Analysis & Design of Bridges

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***Abstract*—** The Indian Road Congress has drafted the specifications resulting in simplified approach of design of box girder bridges. To begin with 55m span, box girder bridge was design as per specifications & it was found that following parameters are significant in the analysis & design of box girder bridges(Depth of Web, DLBM & LLBM at mid span section, DLBM & LLBM at mid support section, Prestressing Force, Eccentricity, Quantity of Steel & Concrete).Accordingly 60m & 70m span bridges were designed.

Index Terms—DLBM, LLBM, girder,Tendon

I. INTRODUCTION

Prestressing is a method of inducing known permanent stresses in a structure or member before the full or live load is applied. These stresses are induced by tensioning the High Tensile Strands, wires or rods, and then anchored to the member being Prestressed, by mechanical means.

The Prestressing counteracts the stresses, produced by subsequent loading on the structures, thereby extending the range of stresses to which a structural member can safely be subjected. This also improves the behavior of the material of which the member or structure is composed. For Example; The Concrete which has relatively a low Tensile strength, shall behave like a member having high tensile strength, after Prestressing.

The High Tensile wires/strands, when bunched together are called Cables. These cables are generally placed inside a cylindrical duct made out of either metallic or HDPE material. The Anchorages, one of the main components of the Prestressing activity, are used to anchor the H.T. Cable after inducing the Load. The whole assembly of the Anchorage and the H.T. Cable is named as '**TENDON'.**

II .STUDY OF IS CODES

i) Standard specification and code of practice for road bridges (section:II)

Load and stresses(IRC:6-2000):

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Clause no:201.1

1) IRC class AA Loading: This loading is to be adopted within certain municipal limits,in certain existing or contemplated industrial areas,in other specified areas,and along certain specified highways.Bridges desiged for class AA loading should be checked for class A loading also,as under certain conditions,heavier stresses may be obtained under class A loading.

2) IRC class A Loading: This loading is normally adopted on all roads on which permanent bridges and culverts are constructed.

3) IRC class B Loading: This loading is normally adopted for temporary structure and bridges in specified areas.

Clause no207.1

Detailed of IRC Loading

207.1.1. For bridge classified under the clause 201.1,the designed live load shall consist of standard wheeled or tracked vehicles or train of vehicles.

207.1.2.Within the kerb to kerb width of roadway, the standard vehicle or train shall be assumed to parallel to the length of bridge, and to occupy any position which will produce maximum stresses provided that minimum clearances two passing or crossing vehicle.

207.1.3 For each standard vehicle or train, all the axles of a unit of vehicle shall be considered as acting simultaneously in position causing maximum stresses.

207.1.4 Vehicle in adjacent lanes shall be taken as headed in the direction producing maximum stresses.

207.1.5 The spaces on carriageway left uncovered by the standard train of vehicles shall not be assumed as subject to any additional live load unless otherwise specified in table.

207.3 Dispersion of load through Fill of Arch Bridges

The dispersion of load through the fills above the arch shall be assumed at 45 degrees both along and perpendicular to the span in the case of arch bridges.

207.4 combination of Live load

This clause shall be read in conjunction with clause 112.1 of IRC:5-1998.The carriageway live load combination shall be considered for the design as shown in table below.

ISSN: 2278 – 7798

Carriageway width	Number of lanes for design purpose	Load combination
1. Less than 5.3m	1	One lane of class a considered to occupy 2.3m.the remaining width of carriageway shall be loaded with $500Kg/m^2$.
2. 5.3m and above but less than 9.6m	2	One lane of class 70R or two lanes of class A
3. 9.6m and above but less than 13.1m	3	One lane of class 70R for every two lanes with one lane of class A on the remaining lane or 3 lanes of class A.
4. 13.1m and above but less than 16.6m	4	One lane of class 70R for every two lanes with one lane of class A for remaining lanes ,if any, or one lane of class Afor each lane.
5. 16.6m and above but less than 20.1m	5	
6. 20.1m and above but less than 23 6m	6	

ii)Standard specification and code of practice for road bridges (section:III)

Cement concrete(Plain and Reinforced):

II. Study of International Specification:

211 Impact

211.1. Provision for impact or dynamic action shall be made by increment of live load by an impact allowance expressed as a fraction or a percentage of the applied live load.

211.2 For class A or class B loading

In the member of any bridge designed either or class A or class B loading(vide clause207.1),this impact percentage shall be determined from following equations which is applicable for span between 3m and 45m.

i) Impact factor fraction for Reinforced concrete bridges =4.5/(6+L)

ii) Impact factor fraction for steel bridges =9/(13.5+L)

Where L is length in metres of the span as specified in clause 211.5.

212. Wind Load

212.1. All structure shall be designed for the following lateral wind forces. These forces shall be considered to act horizontally and in such direction that resultant stresses in the member under consideration are maximum.

212.3. The intensity of wind force shall be based on wind pressures and wind velocities shown in table 4 shall be allow for in design.

215. Centrifugal Forces

215.2 The centrifugal force shall be determined from the following equation:

$C = (WV^2)/(127R)$

Where, C = centrifugal force acting normally to the traffic (1) at the point of action of the wheel load.

W = live load (1) in case of wheel loads, each wheel load being considered as acting over ground contact length specified in clause 207,in tonnes.

V = the designed speed of vehicles using the bridge in km/hr,

R = the radius of curvature in metres.

220. Secondary Stresses

220.3. For reinforced concrete members, the shrinkage coefficient for purposes of design may be taken as $2x10^{-4}$.

222. Seismic Forces

The seismic force as given in clause 222.

III. Analysis & Design of Bridges

One fifty five m span bridge is analysed and designed as per specifications. The details are presented below.

Data:

Span=55m,

Cross-section=multicelled box girder, cell dimension=2x2,

Road width=7.8m,

footpaths=0.6m wide on either side of roadway,

Wearing coat=80mm, thickness of web=300 to27K-15 Freyssinet type anchorages (27 strands of 15.2mm diameter in 110mm diameter cables)

- Thickness of Top & Bottom Slab=300mm
- Concrete grade M-60
- Loss ratio=0.8
- Type of Tendons high tensile strands of 15.2mm diameter conforming to IRC:6006-2000
- Type of supplementary r/f:Fe415 HYSD bars

IV.RESULTS AND DISCUSSION

After preparation of an excel sheets for the span 50, 55,60, 65,70,75 & 80m span, we are finding the results are as follows.

Table 10. Variations in the height of web for different grades of concrete with different span:

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Grade of Concrete	Span	Height of Web
M-40	50	1.8
M-40	55	2.3
M-40	60	2.7
M-40	65	3
M-40	70	3.2
M-40	75	3.7
M-40	80	4.5
M-50	50	1.5
M-50	55	1.8
M-50	60	2
M-50	65	2.4
M-50	70	2.7
M-50	75	3.2
M-50	80	4.1
M-60	50	1.3
M-60	55	1.6
M-60	60	1.7
M-60	65	2.1
M-60	70	2.6
M-60	75	3
M-60	80	3.5

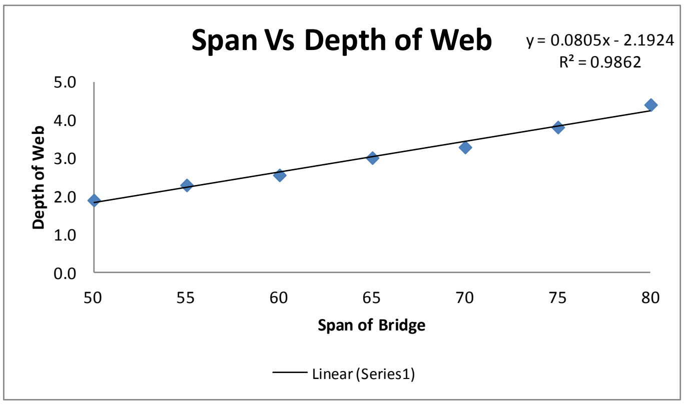


Table 2. Variation in Bending Moments at Mid Span Section with different grade of concrete with different span.

Grade of	Span	Mid Span Section(D) (kN-m)			
		D.L.B.M.	L.L.B.M.	Tot. BM	Ultimate BM
M-40	50	8165.00	4298.53	12463.53	22993.81
M-40	55	10490.06	4728.38	15218.44	27556.04
M-40	60	12968.34	5158.23	18126.57	32348.08
M-40	65	16198.65	5588.08	21786.73	38268.18
M-40	70	19482.40	6017.94	25500.34	44268.44
M-40	75	23868.53	6447.79	30316.32	51922.26
M-40	80	29081.60	6877.64	35959.24	60816.5
M-50	50	7632.50	4298.53	11931.03	22195.06
M-50	55	9711.56	4728.38	14439.94	26388.29
M-50	60	11957.63	5158.23	17115.86	30832.03
M-50	65	14780.58	5588.08	20368.67	36141.09
M-50	70	18090.80	6017.94	24108.74	42181.04
M-50	75	21965.62	6447.79	28413.41	49067.91
M-50	80	28119.34	6877.64	34996.98	59373.11
M-60	50	7336.66	4298.53	11635.19	21751.31
M-60	55	9415.73	4728.38	14144.11	25944.55
M-60	60	11403.69	5158.23	16561.92	30001.11
M-60	65	14248.81	5588.08	19836.89	35343.43
M-60	70	17711.27	6017.94	23729.20	41611.75
M-60	75	21452.14	6447.79	27899.93	48297.68
M-60	80	25809.92	6877.64	32687.56	55908.98

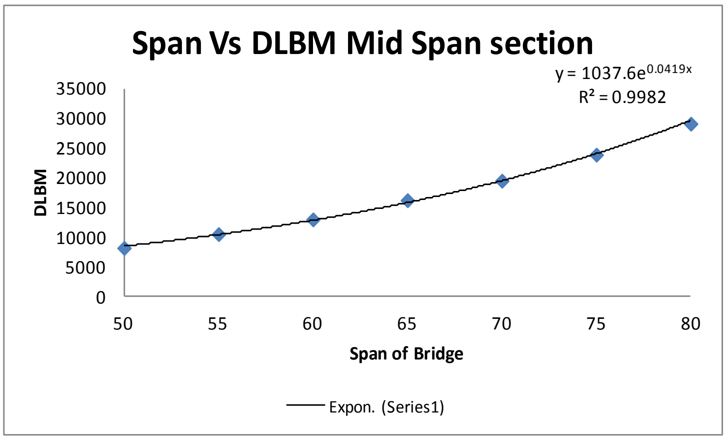
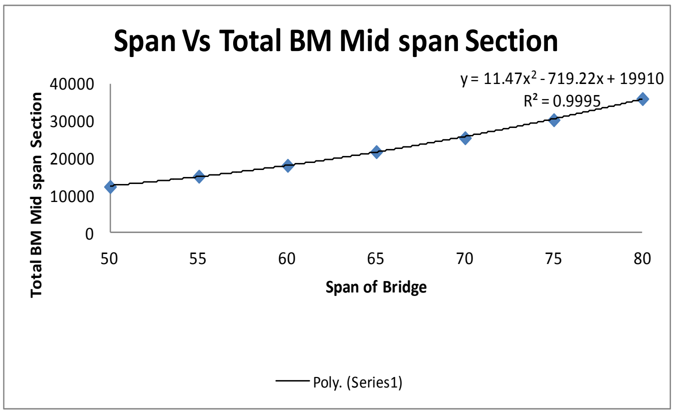


Table 12. Variation in Bending Moments at mid support Section with different grade of concrete with different span.

Grade of Concrete	Span	Mid Support Section(B) (kN-m)			
		D.L.B.M.	L.L.B.M.	Tot. BM	Ultimate BM
M-40	50	14375.00	1986.21	16361.22	26528.04
M-40	55	18468.40	2184.83	20653.25	33164.72
M-40	60	22831.60	2383.45	25215.03	40206.01
M-40	65	28518.80	2582.08	31100.83	49233.32
M-40	70	34300.00	2780.70	37080.70	58401.75
M-40	75	42022.10	2979.32	45001.38	70481.39
M-40	80	51200.00	3177.94	54377.94	84744.86
M-50	50	13437.50	1986.21	15423.72	25121.79
M-50	55	17097.82	2184.83	19282.66	31108.83
M-50	60	21052.17	2383.45	23435.63	37536.91
M-50	65	26022.15	2582.07	28604.24	45488.44
M-50	70	31850.00	2780.70	34630.7	54726.75
M-50	75	38671.87	2979.32	41651.2	65456.12
M-50	80	49505.88	3177.94	52683.83	82203.68
M-60	50	12916.67	1986.21	14902.88	24340.54
M-60	55	16577.00	2184.83	18761.83	30327.59
M-60	60	20076.92	2383.45	22460.38	36074.03
M-60	65	25085.94	2582.08	27668.01	44084.11
M-60	70	31181.82	2780.70	33962.51	53724.48
M-60	75	37767.86	2979.32	40747.18	64100.09
M-60	80	45440.00	3177.94	48617.94	76104.86

ISSN: 2278 – 7798



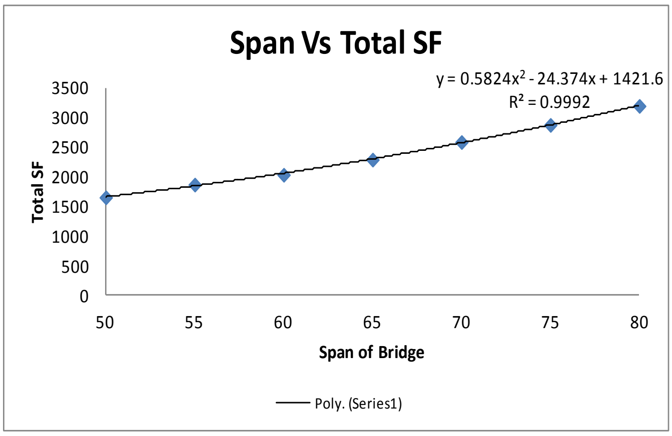


Table 13. Variation in Shear Force Near Mid Support Section with different grade of concrete with different span

Grade of Concrete	Span	Near Mid Support Section(B			
		D.L.S.F	L.L.S.F.	Total SF	Ultimate SF
M-40	50	1426.00	371.14	1797.14	3066.90
M-40	55	1665.52	372.40	2037.91	3429.30
M-40	60	1887.41	373.45	2260.86	3764.70
M-40	65	2176.20	374.33	2550.53	4200.10
M-40	70	2430.40	374.33	2805.50	4583.40
M-40	75	2779.06	375.10	3154.81	5108.00
M-40	80	3174.40	376.33	3550.73	5702.4.0
M-50	50	1333.00	371.14	1704.14	2927.4.0
M-50	55	1541.91	372.40	1914.31	3243.90
M-50	60	1740.31	373.45	2113.76	3544.10
M-50	65	1985.69	374.33	2360.02	3914.40
M-50	70	2256.80	374.33	2631.90	4323.00
M-50	75	2557.50	375.10	2933.26	4775.70
M-50	80	3069.36	376.33	3445.70	5544.90
M-60	50	1281.33	371.14	1652.47	2849.90
M-60	55	1494.94	372.40	1867.34	3173.40
M-60	60	1659.69	373.45	2033.14	3423.20
M-60	65	1914.25	374.33	2288.58	3807.20
M-60	70	2209.45	374.33	2584.55	4251.90
M-60	75	2497.71	375.10	2873.47	4686.00
M-60	80	2817.28	376.33	3193.61	5166.80

Table 14. Variation in Prestressing Force & Eccentricity with different grade of concrete with different span

Grade of Concrete	Span	Prestressing		
		Eccentricity	Force	Cable force Provided (kN)
M-40	50	950.00	10646.00	15000
M-40	55	1147.00	11542.00	15000
M-40	60	1279.00	12941.00	20000
M-40	65	1506.00	13959.00	20000
M-40	70	1644.00	15509.00	20000
M-40	75	1906.00	16641.00	25000
M-40	80	2200.00	17821.00	25000
M-50	50	741.66	12429.92	15000
M-50	55	895.65	13351.21	15000
M-50	60	1004.34	14830.22	20000
M-50	65	1177.27	15890.50	20000
M-50	70	1366.66	17007.48	20000
M-50	75	1575.00	18177.27	25000
M-50	80	2052.94	18337.00	25000
M-60	50	625.92	13907.43	15000
M-60	55	800.00	14326.87	15000
M-60	60	853.84	16365.66	20000
M-60	65	1054.16	16918.84	20000
M-60	70	1290.90	17526.83	20000
M-60	75	1485.71	18708.55	25000
M-60	80	1700.00	19941.49	25000

ISSN: 2278 – 7798

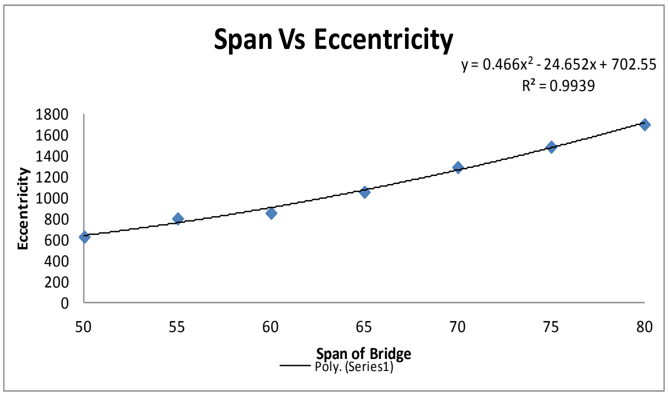


Table 15. Variation in Quantity of Concrete & Steel with different grade of concrete with different span

V. Conclusion

1. The Variations the grade of concrete with load ,moment is decrease with increase in the grade of concrete in RCC Bridges.
2. Excel sheets developed can give design output for any long Span Box Girder Bridge
3. The analysis & design of Box Girder Bridges for any Span can be obtained from the mathematical models without doing lengthy calculations.

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ISSN: 2278 – 7798