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Structural Design with Accelerated Construction Techniques for Flyover Span of 20m in 4-lane Carriageway

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Abstract. This project reports the structural design of flyover having equal spans of length 20m with a four-lane carriage way width of 17.5m including divider of width 1.2m.In our project design of flyover we designed up to the pier portion and the foundation part can designed by foundation engineer depends upon soil characteristics and the site condition. We designed the flyover for IRC 6-2000 CLASS-A loading.We designed a single box beam for the maximum loading conditions. For the design of box beam we took the help of STAAD for transverse analysis. From the STAAD results we studied the critical points in transverse section of box beam and provided reinforcement for the moments at those critical points. We used influence line diagrams (ILDs) for longitudinal analysis of the box beam, for absolute maximum bending moment we designed prestressed box beam as per IS1343-1980. Thus, designed individual members connected by means shear locks. We preferred elastomeric pad bearings and designed them as per IRC 83(part-II)-1987 Section: IX, Bearings, Part-II: Elastomeric Bearings.For design of pier cap and pier we considered a portal frame model and calculated the moments on the pier cap and pier. We designed the pier cap for those moments as per IRC112-2011.

Keywords.STAAD, ILDs, IS1343-1980, IRC 83-1987, IRC112-2011.

INTRODUCTION

Accelerated construction is a process that has been optimized for speed.Accelerated construction techniques should be used where the benefits of accelerated construction have a positive effect on the construction costs and impacts of the project. In many cases accelerated construction techniques can reduce overall project costs. The bridge specific costs on small accelerated construction projects are more than conventional construction (This is not necessarily the case with large scale projects.) It is also anticipated that costs will come down as more accelerated projects are let. The savings in accelerated construction projects are found in other aspects of the project such as time, equipment use and labour savings.

Decisions to use accelerated construction techniques should be made after considering the following issues:

- Temporary Roadways and Bridges
- Reductions in Environmental Impacts
- User Costs
- Political Pressures
- Long Detours.

ADVANTAGES OF ACCELERATED CONSTRUCTION

The cost of construction to highway users is significant. Savings to commuters are not typically reflected in construction budgets for highway projects; however, there is a significant financial impact to the entire community due to travel delays. In many cases, the cost of accelerated construction techniques can be offset by reductions in user costs. Often the need for accelerated construction can be driven by political pressures. The impacts of construction on commuters and businesses in urban areas can be devastating. Accelerated construction can be used to limit the time frames for construction projects in these areas.

SEGMENTAL BRIDGE CONSTRUCTION

A Segmental Bridge is a bridge built in short sections (called segments), that is one piece at a time. And then segments are erected to make the bridge. The bridge is either cast-in-place or precast.

HISTORY OF SEGMENTAL BRIDGE CONSTRUCTION

Segmental bridge construction first appeared in the early 1950s. The first cast-in-place segmental concrete bridge, built in 1950, across the Lane River in Germany. The first precast segmental concrete bridge, built in 1962, across the Seine River in France.

CLASSIFICATION SEGMENTAL BRIDGE

Segmental bridges is classified under the following Categories

- Balance Cantilever Bridges
- Progressive Placement Bridges
- Span-by-Span Constructed Bridges
- Incrementally Launched Bridges

ADVANTAGE OFSEGMENTAL BRIDGE CONSTRUCTIONS

- Very economical for long spans.
- Prefabricated segments provide more quality control.
- The structure can be fully loaded immediately after being prestressed.
- The pre-stressed cables can be inspected and replaced at all times.
- Low weight due to thin bridge sections.
- Industrialization of the construction process.
- Innovations in construction equipment.
- Low maintenance costs.
- Speed of construction, time taken less.

DISADVANTAGE OF SEGMENTAL BRIDGE CONSTRUCTIONS

- High construction loading or high technology is used.
- Need high safety precautions during construction.
- Extra cost (due to more prestressing required).

BOX BEAM

A box beam bridge is bridge in which the main beams comprise girders in the shape of hallow box. The box girder normal comprises either prestressed concrete, structural steel or a composite of steel and reinforces concrete. It is typically rectangle in cross section. Box beam bridges are commonly used for highway flyovers and for modern elevated structures of light rail transport. The box beam can also be a part of portal frame bridges, cable-stayed and suspension bridges of all kinds.

ADVANTAGES OF BOX BEAMS

1. High stiffness against torsion compared to normal girders.
2. Good option when building bridges in highly busy areas.
3. Construction can be done in less time due to the usage of precast elements.
4. Disturbance to the traffic at the time construction is very negligible.
5. The projects can be completed in very short time.
6. Casting of elements and their erection can be carried out simultaneously.
7. High quality in the work is possible with the use of box beams in the super structure.
8. Using box beams in the bridges gives profit for both customer and contractor.
9. Construction of box beam bridges over railway lines gives uninterrupted flow for trains.
10. It causes less pollution to the environment.
11. Box beam usage gives high safety in construction.

DISADVANTAGES OF BOX BEAMS

1. One of the main disadvantages of box beam is that they are difficult to cast in –situ.
2. Box beams are more expansive to fabricate.
3. Girders are not efficient as trusses in resisting loads over long spans.

ANALYSIS AND DESIGN PROCEDURE

Analysis and design of box beam:

We designed a single box beam for the maximum loading conditions. For the design of box beam we took the help of staad for transverse analysis.From the staad results we studied the critical points in transverse section of box beam and provided reinforcement for the moments at those critical points. We used influence line diagrams (ILDs) for longitudinal analysis of the box beam, for absolute maximum bending moment we designed pre-stressed box beam as per IS1343-1980

Design procedure of elastomeric bearings

we designed elastomeric bearings for the reaction loads coming from the box beams in super structure. Dimensions, thickness and number of steel plates and their thickness are fixed as per code IRC83(part- II) and these dimensions are checked against translation, rotation and friction failures according to the code.

Analysis and design procedure for pier cap and pier

For the analysis of pier and pier cap we modelled a portal frame and applied the reactions from box beams on it, and this model is analyzed in staad software. And pier and pier cap are designed for resultsobtained from the staad software.

ADVANTAGES OF ACCELERATED CONSTRUCTION

The cost of construction to highway users is significant. Savings to commuters are not typically reflected in construction budgets for highway projects; however, there is a significant financial impact to the entire community due to travel delays. In many cases, the cost of accelerated construction techniques can be offset by reductions in user costs.

Often the need for accelerated construction can be driven by political pressures. The impacts of construction on commuters and businesses in urban areas can be devastating. Accelerated construction can be used to limit the time frames for construction projects in these areas.

PSC DESIGN

PSC DESIGN OF BOX BEAM

A) REQUIRED DATA

Span of the bridge = 20m

Grade of concrete = M_{40}

Grade of steel = Fe_{415}

Loss of ratio η = 0.8

Assume the member as type-1-memberi.e no tensile stresses are allowed at any stage

$F_{tw} = F_{tt} = 0$

$F_{ct} = F_{cw}$

$F_{ct} = 0.483 \times f_{ci}$

For M_{40}

$F_{ci} = 0.55 \times 40 = 20\ N/mm^2$

$F_{ct} = 0.483 \times 22 = 10.626\ N/mm^2$

Permissible compressive stresses at service stage

Grade	Value of F_{cw}
M_{30}	$0.41f_{ck}$
M40	-
M_{60}	$0.35f_{ck}$

By interpolating

For M_{40}

$F_{cw} = 0.39f_{ck} = 0.39 \times 40 = 15.6\ N/mm^2$

B) CALCULATION OF MOMENTS

From ILD's

live load moment = 675 KNm

Ultimate live load moment $M_l = 1.5 \times 675 = 1012.5$ KNm

Ultimate dead load moment $M_d = 20\%$ of $M_l = 0.2 \times 1012.5 = 202.5$ KNm

C) CALCULATION OF SECTION PARAMETERS

Moment of inertia

$$I = \frac{BD^3}{12} - \frac{bd^3}{12} = \frac{1.56 \times 1.38^3}{12} - \frac{1.01 \times 1.03^3}{12} = 0.2497\ m^4 = 2497 \times 10^8\ mm^4$$

Section is symmetric about both the axis

$$Y_{top} = Y_{bottom} = \frac{D}{2} = 1.38/2 = 0.69\ m = 690\ mm$$

SECTION MODULUS

Section modulus Z

$$Z_{top} = Z_{bottom} = \frac{Ixx}{y} = \frac{2497 \times 10^8}{690} = 361.8 \times 10^6\ mm^3$$

CHECK FOE SECTION MODULUS

$$Z_{t\ required} = \frac{Ml + (1-\eta)Md}{fcw - \eta ftt} = \frac{((1012.5 + (1-0.8)202.5))10^6}{15.6 - 0} = 62.3 \times 10^6\ mm^3$$

$(Z_t)_{provided} = (Z_t)_{required}$

HENCE OK

D) CALCULATION OF PRESTRESSING FORCE

$$P = \frac{A(fsup \times Zt + finf \times Zb)}{Zt + Zb}$$

Section is symmetrical

Therefore, $Z_t = Z_b$

$A = (1.38 \times 1.56) - (1.01 \times 1.03) = 1112.5 \times 10^3\ mm^2$

$$f_{inf} = \frac{ftw}{\eta} - \frac{Md + Ml}{\eta Zb} = 0 + \frac{(202.5 + 1012.5)10^6}{0.8 \times 361.8 \times 10^6} = 4.197\ N/mm^2$$

$$P = \frac{A(fsup \times Zt + finf \times Zb)}{Zt + Zb}$$

$$P = \frac{1112.5 \times (4.197 - 0.559) \times 361.8 \times 10^9}{2 \times 361.8 \times 10^6} = 2023.63\ KN \approx 2050\ KN$$

E) CALCULATION OF ECCENTRICITY

$$E = \frac{Zb \times Zt(finf - fsup)}{A((fsup \times Zt)+(finf \times Zb))} = \frac{(361.8\times10^{6})^{2}\times(4.197+0.559)}{(361.8\times1112.5\times10^{9})\times(4.197-0.559)} = 433.7 \text{ mm}$$

≈ 435 mm

F) CALCULATIONS OF AREA OF STEEL

Assume diameter of wires = 5mm

$A_{st}=\frac{\pi}{4} d^2 = \frac{\pi}{4} \times 5^2 = 19.635 \text{ mm}^2$

G) CALCULATIONS OF NUMBER OF WIRES

Assume effective stress in tendons = 1200N/mm^2

$P = f \times A_{st}$

$$2500\times 10^3 = 1200\times \frac{\pi}{4} \times 5^2 \times n$$

$N_t = 107$

No.of tendons = 107

Each strand has 3 tendons

Therefore,

No.of strands $n_s = \frac{107}{3} = 36$

Each cable has 4 strnads

Therefore,

No.of cables = $\frac{36}{4} = 9$

Therefore,

Provide 5 cables on each side

H) CHECK OF TENSION:

$$\sigma = \frac{\eta P}{A} + \frac{\eta Pe}{Z} - \frac{Ml}{Z} - \frac{Md}{Z} = \frac{0.8\times2500\times10^3}{1062\times10^3} + \frac{0.8\times2500\times425\times10^3}{341.4\times10^6} - \frac{1012.5\times10^6}{341.4\times10^6} - \frac{202.\times10^6}{341.4\times10^6}$$

$= 1.833 + 2.48 - 2.96 - 0.59 = 0.593 < 4.25$ N/mm^2

HENCE SAFE TYPE-1 MEMBERS IS SATISFIED

ANALYSIS RESULTS FOR PIERCAP

MEMBER	LOAD	JT	FX	FY	FZ	MX	MY	MZ
1	1	1	468.46	2063.25	-78.03	-2000.02	92.66	-734.43
		2	-468.46	-1800.3	78.03	1531.84	-92.66	-2076.3
	2	1	35.19	141.5	1.05	-86.2	-7.05	-50.09
		2	-35.19	-141.5	-1.05	92.48	7.05	-161.07
	3	1	37.08	143.57	-4.28	-146.04	3.22	-53.33
		2	-37.08	-143.57	4.28	120.35	-3.22	-169.14
2	1	2	468.46	1800.31	-78.03	-1531.8	92.66	2076.32
		4	-468.46	5051.16	78.03	-3480.8	590.1	-2256.0
	2	2	35.19	141.5	1.05	-92.48	-7.05	161.07
		4	-35.19	86.5	-1.05	-84.22	-2.11	-165.57
	3	2	37.08	143.57	-4.28	-120.35	3.22	169.14
		4	-37.08	312.43	4.28	-233.05	34.25	-155.51
3	1	4	399.93	-5292.1	-188.09	2766.24	103.14	1602.37
		3	-399.93	5555.11	188.09	-1637.6	-103.14	797.21
	2	4	33.68	-90.96	-0.7	62.98	8.99	130.49
		3	-33.68	90.96	0.7	-58.78	-8.99	71.57
	3	4	33.68	-314.82	-11.36	183.93	8.99	130.49
		3	-33.68	314.82	11.36	-115.79	-8.99	71.57
4	1	4	68.53	241	110.06	714.62	-693.24	653.66
		5	-68.53	142.46	-110.06	-714.62	-269.81	-222.54
	2	4	1.52	4.46	1.75	21.24	-6.88	35.08
		5	-1.52	-4.46	-1.75	-21.24	-8.4	3.91
	3	4	3.4	2.38	7.07	49.11	-43.24	25.02
		5	-3.4	-2.38	-7.07	-49.11	-18.66	-4.16

5	1	5	68.53	-142.46	110.06	714.62	269.81	222.54
		6	-68.53	405.41	-110.06	-1374.9	-269.81	188.63
	2	5	1.52	4.46	1.75	21.24	8.4	-3.91
		6	-1.52	-4.46	-1.75	-31.72	-8.4	13.01
	3	5	3.4	2.38	7.07	49.11	18.66	4.16
		6	-3.4	-2.38	-7.07	-91.56	-18.66	16.25

SUPPORT REACTIONS

JOINT	LOAD	FORCE-X	FORCE-Y	FORCE-Z	MOM-X	MOM-Y	MOM Z
1	1	468.46	2063.25	-78.03	-2000.0	92.66	-734.43
	2	35.19	141.5	1.05	-86.2	-7.05	-50.09
	3	37.08	143.57	-4.28	-146.04	3.22	-53.33
3	1	-399.93	5555.11	188.09	-1637.6	-103.14	797.21
	2	-33.68	90.96	0.7	-58.78	-8.99	71.57
	3	-33.68	314.82	11.36	-115.79	-8.99	71.57
6	1	-68.53	405.41	-110.06	-1374.9	-269.81	188.63
	2	-1.52	-4.46	-1.75	-31.72	-8.4	13.01
	3	-3.4	-2.38	-7.07	-91.56	-18.66	16.25

BENDING MOMENT

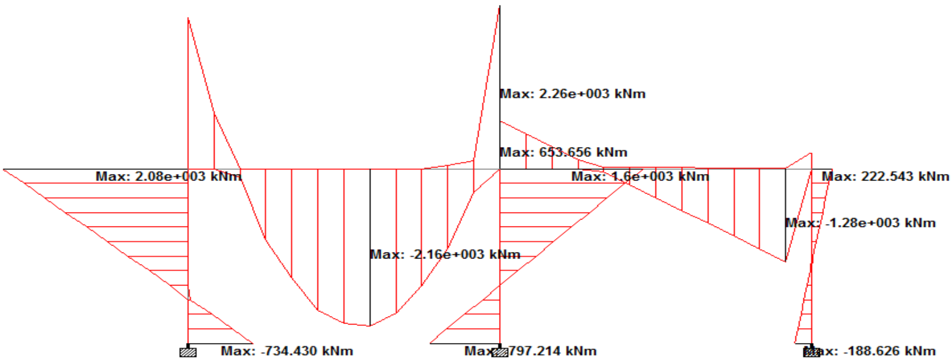

Fig.1. Bending Moment Diagram for Pier Cap

SHEAR FORCE DIAGRAM

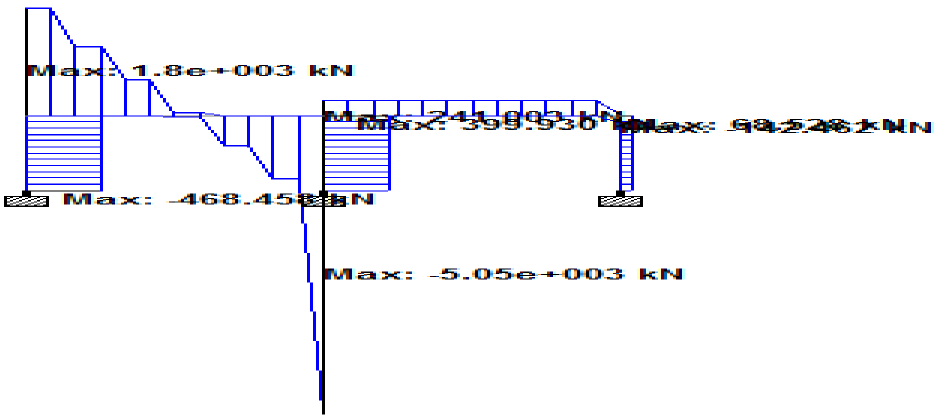

Fig.2. Support Reactions for Shear Force

CONCLUSION

In the design of flyover we partly applied accelerated construction method for the speedy completion of project which helps in saving of money in terms of temporary arrangements to traffic, quality in construction and gives safety in work. Because of time constraint we applied accelerated methods only for the super structure. And the remaining components are designed as per conventional methods. For the purpose of accelerating the fly over we have designed the super structure of flyover as prefabricated prestressed box beams which replace the deck slab, longitudinal and cross girder in the super structure of a bridge.

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