A COMPARATIVE STUDY OF SIMPLY SUPPORTED AND CONTINUOUS R.C.C. SLAB BRIDGES

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Abstract – In general Reinforced concrete slab type deck are often referred to as culverts and are commonly used for small spans. This type of super structure is economical for spans up to 8 m. for longer spans reinforced concrete continuous bridges are generally adopted for longer multiple spans. The bridge deck comprises either the solid slab, Tee beam and slab or box girders continuous over several spans. Continuous solid slab bridges are economical for shorter spans while Tee beam and slab continuous bridges are economical in the span range of 10 to 35 meters. The object of the present work is to convert the simply supported bridges into continuous bridges and then to compare the behavior of continuous bridges with that of simply supported bridges. For this purpose six cases of simply supported are considered. To study the comparison with simply supported bridges, the bending moments developed in continuous bridges are considerably less and consequently smaller sections can be adopted resulting in economy of steel and concrete. The ultimate moment capacity of continuous bridge deck is greater than that of simply supported decks due to the phenomenon of redistribution of moments in continuous structures. Observation shows that up to 6 m span dead load moments are @ 63% of live load moments and at 8 m span theses are almost equal. At 10 m and 12 m spans dead load moments are 1.50 times and 2.40 times of that of dead load moments respectively. Therefore from slab design view point it is better to go for continuous two or three spans in multiple of 4 m, 5 m and 6 m. Present work provides at least two continuous spans may be taken in place of single span when bridge length is more than 6 m.

Keywords— RCC slab, Bridges, Simply Supported Bridges, Continuous solid slab, FEM Method, Deck Slab, STAAD-Pro, etc.

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. The bridge is a structure for carrying the road traffic or other moving loads over a depression or obstruction such as channel, road or railway. There are many types of bridges being built now a days. In present study our main concern is with:

1. Simply supported bridge
2. Continuous bridge

1. Simply Supported Bridge

- Generally length of bridge is divided into number of individual spans.
- For each span, the load carrying member is simply supported at both ends.
- Simply supported bridges should be provided where adjacent spans are unavoidably different in length and depth, or where adjacent spans have widely different geometries with beam layouts that do not lend themselves to continuity, such as varying beam spacing or splayed framing.
- Simply supported bridges may also be preferable where the bridge is part of a facility, such as an interchange, where stage construction will require future removal or addition of one or more spans.
- They are suitable at places where uneven settlements of foundations are likely to take place.
- They are generally best suited for short crossings and where speed of construction is an issue.

2. Continuous Bridge

- In continuous bridges spans are continuous over two or more supports.
- They are statically indeterminate structures.
- They are useful when uneven settlement of supports does not take place.
- In continuous bridges the bending moment and displacement anywhere in the span is considerably less than that in case of simply supported span. Such reduction of bending moment and deflection ultimately results in the economic section for the bridge.
- In continuous bridges the stresses are reduced due to negative moments developed at pier or supports.
- Continuous bridges are typically favoured when a sound foundation is available and span lengths are greater.

COMPONENTS OF BRIDGE

The bridge structure comprises of the following parts:-

1. **Superstructure or Decking:**
   This includes slab, girder, truss, etc. This bears the load passing over it and transmits the forces caused by the same to the substructures.
2. **Bearings:**
   The bearings transmit the load received from the decking on to the substructure and are provided for distribution of the load evenly over the substructure which may not have sufficient bearing strength to bear the superstructure load directly.
3. **Substructure:**
   This comprises of piers and abutments, wing walls or returns and their foundation.
4. **Piers and Abutments:**
   These are vertical structures supporting deck/bearing provided for transmitting the load down to the bed/earth through foundation.
5. **Wing walls and Returns:**
   These are provided as extension of the abutments to retain the earth of approach bank which otherwise has a natural angle of repose.
6. **Foundation:**
   This is provided to transmit the load and evenly distribute it on to the strata from the piers or abutments and wings or returns. This is to be provided sufficiently deep so that it is not affected by the scour caused by the flow in the river and does not get undermined. While the above mentioned are structurally operational parts, for safety hand rails or parapets, guard rails or curbs are provided over the decking in order to prevent vehicle or user from falling into the stream or for the separation of traffic streams.

METHOD OF ANALYSIS

1. Existing Method
2. FEM Method

1. Existing Method

In general Reinforced concrete slab type deck are often referred to as culverts and are commonly used for small spans. This type of super structure is economical for spans up to 8 m. in the case of culverts the slab is supported on the two opposite sides on piers or abutments. The deck slab is designed as a one way slab to support the dead and live loads with impact. National highway bridge deck slabs are generally designed to support the I.R.C. Class AA or A type vehicle loads whichever gives the worst effect. The deck slab is generally designed for the worst effect of either one lane of IRC 70R/Class AA tracked vehicle loading or one lane of 70R/Class AA wheeled vehicle or two lanes of Class A load trains moving on the deck as specified in IRC : 6-2000. Based on analytical investigations Victor has reported that, for the computation of live load bending moment, only one loading condition need be considered, namely Class AA wheeled vehicle for spans up to 4 m and Class AA tracked vehicle for spans exceeding 4 m. For computations of maximum live load shear in two lane bridge decks, Class AA wheeled vehicle controls the design for all spans from 1 to 8 m. The distribution reinforcement in the perpendicular direction to span is designed for 0.3 times the live load moment and 0.2 times the dead load moment in one way slabs. Elastic theory of design is specified to ensure the strength of reinforcement concrete slab decks in IRC: 21-2000 code with stipulations on the stresses developed in steel and concrete to specified values based on the grade of concrete and steel. The IRC: 21-2000 code prescribes for the guidelines.

❖ Design Coefficients for Flexural Members:

Based on the permissible stress compiled in Table 1, the design coefficients to be used for computation of effective depth (d) of slab or beam and the area of reinforcement (A_{st}) in the tension zone along with the neutral axis depth 'n', lever arm factor 'j' and the moment factor (Q) expressed as a function of the permissible stress (σ_{cb}) in concrete as given by the following expressions are compiled in Table 1.

$$n = \frac{1}{(1 + \frac{\sigma st}{m\sigma cb})}$$

$$j = (1 - \frac{n}{3})$$

$$Q = 0.5\sigma cbnj$$

The values of modular ratio 'm' to be used in the computations is 10 as per the specifications of IRC: 21-2000.

Table 1. Design Coefficients

Grade of Concrete & Steel	m	σ_{cb} (N/mm²)	σ_{st} (N/mm²)	N	j	Q
M-15 Fe-250	10	5.00	125	0.28	0.90	0.630
M-15 Fe-415	10	5.00	200	0.20	0.94	0.470
M-20 Fe-415	10	6.67	201	0.25	0.91	0.762
M-25 Fe-415	10	8.33	202	0.25	0.90	1.100

❖ Analysis of Slab Decks:

Reinforced concrete slab decks used for small span culverts are generally spanning in one direction and hence the moments due to dead and live loads are critical in the longitudinal direction i.e. the direction of the moving loads. Bridge deck slabs simply supported on either side have to be designed for IRC loads specified as Class AA or A depending upon the importance and classification of the bridge.

- Solid Slabs Spanning in One Direction:

Single Concentrated load:

In the case of slabs spanning in one direction, the dead load moments are directly computed assuming the slab to be simply supported between the bearings. Live loads of vehicles transmitted through wheels are considered as concentrated loads spread over the contact area of the tyres with the deck slab. The bending moment per unit width of slab developed by concentrated loads on solid slabs may be calculated by assuming the width of slab considered as effective in resisting the bending moment due to concentrated loads.

For a single concentrated load, the effective width may be calculated by the equation,

$$be = Kx\left[1 - \frac{x}{L}\right] + bw$$

Where b_e = effective width of slab on which the load acts, L = effective span

x = distance of center of gravity of load from nearer support

b_w = breadth of concentration area of load, i.e. the dimension of the tyre or track contact area over the road surface of the slab in a direction at right angles to the span plus twice the thickness of the wearing coat or surface finish above the structural slab.

K = a constant depending upon the ratio (B/L) where B is the width of the slab.

The values of the constant 'K' for different values of the ratio (B/L) is compiled in Table 2.

Table 2. Values of Constant 'K' (IRC: 21-2000)

B/L	K For Simply Supported Slabs	K For Continuous Slabs	B/L	K For Simply Supported Slabs	K For Continuous Slabs
0.2	0.80	0.80	1.2	2.64	2.36
0.3	1.16	1.16	1.3	2.72	2.40
0.4	1.48	1.44	1.4	2.80	2.48
0.5	1.72	1.68	1.5	2.84	2.48
0.6	1.96	1.84	1.6	2.88	2.52
0.7	2.12	1.96	1.7	2.92	2.56
0.8	2.24	2.08	1.8	2.96	2.60
0.9	2.36	2.16	1.9	3.00	2.60
1	2.48	2.24	2.0 & Above	3.00	2.60

Two or More Concentrated Loads in Line in the Direction of Span:

When two or more concentrated loads are positioned in a line in the direction of span, the bending moment per unit width of slab shall be calculated separately for each load according to its appropriate effective width of slab as specified under the single concentrated load.

Two or More Concentrated Loads not in Line in the Direction of Span:

In cases where the effective width of slab for one load overlaps the effective width of slab for an adjacent load, the resultant effective width for the two loads equals the sum of the effective widths for each load minus the width of overlap, provided that the slab so designed is tested for the two loads acting separately.

- **Dispersion of Loads along the span:**

The effective length of slab in the direction of the span is computed as the sum of the tyre contact area over the wearing surface of slab in the direction of the span and twice the overall depth of the slab inclusive of the thickness of the wearing surface.

If D = depth of the wearing coat
H = depth of the slab
x = wheel load contact area along the span
v = effective length of dispersion along the span

We have the relation,

$$v = x + 2(D + H)$$

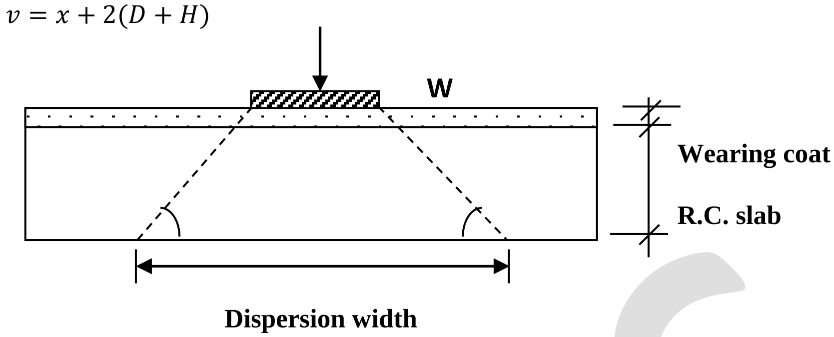


Fig. 1. Dispersion of Wheel Load through Wearing Coat and Deck Slab at 45 angle

Table 3. Permissible Shear Stress in Concrete (Table 12B of IRC: 21-2000)

(100 As) /(bd)	Permissible Shear Stress in Concrete N/mm²				
	Grade of Concrete				
	M-20	M-25	M-30	M-35	M-40 & above
1	2	3	4	5	6
0.15	0.18	0.19	0.20	0.20	0.20
0.25	0.22	0.23	0.23	0.23	0.23
0.50	0.30	0.31	0.31	0.31	0.32
0.75	0.35	0.36	0.37	0.37	0.38
1.00	0.39	0.40	0.41	0.42	0.42
1.25	0.42	0.44	0.45	0.45	0.46
1.50	0.45	0.46	0.48	0.49	0.49
1.75	0.47	0.49	0.50	0.52	0.52
2.00	0.49	0.51	0.53	0.54	0.55
2.25	0.51	0.53	0.55	0.56	0.57
2.50	0.51	0.53	0.55	0.56	0.57
2.75	0.51	0.56	0.58	0.60	0.62
3 & above	0.51	0.57	0.60	0.62	0.63

Table 4. Maximum Shear Stress ($\tau_{c,max}$) in Concrete (N/mm²) (Table 12A of IRC:21-2000)

Concrete Grade	M-20	M-25	M-30	M-35	M-40 & above
$\tau_{c,max}$ (N/mm²)	1.8	1.9	2.2	2.3	2.5

Table 5. Values of K for Solid Slabs (Table 12C of IRC: 21-2000)

Overall Depth of Slab (mm)	300 or more	275	250	225	200	175	150 or less
K	1	1.05	1.1	1.15	1.2	1.25	1.3

2. FEM Method

❖ Stiffness approach using STAAD.Pro-2006

STAAD-Pro is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has intuitive, user friendly GUI, visualization tools, powerful analysis and design facilities. The software is fully compatible with all windows operating systems. This is based on the principles of "concurrent engineering". One can build his model, verify it graphically, perform analysis & design, review the results, sort & search the data and to create a report all within the same graphics based environment.

❖ Variables

(1) To achieve this objective one hinged at middle of span and continuous slab bridges have been analyzed for span lengths 8, 10 and 12 meter.
(2) To achieve this objective two hinged at one third of span and continuous slab bridges have been analyzed for span lengths 12, 15 and 18 meter.
(3) For all span lengths width of bridge taken as 9.5 m.

❖ Load cases considered

(1) Load Case-I: DL (Self weight)
(2) Load Case-II: (i) LL (Class AA- Tracked) (ii) LL (Class A)

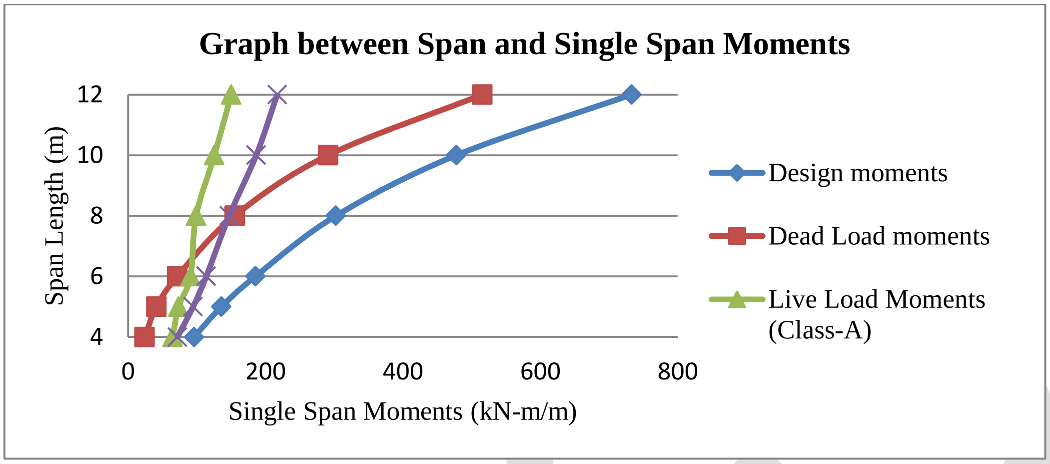
RESULTS

Table 6. Results for Single Span Bridges

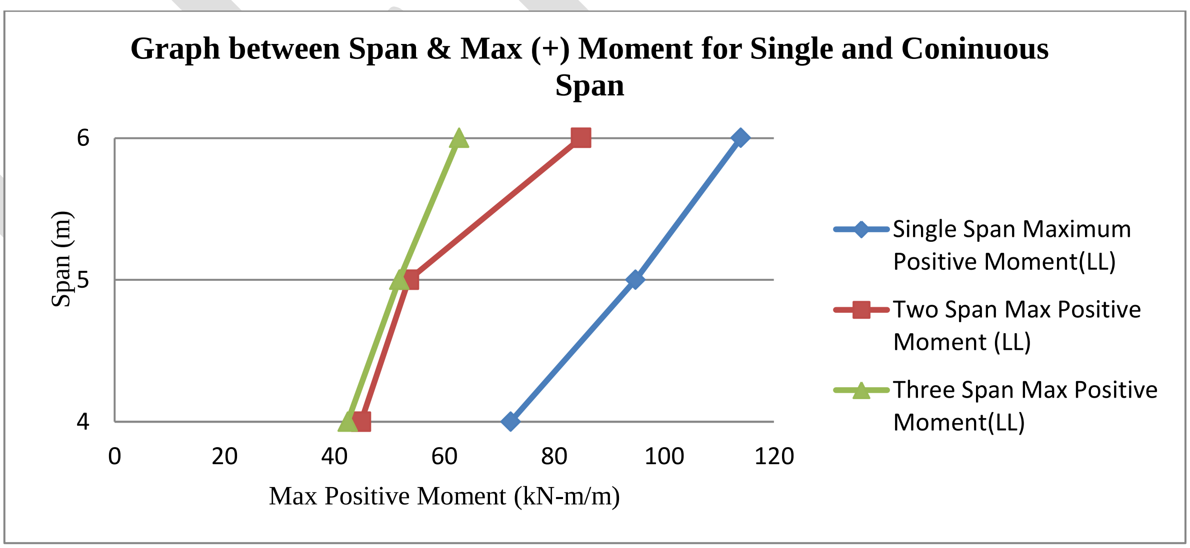
Maximum Bending Moment (kN-m/m) along the Span					
Span (m)	**Method of Analysis**	**Dead Load Moments**	**Live Load Moments (Class A)**	**Live Load Moments (Class AA)**	**Design Moments**
4	Existing	24.268	60.487	72.041	96.309
	FEM	24.053	65.014	72.082	96.135
5	Existing	41.145	69.461	94.831	135.976
	FEM	41.380	73.644	93.423	134.803
6	Existing	71.680	90.958	112.946	184.626
	FEM	71.640	86.341	113.982	185.622
8	Existing	154.350	95.557	145.583	299.933
	FEM	155.452	99.152	147.312	302.764
10	Existing	289.406	123.086	181.860	471.266
	FEM	291.595	125.800	186.721	478.316
12	Existing	515.970	150.362	217.230	733.200
	FEM	513.046	148.207	213.707	726.753

Maximum Bending Moment (KN-m/m) along the span				
Span (m)	**Design Moment**	**Dead Load Moment**	**Live Load Moments (Class A)**	**Live Load Moments (Class AA)**
4	96.135	24.268	65.014	72.082
5	135.976	41.38	73.644	94.831
6	185.622	71.68	90.958	113.982
8	302.764	155.452	99.152	147.312

10	478.316	291.595	125.8	186.721
12	733.2	515.97	150.362	217.23

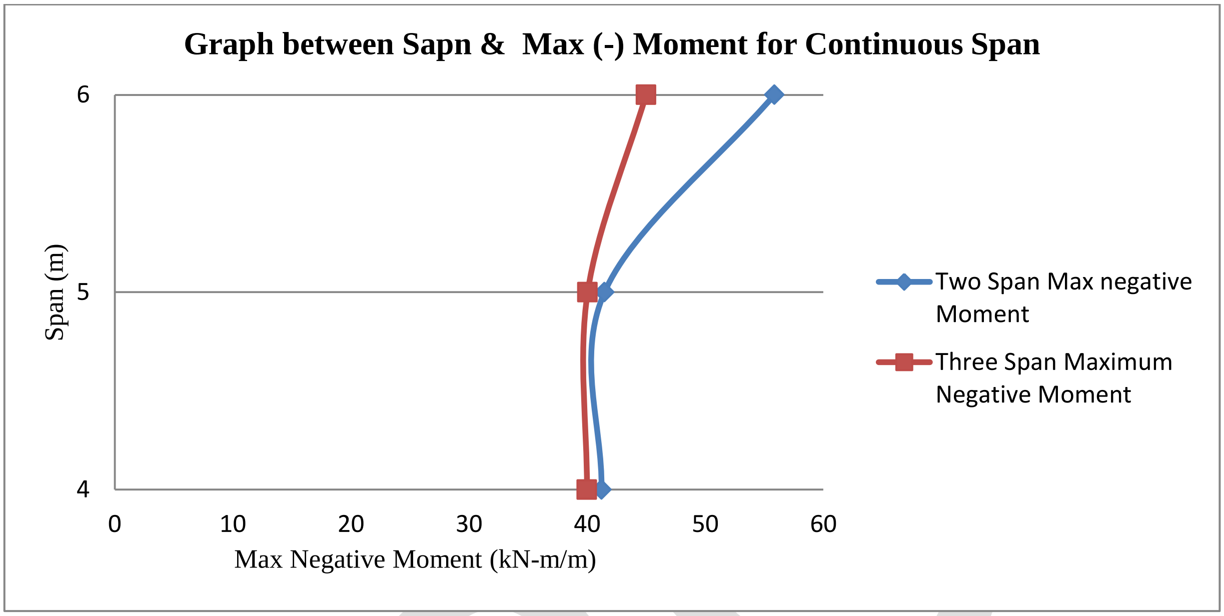


Maximum (+) Bending Moment (kN-m/m) along the span			
Span (m)	**single Span Max LL B.M. (+)**	**Two Span Max LL B.M.(+)**	**Three Span Max LL B.M.(+)**
4	72.082	44.868	42.45
5	94.831	53.55	51.815
6	113.982	84.901	62.695

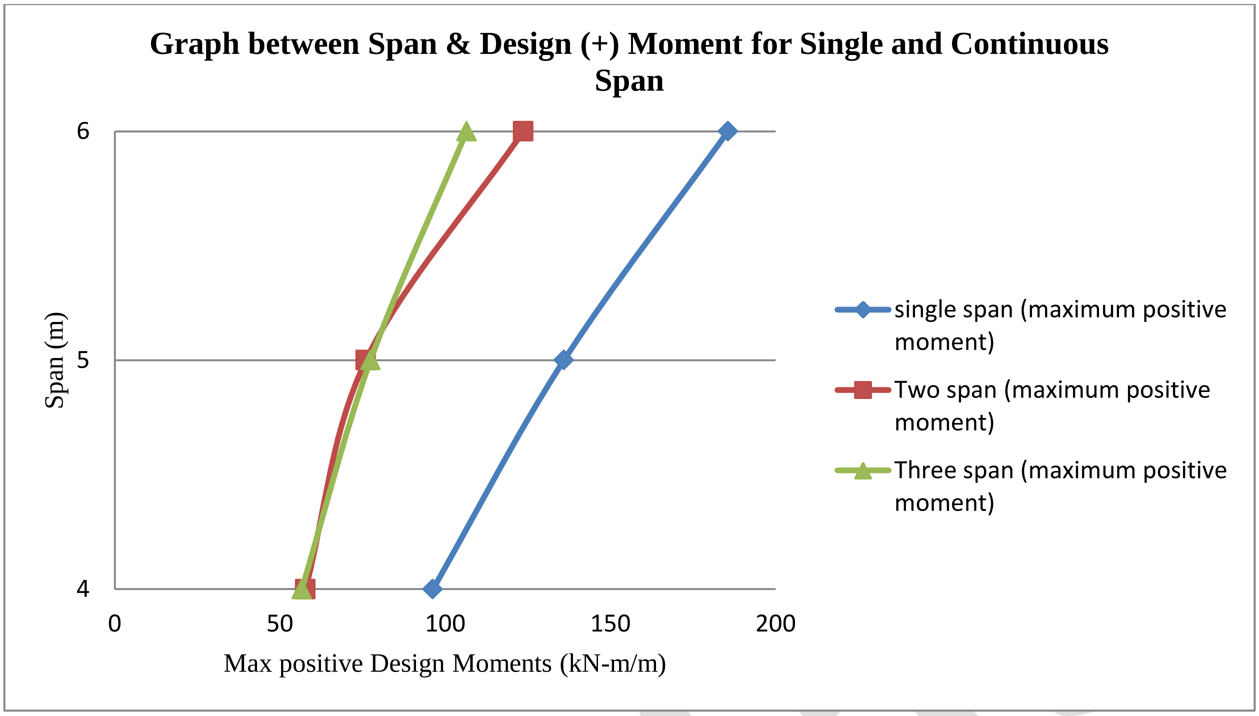


Maximum (-) Bending Moment (kN-m/m) along the span		
Span (m)	**Two Span Max B.M.(-)**	**Three Span Max B.M.(-)**
4	41.222	39.988

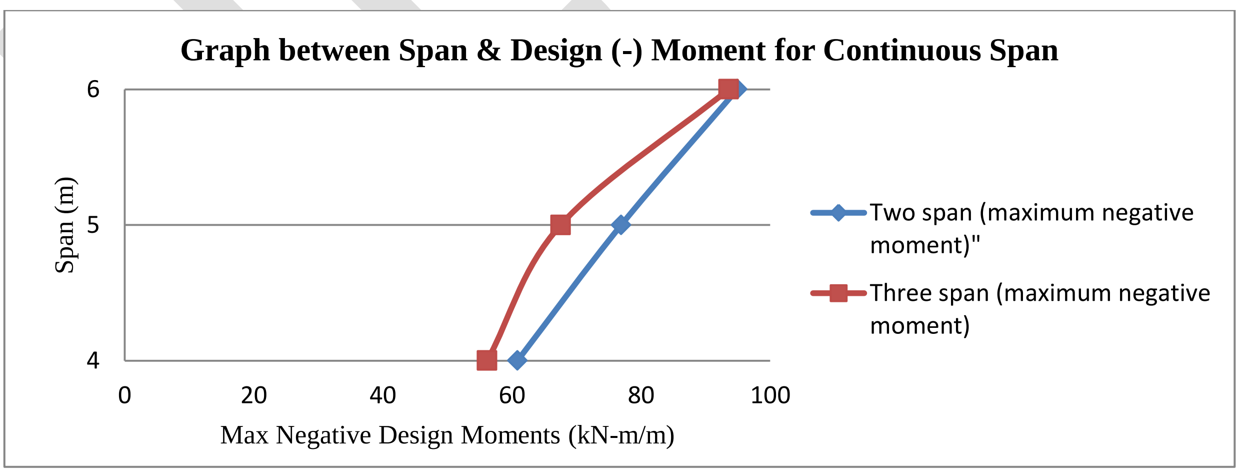
5	41.475	40.045
6	55.859	44.989



Maximum Design Moment (+) along the span			
Span (m)	**Single Span DM (+)**	**Two Span DM(+)**	**Three Span DM(+)**
4	96.309	57.753	56.63
5	135.976	76.026	77.439
6	185.622	123.676	106.513



Maximum Design Moments (-) along the span		
Span (m)	**Two Span DM (-)**	**Three Span DM (-)**
4	60.854	56.168
5	76.916	67.532
6	94.9	93.572



CONCLUSION

1. Upto 6 m span dead load moments are @ 63% of live load moments and at 8 m span these are almost equal. At 10 m and 12 m spans dead load moments are 1.50 times and 2.4 times of that of dead load moments respectively. Therefore from slab design view point it is better to go for continuous two or three spans in multiple of 4 m, 5 m and 6m.

2. Provision of continuous spans in place of single span causes considerable reduction in dead load, live load and design moments.
3. Provision of two spans in place of one span results in reduction in moments from 80% to 90%.
4. Provision of three spans in place of one span results in reduction in moments about 92%.

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