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Working Stress versus Limit State Method-A Gistical View for Designing of RCC Structures

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ABSTRACT

The title of this technical paper deals and demonstrates the pros and cons of WSM versus LSM and highlights the revised code of design of RCC structures as LSM. LSM is better and revised method over working stress and LSM is in vogue .Though in LSM permissible stresses are more than WSM & designed load is multiplied with factor 1.5, even the size of section remains small and steel remains more, even than the cost remains less than WSM. The differentiation must be known by elite readers for getting known the changing procedure of design of RCC structures using both methods.

***Keywords**: Working Stress, Limit State Method, RCC Structures.*

INTRODUCTION

While designing RCC structures like beam, slab, column, portal frame, retaining wall, dam, chimneys, over-head water tanks, bunkers, stair-case and silos etc., it has been observed that out of three methods of designing only two methods are popular and in vogue.

In existing scenario or a decade back only, limit state method has been emphasized and put into the syllabus of civil engineering whether it is in diploma or degree. The past method working stress, was full of easy conceptual basis and mend for mild steel having grade Fe-250, where the hooks are provided at ends of bar, so that the bond between the cement concrete and steel surface could be perfect and no slip could be possible and load of tensile be transferred on steel and compression on concrete, as concrete is better in compression while steel is in tension alike in compression. The steel is now used as HYSD bars or TOR steel bars and have more yield strength like Fe-415, Fe-500, and Fe-550, whose surface has corrugations and due to this the concrete makes better bond with steel surface. By this reason the bars have bends at ends rather than hooks.

Also the grade of cement concrete has been increased from M-15 to M-20, M-25 and M-30 for general and specified works. Similarly the design procedure has been modified and treated as limit state method.

The below paragraph/sub title, demonstrates the actual differentiation in theoretical aspect, materials grade, permissible strength, changing designing concept, checking concept and respective formulas *etc*.

DIFFERNTIAL ASPECT

Since the method of limit state has been in prevailing and commonly in use, hence pros over working stress are being emphasized below in two segments *viz.* first part as working stress and limit state as second part.

Working stress method is based on theoretical aspect and has easy calculation.

WORKING STRESS	LIMIT STATE
(1) Some assumptions are followed up for making simple calculation.	(1)Some assumptions are followed up for making up simple calculation.
(2) Permissible stress of concrete in bending is taken fck/3, here fck=characteristic strength of concrete like M-15,M-20,M-25,M-30,M-35 & M-40 respectively has fck 15,20,25,30,35 & 40 N/square mm. So permissible stress of concrete in bending respectively becomes 5, 7, 8.5, 10, 11.5 and 13.	(2) Permissible stress in concrete **= 0.446fck** For M10,15,20,25,30,35 and 40 Stress in concrete =4.46, 6.69, 8.92, 11.15, 13.38, 15.61 and 17.84 N/sq mm respectively.
(3) Permissible stress of steel in tension is taken fy/1.78, here fy=yield strength of steel, where fy is 250 N/sq. mm, stands Fe-250 grade steel. So permissible stress of steel for fy-250 is 140 N/sq.mm. For Fe-350/415/500/550 the values may be 190/230/275/300 N per sq.mm.	(3) Permissible stress in steel **=0.87fy** For Fe-250,350,415,500 & 550, the respective permissible stress = 217.5, 304.5, 361, 435 & 478.5 N/ sq.mm.
(4) Permissible direct stress of concrete in compression is taken fck/4, where for fck values 15, 20, 25, 30, 35 & 40, direct stress respectively taken 2.5,4,5,6,8,9 & 10 N per sq. mm.	(4) Permissible direct stress of concrete in compression **=0.4fck.** For M10,15,20,25,30,35 & 40 ,respective stress will be 4,6,8,10,12,14 & 16 N/sq.mm.
(5) Permissible stress of steel in compression fsc ,is taken 130,130,190 & 190 N per sq.mm, respectively for Fe-250,350,415 & 500 grade steel.	(5) Permissible stress of steel in compression =**0.67 fy** For Fe250, 350, 415,500 & 550, the respective permissible stress of steel in compression =167.5, 234.5, 278, 335 & 368.5 N/ sq. mm.
(5A) Modular ratio m is taken Es/Ec=modulus of elasticity for steel/modulus of elasticity for concrete Or 280/3 multiplied by permissible stress of concrete in bending. Hence, m=18, 13, 11, 9, 8 & 7 for respective grade of concrete 15,20,25,30 & 40.	(5A) No modular ratio m is taken into account.
(6) C=compressive Force of Concrete T=Tensile Force by Steel	(6) Cu=compressive Force of concrete. Tu= Tensile Force of steel
(7) Lever Arm Za=Actual lever Arm=(d-Xa/3)	(7) Lever Arm Actual lever arm Z=(d-0.42Xu)

Zc=Critical Lever Arm=d-Xc/3	Critical Lever Arm Zumax =d-0.42xumax
(8) Critical neutral axis =Xc (m) (Permissible stress of concrete in bending).d /(m) (permissible stress of concrete in bending) +permissible stress of steel in tension. (For m=18, M-15, Fe-250, X_c=0.39d) (m=18, M-15, Fe-350, X_c=0.32d) (m=18, M-15, Fe-415, X_c=0.28d) (m=18, M-15, Fe-500, X_c=0.246d)	(8)Critical Neutral Axis Xumax [0.0036/Xumax]=[(0.87fy/Es)+0.002]/(d-Xumax) Es=200000N/sq.mm Xumax =(700)(d)/(1100+0.87fy) (For M15 & Fe250,Xumax =0.53d) (For M15 & Fe 350,Xumax =0.51d) (For Fe 415,Xumax =0.48d) (Fe 500,Xumax =0.46/d)
(9) Stress Diagram in compression zone Triangular cbc, Xa, d-Xa, st/m, T, C, Xa/3,Za. Here, cbc=permissible bending stress of concrete in bending Xa=Actual Neutral Axis, T=total tensile force, C=total compressive force	(9)Stress diagram in compression zone Rectangular and parabolic 0.446fck,3Xu/7,4Xu/7,0.42Xu, Tu=total tensile force, Cu=total compressive force.
(10) Compressive force in balance condition Xa=Xc C=b×Xc×cbc/2	(10)Compressive force in balance condition Xu=Xumax Cu=0.36fck.Xu.b
(11) Tensile force=T=steel area×stress T=Ast×st	(11)Tensile Force Tu=0.87fy.Ast
(12) Actual Neutral Axis =Xa Xa=area moment of compression zone with respect to neutral axis=equivalent concrete area moment in tension zone with respect to Neutral axis against tensile steel b×Xa×Xa/2=m×Ast(d-Xa)	(12)For actual neutral Axis Cu=Tu 0.36fck.Xu.b =0.87fy.Ast **Xu=0.87fy.Ast/0.36fck.b** Xu=2.416 fy.Ast/fck.b
(13) Permissible position of Xa and Xc Xa<Xc=under reinforced Means less provided steel as per requirement and by this cause steel will fail before collapse. Xa=Xc=balance section Means steel provided is same as required, by this cause both will fail simultaneously. Xa>Xc=over reinforced , Means provided steel is more than required, hence concrete will fail before the steel.	(13) Permissible position of Xu and Xumax. Xu<Xumax =under reinforced Means less provided steel as per requirement and by this cause steel will fail before collapse. Xu=Xumax =balance Means steel provided is same as required, by this cause both will fail simultaneously. Xu>Xumax =over reinforced =not desired
(14) **Percentage of steel** P%=Ast×100/b.d	(14) **Percentage steel** p%=Ast×100/b.d
(15) Permissible steel For M-15 and Fe-350 p% steel=50×X1xcbc/st	(15) **For Permissible Steel** Cumax=Tumax 0.36.fck.Xumax.b=0.87fy.Ast

0.42% For M25,Fe-415, p%=0.53% For M30,Fe-415,p%=0.61% Less steel than Limit State	p% steel=41.4.Xumax.fck/fy. d (For M15, Fe-350,p% steel =0.88%) For M25, Fe-415,p% steel=1.2% For M30,Fe-415,p%=1.44% More steel than Working Stress
(16) Critical Lever Arm Z=(d-Xc/3) =(d-0.33Xc) For M-15 & Fe-250,Xc=0.39d, Z=0.87d For M-15 & Fe-350, Xc=0.32d,Z=0.89d For M-15 & Fe-415,Xc=0.28d, Z=0.90d	(16) **Critical Lever Arm** Z=(d-0.42Xumax) For M15,Fe250,Z=0.78d For M15,Fe350,Z=0.79d For M15,Fe415,Z=0.80d
(17) Moment of resistance (A) Xa<Xc= under reinforced Moment =M=M steel=Tensile force ×Z M=(Ast×st)(d-Xa/3) (B) Xa=Xc=balance section M steel=Ast×st(d-Xa/3) **Or** M concrete =b×Xa×cbc(d-Xa/3)/2 (C) Xa>Xc=over reinforced Concrete will fail. M concrete =b×Xa×cbc(d-Xa/3)	(17) Bending Moment Condition **(A) Xu< Xumax =Under Reinforced ,**Steel will fail earlier. Moment Mu steel=Tu× lever arm Mu steel=0.87fy.Ast(d-0.42Xu) **(B) Xu=Xumax =balance** Mu=0.36fck.Xumax.b(d-0.42Xumax) **(C) Xu>Xumax =over reinforced =not desired in limit state.** Mu=Mumax =0.36fck.Xumax.b(d-0.42Xumax)
(18) Moment Resistance Factor Q=0.5×cbc ×X1×Z1×b×d×d cbc=permissible compressive stress of concrete in bending X1=Coefficient of neutral Axis,Z1=Coefficient of lever Arm. For M-15 & Fe-250, **Q=0.5×5×0.39×0.87=0.85N/sq.mm.**	(18)Moment Resisting Factor Xu=Xumax Mu limit=Cu max ×Z (For M15,Fe250,Xumax =0.53d) Mu limit=0.149fck.b.d.d **Qu=0.149×15=2.235N/sq.mm for M15**
(19) Designed Load Designed load=Incoming Load If incoming load=50 KN/m then Designed load=50KN/m	(19)Designed Load or Factored Load Designed load=1.5×Incoming Load If incoming load=50KN/m, Designed load=75KN/m Factored moment=1.5×Given Moment Factored Shear =Vu=1.5×Given Shear
(20) Nominal Shear stress or incoming Shear Stress tv=V/b.d V=maximum shear force b.d= shear area	(20) Nominal Shear stress or incoming Shear Stress tuv=Vu/b.d Vu=maximum factored shear force
(21) Shear Force borne by bent-up bar Vb=Asv×sv ×Sin 45° =0.707×Asv×sv Here sv=permissible tensile or shear stress similar to st Asv=area of bent-up bar	(21)Shear Force borne by bent-up bar Vub=Asv×sv×Sin45° =0.707×Asv×0.87fy=0.757×Asv×fy Here Asv=total cross sectional area of bent-up bars.
(22) Shear Force borne by Stirrups Vs=Asv×sv(d/s) Or S=Asv×sv×d/Vs	(22)Shear force borne by stirrups Vus=Asv×sv(d/s) Or Spacing

Here S=spacing d=effective depth of beam Asv=area of two leg stirrup.	s=Asv×sv×d/Vus Here s=spacing of stirrups. sv=0.87fy, Asv=cross sectional area of stirrup. For 8mm size two leg stirrups Asv=2×50=100sqmm.
(23) Shear Force borne by Concrete tc=permissible bond stress of concrete, dependent on %age steel of straight bar at end bottom and concrete grade. This can be taken from tables by Interpolation. %age steel =0.15% or less, tc=0.18, 0.18, 0.19 for M15,20,25 respectively. %age steel =0.25%,tc=0.22, 0.22, 0.23 %age steel =0.50%,tc=0.29, 0.30, 0.31	(23) Shear Force borne by Concrete tuc=permissible bond stress borne by concrete dependent on % age steel and grade of concrete For<=0.15%,0.25%,0.50% of steel M15,tuc=0.28,0.36,0.48N/sq.mm M20,tuc=0.29,0.36,0.49 M25, tuc=0.29, 0.37, 0.50 respectively.
(24) Shear Strength of concrete for Slab The value of K is multiplied by tc for slab. K=coefficient dependent on slab thickness. Slab depth=150mm or less, 175mm, 200mm, 225mm, 250mm, 275mm,300mm or more. K=1.3, 1.25, 1.20, 1.15, 1.10, 1.05, 1.00 respectively.	(24) Shear stress borne by concrete for slab = k×tuc K= coefficient dependent on slab thickness. Slab depth=150mm or less, 175mm, 200mm, 225mm, 250mm, 275mm, 300mm or more. K=1.3, 1.25, 1.20, 1.15, 1.10, 1.05, 1.00 respectively.
(25) Maximum Shear Stress borne by Concrete tc maximum = dependent on concrete grade. tc maximum =1.6,1.8,1.9,2.2,2.3,2.5 for beam under respective grade of concrete M-15,20,25,30,35,40. tc maximum =0.8,0.9,0.95,1.1,1.15,1.25 for slab under concrete grade15,20,25,30,35,40.	(25) Maximum Shear stress borne by concrete. tuc maximum = dependent on concrete grade. tuc maximum =2.5,2.8,3.1,3.5,3.7,4.0 for respectively concrete grades M15,20,25,30,35,40. tuc maximum = 3.25, 3.5, 3.72, 4.025, 4.07, 4.20 for slab under concrete grade 15, 20, 25, 30, 35, 40.
(26) tv>tc maximum =need to change the design.	(26) tuv>tuc maximum =need to change the design.
(27) Design for Shear Reinforcement. (A)tv<tc/2=No shear arrangement required (B)tv=tc/2 or tv=tc ,Shear needed to adjust with stirrups with minimum spacing. S=0.87fy.Asv/0.4b,Here S=spacing, b=width of beam. (C)tv>tc<tc maximum for beam Or tv>k×tc <tc maximum Then tr=tv-tc here tr=remaining shear stress Vr=remaining shear force =tr×b.d Vb=shear force borne by bent-up bar=0.707×Asv×sv for sin 45°, Asv=area of bent-up bar, Vs=Vb/2=shear force borne by	(27) Design for shear Reinforcement. (A) tuv<tuc/2=No Shear (B) tuc>or =tuv minimum shear Spacing Sv=0.87.fy.Asv/(0.4b) (C)tuv>tuc<tuc maximum **or** tuv>k.tuc<tuc maximum shear remaining =tur=tuv-tuc Vur=tur.b.d Vub=0.707.Asv.sv Vus=Vur/2 and Vub>Vur/2

stirrups. Here Vb>Vr/2, Spacing S=Asv×sv×d/Vs S should not be more than the lesser value of 0.75d or 300mm.	Spacing S=0.87fy.Asv.d/Vus 0.75d or 300mm Overall whichever is less.
(28) Development length Ldt=development length in tension =bar dia.×st/4 tbdt Here, tbdt =permissible bond stress in tension st=permissible tensile stress of steel. Value of tbdt=0.6,0.8,0.9,1.0,1.1 for Fe-250 grade and respective grades of concrete like M-15,20,25,30,35 Value of tbdt=0.96, 1.28, 1.44, 1.60, 1.76 for Fe-415 or 500 grade with respective concrete grade like M-15, 20,25,30,35.	(28) Development Length Ldt=development length in tension =0.87fy.bar diameter/4tbdt tbdt is dependent on bar size, surface roughness of bar, compaction and grade of concrete. tbdt =1.2,1.4,1.5,1.7,1.9 for plain bars for respective concrete grades M20, 25, 30, 35, 40. Also tbdt for deformed bars=1.92, 2.24, 2.4, 2.72, 3.04 for respective grades of concrete.
(29) Development length of steel in compression =Ldc= bar dia.×st/5 tbdt	(29) Ldc =development length of steel in compression =0.87fy.bar diameter/5 tbdt.
(30) Checking in development length Ldt<=1.3 M1÷V +Lo Here M1=bending moment of straight bar at ends bottom, V=shear force, Lo= Anchorage length=12×bar dia or d, whichever is more.	(30) Checking in development length Ldt<=M1÷Vu+Lo
(31) Design step for singly RCC beam (a) depth d assumed=span/10 to span /15 (b) b=d/2 to d/3 (c) Dead load of beam Wd=b×D×1×density of rcc (d) Live Load wlive=Given (e) Total load w=wd+wlive (f) Effective length l=L+B or L+d whichever is less. (g) Maximum bending Moment M=w.l.l/8 say (h) moment resisting factor Q=0.5.cvc.(X1).(Z1) (i) d required=M/Q.b whole power 0.5 (j) compare d required & d assumed D assumed> or = d required it's ok If d assumed< d required, then again design. (k) Ast required=M/st.z1.(d required) (l) Ast min.=0.85 bd/fy (m) Ast max=0.04b.D (n) Ast required>Ast min, Ast required<Ast max (o) N=number of bars=Ast/ast Ast actual=(N)(ast) (p) Decide number of bent-up bars. (q)Check the beam in Shear and Bond**, not in**	(31) Design of Singly reinforced beam (a) Assumed d=span/10 to span /15 (b) b=d/2 to d/3 (c) Dead load of beam Wd=b×D×1×density of rcc… (d) Live Load wlive=Given (e) Total load w=wd+wlive **Factored load wu=1.5 (wd+wl)** (f) Effective length l=L+B or L+d whichever is less. (g) Maximum Bending Moment M=wu.l.l/8 (h) Qu=0.36fck.Xumax (10.42Xumax/d)/d (i) d required =(Mu/Qu.b) whole power 0.5 (j) compare d required & d assumed **Condition**:- D assumed> or = d required it's ok If d assumed< d required, then again design. If under reinforced means d assumed>d required Mu=0.87fy.Ast.d[1-Ast.fy/b.d.fck]

deflection

IN SHEAR
tv>tc<tc maximum for beam
Or
tv>k×tc <tc maximum
Then tr=tv-tc
here tr=remaining shear stress
Vr=remaining shear force =tr×b.d
Vb=shear force borne by bent-up bar=0.707×Asv×sv for sin 45°,
Asv=area of bent-up bar, Vs=Vb/2=shear force borne by stirrups.
Here, Vb>Vr/2, Spacing S=Asv×sv×d/Vs
S should not be more than the lesser value of 0.75d or 300mm.

IN BOND
Development length
Ldt=development length in tension
=bar dia.×st/4 tbdt
Here tbdt =permissible bond stress in tension
st=permissible tensile stress of steel.
Value of tbdt=0.6,0.8,0.9,1.0,1.1 for Fe-250 grade and respective grades of concrete like M-15,20,25,30,35
Value of tbdt=0.96, 1.28, 1.44, 1.60, 1.76 for Fe-415 or 500 grade with respective concrete grade like M-15, 20, 25, 30, 35.

Development length of steel in compression =Ldc= bar dia.×st/5 tbdt
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Development length
Ldt<=1.3 M1÷V +Lo
Here M1=bending moment of straight bar at ends bottom, V=shear force, Lo= Anchorage length=12×bar dia or d, whichever is more.
Ast=area of straight bar without bent-up bar.

NO CHECK IN DEFLECTION

(k) Get Ast required
No of bars required =Ast/ast round off.
For balance means d=d required
Mu=Ast×0.87fy(d-0.42Xumax)

(l) Ast min.=0.85 bd/fy
(m) Ast max=0.04b.D
(n) Ast required>Ast min,
Ast required<Ast max
(o) N=number of bars=Ast/ast
Ast actual=(N)(ast)
(p) Decide number of bent-up bars.
(q)Check in shear, bond and **deflection**

IN SHEAR
tuv<tuc/2=No Shear
tuc>or =tuv minimum shear
Spacing Sv=0.87.fy.Asv/(0.4b)
tuv>tuc<tuc maximum
or
tuv>k.tuc<tuc maximum
shear remaining =tur=tuv-tuc
Vur=tur.b.d
Vub=0.707.Asv.sv
Vus=Vur/2 and Vub>Vur/2
Spacing S=0.87fy.Asv.d/Vus
0.75d or 300mm
Overall whichever is less.

IN BOND
Development Length
Ldt=development length in tension
=0.87fy.bar diameter/4tbdt
tbdt is dependent on bar size, surface roughness of bar, compaction and grade of concrete.
tbdt =1.2,1.4,1.5,1.7,1.9 for plain bars for respective concrete grades M 20, 25, 30, 35, 40.
Also tbdt for deformed bars=1.92, 2.24, 2.4, 2.72, 3.04 for respective grades of concrete.

Ldc =development length of steel in compression =0.87fy.bar diameter/5 tbdt.

Development Length
Ldt<=M1÷Vu+Lo
M1=Ast×0.87fy×Z
Ast=area of straight bar without bent-up bar.

	-- **CHECKING IN DEFLECTION** service stress fs= 0.58.fy(Ast required/Ast provided) From graph get modification factor k (l/d) maximum =20.k for simply supported beam (l/d)maximum =7k for cantilever beam (l/d)actual <[l/d]maximum.
(32) Doubly Rcc beam (a) Critical Neutral Axis Xc=(m.cbc.d/m.cbc+st --- -- (b) Actual Neutral Axis **Xa** b.Xa.Xa/2+(1.5m-1)Asc(Xa-d')=m.Ast(d-Xa) --- -- (c) Lever Arm for singly or due to concrete Z'=(d-Xc/3) Lever Arm due to Asc Z''=(d-d') --- -- (d) Compressive Force due to singly C'=b×Xc×cbc/2 Compressive Force due to Asc C''=(1.5m-1)Asc×cbc' Here cbc'=stress on the surface of Asc. cbc'=cbc(Xc-d')/Xc --- -- (e) Bending Moment M'=bending moment due to singly =C'×Z' =b×Xc×cbc (d-Xc/3)/2 M''=Bending Moment due to Asc (1.5m-1) Asc× cbc'(d-d'') --- -- (f) Stress of Steel in Compression sc=130,130,190,190N/square mm for Fe-250,350,415,500. Asc=10 square mm Equivalent area of concrete in compression= (1.5×18-1)×10=260 square mm. --- --	(32) Doubly Rcc beam (a) Critical Neutral Axis Xumax =700d/(1100+0.87fy) --- (b) Actual Neutral Axis **Xu** Total compressive force C C=C'+C''=compressive force due to compression zone concrete +Compressive force due to Asc C'=0.36fck.Xu.b C''=fsc.Asc-fcc.Asc C=0.36fck.Xu.b+Asc(fsc-fcc) Tensile force=T=0.87fy.Ast C=T So, Xu=(0.87fy.Ast-Asc.fsc)/0.36fck.b Neglecting fcc (c) Lever Arm For Z'=L.A.=(d-0.42xumax) For Z''=L.A.=(d-d') -- (d) Compressive Force C=0.36.fck.Xumax.b+Asc.fsc -- (e) Bending Moment M=M'+M'' M'=C'×Z'=0.36.fck.Xumax.b(d-0.42xumax) M''=C''×Z''=fsc. Asc (d-d') --- (f) Stress of steel in compression fsc Dependent on d'/d fsc=217,217,217,217 for Fe-250, respectively d'/d for 0.05,0.10,0.15,0.20. fsc=355,353,342,329 for Fe-415. fsc=424,412,395,370 for Fe-500. fsc=458,441,419,380 for Fe-550. --- (g) Determination of Moment Given data b,d,Asc,Ast,d'. Xu=(0.87fy.Ast-fsc.Asc)/0.36fck.b fsc can be from d'/d from table

(g) Determination of Moment Given data b,d,Asc,Ast,d'. Xc=m.cbc.d/m.cbc+st Get Xa from equation b.Xa.Xa/2 +(1.5m-1)Asc(Xa-d')=m.Ast(d-Xa) **Condition:- If Xa>Xc=over reinforced** Concrete Will fail, hence moment Mc=b.Xa.cbc(d-Xa/3)/2+(1.5m-1)Asc.cbc'(d-d') If **Xa=Xc=balance section** Mc=b.Xa.cbc(d-Xa/3)/2 + (1.5m-1)Asc.cbc'(d-d') If **Xa<Xc=under reinforced** Steel will fail. Now transfer the st to cbc' at top of beam on compression zone. Also at Asc get the value of cbc" b.Xa.cbc'(d-Xa/3)+(1.5m-1)Asc.cbc"(d-d') -- (i) Finding Asc and Ast Xc=(m.cbc.d/m.cbc+st) cbc'=cbc(Xc-d')/Xc M1=Moment due to singly =b.Xc.cbc(d-Xc/3)/2 M2=M-M1=Moment due to Asc M2=(1.5m-1)Asc.cbc'(d-d') Asc can be had from above. Ast1=steel required for singly. Ast1=M1/st(d-Xc/3) Ast2=area of steel in tension due to Asc Ast2=M2/sc(d-d') **Ast=Ast1+Ast2=total steel in tension**.	Xumax=700d/1100+0.87fy Condition **Xu>Xumax**=over reinforced Mu is calculated by Xumax=Xu If **Xu=Xumax** Mu=0.36fck.Xumax.b (d-0.42 Xumax) + Asc. (fsc-fcc)(d-d') If Xu<Xumax Mu=0.36fck.Xu(b)(d-0.42Xu)+Asc(fsc-fcc)(d-d') --- **(i)Finding Asc and Ast** **Ast'=Mulimit /(0.87 fy(d-0.42Xumax)** **Mu"=Mu-Mlimit** **Ast"=Mu"/(0.87.fy)(d-d')** **Ast=Ast'+Ast"** **Asc=Mu"/fsc.(d-d')**
(33) **Tee Beam Design** (a) Depth of T beam d=effective depth =span/10 to span/15, bw = width of beam=d/3 to 2d/3 (b) bf= width of flange=lo÷6+ bw+6Df **Or** bf=bw+ A/2+B/2 (c) **NEUTRAL AXIS** Critical Neutral Axis Xc=(m.cbc.d/m.cbc+st) Actual Neutral Axis Xa, when Xa<Df or Xa=Df bf.Xa.Xa/2 =m.Ast.(d-Xa)	(33) **Tee Beam LSM** (a) Depth of T beam d=Span/10 to Span/15 Breadth of beam bw =d/3 to 2d/3 (b) Width of flange =bf =lo÷6+bw +6Df **Or** bf=bw+ A/2 +B/2 (c) **NEUTRAL AXIS** Critical Neutral Axis = Xumax =700d/(1100+0.87fy) Actual Neutral Axis Xu, when Xu<Df or Xu=Df

If Xa>Df, then bf.Df(Xa-Df/2)+bw (Xa-Df)(Xa-Df)/2 =m.Ast(d-Xa) Get Xa. If Xa<Xc=under reinforced Xa=Xc=balance Xa>Xc=over reinforced (g)Lever Arm Xa<Df Lever Arm=d-Xa/3 Xa=Df Lever Arm=d-Df/3 Xa>Df Z'=d-y Z"=[d-(Df+(Xa-Df)/3] (h) **Compressive Force C** When Xa<Df C=bf.Xa.cbc(d-Xa/3)/2 When Xa=Df C=bf.Df.cbc(d-Df/3)/2 When Xa>Df C=C'+C" C'=bf.Df(cbc+cbc')(d-y')/2 y'=(2.cbc+cbc')(Df/3)/(cbc+cbc') C"=(bw)(Xa-Df)(cbc'/2)(Z") Z"=d-[Df+(Xa-Df)/3]	Xu=0.87.fy.Ast/0.36.fck.bf If Xu>Df, Also Xu=Xumax and Df<3.Xu/7 or Df=3Xu/7, then stress block will lie rectangular and remaining parabolic. If Df>3.Xu/7, then stress block will lie rectangular upto 3Xu/7 and rest parabolic. If Xumax =Xu,Xu>Df and Df/d< or =0.2 or Df<3Xu/7 Cu=0.36.fck.bw.Xumax+0.446fck(bf-bw).Df Total tension Tu= 0.87 fy.Ast IF Xumax =Xu,Xu>Df and Df/d>0.2 Cu=0.36.(Xumax/d)fck.bw.d.d + 0.45 fck(bf-bw).Yf Here Yf=0.15 Xu+0.65 Df Xumax >Xu, Xu>Df, Df<3Xu/7 Cu=0.36fck.bw.Xu+0.446 fck(bf-bw).Df Tu=0.87fy.Ast Xumax >Xu>Df, Df>3Xu/7 Cu=0.36fck.bw.Xu+ 0.45fck.Yf(bf-bw) Here Yf=0.15Xu + 0.65.Df, Yf<Df or Yf=Df Xu>Xumax means over reinforced Redesign
(34**) Column Design** (a) Effective Length l l=0.65 L for both end fixed l=0.80L when one end fixed and another end free. (b) Short Column l/b<=12 Long Column l/b>12 Column Axial Load P=Ac.cc+Asc.sc (c) Longitudinal bar dia=12 mm to 50 mm. Lateral ties bar dia=8mm to 12 mm or bar dia/4, whichever is maximum. (d) Independent ties spacing	(34) **Column Design** (a) Effective Length l l=0.65 L for both end fixed l=0.80L when one end fixed and another end free. (b) Short Column e-min=l/500 +D/30 >or=20 mm e-min should not be greater than 0.05D Column factored load Pu=0.4fck.Ac+0.67fy.Asc (c) Longitudinal bar dia=12 mm to 50 mm. Lateral ties bar dia=8mm to 12 mm or bar dia/4, whichever is maximum.

Least dimension of column or 16×bar diameter or or 300mm whichever is less. (e) Spiral reinforcement Pitch max=75 mm or Core diameter/6 whichever is minimum Pitch minimum =25 mm or 3× ties dia Whichever is less. (f) cbc and cc value M15-cbc=5, cc=4, M20-cbc=7, cc=5, M25-cbc-8.5, cc=6, M30-cbc-10, cc=8, Fe-250-st=140, sc=130, Fe-350-st=190, sc=190, Fe-415-st=230, sc=190,Fe-275-st=275, sc=190 N/square mm. (g) Strength for short Column for non helical P=Ak.cc+ Asc.sc Ag=gross area of column =3.14×d×d/4 Dk=Core diameter =D-2×cover+2×ties diameter Ak=Core Area=(3.14×Dk×Dk/4)-Asc Vus=volume of spiral for per pitch height.	(d)Independent ties spacing Least dimension of column **or** 16×bar diameter or or 300mm whichever is less. (e) Spiral reinforcement Pitch max=75 mm or Core diameter/6 whichever is minimum Pitch minimum =25 mm or 3× ties dia Whichever is less. --- (f) NO NEED --- (g) Strength for short Column for non helical Factored load Pu=0.4fck.Ac+0.67fy.Asc

CONCLUSION

The title demonstrates the pros and cons, while differentiating the WSM to LSM method of designing of RCC structures. In existing scenario LSM method is in vogue and while designing, the incoming load is multiplied by load factor 1.5 and also the permissible stresses are more in steel and concrete in bending and in compression too. Even this act, the section in LSM remains small and steel used remains more than WSM, even this, the valuation remains economical for LSM. Though steel is costlier than concrete by 70 times, even than designing of RCC sections through LSM are cheaper. The technical paper is covering maximum differentiation as seemed sufficient and enough for learning purpose. Effective points will enhance the reader's knowledge.

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