Earthquake Resistant Architecture

Lecture 9

Seismic Design of RC Buildings

seismic design for RC structures very important when you come to the present day and in recent times as I said the reinforced concrete buildings is been become very common in India particularly in towns and cities we also discussed that basically or reinforced concrete would consist of concrete and reinforcing steel bars in concrete can be molded into any form and steel can be bent into many forms because the which multiple different types of different construction shapes are possible in RC basically we're trying to understand RC basically we were trying to understand what happens when you know a joint like this is created.

When different types of opening the cradle what happens when there are multiple openings in the same office hazard when they are like so many openings like this we will this kind of building structural stable it comes to earth quake I will be is give up when earthquake strikes is what we're trying to understand so as I discussed in the previous lectures and RC building mainly consists of beams, The Slap the columns, the foundations and the walls. so beams and RC buildings and the earthquake is a first topic that you're going to see right now so in RC building the vertical and horizontal members that is the columns and the beams are built integrally with each other if you can see a column and beam should have perfect joints each other.

When the load is produce in the slab it transfer it to the beam and from beam to assess movably transfer through the columns and then go to the foundation under the action of loads they act together as a frame transferring forces from one to another beams in RC buildings have two sets of Steel reinforcement namely long straight bars called longitudinal bars placed along the length and close bars of small diameter Steel bars call stirrups place vertically of regular intervals along with the full length we can see in this picture you can see the vertical stirrups that is smaller diameter Steel bars a that are made close rules and a place at regular intervals along full length of the beams these are the stirrups and the longitudinal bar.

This is the longitudinal bar, there is a larger diameter Steel bars that go to the full length of the beam how much ever belong The Beam is this whole thing go through and through and then I all along with that you will have such stirrups placed at equal interval.

Beam sustain into two major types of failures namely the flexural or bending failure

As A beams sags under increase loading it can fall into two possible ways is relative more steel is present on the tension face concrete crushes in compression so this is a brittle failure and is therefore undesirable.

If relatively less steel is present on the tension face the steel yields first and redistribution occurs in the beam until eventually the concrete crushes is compression ductile failure and hence it is desirable so next flexural of bending failure while talking about it more still on tension face is not necessarily desirable so the ducktail failure there is characterized with many vertical cracks starting from the structured beam face. So if you can see you can see here the flexure failure so the bottom phase stretches intention and the vertical crack develop.

It kind of bends and multiple cracks are produced in the centre the next is a shear failure in a beam may also fail due shearing reaction shear creak is in client at 45 degree to the horizontal near the support and glows towards the top and bottom freezer if you can see so you can see the shear failure that the 45 degree failure happens at 45° crack kind of happens that is an incline cracker this happens due to shear failure closed loop stirrups to avoid such shearing action shear damage occurs in the area of the stirrups Is insufficient .

Design strategy designing of beam involve the selection of its material properties that is the grades of Steel bars and concrete and shape and size they usually selected as a part of an overall design strategy of the word building and amount of distribution of Steel to be provided in the be must be determined by performing design calculation.

Longitudinal provided to resist flexural cracking on the side of the beam that stretches since both top and bottom freezer stretch during strong earthquake shaking longitudinal steel bars are required on both ways of the end and on the bottom phase of the midline.

If you can see in the picture you can see the location amount of longitudinal Steel bars in being so this particular Steel bars kind of rushes the tension due to flexure if you can see bottom steal at supports at least half of the top and you should have at least 2 bars that goes the full length that will give longitudinal bars like a mentioned before the Indian.

The Indian reptile detailing code prescribes that at least two bars go to the full length of the beam at the top as well as in the bottom of the beam like the pictures shows and at the end of the beans amount of Steel provide the bottom is at least half at the top So stirrups in RC beams helps in three ways namely they carry the vertical shear Force and therefore there is a diagonal crack. Then they protect the concrete from bulging out word towards were duplexer and they prevent the buckling of the compressed longitudinal bars due to flexure.

In moderate to seismic zones the Indian Standards describe the following requirements related to stirrups in reinforced concrete beams. SO the diameter of the stirrup must be at least 6mm long in beams more than 5 mm long it must be least 8 mm.

Both ends of the vertical stirrups be band into 135 degree hook an extended sufficiently beyond this hook to ensure that the staff stirrups does not open out in an earthquake. In this picture this is a particular 135 degree hook that I just spoke about so it's very important that the stirrups goes way longer than its needs to be because we should not open during the earthquake when the earthquake force acts so the spacing of vertical stirrups in any portion of the beam should be determined from calculation the maximum spacing stirrups is less than half the depth of the beam in this particular picture location the amount of vertical stirrups in the beam so the spacing of stirrups has to be determined in the calculation based on that space, For the length of twice at the end of the beam from the face of the column on even more stringent spacing of stirrup is specified namely of the spacing mentioned above so Steel reinforcement bars are available usually in length 12-14 m thus it become necessary to overlap the bar when the Beans of longest length are to be made as the location of the lap the bar transfer large forces from to another that such laps of longitudinal bars are made away from the face of the column not my location where they are likely to stretch by the large amount in that is bottom of the location locations of lap Vertical stirrups should be provided at a closer spacing.

Columns in RC Buildings and Earthquakes

Next Topic that we would be covering is the columns in RC buildings and earthquakes so in columns the vertical members in RC buildings that they can contain two types of Steel reinforcement again that is a long straight bars, link that is a longitudinal bar as I mention for the beam and then the closed loop of smaller diameter Steel was called a transversal ties place or horizontally at regular intervals along the full length so this also like you have only stirrups are the longitudinal vertical bars and then you have the close ties like the transfers ties.

So you should have a vertical space in between them columns can sustain two types of damage namely axial flexure or combined compression of bending and shear failure. shear failure is brittle and must be awarded in columns by providing transfer ties at close, if you can see this is one kind of failure that happen to this was the longitudinal bar and the vertical bars in this was the transverse ties, so it kind of the whole column kind of collapsed so designing a column in walls a selection of materials to be used that is the grades of concretes and steel bars are determine the shape and size of the cross section and calculating the amount and distributor Steel reinforcement the first two part of the overall design strategy of the whole building the Indian ductile detailing code requires columns to be at least 300 mm wide a column with the public 200 mm is allowed unsupported length is less than 4 meter and beam length is less than

5 columns are required to resist earthquake forces must be designed to prevention failure by skilful selection of reinforcement .

Next particular thing they will be discussing is a vertical bars tied together closely spaced horizontal fies help in three ways that is the carry the horizontal shear force is induced by earthquake and thereby resist is diagonal creaks they hole together the vertical bars and prevent them from exceedingly bending out words and in technical terms of bending phenomenon is called buckling so what happens when the vertical bars are held together at times what happen and the force acts bend outwards so this kind of creates the phenomenon called buckling with the very major in a problem when it comes to earthquake efficiency so this vertical bars when they tried together they kind of help the structure from buckling.

So if you can see in the figure contain the concrete in the column within the close loops the end of the ties we went at 1:35 degree if you can see exactly like I told about the beam stirrups again will have to provide a 135 degree hook so that the end of such no ties does not open during the earthquakes shaking so and the length of the hook should be 10 times the diameter of the tie so I a time to shear failure happens at the large spacing of ties and lack of 135 degree

Hook and them causing brittle due to failure so this is a picture from you know the Bhuj earthquake that happened in 2001 and this particular thing happen because of the large spacing of ties and is 135 hook that is 135 degree provided then. The Indian standard IS 13920 - 10993 prescribes following details for earthquake resistant columns

closely spaced size must be provided at the two ends of the columns over a link not listen larger dimension of the column as 16 the column height of 450 mm.

Over the distance specified in item above and below the beam column junction the vertical spacing of the ties in column should not exceed D/4. The D is the smallest dimension of the column spacing needs to be less than 75 mm no more than hundred mm these are the other locations ties space as per calculated one or more than D/2.

The length of the tie beyond the 135 degree bend must be at least 10 times diameter of Steel bars used to make the close ties this extension beyond should not be and should not be less then 75mm.

so I whichever bigger I like it 75 mm is bigger than the dimensions diameter than 75 mm and should be considered and the diameter 10 diameters more than 75 mm and 10 times with clear details construction Drawings with clear details of closer ties are helpful in effective implementation of construction site in columns with the spacing between the corner bar exceeds 300 mm the Indian Standard prescribes additional links with 180 degree hooks tries to be effective in holding the concrete in place and prevent the buckling of vertical bars this is links

and go around with vertical bars and horizontal close by special care is required implement it properly at site

If we can see in the picture you can see extra lens required to keep the concrete at place. Than this 180 degree links on both vertical bars and horizontal bars in both of vertical bars are required. so basically the 135 degree hook and then this 180 degree link on both the vertical again Hold and stronger.

Lapping Vertical Bars

In the construction of RC building the limitation in available in length of the bars and due to constraints in construction there are numerous occasions when Column bars have to be joint a simple way of achieving this is by overlapping with two bars at least a minimum specified length called lap length.

The lap length depends on the types of reinforcement and the concrete and so for ordinary situations it's about 50 times the bar diameter of the standard prescribed the lap length be provided only in the middle of the column and not where is top or bottom and also only half the vertical bars in the columns are to be lap time in any story so far the laps are provided types must be provided along the length of the lab and spacing time not more than 150 M.

if you can see this particular figure it shows the vertical bars been placed at close ties in the columns if you can see this also the spacing of the ties that should not be more than D/ 4 and that even if the end it should not be less than 75 mm and not more than an 100 mm so lapping of the vertical bars in the middle and of the column middle of the column looks like this.

Next is the beam and column joint will be discussing about as I said in my other lectures the place is where beam and column joint very important when Earthquake efficiency of RC building when you see as I said the lot of tension was created the forces transferred from the slap to the beam is continuously go to the column and the column transverse is the foundation and load disperses So when that happens the when the joint between the beam and the column is not strong enough then this particular load transfer won't be equal if I were to say it won't be a smooth and then it won't be equal to when that happens buckling happens and if beam kind of a bends and Falls and destruction happens in RC buildings of columns are common to beams and intersection are called beam column joint.

Since constituent materials have limited strengths joints limited force carrying capacity when force larger than they are applies during earthquake joints. Repairing them is difficult and so does be avoided So beam column joints must be designed to resist earthquake effects so you can see in this picture you can see the beam column joints at critical path of the building is much so when does overlap volume common to beams and columns so when there is overlap

volume common to Beams and columns the in the beam column joint does not properly done the buckling happen. Under and earthquake shaking the beam adjoining a join the subjected to moments in the name there is clockwise or counterclockwise direction in this picture and you can see that there are two types of action from clockwise and counterclockwise action that happen so under this moment of the beam column.

One Direction and the bottom ones in the opposite direction in this particular picture you can see other two types of person that you know about that happen so is a side of the a particular beam column joint felled in each direction so that kind of to create a problem when comes to earthquake construction so the large column with and good concrete helps in holding the beam pass together the distortion of joints causes a diagonal cracking and that's the crushing of concrete and it might as well to the following of the whole structure.

These forces a balance by Bond stress developed between the concrete and Steel in the joint region if the column is not wide enough for the if the strength of the concrete and this point is low there is insufficient group of concrete on the steel bar in such circumstances the bars left inside the join region and the beams lose their capacity to carry the load for the under the action of the about full push forces at the top and bottom and joins undergo geometric distortion one diagonal length of the joining Gates and the other compression other compression C the column cross-sectional size in some insufficient the concrete in the joint developed by diagonal cracks so what happens when the column is not a wide enough and other concrete strength is not in the joint is very low then what happens grief of the concrete and steel bars is insufficient for the whole structure to hold on so that kind of create destruction that reduces the capacity of the particular beam to carry the load so and again as I said before there is a pull and push action that happens on either Direction One side one side so when either side of the pull and other side push so when is the either side of the joints as the pulled from the directions to there in there is always a diagonal crack that can be form which is very common in places where the RC construction is not made at adherent to the earthquake norms when that happens that the diagram cracking a happens and that kind of gives up to the crossing of the whole structure.

This particular pictures shows in a straight providing horizontal ties in the join in the stage 1 you can see the beam top bars are not placed but horizontal ties in the joint region are stack dots the show in the step two you can see the top bar of the beans are inserted in the beam stirrups if you can see and beam reinforcement is lowered into the form works whole thing is stirrup and the whole thing is lowered into the form work and the stage 3 you can see the ties in the joint region are raised to the final locations tied with binding wire and column ties continued, So you can see basically will have the beam top bar and then first you are the beam

top was not place and then you are the horizontal ties stack dots and then you will have the highest place then you have the whole thing and then you have the ties in each joints kind of adding up and stacking up the complete structure of the join this is how the joint will look at joint ties will look at the joint.