Notes

General requirements for earthquake resistant structures :

1. No member should be smaller than 200mm
2. The width to depth ratio for no member should be smaller than .3
3. The depth of member should not be more than 1/4 of the clear span
4. The factored axial stress on the member shall not exceeed .1of Fck
5. The positive steel at any joint face must be atleast half the negative steel at that face
6. Anchorage length should be **ld+10xbar Dia**
7. The spacing of stirrups over the length 2d should not be less then the following :
    1. 100mm
    2. 8 times the dia of the smallest bar used at the junction
    3. d/4
8. The first hoop shall not be placed at a distance more than 50mm
9. Else where the stirrups can have spacing more then d/2
10. The shortest dimension for members(Beams) should not be less then 300 mm for beams longer then 5m or 4 metres of unsupported length
11. Not more than 50% of the bars shall be spliced(Overlapped) at one section.
12. Lap splices should be provided only at the central half of the member
13. Not more than 150mm spacing should be provided in stirrups in case of splices.
14. The spacing of the stirrups shall be not more than .5 x The least lateral dimension , in case of the column.
15. Design shear force shall be the maximum of the shear force of the member as per analysis.
16. Special Confining reinforcement is provided usually for the discontinuous walls on both sides of the column, where there is no wall on both the sides, this is due to the fact that the column starts behaving as short column in case of earthquake and undergoes brittle failure and hence that part of column needs to be specially confined.
17. Special confining reinforcement should be provided for the length 'lo' and lo – should not be less than -
    1. 450mm
    2. 1/6 of the original span

3. Larger lateral dimension of the member where yielding occurs

18. The column with special confining reinforcement should be provided in the column when it is terminated in the footing and it should enter atleast 300mm into the footing.
19. When the point of contraflexure is not within the middle half of the member(column), Special Confining Reinforcement should be provided over the complete column.
20. The spacing of the SCR, shall not be more than 100mm and not less than 75 mm and not less than 1/4 of the minimum member dimension.
21. Use minimum 8mm dia for SPR
22. 8 mm dia at spacing 70 mm is generally used
23. At the end of the column, from which the beams span in all the directions and all beams are having width atleast .75 x width of the respective column face, the SPR can be reduced by 50% , with spacing not exceeding 150mm.

1. Earthquake time period means when an earthquake occurs, the structure will shake at that time period.
2. In accordance with that we put the earthquake loads on the structure
3. Higher the design lateral force, more would be the stiffness
4. Earthquake displacement produces reversal of stresses due to the oscillatory displacements.But this is not the case with the wind forces. Wind forces have non zero mean Component of pressure.
5. Reversal of stresess occurs only when there are large variations of wind pressure over the large duration of time. On the other hand the motion of the ground is cyclic during an earthquake, which is about a mean position/neutral position of the structure.
6. Earthquake resistant design is not earthquake proof design.
7. Sufficient lateral stiffness is required to ensure that building does not get damaged under minor shaking.
8. The frame should be consistent under major earthquakes also, although it is allowed to get deformed or have more deflections.
9. Natural frequency of the building means that the building is continously shaking at that frequency and reversal of stresses are easily bearable by the building at the natural frequency generally.
10. Vibration analysis and mode shifts gives the information of the frequency in case of an earthquake (Vibration of the ground).
11. The property of the structure to withstand large displacements through structural damage (During earthquake generally), without collapse and undue loss of strength – is called ductility of the structure.
12. Higher the strength – more would be the ductility; this means more the characterstic strength more would be the ability to deform for the structure and good post yield deformability, provided the structure has good lateral stiffness.

13. The shape of the building needs to be convex as it has direct load transfer paths while concave buidings necessates bending of the load paths, which results in the bending of the load paths where the load paths bend.
14. When the shape of the building permits opening in the shape, the load transfer path towards the ground – bends and this case is classified as **complex structure.**
15. A building is a vertical cantiliver
16. Four virtues of the Earthquake resistant structure are :
    1. Good seismic configuration – i.e. Least complexities
    2. Lateral stiffness
    3. Lateral Strength
    4. Good overal ductility
17. Double demand of building during an earthquake -
    1. Need large deformation capacity in the building
    2. Need to sustain induced forces
18. Columns and structural walls should be stronger than the connecting beams.
19. Force based ERD involves base shear calculations and applying the base shear to the building to resist them.
20. Sa/g – is structural flexibility factor ; Seismic zone factor Z, I- importance factor to increase the elastic range of the building which hence reduces plastic deformations.
21. The net shaking of the building is the combined effect of the natural frequency and the different frequencies in which it is vibrating.- this is accounted by **Sa/g.**
22. Response reduction factor is used to reduce the cost of the building as it is more for ductile buildings and less for the brittle ones.
23. Buildings accomodating the base shear calculations of IS-1893 can be termed as earthquake resistant buildings.
24. The earthquake forces should be uniformly distributed throughout the building instead of localizing them anywhere.
25. Buildings offer least resistance when shaken with their natural frequency then at any other frequency. Therefore the amplitude of the vibration increases when shaken with natural frequency.
26. Usually increase responce can be seen at these conditions but not the resonance condition wihch can be detrimental ; reasons – earthquake does not produce only one frequency, but frequencies keep on changing at every instant of time; and second reason is – even if the natural frequency of the structure is very near to the earthquake frequency then also it requires some time to build up resonance condition, which does not happen as the frequencies of earthquake keeps on changing.
27. Increasing the column size increases the stiffness and hence increases the time period or reduces the frequency.
28. Reducing the column sizes reduces the stiffness therefore without reducing the column size we can reduce their reinforcement.
29. Havier buildings have higher natural time period
30. Natural period increases with increase in the height as the stiffness decreases as the height increases.
31. Stiffness due to URM(Un Reinforced Masonary), when considered in the model then the stiffness is greately affected and it is comparitively more affected in shorter structures than higher structures.
32. In general, lower fundamental time period attracts higher earthquake design force.
33. Higher beam flexural stiffness than the columns leads to shear type failure of beams only, for analysis. But actually they lie between flexural and shear type buildings.

34. Flexure failure is preffered in beams and beams should be carefully designed for the shear failure.
35. Shear failure occurs at the mid depth of the beams near the support and can be resisted by providing stirrups.
36. At the ends of the beams, the amount of steel provided at the bottom should be atleast half as provided at the top.
37. The bars available are generally 12-14 m in length and hence they need to be lapped somewhere inside the beam. Care should be taken that they are not lapped near the support(2d from the support) and where-ever they are lapped spacing of the stirrups is maximum 150mm.
38. To achieve ductile failure, we need to ensure that the steel reaches its failure in tension before concrete reaches failure in compression.
39. We prefer strong column and weak beam design.
40. We want to achive ductility in the overall structure, so that when it fails it elongates rather than the brittle behaviour of breaking suddenly. To do this we need to ensure the ductile members in the structure are of weaker strength than the brittle members of the structure, hence on application of tensile force the ductile member will fail first leading to the extension/elongation of the building and not brittle failure.Hence we ensure that beams are the ductile members and they are comparitively weaker.
41. Walls make the columns restrained from moving.
42. The short column is stiffer than the long column and where both the types of columns are present on same floor level then care should be taken to avoid the short column effect.
43. Short column effect leads to the more force being attracted by the short columns compared to the long columns during an earthquake and if the column is not designed for that force then they would undergo shear failure.
44. The anchorage or development length for longitudinal beam bars stopping at the column beam junction is – 50xdia of bar (for Fe415).This length is measured from the face of the column and continues till the end of the bar length.
45. Piles – under reamed – for bored cast in situ piles – we have to provide the dia of bulb to be 2.5 times the dia of the stem. These piles prevent uplift and are most suited for Black cotton soil.
46. Pile capacity depends on the following factors:
    1. Soil Strata
    2. Pile dimensions
    3. Projected area of the bulb
    4. Skin friction along the pile stem
47. The spacing of the stirrups should not be more than stem dia or 300 mm, which ever is less.
48. A minimum no. 4,10mm dia should be provided.
49. Minimum clear cover should be 40mm
50. Generally single underreamed piles are used till double storey and then we use double underreamed for further storey building, in expansive soil.
51. The bearing capacity of these piles is the sum of total skin friction and total point resistance.
52. The distance between the two underreamings is taken as -1.5 x underreaming diameter
53. The minimum center to center spacing of the piles is taken as – 1.5 x underreaming diameter. And the maximum spacing is 3 m.

54. As a result of pile-soil-pile interaction, the deflections in pile in individual pile is more and hence we use percentage factor to computer the group capacity.
55. The chance for shear occurs in the shaft between the two underreams, which can be thickened.
56. The orientation should be done primarily on the basis of maintainig the stiffness in the foundation, so that the group piles do not allow the soil to be weakened. It will act like the roots of the plants. Hence preventing the movement of the soil in the opposite directions.
57. Highly flexible soil makes the footings as good as fixed and rocky soil makes them fixed. The flexibility is generally seen in case of isolated footings.
58. This flexibility creates more chances of lateral sway in the lower storeys than in the higher storeys. The overall response of the building turns into shear type.
59. We design buildings for shear type response, which means the columns and beams fail in shear.
60. Hinged column base will lead to the higher mode shape.
61. No two periods of natural translation should be within 15% of the natural period of the largest translation.
62. Buildings consisting of the open ground floors(Stilt Storey), is problematic, as due to the increased(4 to times) stiffness of the upper storey, the buildings may fail due to the soft ground storey, the simple way we can avoid this is by making brick infills at all fourcorners,also the ground columns(soft storey columns) should be designed for 2.5 times shear and moments

63. Ultimately, we want the columns to remain stiff and beams soft, for the ductile detailing.
64. The extra length of the stirrups cross T, should be atleast 65mm or 6 times the diameter of stirrups.
65. Lift cores should not be provided at one end of the building as this may lead to high torsional shear on the columns.
66. If ductile detailing is followed, IS-13920, permits the response reduction factor to be 5, which if otherwise should be taken =3.
67. Horizontal projections should be designed to resist the vertical force, based on the vertical design seismic coefficient(IS1893,4.4.1), = half the horizontal seismic coefficient.
68. These projected member should be designed for **force =** 5 times the horizontal seismic coefficient x weight of the projection
69. All bad Construction techniques are revealed during an earthquake.Even a good design cannot escape that.
70. For the present day requirement of large colum free spaces, the periphery columns and beams should be made strong and the inner columns can be releived from the earthaquake forces.
71. Direction'x' regards to direction of the axis in softwares.
72. Shell type = in plane and out-of-plane stiffness
    Membrane type = in plane stiffness only.. think shear wall
    Plate type = out-of-plane stiffness only
73. membrane in ETABS is just for load distribution on the beams, but if you want to consider the stiffness of the slabs for the purpose of seismic analysis you need to assign it as a shell element; which will give the slab its out of plane stiffness i.e. the capacity of holding the columns together to the slab.

74. Thick shell considers the shear deformation of the slab whereas the thin shell does not, it only considers the bending deformations, although thin slabs makes the analysis faster.
75. Ordinary Moment-Resisting FrameIt is a moment-resisting frame not meeting special detailing requirements for ductile behaviour.
76. 4.15.2 Special Moment-Resisting FrameIt is a moment-resisting frame specially detailed to provide ductile behaviour and comply with the requirements given in IS 4326 or IS 13920 or SP6(6).
77. Mux(moment about major axis) AND Muz(moment about minor axis)
78. Secondary beams are just meant to offer point load on the main beams, their purpose is to transfer the load of the floor to the main beams thereby helping to support the slab.Therefore the secondary beams are also called – **Floor Beams.**
79. The main purpose of the column is to transfer load for which it is designed, so we can say whenever the column bends along its axis, that the load has been applied eccentrically.