

PRATICAL GUIDANCE FOR DESIGN OF BUILDINGS.

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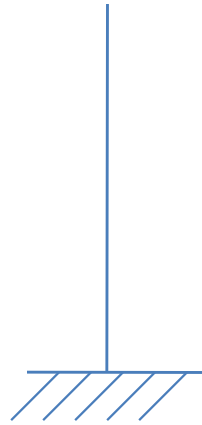
Introduction:

- So far we have been taught some basic features of the software Staad, Etab, Sap 2000, Strudwin, Nisa Design Studio and project Management programs-MS Project and Primavera.
- One should be well verse with the usage of software since if we input wrong data we will get wrong output. Necessary to understand how to use the software and how to check the output results since the mistake will lead to unpleasant result in the project. Specially use of software for Seismic design.

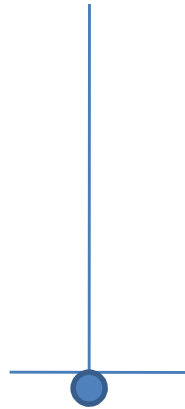
- I will explain some of the important notes while using the softwares and practical problems while designing and execution of works:
- In college everything cannot be taught and one has to learn by his own with experience gained by mistakes and through some experienced engineers, seminar and workshop and of course by journals and magazines.

Building footings:

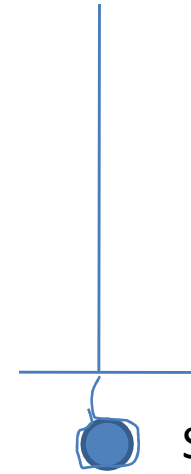
- In buildings the foundation is to rest on soil and at odd times on rock. In such a situation how to provide one of the end conditions to the footing as listed below:
- FIXED .
- PINNED.
- FIXED BUT F_x, F_z, M_x, M_y, M_z ETC
- SPRING SUPPORT.



Fixed end



Hinged end



Spring support

The best solution is to provide

FIXED if the footing is Raft, Pile cap or rock.

Otherwise PINNED is proposed.

But with my experience fixed or pinned will do the same provided a continuous PLINTH BEAM is provided either at top of footing or at a the NGL. Reference can be made to page 164 of Seismic design of Reinforced Concrete and Masonry buildings by T.Paulay and M.J.N.Priestley.

Plinth beam:

- If the beam is made to rest on ground and connected to the columns or piles then BM value can be taken from $WL^2/50$ to $WL^2/30$ based on each engineers experience and judgement.
- Also it shall be designed for column base moments so that only vertical column load goes to the column footing. For earthquake loading also, the plinth beams are designed for column base shear acting as direct tension or compression together with the column moments.

Plinth beam helps to reduce the moment to the column and also helps to reduce the differential settlement by means of tying all the columns.

Reference can be made to:

- Structural design of Multistoreyed Buildings By U.H.Varyani.
- Handbook of Concrete engineering by Mark Fintel.
- Pile foundations designs and construction by Satyendra Mittal.
- IS code 2911(part-III) 1980.

- Plinth beam: If it is made to rest on N.G.L
- Grade beam:

If the connecting beam is at the top of footing it is called Grade beam.
Vide page 395 to 398 –Foundation Engineering by Dr.P.C.Varghese.

It is advised to connect all the columns in a framed building by means of Plinth beams. This will enhance the building's stability and reduce unequal settlement. The column footing will have no or very less BM.

Vide page 159-Handbook of concrete engineering by M.Fintel.

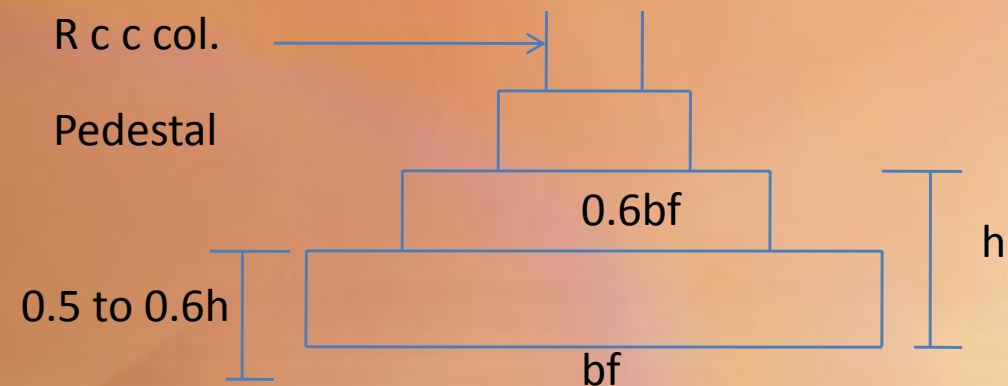
It states:

Furthermore, it is common practice to use, for reasons of stability, a minimum of two piles if a foundation beam or similar provides lateral support; and a single pile only if lateral support can be provided in two directions.

STEPPED FOOTING.

Usually independent footings with sloped shapes. This type of footing is cumbersome to cast, compaction by means of mechanical vibrator and cure.

Why not try with STEPPED footing? It is easy to compact and cure. The main disadvantage is the cost is more than the sloped footing, shuttering is extra and there is a separation plane between the steps which is difficult to bond if it is cast in two different operations.



Reference:

Vide page 154 of Handbook of concrete engineering by Mark.Fintel.
For design you can also refer the page 864 of Limit state design of Dr.RamChandra.

Columns:

Naturally engineers as well as builders prefer Square, Rectangular and round shapes because its easiness of shuttering.

Columns of  + L T

Attempt should be made to make use of the Cross, T, L shapes which facilitates the placement of bars thereby reducing congestion of bars, easy filling of concrete and take more forces and moment.

Its drawback is the cost of shuttering but this will be offset by using it for buildings with more storeys.

Design aids available:

- Many software like Etab. Sap 2000 and Strudwin etc offers facility the use of these shapes.
- Handbook of RC design by S.N.Sinha.
- PWD handbook.
- Structural design of Multistoreyed Buildings By U.H.Varyani.
- Also a thought of using Hallow square, octagonal and rectangular shapes may be made if required.

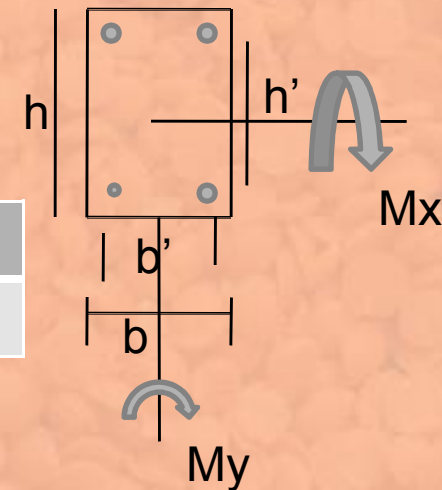
A good formula to design column subjected to bi axial moments

As per BS 8110, the two moments M_x , M_y acting on a section can be reduced to a single moment about given axis, using the formulae:

a. For $M_x/h' \geq M_y/b$, $M'_x = M_x + \beta h'/b' M_y$

b. For $M_x/h' < M_y/b'$ $M'_y = M_y + \beta b'/h' M_x$

Where h, h', b, b' are shown in fig. and β is given in Table below and β depends on $P_u/f_c k b h$.



$P_u/f_c k b h$	0	0.1	0.2	0.3	0.4	0.5	≥ 0.6
β	1.0	.88	.77	.65	.53	.42	.30

Beams:

It is true that the buildings are modeled using its centre line distances.

The software most of them yields the Bending moment at the centre line. Etab is providing the Bending moment at the face of column.

It is not only economical but the correct basis is to design the beams for BM at the face of the support. If the software does not yield the BM at the face of column interpolate it and use it.

Ref: Reinforced concrete design by Unnikrishna Pillai & Menon.

Provisions in IS CODE 456-2000

- Clause :22,6 Critical Sections for Moment and Shear 23 BEAMS
- Clause : 22.6.1

For monolithic construction, the moments computed at **the face of the supports** shall be used in the design of the members at those **sections**. **For nonmonolithic construction the design of the member shall** be done keeping in view **22.2**.

- Clause : 22.6.2.1

When the reaction in the direction of the applied shear introduces compression into the end Region of the member, sections located at a distance less than ***d from the face of the support may be*** designed for the same shear as that computed at distance ***d (see Fig. 2)***.

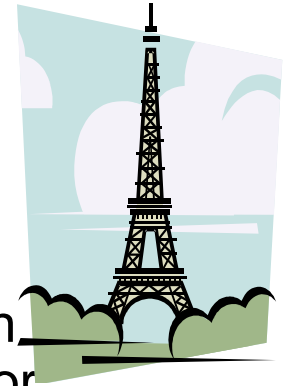
- NOTE-

The above clauses are applicable for beams generally catering uniformly distributed load or where the principal load is located farther than $2d$ from the face of the support

Moment Redistribution:

- Moment Redistribution is carried out to achieve economy and to reduce steel congestion in Beam and column joints.
As per **IS 456-2000**
- Clause 22.7 **Redistribution of Moments states that**
- Redistribution of moments may be done in accordance with 37.1.1 for limit state method and in accordance with B-I.2 for working stress method. However, where **simplified analysis using coefficients is adopted, redistribution of moments shall not be done.**
- Also as per **IS 13920-1993**

Clause 6.2.4 The steel provided at each of the top and bottom face of the member at any section along its length shall be at least equal to one-fourth of the maximum negative moment steel provided at the face of either joint. It may be clarified that **redistribution of moments permitted in IS 456 :1978 (clause 36.1) will be used only for vertical load moments and not for lateral load moments.**



Clause 26.3.3 ***Maximum Distance Between Bars in***
(IS CODE 456-2000) ***Tension***

Unless the calculation of crack widths shows that a greater spacing is acceptable, the following rules shall be applied to flexural members in normal internal or external conditions of exposure.

a) Beams - *The horizontal distance between parallel reinforcement bars, or groups, near the tension face of a beam shall not be greater than the value given in Table 15 depending on the amount of redistribution carried out in analysis and the characteristic strength of the reinforcement.*

Table 15 Clear Distance Between Bars (Clause 26.3.3)

NOTE- The **spacings** given in the table are not applicable to members subjected to particularly aggressive environments unless in the calculation of the moment of resistance f_y , has been limited to 300 N/mm^2 in limit state design and σ_u , limited to 165 N/mm^2 in working stress design.

f_y	-30	-15	0	+15	+30
	Clear Distance between bars				
N/mm^2	mm	mm	mm	mm	mm
250	215	260	300	300	300
415	125	155	180	210	235
500	105	130	150	175	195
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b) Slabs

- 1) The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300 mm whichever is smaller.
- 2) The horizontal distance between parallel reinforcement bars provided against shrinkage and temperature shall not be more than five times the effective depth of a solid slab or 450 mm whichever is smaller.

From the above it is clear that Max. allowed MRD is only 30% but it is advised to limit to 10%. **Also it can not be made use if the structure is designed for EQ.**

With respect to the spacing even though it is given for beam hope that it can be applied to slab which is for 0% redistribution.

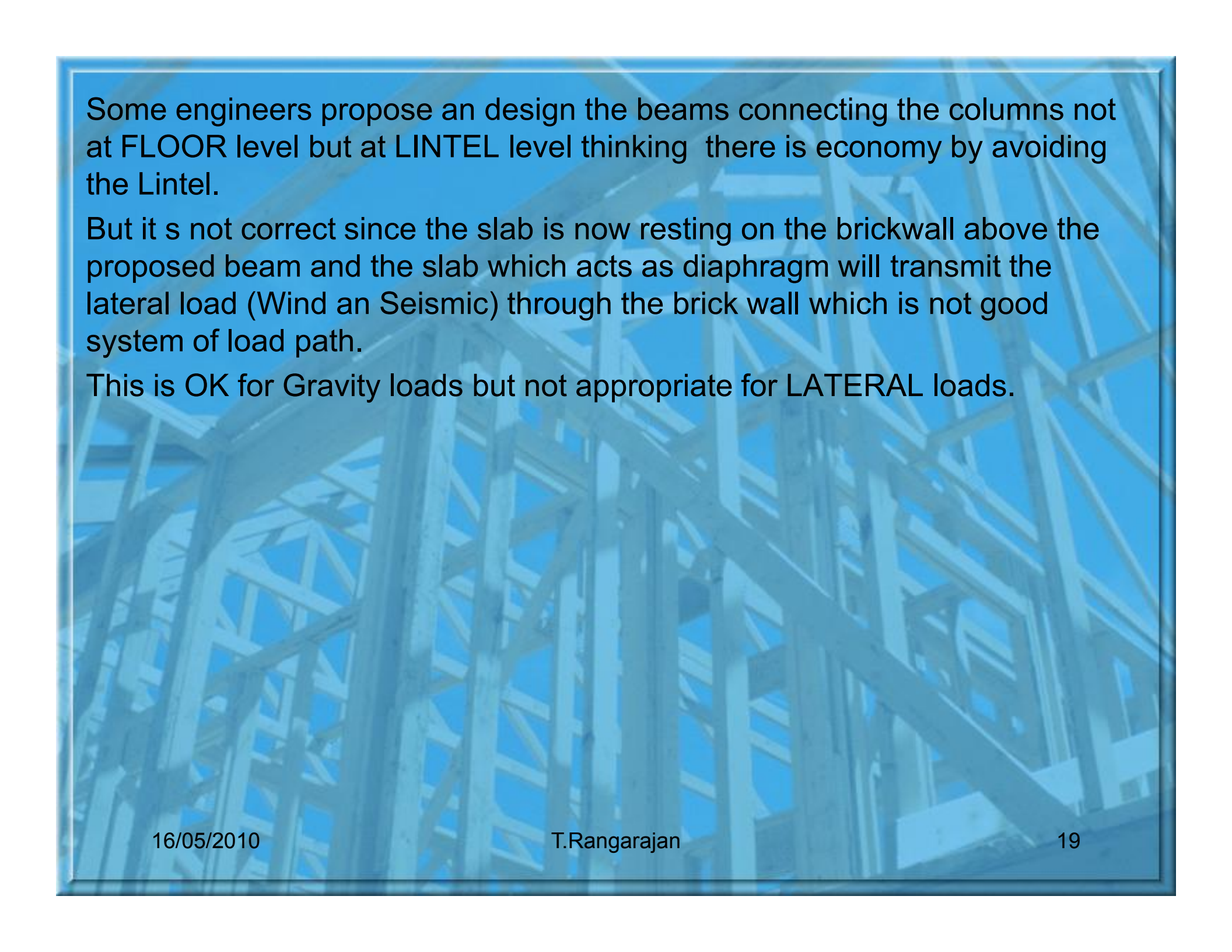
It is recommended to limit the spacing of any dia bar in slabs for Main reinforcement to a maximum of 200mm . This is in view to limit the crack width and distribution of the same.

Distribution bar at 400mm.

Ref: 1.Khanna's Handbook. Vide chapter 8 page 24.

2. Design of Concrete Members with Ribbed-Torsteel by R.Chandra from Tar-Steel Research foundation in India, Bangalore.

The code does not classify the slab whether it is for floor or roof. It adopts the same spacing to all environment. But as the roof slab is subject to more DL as well as to harsh weathering agents-Sun, rain and wind it is **suggested to provide at least 0.2% instead of 0.12% for main Tor steel.**



Some engineers propose an design the beams connecting the columns not at FLOOR level but at LINTEL level thinking there is economy by avoiding the Lintel.

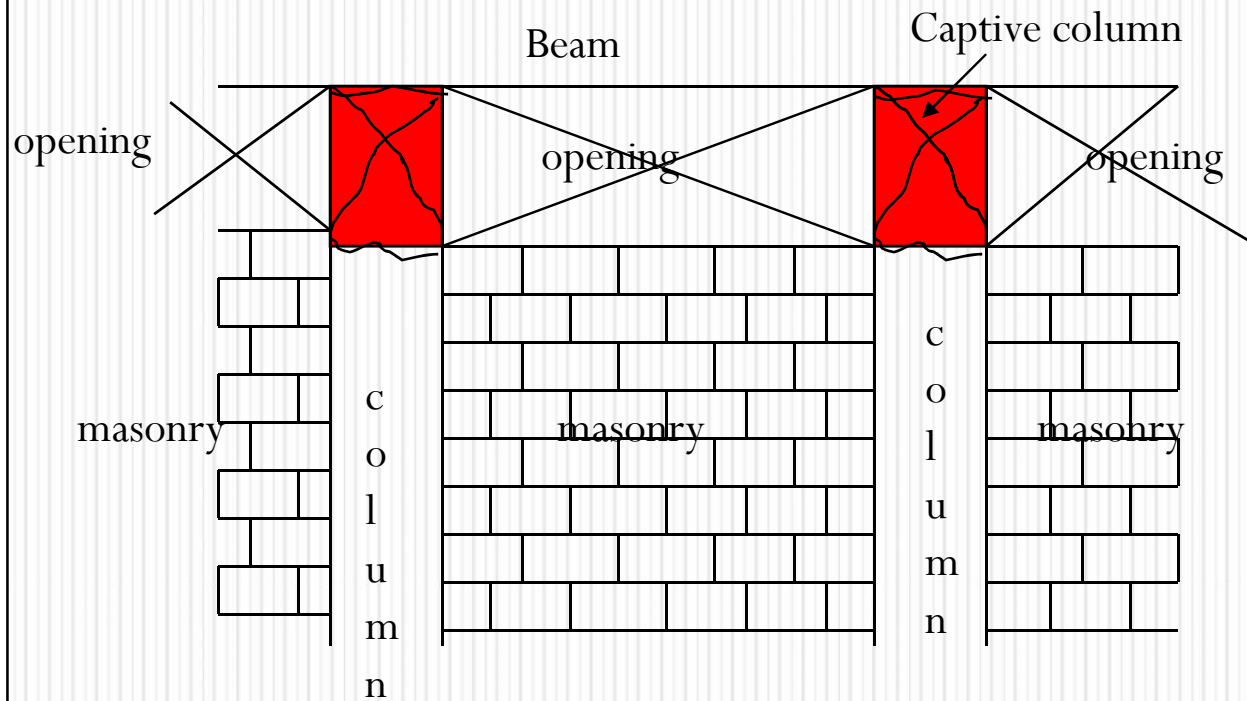
But it s not correct since the slab is now resting on the brickwall above the proposed beam and the slab which acts as diaphragm will transmit the lateral load (Wind an Seismic) through the brick wall which is not good system of load path.

This is OK for Gravity loads but not appropriate for LATERAL loads.

Few technical aspects
for Seismic

SOME SOLUTIONS TO IMPROVE THE CAPTIVE COLUMN TO AVOID DAMAGES

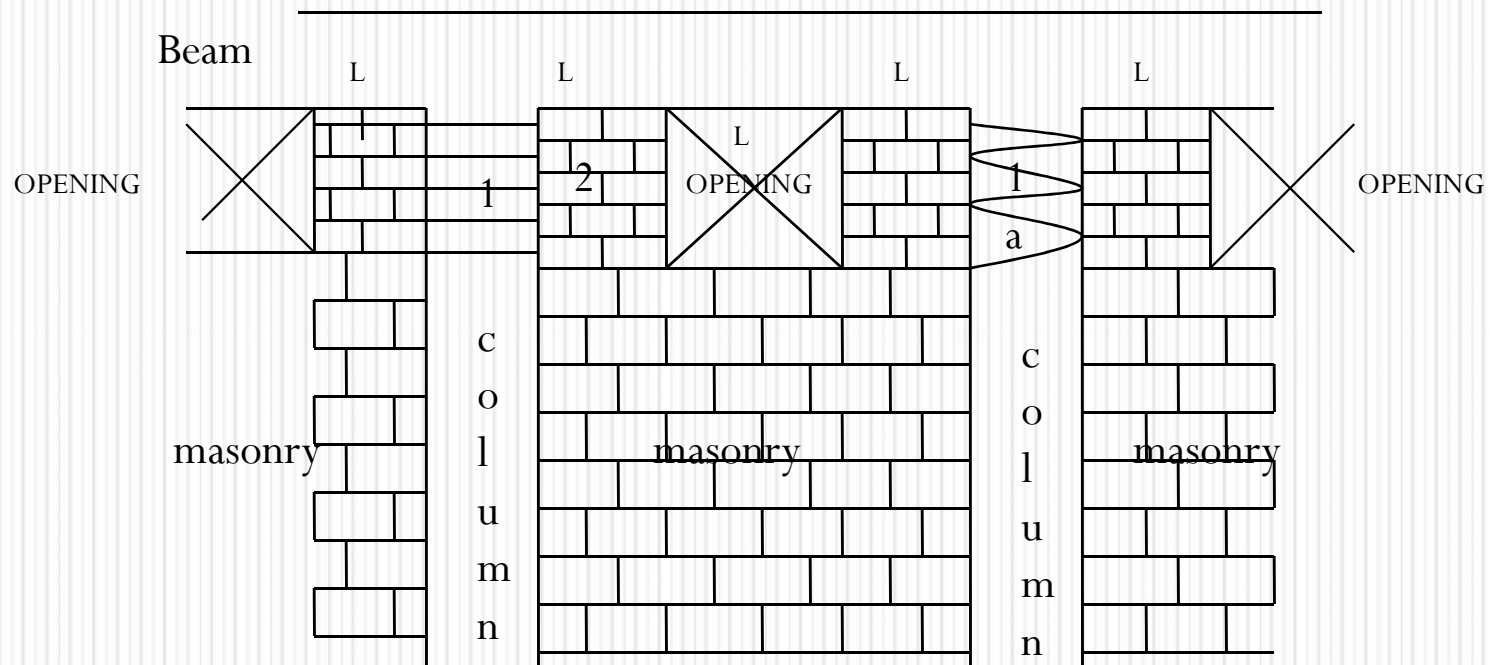
CAPTIVE COLUMNS:



Solution:

1. Add ties at closer spacing. Preferably spiral ties.
2. Provide masonry walls on either side equal to twice the opening sizes by reducing the openings.
3. The best solution is to avoid the opening so that no captive column is created.

CAPTIVE COLUMNS: SOLUTIONS.

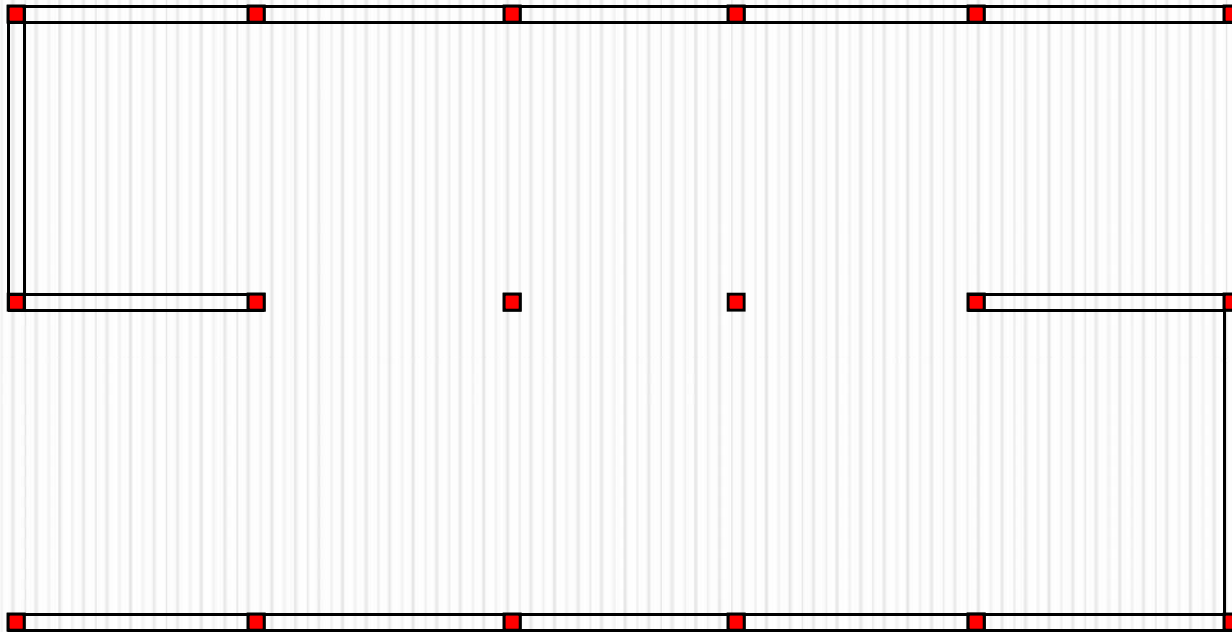


SOFT STOREY

SOFT STOREY:

This case is usually by providing car park at the ground floor.

In this case try to provide masonry walls as possible as to provide stiffness to columns.



If not possible design the columns and beams in soft storey for moments and shears by 2.5 times from the analysis results. Clause 7.10.3a –IS 1893(part1)-2002

b) Besides the columns designed and detailed for the calculated storey shears and moments, shear walls placed symmetrically in both directions of the buildings as far as away from the centre of the buildings as feasible; to be designed exclusively for 1.5 times the lateral storey shear forces calculated as before. (clause 7.10.3.b)

c) In another solution is to provide (cross bracings (in elevation)) without hindrance to vehicular movements.



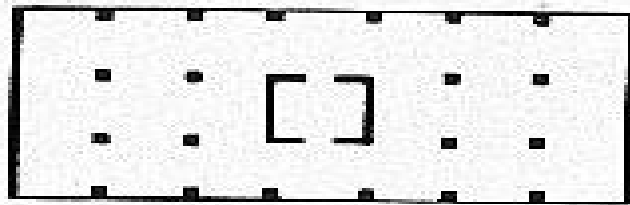
POUNDING OF STRUCTURES

To avoid POUNDING with the adjacent buildings it is necessary to separate the buildings by a distance $=2 \times 0.005 \times h$ where $0.005h$ is the admissible drift and h is the height of the building.

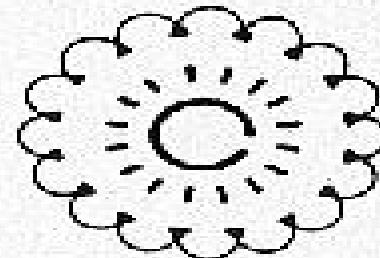
At each storey level, the height to-thickness ratio of shear walls is to be well maintained; the standard is $<635\text{mm}$ (25 in) in reinforced concrete walls, $<760\text{ mm}$ (30 in) in reinforced masonry walls, and $<330\text{ mm}$ (13 in) unreinforced masonry walls.



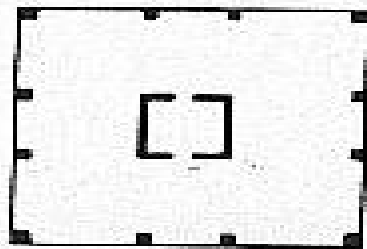
Effect of Shear Wall Location



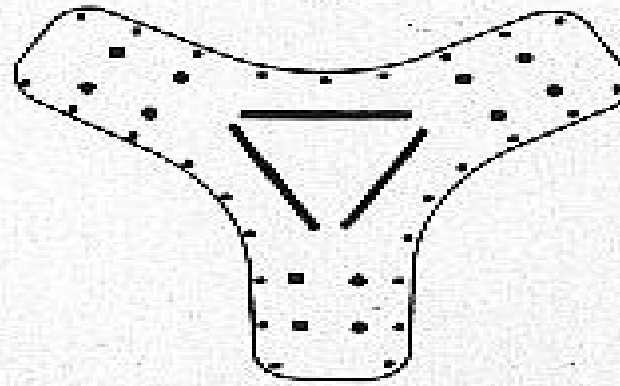
(a)



(b)

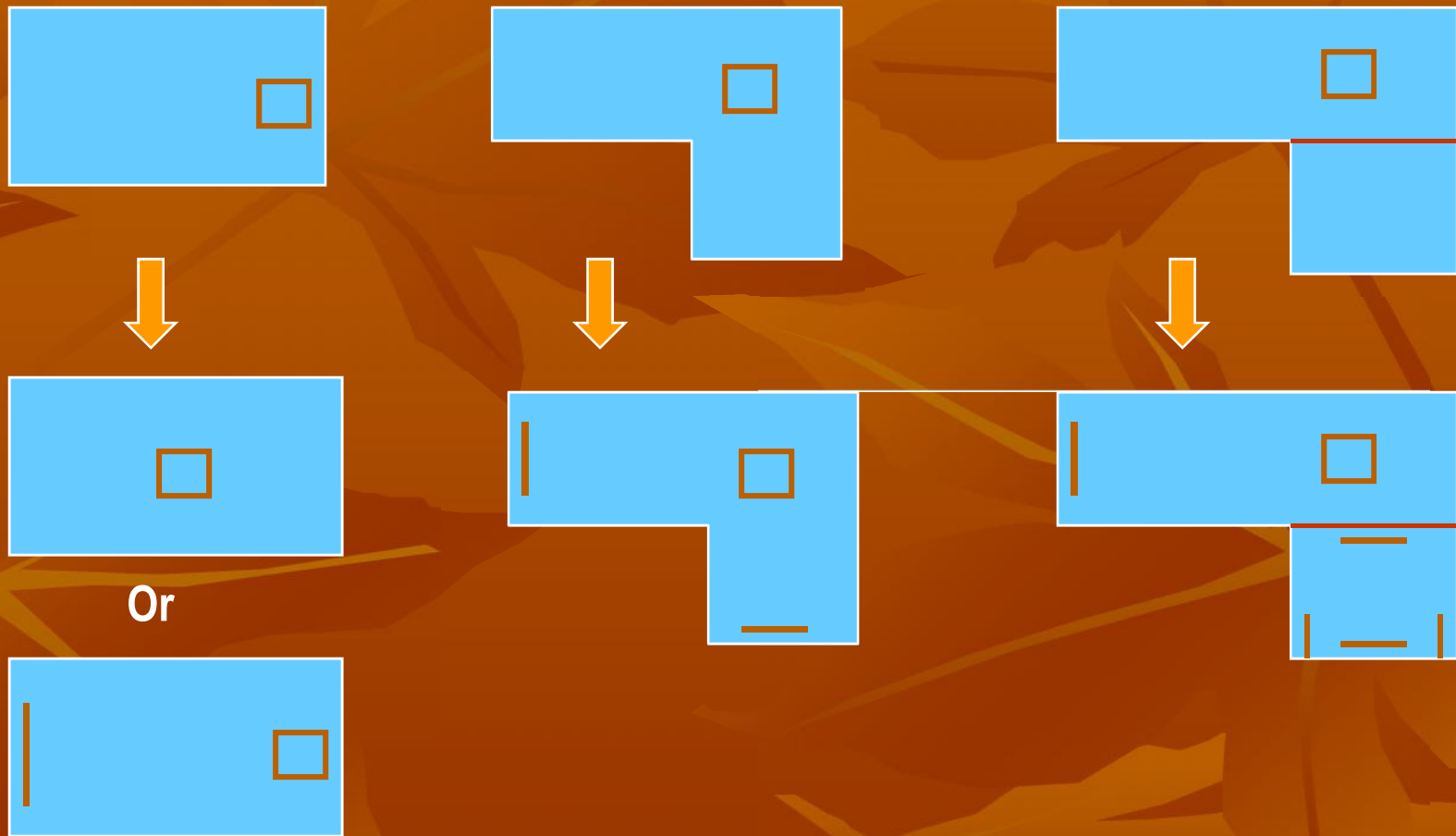


(c)

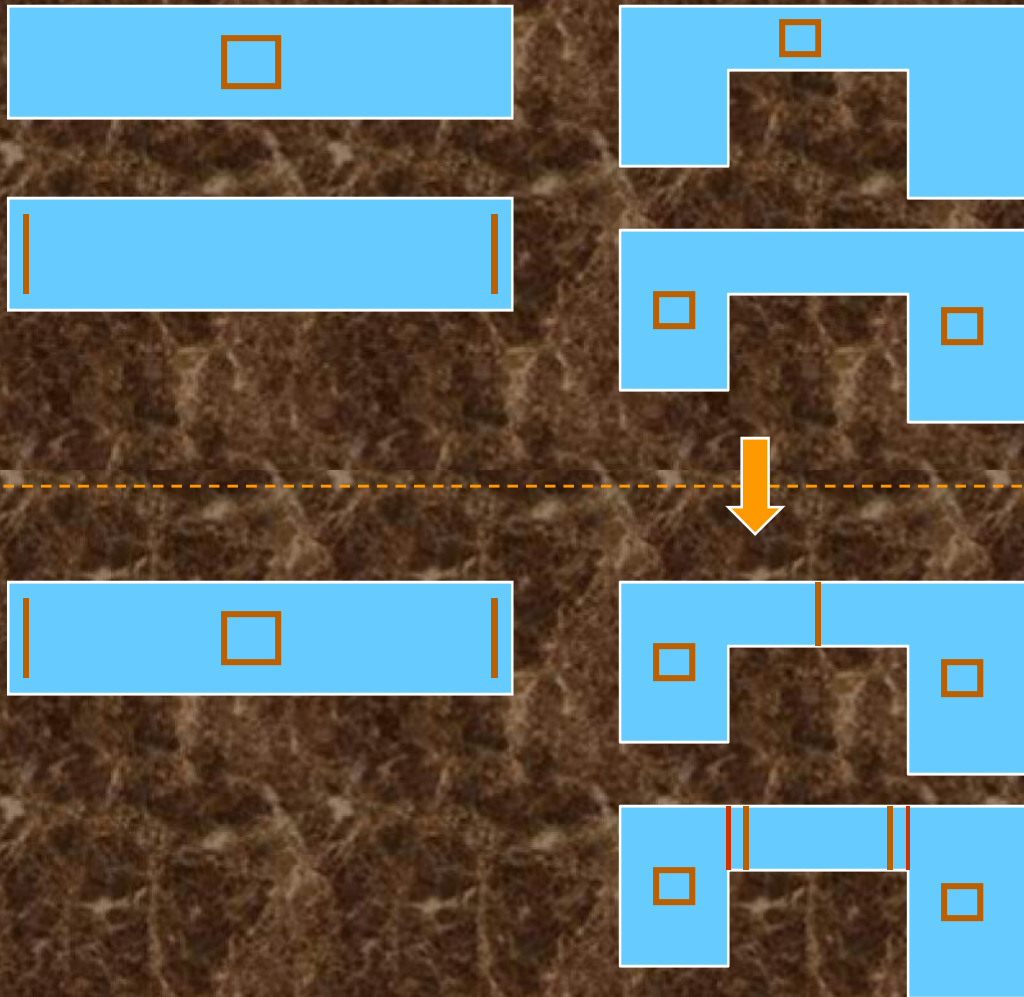


(d)

Avoid Eccentricity in Plan



Reduce In-plane Bending in Floor



REINFORCING DETAILING OF R.C.C MEMBERS

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- A design engineer's responsibility should include assuring the structural **safety** of the design, **details, checking** shop drawing.
- Detailing is as important as design since proper detailing of engineering designs is an essential link in the planning and engineering process as some of the most devastating collapses in history have been caused by defective connections or **DETAILING**. There are many examples explained in the book" **DESIGN AND CONSTRUCTION FAILURES** by Dov Kaminetzky.
- Detailing is very important not only for the proper execution of the structures but for the safety of the structures.
- Detailing is necessary not only for the steel structures but also for the RCC members as it is the translation of all the mathematical expression's and equation's results.

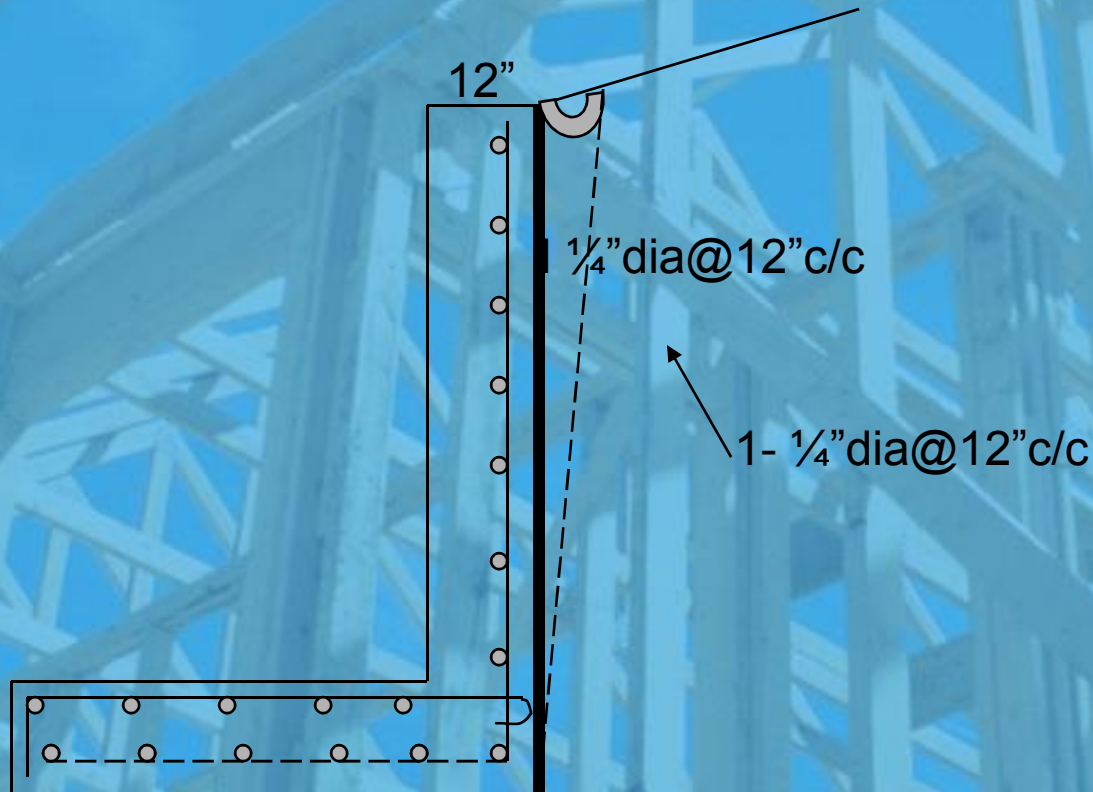


- For the RCC members for most commonly used for buildings we can divide the detailing for
 1. **SLABS-WITH OR WITHOUT OPENINGS.(RECTANGULAR,CIRCULAR,NON-RECTANGULAR-PYRAMID SLAB,TRIANGULAR ETC)**
-BALCONY SLAB,LOFT SLAB,CORNER SLAB etc
 2. **BEAMS- WITH OR WITHOUT OPENIGS.(SHALLOW & DEEP BEAMS)**
 3. **COLUMNS.(RECTANGULAR,L-SHAPE,T-SHAPE, CIRCULAR,OCTAGONAL,CROSS SHAPE etc)**
 4. **FOUNDATIONS.**
- **Detailing for gravity loads is different from the lateral loads specially for the SEISMIC FORCES.**
- **Apart from the detailing for the above there is a different detailing required for the Rehabilitation and strengthening of damaged structures.**
- **We will now dwell on the DETAILING OF MEMBERS FOR THE GRAVITY AND SOME CODAL DETAILINGS AS PER IS CODE IS 13920 AND IS 4326 AS REQUIRED FOR SEISMIC FORCES.**

DO'S & DONOT'S FOR DETAILING

- **DO'S-GENERAL**

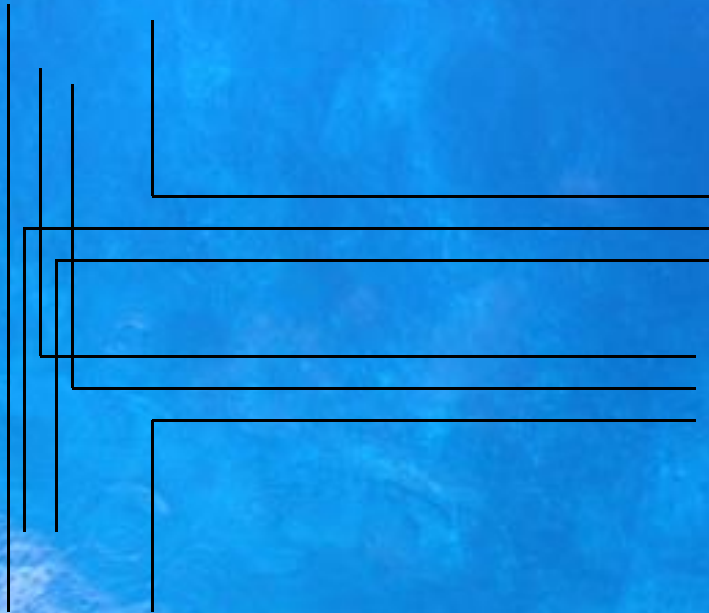
1. Prepare drawings properly & accurately if possible label each bar and show its shape for clarity.




Cross section of retaining wall which collapsed immediately after placing of soil backfill because 1/4" rather than 1-1/4" dia. were used. Error occurred because Correct rebar dia. Was covered by a dimension line.

2. Prepare bar-bending schedule , if necessary.
3. Indicate proper cover-clear cover, nominal cover or effective cover to reinforcement.
4. Decide detailed location of opening/hole and supply adequate details for reinforcements around the openings.
5. Use commonly available size of bars and spirals. For a single structural member the number of different sizes of bars shall be kept minimum.
6. The grade of the steel shall be clearly stated in the drawing.
7. Deformed bars need not have hooks at their ends.
8. Show enlarged details at corners, intersections of walls, beams and column joint and at similar situations.


9. Congestion of bars should be avoided at points where members intersect and make certain that all rein. Can be properly placed.
10. In the case of bundled bars, lapped splice of bundled bars shall be made by splicing one bar at a time; such individual splices within the bundle shall be staggered.
11. Make sure that hooked and bent up bars can be placed and have adequate concrete protection.



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12. Indicate all expansion, construction and contraction joints on plans and provide details for such joints.
 13. The location of construction joints shall be at the point of minimum shear approximately at mid or near the mid points. It shall be formed vertically and not in a sloped manner.

DO'S – BEAMS & SLABS:

1. Where splices are provided in bars, they shall be , as far as possible, away from the sections of maximum stresses and shall be staggered.
2. Where the depth of beams exceeds 750mm in case of beams without torsion and 450mm with torsion provide face rein. as per IS456-2000.
3. Deflection in slabs/beams may be reduced by providing compression reinforcement.
4. Only closed stirrups shall be used for transverse rein. For members subjected to torsion and for members likely to be subjected to reversal of stresses as in Seismic forces.

- 
5. To accommodate bottom bars, it is good practice to make secondary beams shallower than main beams, at least by 50mm.

Do's –COLUMNS.

1. A reinforced column shall have at least six bars of longitudinal reinforcement for using in transverse helical reinforcement.-for CIRCULAR sections.
 2. A min four bars one at each corner of the column in the case of rectangular sections.
 3. Keep outer dimensions of column constant, as far as possible , for reuse of forms.
 4. Preferably avoid use of 2 grades of vertical bars in the same element.
- **DONOT'S-GENERAL:**
 1. Reinforcement shall not extend across an expansion joint and the break between the sections shall be complete.
 2. Flexural reinforcement preferably shall not be terminated in a tension zone.



3. Bars larger than 36mm dia. Shall not be bundled.
4. Lap splices shall be not be used for bars larger than 36mm dia. Except where welded.
5. Where dowels are provided, their diameter shall not exceed the diameter of the column bars by more than 3mm.
6. Where bent up bars are provided, their contribution towards shear resistance shall not be more than 50% of the total shear to be resisted. **USE OF SINGEL BENT UP BARS(CRANKED) ARE NOT ALLOWED IN THE CASE OF EARTHQUAKE RESISTANCE STRUCTURES.**



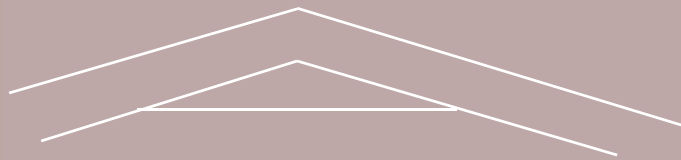
- Minimum and max.reinforcement % in beams, slabs and columns as per codal provisions should be followed.
- **SLABS:**
- It is better to provide a max spacing of 200mm(8”) for main bars and 250mm(10”) in order to control the crack width and spacing.
- A min. of 0.20 to 0.24% shall be used for the roof slabs since it is subjected to higher temperature. Variations than the floor slabs. This is required to take care of temp. differences.
- It is advisable to **not to use 6mm bars** as main bars as this size available in the local market is of inferior not only with respect to size but also the quality since like TATA and SAIL are not producing this size of bar.
- **BEAMS:**
- A min. of 0.2% is to be provided for the compression bars in order to take care of the deflection.



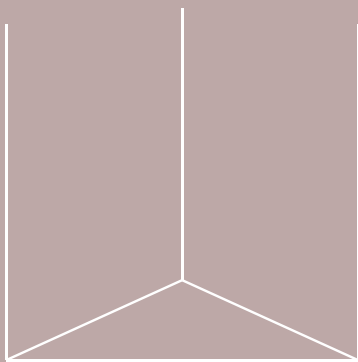
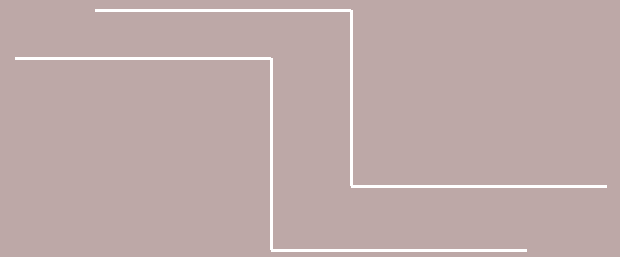
DETAILING OF SLABS.

Different shapes of slabs used in the buildings.

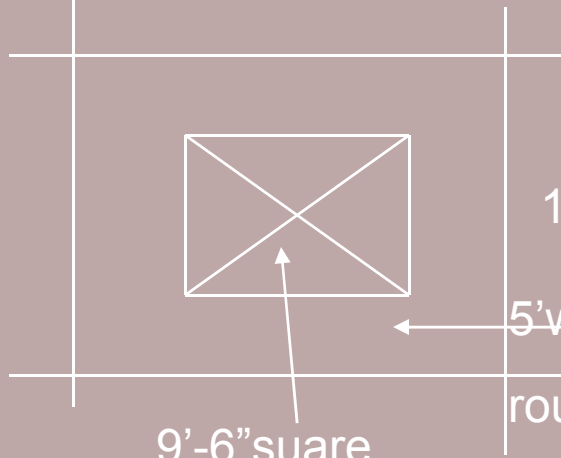
6" depression for OT & 9" for sunken slabs.



Portico slab in elevation

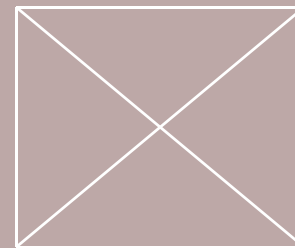


Portico slab in plan



9'-6" square opening

Portico and other rooms roof slab in plan



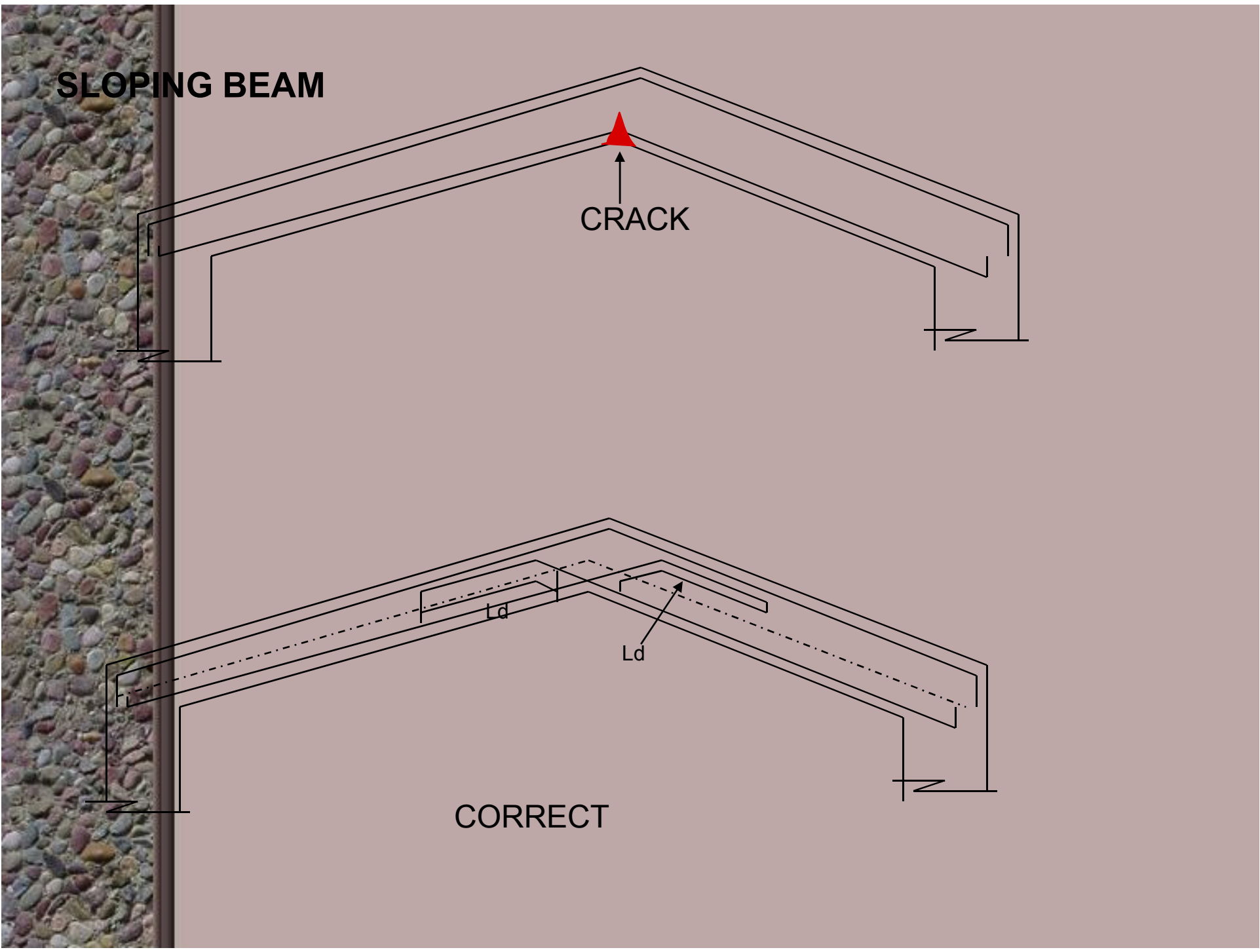


- **The stirrups shall be min.size of 8mm in the case of lateral load resistance .**
- **The hooks shall be bent to 135 degree .**

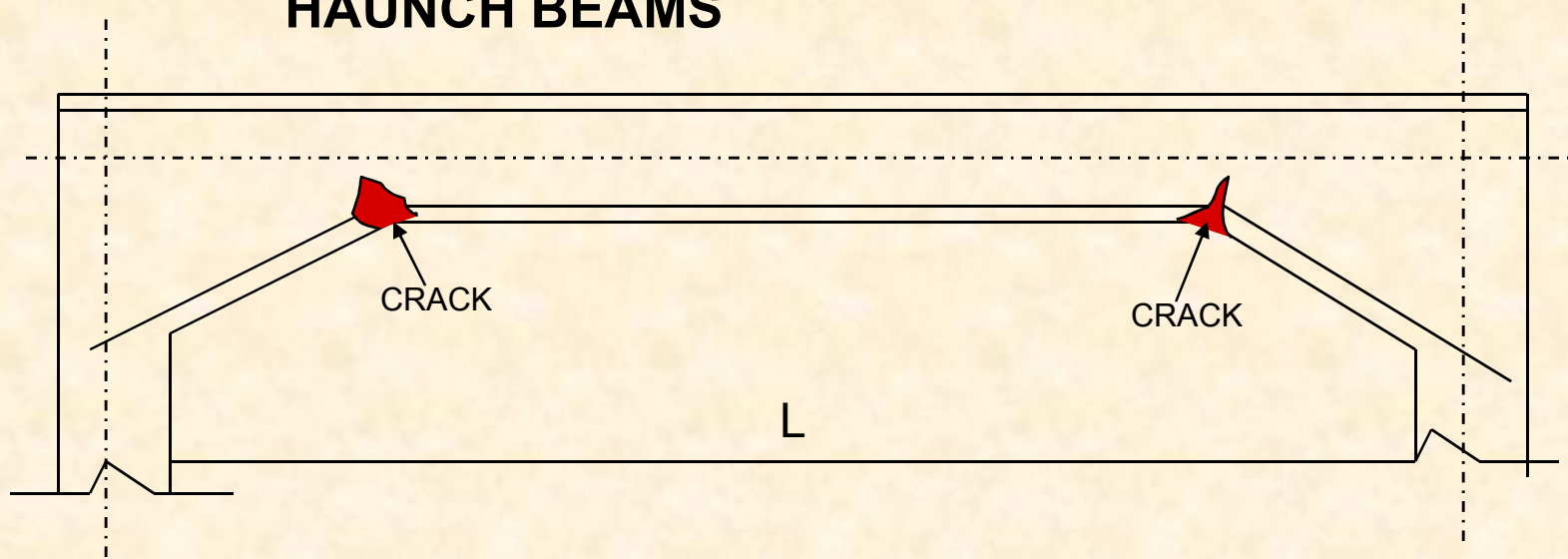
SLOPING BEAM

↑
CRACK

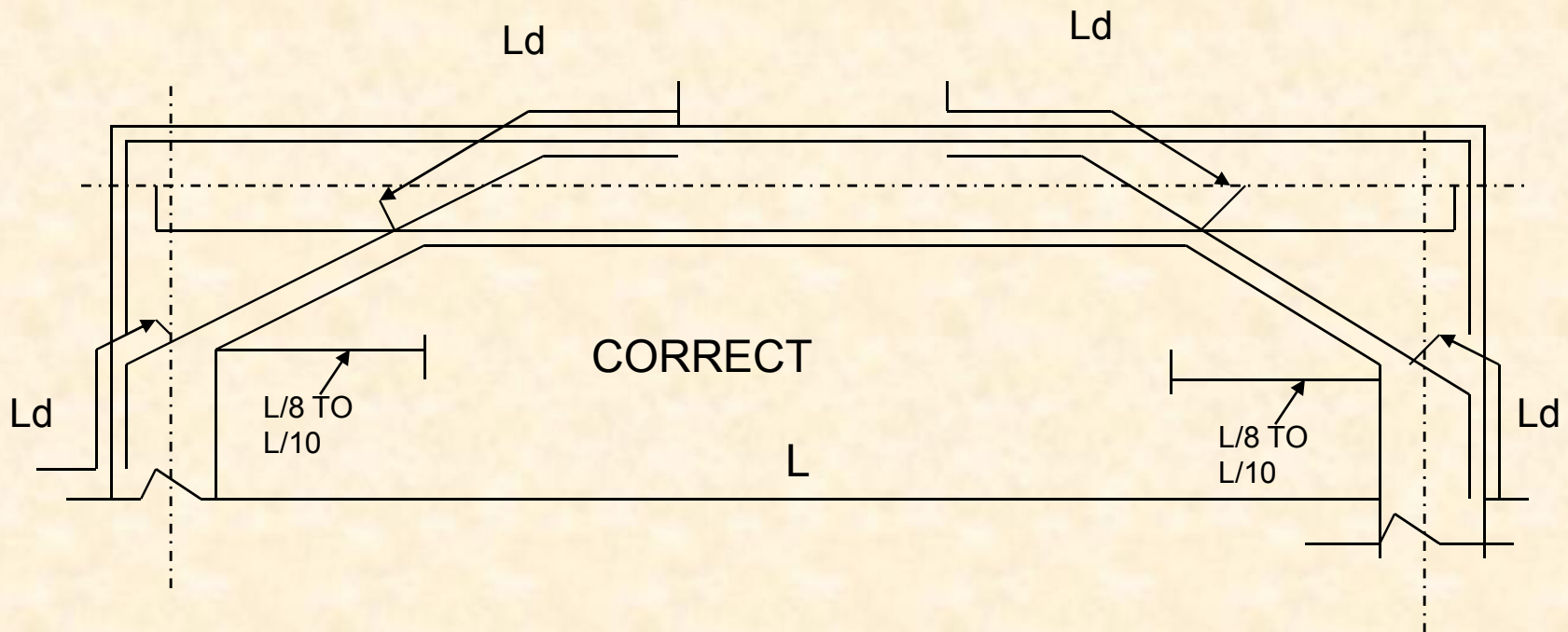
CORRECT



HAUNCH BEAMS



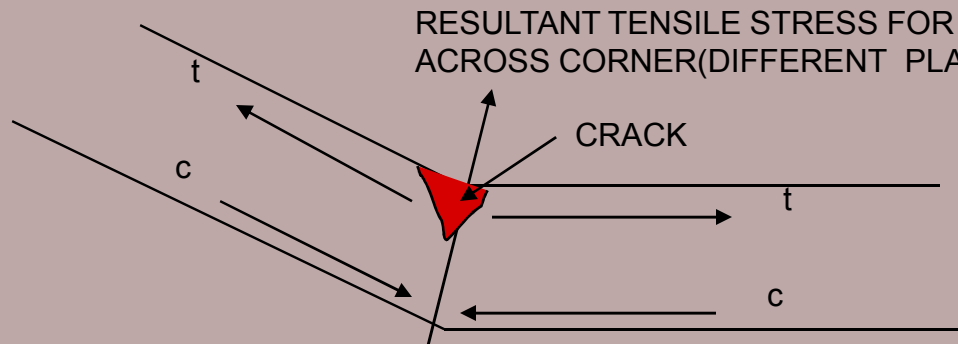
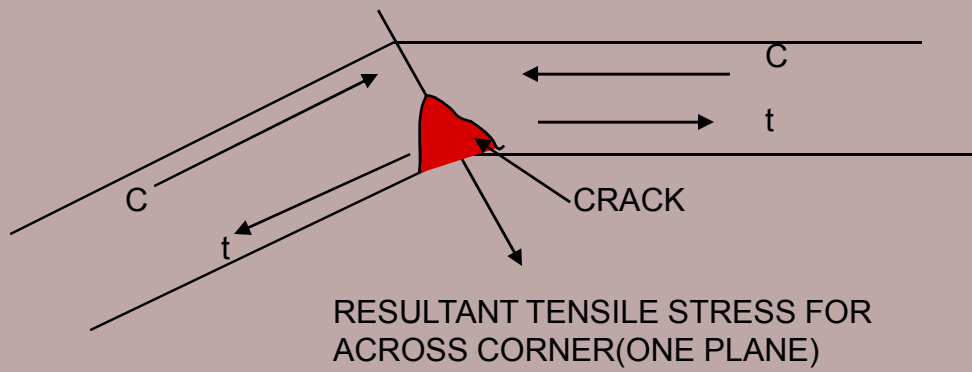
INCORRECT



STRESSES AT CORNERS

C-COMPRESSION

T-TENSION



As there is no time to elaborately explaining ,the following topics are not covered :

- 1.Flat slabs, Folded plates, shell structures-cylindrical shells, silos,
- 2.Staircases- helical staircase, central beam type, cantilever type etc.
- 3.Different types of foundations-raft, pile foundation, strap foundation etc.
- 4.Retaining wall structures,
- 5.Liquid retaining structures.
- 6.Deep beams.
- 7.Shear wall, walls.

Hope that I have enlighten some of the detailing technique for the most commonly encountered RCC members in buildings.

In the above statements if some of members can find different method or any new detailing system it will be of immense help not only for me but to other young engineers who should learn in wright ways and not wrong lessons.



REFERENCES FOR DETAILING:

- 1. HANDBOOK ON CONCRETE REINFORCEMENT AND DETAILING-SP:34(S&T)-1987.**
- 2. MANUAL OF ENGINEERING & PLACING DRAWINGS FOR REINFORCED CONCRETE STRUCTURES- (ACI 315-80)**
- 3. MANUAL OF STANDARD PRACTICE –CONCRETE REINFORCING STEEL INSTITUTE.**
- 4. TWARD BOARD MANUAL FOR RURAL WATER SUPPLY SCHEMES.**
- 5. DESIGN PRINCIPLES AND DETAILING OF CONCRETE STRUCTURES. By D.S.PRAKASH RAO.**
- 6. SIMPLIFIED DESIGN-RC BUILDINGS OF MODERATE SIZE AND HEIGHT-BY PORTLAND CEMENT ASSOCIATION,USA.**
- 7. DESIGN AND CONSTRUCTION FAILURES BY DOV KAMINETZKY.**

8. IS:2502-1963 CODE OF PRACTICE FOR BENDING AND FIXING OF BARS FOR CONCRETE REINFORCEMENT.
9. IS:1893:2000.
10. IS:4326.
11. IS:456:2000
12. REINFORCED HAND BOOK BY REYNOLD.



PRACTICAL TIPS

1)SULPHATE RESISTING CEMENT is considered INEFFECTIVE in an environment where both Sulphates and Chlorides are present.

Reason: SRC has a low content of C_3A to reduce the influence of Sulphate attack. But in an environment with both sulphates and chlorides, the C_3A in the cement reacts preferentially with the Sulphates and enough C_3A is left to bind the chlorides.

**2)The basic mechanical properties for
“Structural design” for steel reinforcement
are:**

- a) The characteristic yield strength
 - b) Ultimate tensile strength
 - c) Elongation
-

- 3) Why Fe500 and above grade of steel reinforcing bars are not allowed for members subject to SEISMIC forces?

- Reason: The bars having yield strength higher than 500N/mm^2 tend to possess lower percentage elongation which is not acceptable for Seismic prone structures since plastic hinge formation is not possible.

- 4) Do you know that:
- For steel bars to lose one mm diameter due to corrosion, it takes about 12.5 years. But due to practical reasons the number of years reduces due to hostile corrosive environment.
- For 6mm dia. To corrode completely it takes about 75 years.

- 5)Cracking levels depend on,
 - d) tensile strength of concrete.
 - e) The cover thickness.
 - f) The diameter of rebar &
 - g) Rate of corrosion.
-
- 7)Corrosion takes place only in the presence of **MOISTURE & OXYGEN.**

- 6) The relation between the cube strength & cylinder strength is
- $f'_c = 0.8 f_{ck}$ where f'_c = cylinder strength,
 f_{ck} = cube strength.

- 7) The static Modulus E_c (Mpa) in terms of characteristic cube strength f_{ck} (Mpa) ,
 - $E_c = 5000\sqrt{f_{ck}}$ N/mm², (IS code),
 - $E_c = 0.0427\sqrt{\beta^3 f'_c}$ (ACI code),
 - $= 4500\sqrt{f_{ck}}$ where $\beta = 2400 \text{ Kg/m}^3$.

- 8) Hanger bars of nominal diameter used for the purpose of holding stirrups DO NOT normally qualify as Compression reinforcement –unless the area of such bars is greater than 0.2% of sectional area of the member.
- 9) Shall we use Fe500 grade of steel for stirrups to resist the shear forces?
- **No.** Under clause c1.39.4, the IS code IS 456 limits the value of Fe 415Mpa as high strength reinforcement may be rendered brittle at sharp bends of the WEB reinforcement, also a shear compression failure could precede the yielding of the high strength steel.

10) In frame analysis, centre line dimensions of beams and columns are generally used to define the geometry of frame “line diagram”. The BM obtained is on Centre line which has to be reduced by $Vb/3$. ie $M_s - Vb/3$ where M_s is the moment at centre line and V is the shear at the centre line and b is the width of the column or beam. This enables to get lesser steel area which aids in avoiding congestion of reinforcement at the beam column joint to some extent. (vide page 309 –RC DESIGN By S.Unnikrishna Pillai and Devadas Menon.)

11)It may be clarified that **REDISTRIBUTION of MOMENTS** permitted in IS 456:2000 will be used only for **VERTICAL LOAD MOMENTS AND NOT FOR LATERAL LOAD MOMENTS.** (clause 6.2.4 of IS 13920:1993)

12) The contribution of bent up bars & inclined hoops to shear resistance of the section shall **not be** considered while designing against the **SEISMIC FORCES.** (clause 6.3.4 of IS 13920:1993)

- 13) To find the depth of RCC member from the moment for M20 & Fe 415,
- $d = 670.82 \sqrt{M/b}$ where M is Knm, b=breath of the member in mm & d is in mm.
- This is for the balanced reinforced section.

- 14) to find the steel for a singly reinforced section of M20 and Fe415,
- $A_{st} = 3077.44 * M/d$ where M in Knm,
- d in mm & A_{st} in mm^2 .
- When M/bd^2 is less than 1.27 the steel area should be calculated using the lever arm $z = 0.95d$.

15) Strength of concrete for various period are:

■ Days/months	strength
■ 7 days	2/3 of 28day strength(CP114)
■ 28 days	1.0
■ 2 months	1.1 (Table 5.1-p298-Properties of Concrete by Adam Neville.)
■ 3 months	1.16
■ 6 months	1.2
■ 12 months	1.24

16) The relation between the 28-day strength and 7 day strength which lies between as given in Germany is

- $f_{c28} = 1.4f_{c7} + 1.0$ &
- $f_{c28} = 1.7f_{c7} + 5.9$ where f_c being expressed in Mpa.
- (page 300 – Properties of concrete by Adam Neville)
- ACI RECOMMENDS
- $f_{cm}(t) = f_{28} \{t / (4 + 0.85t)\}$
- For 7 days the value comes to 0.71% of 28 days strength.
- For 3 days the value comes to 0.458% of 28 days strength.

17) For rough estimation of reinf. Steel in construction projects following thumb rules may be adopted:

- SLAB 50 TO 80Kg/m³ of concrete.
- Sunshade 50 Kg/m³ of concrete.
- Lintels 80Kg/m³ of concrete.
- Beams 100TO 150 Kg/m³ of concrete.
- Columns 150 to 225 Kg/m³ of concrete.
- Footing slab 80Kg/m³ of concrete.

Thank you

