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Performance Based Evaluation of Bridge Superstructure with Special Reference to Construction Resources

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Abstract—*Now a days, Performance based selection of bridge superstructure is important for analysis and designing of bridge but construction resources affects the execution of a bridge as a whole which is hence also an important factor for evaluation of bridge superstructure for a structural engineer. This paper consists of the case study of 3 span continuous bridge superstructure (existing in India) in comparison to a simply supported bridge superstructure (Proposed). The structures were modeled in MIDAS Civil software. The optimization is done using variation in geometry of the box girder, size and number of prestressing tendon, bearing type. The bridge is checked for the stresses, deflection, and cost.*

Keywords*: - Box Girder, performance based, construction resources, Prestressed Concrete, Segmental construction.*

1. INTRODUCTION

Bridges, that are typically concrete box structure types, constructed by progressively connecting together repetitive elements to form a complete structure are precast segmental bridges. Precast construction means that bridge segments are prefabricated at a location different than the site, transported to the site, and installed there. Prestressed concrete box girder results in a very compact structural member, which combines high flexural strength with high torsional strength.

The existing bridge superstructure is a prestressed box girder. It is 3-span continuous bridge superstructure which is also a segmentally precast post tensioned girder. This continuous superstructure consists of a pin bearing which is the major reason for the delay of the construction process of the bridge.

The proposed structure includes a simply supported bridge deck of same span. The geometry of the section is varied and analyzed in MIDAS civil software.

2. PROPERTIES

The span of the bridge is 27 m. Width of the bridge is 9.8m. Type of construction is precast segmental box girder construction.

2.1. Cross sectional Properties

The depth of box girder is 2.45m and width of carriageway is 9.8m. The average deck slab thickness is 250 mm, web thickness and soffit thickness is 435 mm and 500mm respectively at support section i.e. segment S1 and 435mm and 200 mm respectively at segment S4 and 350mm and 200mm respectively at segment S6. Segment S2 has uniformly varying section between segment S1 and S4 with additional concrete blister block. Segment S5 has uniformly varying section between segment S4 and S6. The Fig. 1 is the cross sectional view of segment S1 at diaphragm and Fig. 2 is the cross sectional view of same segment S1 after the diaphragm wall.

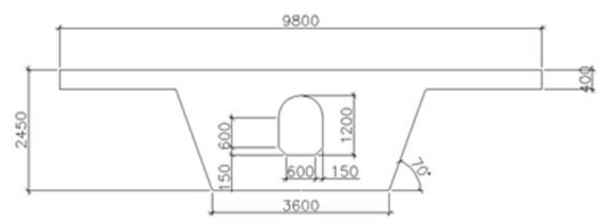

Fig. 1: Cross sectional view of segment S1 at diaphragm (above the bearings)

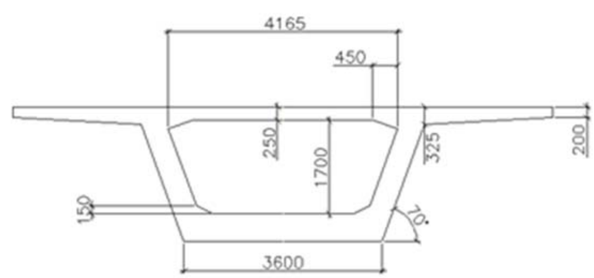

Fig. 2: Cross sectional view of segment S1 (typical box section)

2.2. Longitudinal arrangement of the segments

The stage of construction as well as the longitudinal arrangement of the segments is represented in Fig. 3. It also shows the bearing types at different piers.

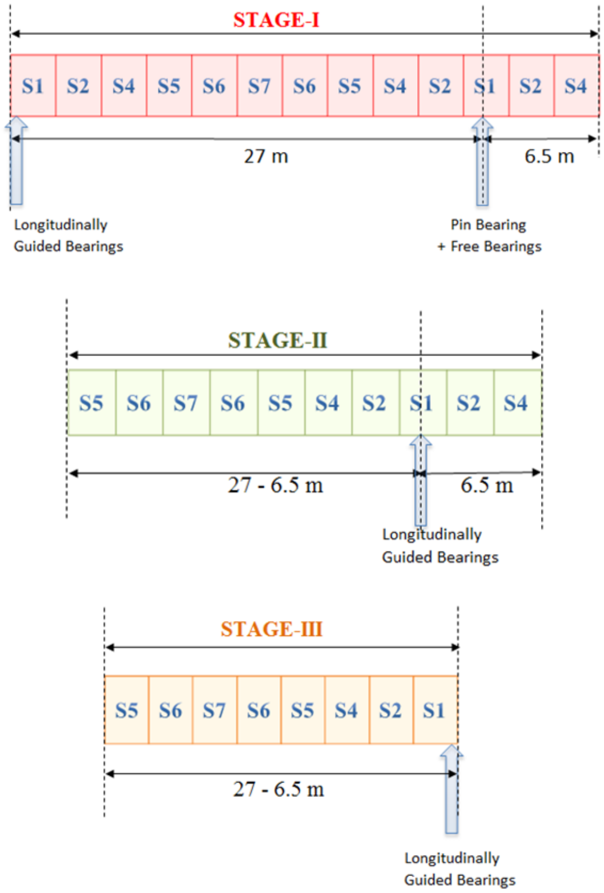

Fig. 3: Longitudinal Arrangement of Bridge

3. LOADING CONSIDERATION

Dead Load

Dead load includes self-weight of structural component of bridge superstructure is applied as per the construction sequence of the bridge superstructure. Table 1 gives the segment properties of continuous bridge model.

Table 1: Segment Properties

Segm-ent	Area (m^2)	Width (m)	Avg. Area (m^2)	Vol. (m^3)	Grade (N/mm^2)	Weight (kN)	W (MTon)
S1A	11.9	0.7	8.2	8.3	25	208	40
	6.1	1.24		7.5	25	189	
S2	6.1	2.5	5.6	14.1	25	353	35
	5.2						
S4	5.2	3	5.2	15.6	25	390	39
S5	5.2	3	5.0	15.1	25	377	38
	4.8						
S6	4.8	2.5	4.8	12.1	25	303	30
S7	4.8	2	4.8	9.7	25	242	24
S1B	11.9	1	9.0	11.9	25	296	45
	6.1	1		6.1	25	152	

Super imposed dead load

SIDL load is divided into two categories

3.2.1. Dead Load of Wearing Surfaces and Utilities

Table 2: Dead Load of Wearing Surfaces and Utilities

Wearing Coat	Thickness of Wearing Coat (mm)	Width of Deck (mm)	Unit Wt. (kN/m^3)	Total Wt (kN/m)
	86	9800	18	15.17

Loading of 15.17 kN/m is applied over the bridge deck.

3.2.2. Dead Load of Component and Attachments

Table 3: Dead Load of Component and Attachments

Crash Barrier Load	Area (mm^2)	Unit Wt. (kN/m^3)	No. of Units	Total UDL (kN/m)
	342047	25	2	17.1

Therefore load of 17.1 kN/m is applied over the bridge deck at the parapet position.

Prestressing Force

Prestressing force as per cable profile including the losses has been applied. The high tensile steel for prestressing shall consist of uncoated, stress relieved, low relaxation strands conforming to class II of IS: 14268-1995 (with a breaking load of 260.7 kN for 15.2 mm strand). Following parameters shall be used for prestressing design as per Table 4

Table 4: Parameters for Prestressing Design

Wobble coefficient of the sheathing duct/strand	k = 0.002 per meter
Friction coefficient of the sheathing duct/strand	m = 0.17 per radian
Wedge slip at decking end	6 mm
Shrinkage strain, Creep and Relaxation	As per IRC: 112, 2011
Stressing to be done for segmental construction	After 3 days or after strength achieved 36 MPa, whichever comes later.
Type of cable	Cable consisting of 15.2 dia strands of 19 nos or less
Type of sheaths	HDPE
Duct diameter	105 mm
Minimum c/c distance between cables	210 mm

The cable arrangement of the continuous bridge model is as shown in the Fig. 4.

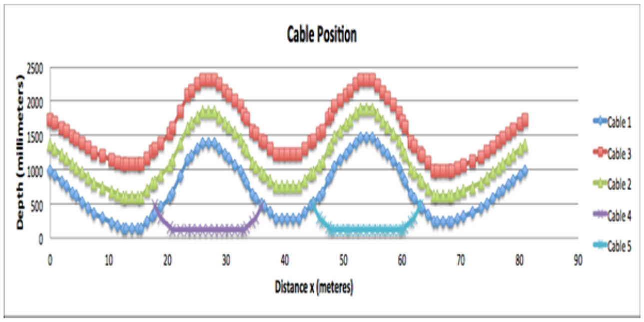

Fig. 4: Cable Positioning along the span

Live Load (LL)

Vehicular Live Load for clear carriageway of 9000mm is applied as per IRC: 6-2010.[7]

i. Class A Wheeled Vehicle – 1 Lane
ii. Class A Wheeled Vehicle – 2 Lane
iii. 70R Wheeled Vehicle – 1 Lane

The impact factor for the appropriate loading class is considered as per clause 208 of IRC: 6-2010. [7]

Differential Settlement of Supports

A total differential settlement of 4.0 mm is considered between Pier 1 and Pier 3 with 0.5*E_c. So in analysis a total differential settlement of 2.0 mm is considered between Pier 1 and Pier 3 with full E_c.

Creep & Shrinkage

The structure is analyzed for creep & shrinkage in accordance with IRC: 112-2011.[8] The life of structure considered is 100 years & the analysis is carried out for losses due to long term effects.

4. OPTIMIZATION OF BOX GIRDER SECTION

The depth of the box girder in the continuous model is 2.45 m. So for considering the simply supported model the depth of the section is varied from 3m depth, as above this depth the bridge starts to behave as more of a RCC girder than a PSC girder, to 1.8 m depth, as below this depth no room is left inside the box girder for workability during construction. The sections and properties of the simply supported models are varied linearly and their area of cross section is kept almost same as that as in continuous model. The parameters which are varied are web thickness and soffit thickness as shown in Fig. 5 and Fig. 6 but the deck thickness is kept constant as it governed by transverse analysis, as the live load of both the structure is same.

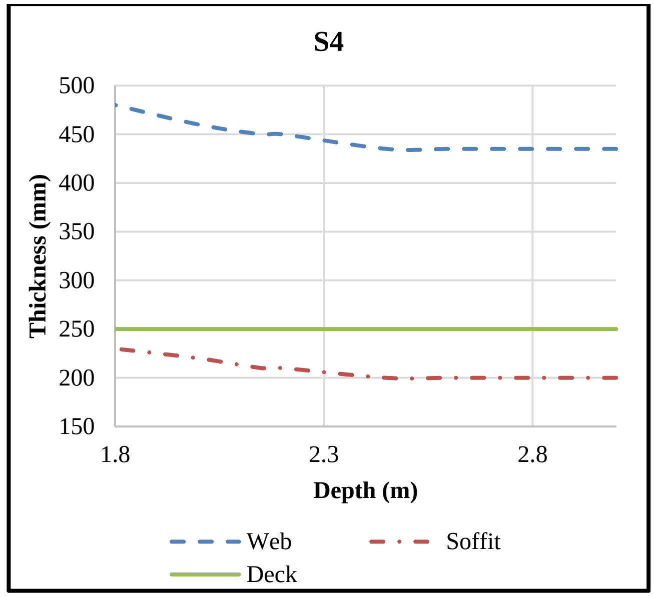

Fig. 5: Variation of Thickness (mm) v/s Depth of section (m) at segment S4

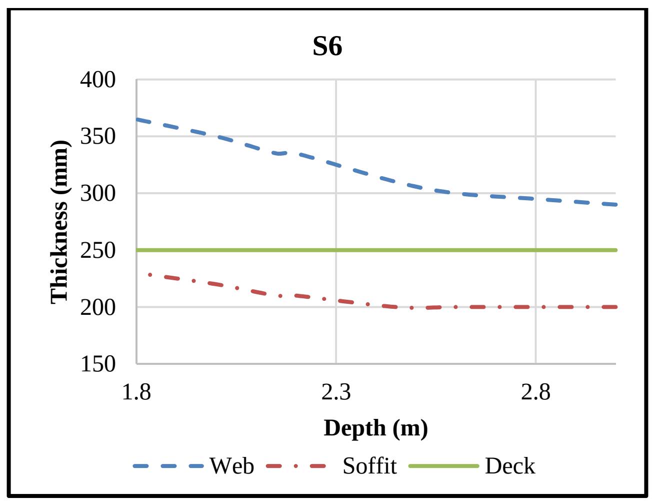

Fig. 6: Variation of Thickness (mm) v/s Depth of section (m) at segment S6

The variation of Area and the Moment of Inertias of different segments at different depth sections are as shown in figures below.

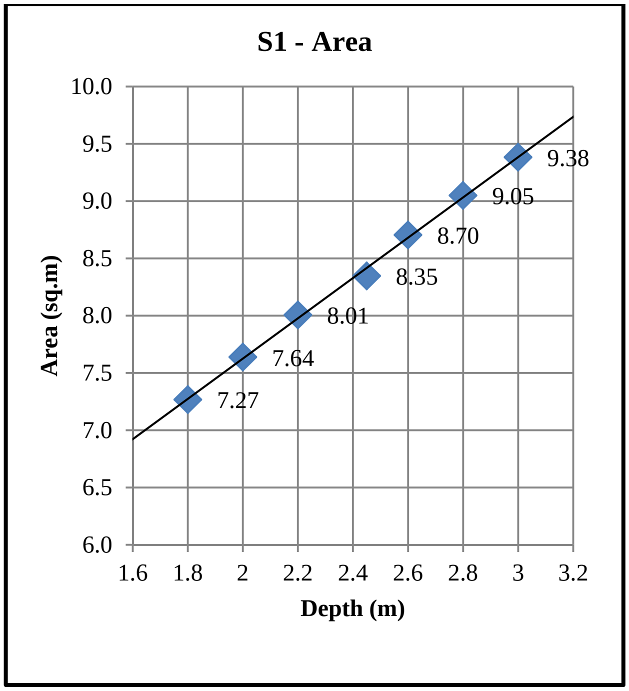

Fig. 7 Variation of Area (sq. m) v/s Depth of section (m) at segment S1

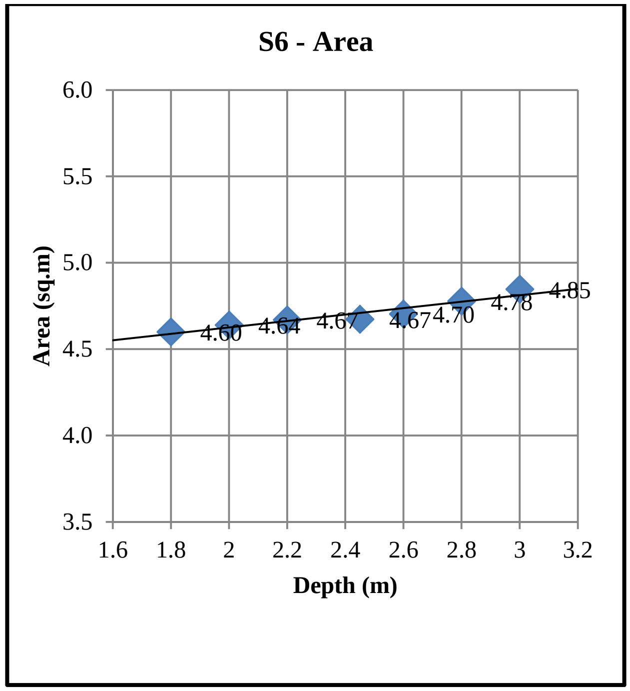

Fig. 9 Variation of Area (sq. m) v/s Depth of section (m) at segment S6

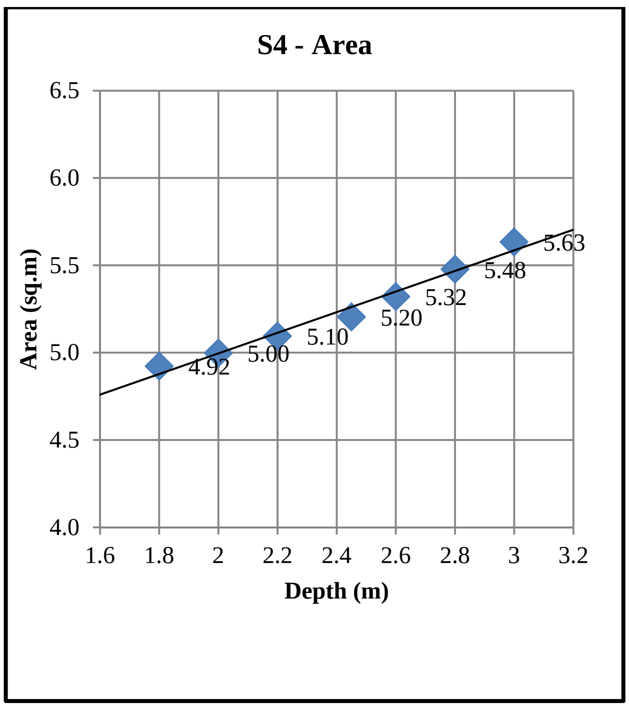

Fig. 8 Variation of Area (sq. m) v/s Depth of section (m) at segment S4

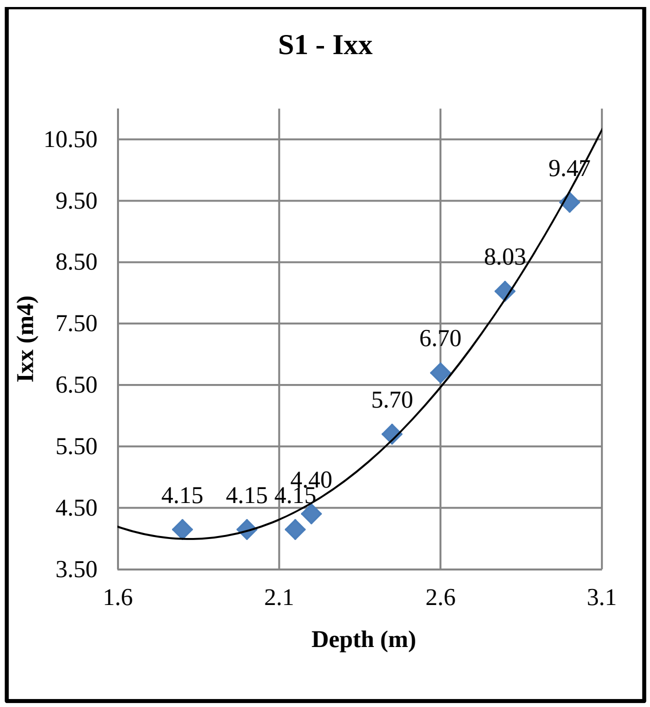

Fig. 10 Variation of Ixx (m^4) v/s Depth of section (m) at segment S1

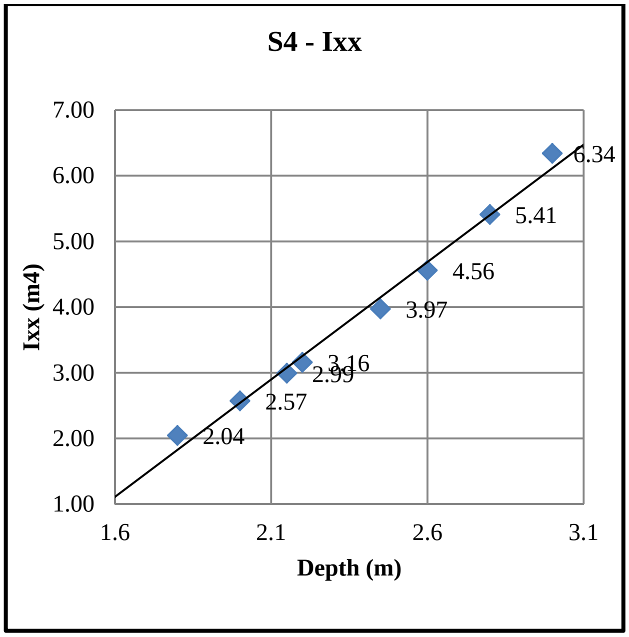

Fig. 11 Variation of Ixx (m^4) v/s Depth of section (m) at segment S1

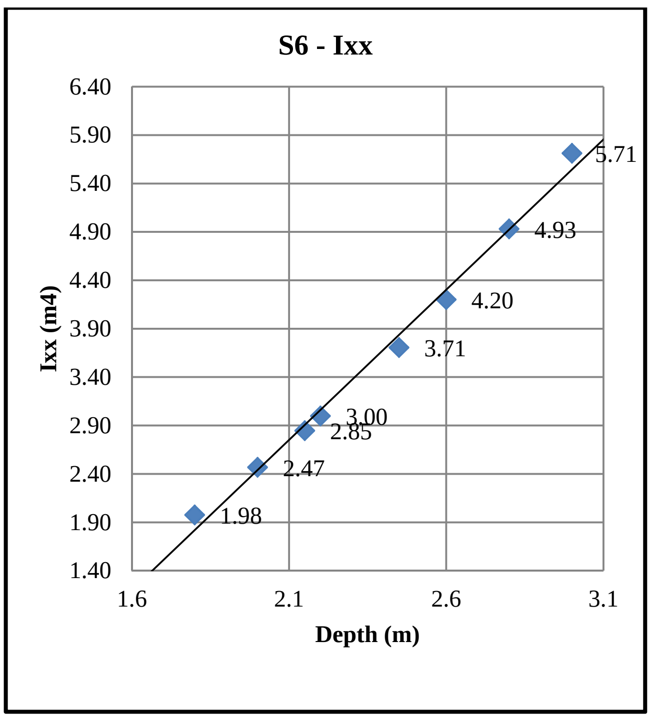

Fig. 12: Variation of Ixx (m^4) v/s Depth of section (m) at segment S1

5. MATHEMATICAL MODELING

Mathematical Modeling of the structures has been done in MIDAS software using beam element and taking PSC box girder as the sectional element. The continuous bridge structure is as shown in the Fig. 13 and simply supported bridge structure is as shown in Fig. 14.

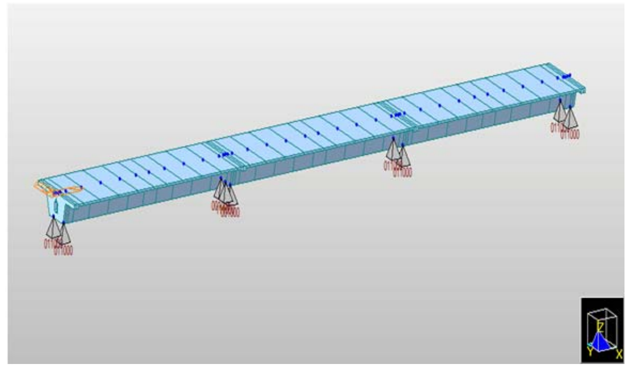

Fig. 13 Mathematical Modeling of the continuous bridge in Midas

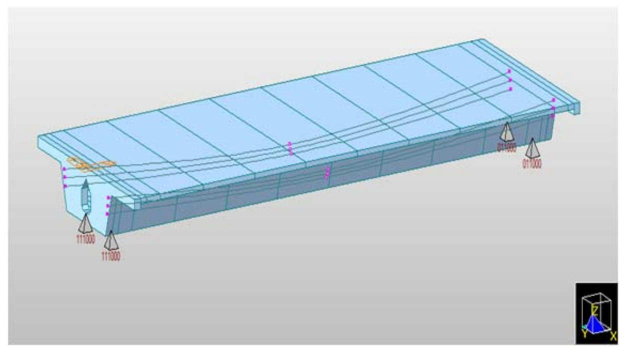

Fig. 14 Mathematical Modeling of the Simply Supported Bridge in Midas

6. CONSTRUCTION RESOURCES

The estimated time cycle per span for continuous bridge construction was 11 days. But the average actual time cycle during construction was about 12.5 days. The reason for the additional time taken during construction is as ground staged supporting system is used for construction. The late setting of the grouts in the winter season and the difficulties faced on the site while anchoring cables at coupler locations especially at the curved spans.

In other similar projects like in Simply Supported segmental construction with similar weights of segments and same site conditions construction agency could launch a span in 7 days. The reason for the early completion of the project could be mainly due to use of launching girder. So, there is a saving of 5.5 days per span. Thus it is early completion of project with lesser number of resources.

7. RESULTS AND CONCLUSIONS

The variation of the Total Cost (in Lakhs) v/s Depth (m) for the simply supported model is been shown in the Fig. 15.

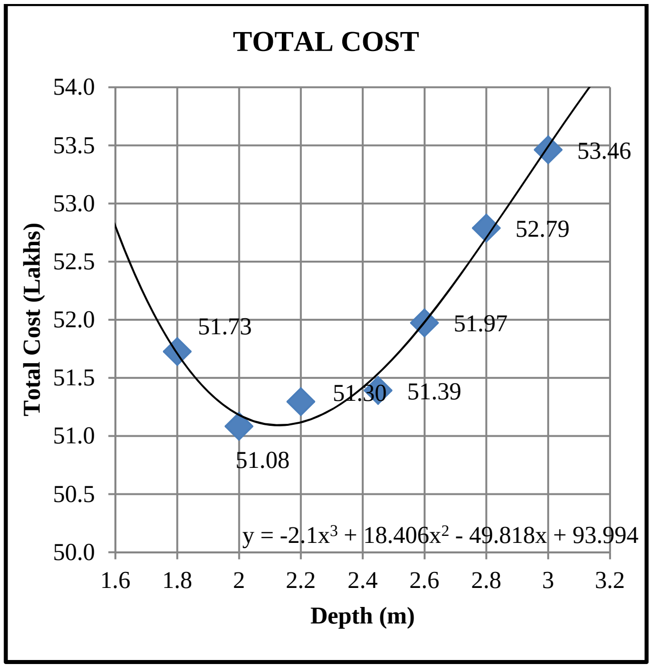

Fig. 15: Graph showing relation between Total Cost (Lakhs) v/s Depth (m)

All the bridge models are found to be safe in stresses as well as deflection criteria as per IRC 112-2011.

The Total cost is calculated by considering the quantities of concrete, reinforcement, PT cables, cable ducts, number of couplers, type and number of bearings, expansion joints, PT glue, formwork, and launching method used.

The average cost for construction for three spans continuous model is 170.43 Lakh Rupees.

From the graph it is observed that box girder of depth 2.15m could be used for simply supported span segmental construction, which will act as a more economical for construction with respect to time, money and material instead of continuous three spans. The simply supported model in this case also saves a huge number of days for the total project construction. Also as observed proposed model saves concrete, reduces dead load, reduces pressing tendon quantity, does not require couplers and eases in replacing the structure in case of damage.

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