International Journal of Research
Available at https://edupediapublications.org/journals

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

Analysis & Design of Prestressed Concrete Bridge

GantaAnil & T.Ajith
M.Tech (Structural Engineering), AssistantProfessor (Civil engineering Department)
AVN Institute of engineering and technology.AVN Institute of engineering and technology.

ABSTRACT: *Prestressed concrete is a technique that greatly increases load bearing strength of concrete sections. A fully prestressed concrete member is usually subjected to compression during service life. This rectifies several deficiencies of concrete. High span to depth ratio is possible due to prestressing. This decreases the size of the members which makes the project more economical.*

No significant work has been conducted to identify the influence of intermediate diaphragms on load distributions and effects of skew angle on design parameters. Especially there are no guidelines provided by IRC on providing of intermediate diaphragms. We can observe most of bridges with I and T sections have no diaphragm. This study aims to quantify the intermediate diaphragm influence on load distributions. The presented information will help examine the functions of intermediate diaphragms and develop policies of intermediate diaphragm practice for prestressed concrete bridges.

In this study the effect of intermediate diaphragms on distribution of vehicular loads to each of the longitudinal beams are investigated. The bridge was tested first with the different thicknesses and then with intermediate diaphragms placed at suitable locations. It was found that the intermediate diaphragms transmit load laterally very efficiently. The maximum bending moment and deflections in girders transmitted directly under the vehicular loads were slightly reduced by the use of the diaphragms, when the bridge was loaded with IRC loading. Also the effect of skew angle was studied by comparing with the test results with non skew bridges of similar dimensions

.

INTRODUCTION:A bridge is a structure providing passage over an obstacle without closing the way beneath. The required passage may be for a road, a railway, pedestrians, a canal or a pipeline. The obstacle to be crossed may be a river, a road, railway or a valley. In other words, bridge is a structure for carrying the road traffic or other moving loads over a depression or obstruction such as channel, road or railway. A bridge is an arrangement made to cross an obstacle in the form of allows ground or a stream or a river without closing the way beneath.

PrestressedConcretre:

Prestressed concrete is a technique that greatly increases load bearing strength of concrete beams. A prestressed concrete is different from conventional reinforced concrete structure due to application of initial load on the structure prior to use. The initial load or prestress is applied to enable the structure to counteract the stresses arising during the service period.

The development of prestressed concrete can be studied in the perspective of traditional building materials. In the ancient period, stones and bricks were extensively used. These materials are strong in compression, but weak in

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

tension. For tension, bamboos and coir ropes were used in bridges. Subsequently iron and steel bars were used to resist tension. These members tend to buckle under compression. Wood and structural steel members were effective both in tension and compression. In reinforced concrete, concrete and steel are combined such that concrete resists compression and steel resists tension. This is a passive combination of the two materials. In prestressed concrete high strength concrete and high strength steel are combined such that the full section is effective in resisting tension and compression. This is an active combination of the two materials.

For concrete, internal stresses are induced (usually, by means of tensioned steel) for the following reasons.

1. The tensile strength of concrete is only about 8% to 14% of its compressive strength.
2. Cracks tend to develop at early stages of loading in flexural members such as beams and slabs.
3. To prevent such cracks, compressive force can be suitably applied in the perpendicular direction.
4. Prestressing enhances the bending, shear and torsional capacities of the flexural members.
5. In pipes and liquid storage tanks, the hoop tensile stresses can be effectively counteracted by circular prestressing.

In India, the application of prestressed concrete diversified over the years. The first prestressed concrete bridge was built in the 1948 under the Assam Rail link project. Among bridges, the Pamban road bridge at Rameshwaram, Tamilnadu remains as a classic example of the use of prestresses concrete girders.

Limitations of Prestressing:

Although prestressing has advantages, some aspects need to be carefully addressed.

1. Prestressing needs skilled technology. Hence, it is not as common as reinforced concrete.
2. The use of high strength materials is costly.
3. There is additional cost in auxiliary equipments.
4. There is need for quality control and inspection

LOSSESIN PRESTRESSED CONCRETE:

Elastic shortening:

Pre-tensioned Members: When the tendons are cut and the prestressing force is transferred to the member, the concrete undergoes immediate shortening due to the prestress. The tendon also shortens by the same amount, which leads to the loss of prestress.

Post-tensioned Members: If there is only one tendon, there is no loss because the applied prestress is recorded after the elastic shortening of the member. For more than one tendon, if the tendons are stretched sequentially, there is loss in a tendon during subsequent stretching of the other tendons.

The elastic shortening loss is quantified by the drop in prestress (Δf_p) in a tendon due to the change in strain in the tendon ($\Delta \varepsilon_p$). It is assumed that the change in strain in the tendon is equal to the strain in concrete (ε_c) at the level of the tendon due to the prestressing force. This assumption is called strain compatibility between concrete and steel.

Friction losses: The friction generated at the interface of concrete and steel during the

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

stretching of a curved tendon in a post-tensioned member, leads to a drop in the prestress along the member from the stretching end. The loss due to friction does not occur in pre-tensioned members because there is no concrete during the stretching of the tendons.

The friction is generated due to the curvature of the tendon and the vertical component of the prestressing force. The following figure shows a typical profile of the tendon in a continuous beam.

Anchorage slip: In a post-tensioned member, when the prestress is transferred to the concrete, the wedges slip through a little distance before they get properly seated in the conical space. The anchorage block also moves before it settles on the concrete. There is loss of prestress due to the consequent reduction in the length of the tendon.

The total anchorage slip depends on the type of anchorage system. In absence of manufacturer's data, the following typical values for some systems can be used.

Time dependent losses:

Creep losses: The delayed shortening of concrete due to the compression induced by prestress will affect all the tendons. It is the compression at the level of the tendons that creates the loss. Consequently, for a tendon that is not at the neutral axis, the stress under which the concrete creeps is affected by bending in the beam. The loss should be assessed under the long-term dead load condition of the deck. If the cables are bonded to the concrete, the loss due to creep will belocal to a particular concrete section, and will not be averaged out along their length. If the tendons are unbounded, the creep loss will be averaged out over the length of the tendon

The total amount of creep will be affected by the same factors that affect the total amount of shrinkage. However, creep is also strongly affected by the age at which the concrete is first loaded, being less for older concrete. Consequently, when stressing tendons early to allow a rapid turn-round of false-work and a short construction cycle, it is important to stress as few tendons as possible in the first phase, delaying the stressing of the remainder to as late as possible in the cycle.(Loss in prestress due to creep of concrete initially decreases if humidity increases and subsequently increases if the humidity continues to increase).

As per clause 11.2, IRC 18-2000, loss of stress in steel due to creep of concrete can be estimated if the magnitude of creep strain is known which depends on the maturity of concrete.

The loss of stress in steel due to creep of concrete = ε_{cc} xE_s

Where, ε_{cc} = Ultimate creep strain for a sustained unit stress

Shrinkage losses: Whereas one would expect that the shortening of concrete due to shrinkage would be a reasonably well-documented characteristic, there remain a very wide variety of values recommended, or indeed imposed, by various national rules. The codified value of total concrete shrinkage strain lies between approximately 200 × 10–6 and600 × 10–6. The rate at which shrinkage occurs is very important for assessing the consequent loss of prestress. Most cast-in-situ concrete is stressed at between

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

2 and7 days from casting, while precast concrete is likely to be several weeks old before it is stressed. It is necessary to make the best estimate of the amount of shrinkage remaining after stressing to calculate the loss of prestress.

The rate of development as well as the total amount of shrinkage depends on a variety of factors, which include the thickness of the concrete, the humidity of the air, the quantity of and type of cement, total amount of water at the time of mixing. This loss in a tendon, stressed at a particular age of concrete. is the product of the Residual Shrinkage Strain in concrete from that day onwards and ***E*** the modulus of elasticity of cable steel, and this product, a stress, can then be expressed as a percentage of average initial stress in the tendon.

The loss of stress in a tendon due to shrinkage of concrete may be approximated by

$$\nabla\sigma_p = \varepsilon_{sh} \text{ x } E_s$$

The strain due to shrinkage can be known from table-3 IRC18-2000 which is depends on the age of concrete

Relaxation losses: Cable steel under constant tension tends to relax in as much as its stretched fibers creep away from each other. This reduces the prestressing force in the tendon and the magnitude of reduction depends on how much stress- relieving has gone into the steel in its manufacturing process. It ranges between 4 to 7 per cent of the (average) initial prestressing force (or stress) in the tendon and most of it is assumed to occur in the first 1000 hours after tensioning the tendon, with majority of it occurring in its earlier Stages. Most modern strand has a relaxation that does not exceed 4.5 percent in low relaxation steel and 9 percent in normal relaxation steel of the initial stressing force at 1,000 hours. This can be obtained from clause 11.4, IRC-18-2000

DIFFERENT TYPESOF LOADS ONBRIDGE:

Dead Load:

The dead load carried by the girder or the member consists of its own weight and the portions of the weight of the superstructure and any fixed loads supported by the member. The dead load can be estimated fairly accurately during design and can be controlled during construction and service.Clause 203, IRC-6-2000 gives the values of dead load to be considered.

Super Imposed Dead Loads: The weight of superimposed dead load includes footpaths, earth-fills, wearing course, stay-in -place forms, ballast, water-proofing, signs, architectural ornamentation, pipes, conduits, cables and any other immovable appurtenances installed on the structure.

Moving Loads: Live loads are those caused by vehicles which pass over the bridge and are transient in nature. These loads cannot be estimated precisely, and the designer has very little control over them once the bridge is opened to traffic. However, hypothetical loadings which are reasonably realistic need to be evolved and specified to serve as design criteria. There are four types of standard loadings for which road bridges are designed as per clause 201.1, IRC-6-2010.

Footpath Load: For all parts of bridge floors accessible only to pedestrians and animals and for all footways the loading shall be considered as 400kg/m^2. Where crowd loads are likely to occur, such as, on bridges located near towns which are either centers of pilgrims or where large congregational fairs

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

are held seasonally, the intensity of footways loading shall be increased from $400kg/m^2$ to $500k/m^2$.

Kerbs, 0.6m or more in width, shall be designed for the above loads and for a local lateral force of 750kg per meter, applied horizontally at the top of kerb. If the kerb width is less than 0.6m, no live load shall be applied in addition to the lateral load specified above.

Water currents: Any part of a road bridge which may be submerged in running water shall be designed to sustain safely the horizontal pressure due to the force of the current

On the piles parallel to the direction of the water current, the intensity of pressure shall be calculated from the equation

$$P=52KV^2$$

Where

K= constant depending upon the shape of pier.

V=velocity of the current at the point where pressure intensity is being calculated.

Centrifugal Force: Where a bridge is situated on the curve, all the portions of the structure affected by the centrifugal action of moving vehicle are to be proportioned to carry safely the stress induced by this action in addition to all other stress to which they may be subjected.

Centrifugal force is determined by the following equation.

$$C = W \times V^2/(127 \times R)$$

W = Lived load (tones)

V = Design speed of vehicle (km/hours)

R= Radius of curvature (meters).

Temperature Stress: Effect of temperature difference within the superstructure shall be derived for positive temperature differences which occur when conditions are such that solar radiation and other effects cause a gain in heat through the top surface of superstructure. Conversely, reverse temperature difference are such that heat is lost from the top surface of the bridge deck a result of re radiation and other effects.

EFFECTS OF DIAPHRAGM ON DESIGN PARAMETERS: In this study, a simply supported prestressed concrete I section bridge is considered to compare load distribution for different thickness of slab. 7 cases were considered for this study given in Table 5.1. Only moving loads are considered for analyzing all the 7 cases, as it is evident that design parameters like bending moment, shear force etc. increase with increase in member thickness.

SKEW-0(Design parameters for Skew angle 0°)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-2093.8	-1237.8	-519.36
G-2	-1646.7	-1285.9	-1067.6
G-3	-1067.6	-1285.9	-1646.7
G-4	-519.36	-1237.8	-2093.8

Maximum deflection (mm)

	Left	Center	Right
G-1	-7.373	-4.054	-1.75
G-2	-5.824	-4.872	-3.608
G-3	-3.608	--4.872	-5.824
G-4	-1.75	-4.054	-7.373

International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue-01
January 2018

Maximium reaction at supports left (Kn)

	Left	Center	Right
S-1	224.007	100.886	31.246
S-2	526.732	353.677	200.891
S-3	200.891	353.677	526.732
S-4	31.246	100.886	224.007

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	224.296	102.543	30.788
E-2	578.887	386.901	170.754
E-3	170.754	386.901	578.887
E-4	30.788	102.543	222.296

SKEW-15(Design parameters for Skew angle 15)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-2063.8	-1224.5	-526.95
G-2	-1694.4	-1287.2	-1073.2
G-3	-1069.7	-1278.4	-1662.7
G-4	-525.95	-1225.1	-2071.4

Maximum deflection (mm)

	Left	Center	Right
G-1	-7.259	-4.003	-1.788
G-2	-5.781	-4.853	-3.594
G-3	-3.606	--4.851	-5.785
G-4	-1.786	-4.005	-7.268

Maximium reaction at supports left (Kn)

	Left	Center	Right
S-1	236.236	109.135	33.088
S-2	504.159	363.158	210.75
S-3	198.445	336.596	519.938
S-4	30.186	92.285	214.071

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	210.131	97.139	29.755
E-2	570.185	363.368	164.592
E-3	176.794	389.703	549.822
E-4	32.615	110.793	233.497

SKEW-30(Design parameters for Skew angle 30)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-2025.3	-1213.54	-543.52
G-2	-1717.11	-1270.21	-1057
G-3	-1055.92	-1255.8	-1690.41
G-4	-542.785	-1211.21	-2028.59

Maximum deflection (mm)

	Left	Center	Right
G-1	-7.10	-3.926	-1.83
G-2	-5.65	-4.724	-3.51
G-3	-3.523	-4.705	-5.636
G-4	-1.831	-3.919	-7.107

Maximium reaction at supports left (Kn)

	Left	Center	Right
S-1	255.625	123.516	39.733
S-2	471.35	361.507	216.599
S-3	193.498	321.251	509.24
S-4	31.067	84.885	206.008

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	196.459	89.644	30.438
E-2	553.096	345.287	150.714
E-3	182.591	395.522	510.845
E-4	39.397	124.787	254.022

SKEW-40(Design parameters for Skew angle 40)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-2025.3	-1187.52	-555.216
G-2	-1717.11	-1232.34	-1.37.42
G-3	-1055.92	-1221.56	-1694
G-4	-542.785	-1186.16	-1959.8

Maximum deflection (mm)

	Left	Center	Right
G-1	-6.866	-3.782	-1.85
G-2	-5.49	-4.559	-3.418
G-3	-3.411	-4.541	-5.456
G-4	-1.858	-3.777	-6.853

Maximium reaction at supports left (Kn)

	Left	Center	Right
S-1	286.258	140.23	49.233
S-2	472.123	392.645	225.6
S-3	179.109	319.335	510.196
S-4	32.56	94.524	202.923

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	192.12	97.783	30.589
E-2	558.776	322.072	145.838
E-3	180.628	390.21	512.547
E-4	47.25	154.723	293.277

SKEW-40(Design parameters for Skew angle 40)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-1905.36	-1181.05	-571.493
G-2	-1718.59	-1203.28	-1005.48
G-3	-1002.22	-1189.32	-1694.27
G-4	-573.368	-1181.31	-1915.81

Maximum deflection (mm)

	Left	Center	Right
G-1	-6.697	-3.711	-1.881
G-2	-5.298	-4.351	-3.291
G-3	-3.283	-4.331	-5.251
G-4	-1.888	-3.71	-6.696

Maximium reaction at supports left (Kn)

	Left	Center	Right
S-1	302.963	142.11	57.581
S-2	474.115	402.047	230.68
S-3	173.544	313.933	500.82
S-4	31.45	84.23	198.709

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	185.678	80.799	30.293
E-2	543.346	326.405	147.022
E-3	178.809	392.737	466.259
E-4	57.676	153.081	301.437

SKEW-50(Design parameters for Skew angle 50)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-1436.24	-1000.88	-556.659
G-2	-1249.69	-1017.33	-866.418
G-3	-870.347	-1012.01	-1245.29
G-4	-575.042	-989.951	-1431.13

Maximum deflection (mm)

	Left	Center	Right
G-1	-5.346	-3.614	-1.745
G-2	-4.166	-3.663	-3.244
G-3	-3.228	-3.646	-4.153
G-4	-1.754	-3.614	-5.306

Maximium reaction at supports left (Kn)

	Left	Center	Right
S-1	299.299	169.23	63.516
S-2	454.829	365.468	222.823
S-3	183.686	302.634	508.235
S-4	31.345	78.522	182.259

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	187.753	82.213	30.374
E-2	544.536	334.765	147.908
E-3	182.41	396.003	489.604
E-4	48.262	139.625	280.703

SKEW-60(Design parameters for Skew angle 60)

Maximum bending moment(KN-m)

	Left	Center	Right
G-1	-1448.87	-983.118	-563.814
G-2	-1622.5	-989.653	-773.303
G-3	-764.966	-982.833	-1606.81
G-4	-564.788	-982.79	-1470.77

Maximum deflection (mm)

	Left	Center	Right
G-1	-5.402	-3.009	-1.72
G-2	-4.155	-3.156	-2.478
G-3	-2.464	-3.122	-4.107
G-4	-1.713	-2.994	-5.369

Maximium reaction at supports left (KN)

	Left	Center	Right
S-1	422.438	236.989	99.158
S-2	382.662	356.317	208.368
S-3	164.063	279.152	506.886
S-4	25.899	60.231	177.484

Maximum reactions at supports right (KN)

	Left	Center	Right
E-1	164.281	60.518	24.909
E-2	529.165	295.523	135.246
E-3	166.596	368.111	399.167
E-4	121.729	237.929	406.651

DESIGN OF PRESTRESSED BRIDGE:

A simply supported bridge of span 26meters (center to centre distance between expansion joints) and 12meters wide is considered. The superstructure consists of Four I section girders with 200mm thick slab above spaced at 3meters in transverse direction. One end diaphragm on each bearing are provided and three intermediate diaphragms are provided at a distance of L/4, L/2, 3L/4 from support. Footpaths of 1meter at both ends are provided for pedestrian. The grade of concrete and steel adopted was M40 and M415 respectively. The analysis of super structure was done using grillage analysis in STAAD Pro.

Span arrangement:

1. Center to center distance between expansion joints = 26meters
2. Center to center distance between bearings = 24.9meter.
3. Total length of girder = 25.7meters

Section properties of Girders:

	End Section(T)	Middle Section(I)
Area of section(m^2)	1.2833	0.7241
Moment of inertia (I_{xx})(m^4)	0.1249	0.01077
Moment of inertia (I_{yy}) (m^4)	0.5012	0.4634
Moment of inertia (I_{zz}) (m^4)	0.4399	0.3228
Neutral axis from top(m)	0.998	0.983
Neutral axis from bottom(m)	1.002	1.017
Section modulus(Zt) (m^3)	0.4475	0.3234
Section modulus(Zb) (m^3)	0.4326	0.3223

Interpretation:

- Bending moments are decreasing around 5% – 8% up to 45degrees skew and later decreasing up to 15 percent when the skew is increased to 60.
- Deflections are decreasing around 8% – 10% up to 45degrees skew and later decreasing up to 20 percent when the skew is increased to 60.
- Reactions at S1 and E4 are increasing gradually up to skew 50 and sudden increase of reactions after skew 50 and the locations are shown in the figure below.

RESULTS:

Maximum bending moment at the different sections along the span.

Distance(m)	Girder (KN-m)	Deck slab (KN-m)
0	-4.42	-3.47
2	434.59	376.33
2.5	527.79	463.2
3.11	634.29	564.73
6.23	1072.92	1003.39
9.34	1336.12	1239.93
12.45	1423.88	1344.533
15.56	1336.4	1238.6
18.68	1073.82	1002.6
21.79	632.6	566.48
22.4	527.79	463.25
22.9	434.59	376.36
24.9	-4.42	-3.47

Maximum bending moment at the different sections along the span.

Distance(m)	Girder (KN-m)	Deck slab (KN-m)
0	249.84	195.24
2	192.67	184.01
2.5	180.12	174.05
3.11	169.08	166.62
6.23	112.72	131.45
9.34	56.37	66.39
12.45	0	23.69
15.56	56.28	66.67
18.68	112.58	131.61
21.79	169.26	166.46
22.4	180.12	174.07
22.9	192.67	184.23
24.9	249.84	195.25

Conclusion:

This paper gives basic principles for portioning of concrete box girder to help designer to start with project. Box girder shows better resistance to the torsion of superstructure. The various trail of L/d ratio are carried out for Box Girder Bridges, deflection and stress criteria satisfied the well within permissible limits. As the depth increases, the prestressing force decreases and the no. of cables decrease. Because of prestressing the more strength of concrete is utilized and also well governs serviceability.

REFERENCES:

[1] Irc:18-2000 “Design Criteria For Prestressed Concrete Road Bridges(Post- Tensioned Concrete).
[2] Irc:6-2000” Standard Specifications And Code Of Practice For Road Bridges”.
[3] Is:1343-1980”Code Of Practice For Prestresed Concrete.
[4] Analysis And Design Of Substructures By Swami Saran.
[5] Essentials Of Bridge Engineering By S.Ponuswamy.
[6] Irc-(Sp-2001-1)
[7] Irc-5 Bridge Code Section1 General Feature’s
[8] Irc-6 Section 2 Bridge Code Lloads And Stresses.
[9] Irc-78 Bridge Code Section 6 Substructure And Foundation.