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Comparative Study of RCC Slab Bridge by Working Stress (IRC: 21-2000) and Limit State (IRC: 112-2011)

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ABSTRACT:

This paper focuses on the methodology of design and analysis of Slab Bridge by working stress method and limit state method. Two models of slab bridges with different carriageway widths are analyzed using STAAD PRO V8i as per IRC standards. Grillage analogy is adopted for the analysis of the models which compares the change in economy by varying the carriageway widths.
Keywords: %p steel, Limiting moment, VED applied shear force, VRDC shear resisting without shear reinforcement, VRDS shear resisting capacity with shear reinforcement.

1. INTRODUCTION:

Bridge design methods are different in different parts of the world. While many codes are currently dealing with limit state method, South Asian countries like India, Nepal etc are new to this design practice. IRC has published new code IRC 112:2011 combining specifications for both RCC and prestress concrete bridges. They introduces durability of concrete, general detailing requirements of different bridge members, grade of concrete and grade of steel compared to IRC:2000 which is working stress method. One of the most important types of bridge is Slab Bridge which is economical up to 8m. Due to its easy fabrication of formwork, reinforcement detailing and placement of concrete it is considered to be the simplest and are designed as one way slab to support the dead load and live load with impact.

2. BASIS OF DESIGN:

Use of elastic theory can be implemented for the strength of a reinforced concrete structural member with following assumptions:

(i)The modulus elasticity of steel adopted is 200Gpa.

(ii)The modular ratio of 10 is adopted.

(iii)The tensile strength of concrete is ignored.

In WSM approach, service loads are used in design and strength of material is not fully utilized. Calculation of stresses acting on structural members is based on elastic method which is designed not to exceed certain limit.

The structure during its lifetime may not experience stresses equal to ultimate state. Under such scenario, the most economical design can hardly be obtained by using working stress approach which is now commonly used in the design of temporary works.

In LSM approach, following limit states are introduced
1.Ultimate limit states (ULS)

a. Limit state of equilibrium: When subjected to various design combinations of ultimate loads, the bridge or any of its components, is considered as a rigid body, and shall not become unstable.

b. Limit state of strength: The bridge or any of its components shall not lose its capacity to sustain the various ultimate load combinations by excessive deformation, transformation into a mechanism, rupture, crushing or buckling.

2. Serviceability limit states (SLS):

a. Limit state of internal stress: The internal stresses developed in the materials of structural elements shall not exceed the specified magnitudes when subjected to combination of serviceability design actions. The stresses are to be estimated using resistance models to represent the behavior of structure, as stipulated in the Code.

b. Limit state of crack control:

(1) The cracking of reinforced, partially prestressed and prestressed concrete structures under serviceability load combinations is kept within acceptable limits of crack widths in such a way as not to adversely affect the durability or impair the aesthetics.
(2) Alternatively, the control of cracking deemed to be satisfied by following restrictions on amount and spacing reinforcement.

c. Limit state of deformation:

(1) The deformation of the bridge or its elements when subjected to combination of design actions shall not adversely affect the proper functioning of its elements, appurtenances, and riding quality
(2) Deformations during construction shall be controlled to achieve proper geometry of finished structure.

d. Limit state of vibration:

(1) For footbridges or component of bridges specifically designed to carry footway loading, the direct verification of vibration limits is required, for which specialist literature may be referred.

(2) For special types of bridges and their components dynamic effects under action of wind are required to be calculated and verified to be within acceptable limits. Model tests are required under certain circumstances.

(3) For other types of bridges, the limit state of vibration under serviceability load combinations is deemed to be satisfied by limiting deflection of elements.

e. Limit state of fatigue:

The bridge or any of its components shall not lose its capacity to carry design loads by materials reaching fatigue limits due to its loading history.

3. PARAMETRIC STUDY:

The loads considered are Dead load, SIDL and Live loads. Loadings are used as per IRC 6: 2014 for different carriageway widths. The loading combination for LSM is,
1.35*(DL) +1.75 *(SIDL) + 1.5*(LIVE LOAD).
The bending moments and shear forces are given by:

WSM, IRC 21:2000

Bending moment
Considering compressive force
Mbal=0.5*σc*n*j*b*d2
Where,
σc = Limiting value of concrete
n=(m*σc)/(m*σc+σs)
m=modular ratio=10
σs=limiting value of stress for steel
j=1-n/3

Considering tensile force
M= σs*Ast*j*d
Where,d=effective depth of the section
Ast =Area of the steel provided
j=1-n/3

Shear Force
1.Clause A 4.6.1 (1),pg.254
τv=v/b*d
2.Clause A 4.6,1 (4),pg. 257
Vs=V- τc*b*d
Asw=Vs*s/(σs*d*(sin w+cosw))
3.Clause A4.6.1(5),pg. 258
ρw,min=Asw/b*s=0.4/0.87*fy≤415MPa

LSM, IRC 112:2011

Bending moment
Considering compressive force
Mlim = C*fck*b*d2*(xu,max)/d*(1-B*(x u,max)/d)
Where,C=co-efficient depends on stain values of material
Fck = Grade of concrete
b=breadth of the section
d=effective depth of the section
B=Coefficient depends on geometry
xu,max=limiting value of neutral axis

Considering tensile force
Mu = 0.8*fy*Ast*b*(1-B*(x u,max)/d)
Where ,
0.8 is constant for limiting stress value
fy=grade of steel
Ast=area of steel required
b=breadth of section
B=coefficient depends on geometry of section
xu,max=limiting value of neutral axis

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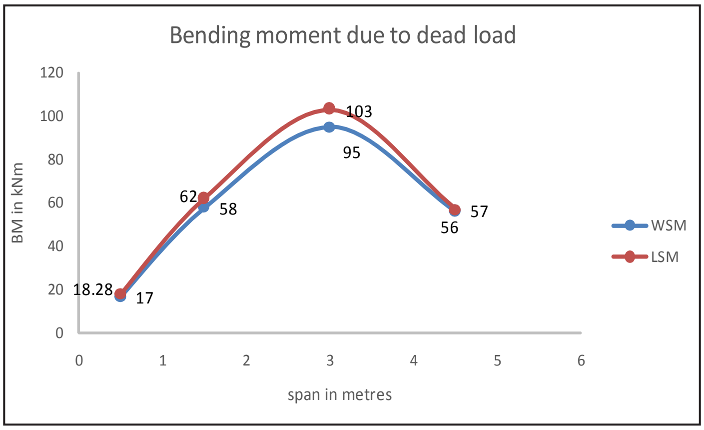
Shear Force
1.clause 10.3.2.,pg. 88
VRdc =[0.12K(80*ρl*fck)0.33 +0.15*σcp]*bw*d

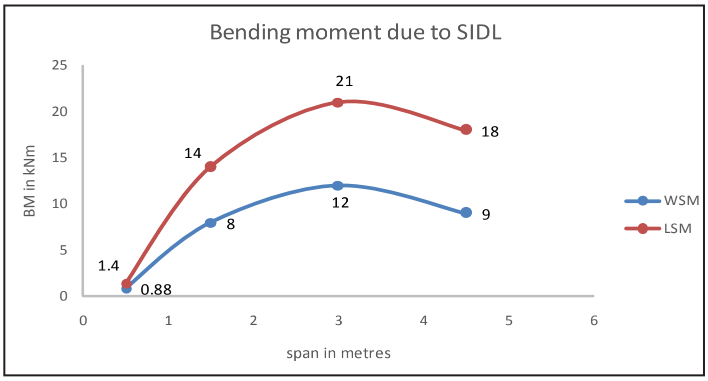
2.Clause 10.3.3.2 ,pg.90 for vertical reinforcement
VRds=Asw/s*z*fywd*cotθ
VRd,max = αcw*bw*z*v1*fcd/(cotθ+ tanθ)
Asw,max *fywd/bw*s≤0.5* αcw v1*fcd

3.Clause 10.3.3.3 ,pg.91 for inclined reinforcement
VRds=Asw/s*z*fywd*(cotθ +cotαl)
VRd,max = αcw*bw*z*v1*fcd*(cotθ+cotαl)/(1+ cot2θ)
Asw,max *fywd/bw*s≤0.5* αcw v1*fcd/sinαl
4. Clause 10.3.3.5,pg. 95,min. reinforcement ratio
ρmin= 0.072*√fck/fyk

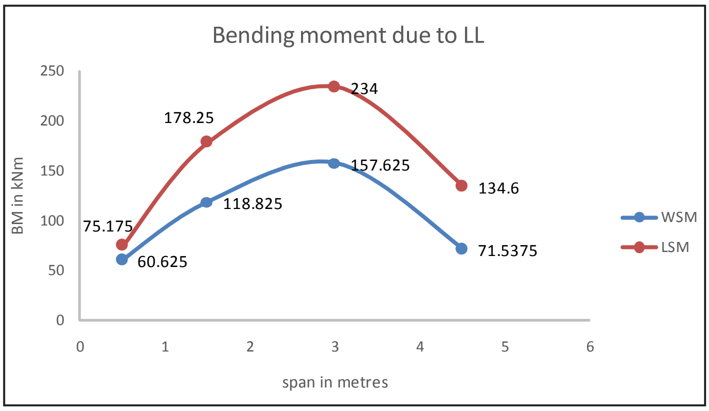
1. Chart shows the difference in bending moment for WSM & LSM due to Dead load for 7.5m carriageway width



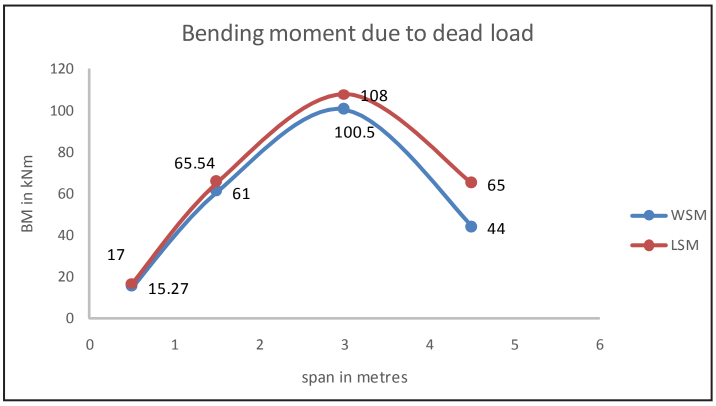
2. Chart shows the difference in bending moment for WSM & LSM due to SIDL load for 7.5m carriageway width



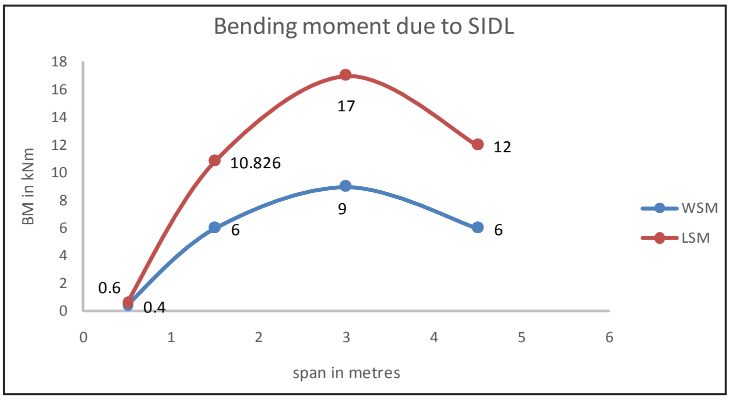
3. Chart shows the difference in bending moment for WSM & LSM due to Live load for 7.5m carriageway width



4. Chart shows the difference in Bending moment for WSM & LSM due to Dead load for 15m carriageway width



5. Chart shows the difference in bending moment for WSM & LSM due to SIDL load for 15m carriageway width



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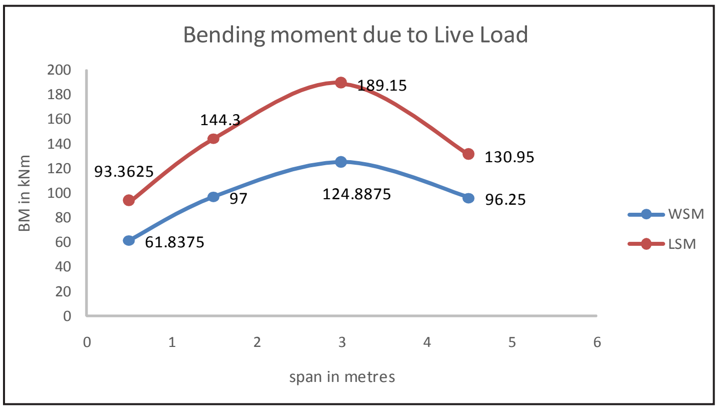
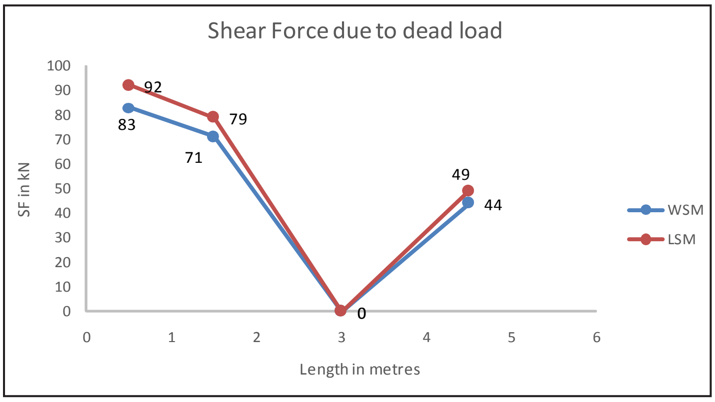
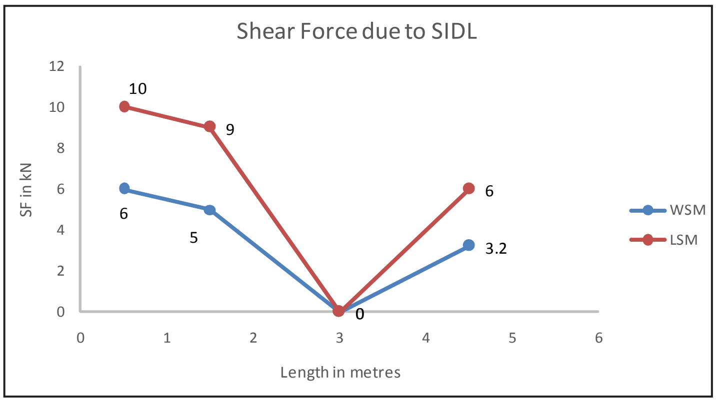
6. Chart shows the difference in bending moment for WSM & LSM due to Live load for 15m carriageway width



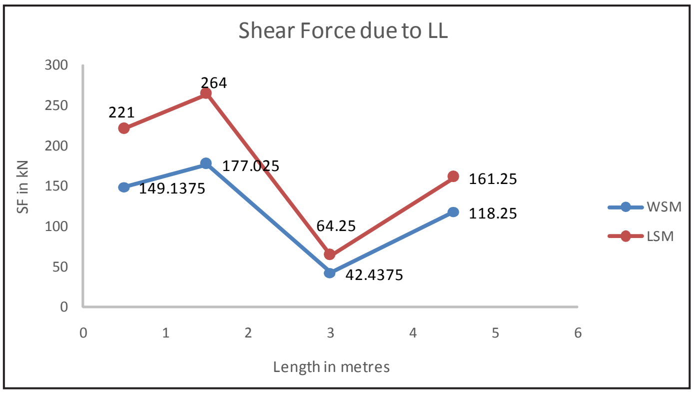
7. Chart shows the difference in Shear force for WSM & LSM due to dead load for 7.5m carriageway width



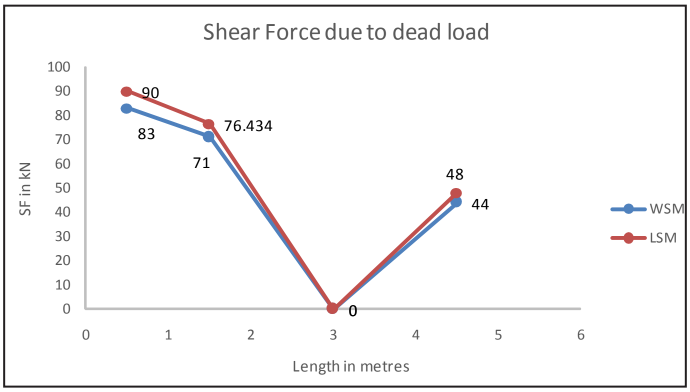
8. Chart shows the difference in Shear force for WSM & LSM due to SIDL load for 7.5m carriageway width



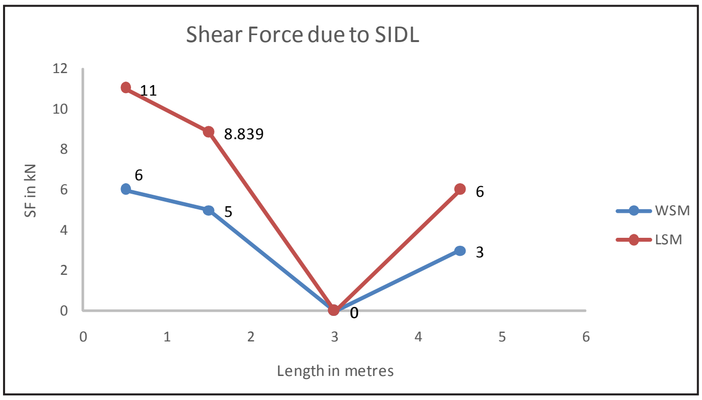
9. Chart shows the difference in Shear force for WSM & LSM due to Live load for 7.5m carriageway width



10. Chart shows the difference in Shear force for WSM & LSM due to Dead load for 15m carriageway width



11. Chart shows the difference in Shear force for WSM & LSM due to SIDL load for 15m carriageway width



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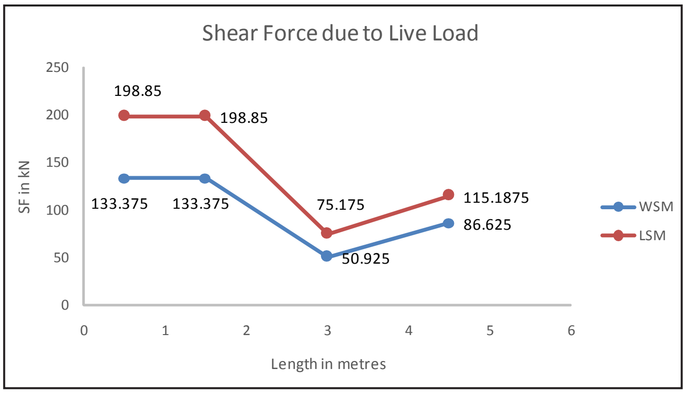
12. Chart shows the difference in Shear force for WSM & LSM due to Live load for 15m carriageway width



CONCLUSION:

Based on above charts we can conclude,

1.By observing 1st & 4th chart, maximum bending moment for carriageway widths 7.5m and 15m are almost same that is reinforcement detailing will be also almost same. Change in carriageway widths does not affect the detailing.

2.In above charts maximum bending moment is obtained at the centre of span and maximum shear force is obtained at the support.

3.Class AA tracked vehicle gives maximum live load shear force for both models as in chart 9 and chart 12 respectively. It is due to maximum UDL load with less contact length.

4.In 3rd, 6th, 9th, & 12th charts the variation in WSM and LSM is not only due to different loading cases but also due to change in Impact factor for different live loads.

5.In 2nd &5th charts, maximum BM due to SIDL is obtained for carriageway width of 7.5m where there is no considerable change in SF due to SIDL for both carriageway widths.

6.The thickness of slab was 500mm for WSM which was reduced to 400mm for both carriageways still there is about 20% saving in amount of concrete and 5-10% saving in amount of reinforcement for LSM that is LSM is considerably economical design compared to WSM.

NOTATIONS:

fck : characteristic compressive strength of concrete
fy :characteristic strength of steel
b : breadth of the section
d : Effective depth of the section
m : modular ratio=10
Ast : Area of steel provided or required
τ: Design shear stress at any cross section
τmax: maximum permissible shear stress.
S: spacing of the stirrups
M: bending moment at cross section
As: Gross area of concrete section in mm2
VRdc : Shear resistance of the section without shear reinforcement
bw : width of web in case of t-beam or width of section.
σst =limiting value of stress for steel.
VRd,max = Ultimate shear resisting capacity of the member with shear reinforcement
fcd = design value of concrete compression strength.

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