applying the suggested method to cast a span of 30m within 18days. On the first day the central 4meters should be casted. Then on the third day another 4meters should be casted, 2meters on each side of the central previously casted portion. The process should be repeated each 3days till the completion of the casting process on the 18th day. The end portions could be accelerated by increasing the length of the increment; that's due to its minor effect upon deflection which was noticed during the test.

It should be noted that the width of each casting segment could be altered for each bridge case according to the judgment of the consultant engineer.

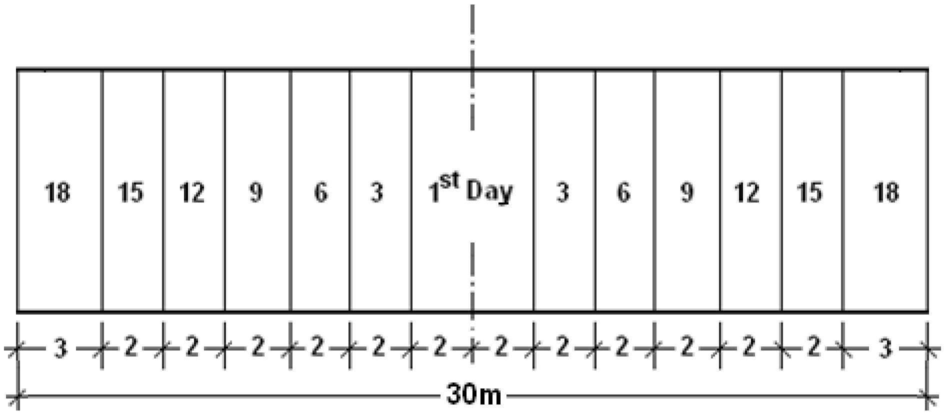

Fig 7 Suggested Concrete Casting Sequence for a Bridge Deck Slab Spanning 30m

Conclusions

The following Conclusions have been reached:

- Inevitable Deflection occurs, if a concrete bridge deck slab has been casted without using a proper shoring system.
- Permanent Deck Slab Deflection can be reduced by 62.5%, if Concrete casting process has been done according to the following Procedure: Starting segmental Concrete Casting at mid bridge span, attending concrete partial hardening to take advantage of the strength of the composite action of the mentioned part and then proceeding -within stages- till reaching both ends of the bridge panel span.

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