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# REVISION OF IS: 13920 – A REVIEW (PART 1)

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**Abstract-** *Reinforced cement concrete (RCC) structures are designed with concrete taking only compression and steel reinforcement designed to take the tension. Hence for the enhanced seismic performance of these structures, ductile detailing of the steel reinforcement is necessary. The Indian Standard IS: 13920 - 1993 catered to the provisions for ductile detailing of RC structures subject to seismic forces, in India so far. The unsatisfactory performance of RC structures in earthquakes after 1993 developed the need to revise the existing provisions of seismic design and detailing. Hence led to the revision of the relevant codes. Following the series of revision of codes IS: 13920 has been revised recently to IS: 13920-2016. This code is mandatory for seismic resistant design in seismic zones III, IV and V. A study has been made to review the codal provisions of the revised code IS: 13920-2016, the modifications in the provisions have been described and detailed along with the reasons of modifying the provisions.*

***Index terms-*** *RC structures, ductile design and detailing, seismic resistance, IS: 13920*

## I. INTRODUCTION

The Indian standard IS: 13920 for Ductile Detailing of Reinforced Concrete (RC) structures subjected to seismic forces, was first adopted by the Bureau of Indian Standards in the year 1993. This code was developed to separate the provisions of earthquake resistant design and detailing of RCC structures from IS: 4326- 1976 [1] which was the code of practice for earthquake resistant design and construction of buildings. The performance of RCC structures designed and detailed as per IS: 4326- 1976 during the earthquakes that occurred after 1976 showed that there were many deficiencies and shortcomings in the existing provisions which needed to be corrected. Hence the development of IS: 13920 – 1993 [2].

Revision in codes is an integral and continuous process in BIS (Bureau of Indian Standards). All the codes are updated and revised from time to time according to advancements in the relevant field. IS: 13920-2016 [3] is the first revision of the code IS: 13920-1993. IS: 13920-2016 has been referred as the new code in this study. This paper is part 1 of a series of two papers. This part incorporates the changes if any in the scope, terminology, the related list of standards, general specifications, beams and column. The part 2 will incorporate the modifications in the provisions for special confining reinforcement, beam column joints, special shear walls and gravity columns.

## II. MAIN FEATURES OF IS: 13920-1993

- The deficiencies in the provisions of IS: 4326- 1976 have been corrected in this code.
- The code stresses upon providing sufficient toughness and ductility to the beams and columns to enhance their energy dissipation characteristics during earthquakes. Hence designing and detailing of beams and columns following strong column weak beam theory have been incorporated.
- RCC shear walls have been included with the provisions for their design and detailing for earthquakes.
- Minimum strengths have been specified for the materials of RCC structures.
- The minimum and maximum reinforcements have been modified. More detailed provisions have been provided for joints, splices and anchorages.
- Constrains have been applied on dimensions of structural elements.
- Seismic resistant design provisions for RCC structural walls have been provided.

## III. NEED FOR REVISION

The unsatisfactory performance of RCC structures during the earthquakes post 1993 viz. Jabalpur earthquake of 1997, Bhuj earthquake of 2001, Indian Ocean earthquake of 2004, Kashmir earthquake of 2005, Sikkim earthquakes of 2006 and 2011 posed the need to improvise the existing provisions of detailing of RCC structures. Hence the first revision of IS 13920 was taken up and has been incorporated in 2016.

 

## IV. SIGNIFICANT CHANGES

- The title includes the term 'design' along with detailing to show the importance of provisions related to sizing and proportioning of sections and calculation of reinforcements in RCC members.
- Redrafting and systematic representation has been made of most of the provisions of the earlier version of the code.
- Minimum ratio of strengths of columns and beams at a beam-column joint has been specified keeping in view strong column-weak beam theory.

## V. EXTENSION OF SCOPE

The scope of this code has been extended to include all lateral load resisting systems of monolithic reinforced concrete (RC) structures located in seismic zones III, IV and V including RC moment resisting frames, RC moment resisting frames with unreinforced masonry infill walls, RC moment resisting frames with RC structural walls and RC structural walls. The code now includes flat slab structures and suggests that they must also have a lateral load resisting system capable of giving a performance similar to that referred in this standard. However for their design, the code suggests to use specialist literature alongwith required experimentation and non linear dynamic analysis.

The code also gives the freedom to the designers to select the elements that form a part of the lateral load resisting system which are required to be designed as per this code. The code also emphasizes to consider the effect of other elements including structural and non structural elements on the seismic response of the structure.

## VI. ADJUNCT REFERENCES

The list of standards adjunct with this code is now extended to included IS 1343 [4], Parts 1, 2 and 4 of IS: 1893 [5], [6], [7], IS: 4326 and IS: 16172 [8] along with IS 456 [9] and IS: 1786 [10] which were already there. The code encourages using the latest revisions of these standards.

## VII. ADDITION IN TERMINOLOGY

The definitions in the new code include some new names viz. beams, columns, cover concrete, gravity columns and special shear walls. The gravity columns is a new term for the standard which refers to those columns which do not form a part of the lateral load resisting system and are designed only for forces due to gravity loads. The definitions of links which were earlier named hoops, moment resisting frames (MRFs) including special and ordinary moment resisting frames and shear walls have now been modified and are more easily understandable. The terms cross tie, curvature ductility and shell concrete have now been dropped from the definition section of the new code. Though cross ties have been referred in further sections of the code.

## VIII. GENERAL SPECIFICATIONS

Minimum grade of concrete is now M20 for any building and M25 for buildings with height > 15 m and located in seismic zones III, IV and V. This grade will be higher subject to exposure conditions mentioned in IS 456. Higher grades of concrete facilitate ductile behaviour [11].

The reinforcement grades required are the same but two conditions are added. Firstly the actual 0.2% proof strength of the steel bars obtained from tensile test should not exceed their characteristic 0.2% proof strength by more than 20%. This is to avoid the shear or bond failure prior to the formation of flexural hinge. This may hamper the concept of capacity based design. Secondly the actual ultimate strength should be atleast 1.15 times the actual 0.2% proof strength. In such a case the plastic moment will also exceed the yield moment with a similar ratio thus increasing the length of yield zone which is required for the inelastic rotation capacity of the element.

The code suggests not to extend the lintel beams upto the adjacent columns so as to avoid the short column effect which attracts high shear during earthquake. But if they are extended they should be modeled in the same way as they are provided, for the purpose of structural analysis. The same applies to the staircase beams and slabs also.

The code suggests providing regular plans avoiding irregularities along both orthogonal directions for RC regular MRFs. The code IS 1893 (Part 1) – 2016 [5] lists these irregularities which when present, the detailed non-linear analysis of the frame is required.

 

## IX. REVISION IN PROVISIONS FOR BEAMS

The title of the section for beams has been revised from 'Flexural Members' to 'Beams'. It applies to those beams which are subjected to factored axial compressive stress upto 0.08 $f_{ck}$. Here $f_{ck}$ is the characteristic compressive strength of concrete. This limit was $0.1f_{ck}$ earlier.

Limit has now been applied to the maximum width of the beam which is as follows:

$b_w \leq [c_2 + 2x]$ where $b_w$ is width of beam,

$c_2$ is width of supporting member

$x$ = minimum $[(c_2); (0.75c_1)]$ where $c_1$ is the lateral width of supporting member (dimension perpendicular to $c_2$ in the same plane].

This limit has been applied to ensure that atleast 75% of the longitudinal beam reinforcement is within the core of column, for effective column compression necessary for the beam bars passing through the joint [11].

The code also provides a figure showing the details of transverse reinforcement for the beam whose width exceeds $c_2$.

**Beam longitudinal reinforcement**

Minimum two 12 mm bars are provided at top and at bottom of beam throughout the length to take care of moment reversal in the event of an earthquake. This provision existed earlier too but the minimum diameter was not specified.

The clause for minimum and maximum reinforcement ratios remain the same but for beams framing into column, it is now required that the longitudinal reinforcement at the bottom face should be atleast equal to half the steel at the top face at the same section. The clause for redistribution of moment for vertical moment has been dropped.

There was a clause earlier for internal joint where both face bars of beams were to be taken continuously through the column. This clause has now been dropped.

The provisions for lap splices are the same with only one clarification that more than 50% of area of bars on either top or bottom face shall be not be spliced at any one section. Earlier the code had not clarified top or bottom or both faces.

**Mechanical Couplers**

The provisions for mechanical couplers have been added in the new code. They have been permitted to be used where span of beam is greater than the manufactured length of longitudinal bars.

The mechanical splices should conform to IS: 16172. Only those mechanical splices are permitted which would be able to develop strength equal to the specified tensile strength of the spliced bars for the following locations:

- Distance = twice the depth of member from the member face.
- Locations where there are chances of yielding of reinforcement.

The spacing between the adjacent longitudinal bars should be based also on the outer size of the coupler. This has been done to allow an easy flow of concrete.

**Welded splices**

The code now clarifies the use of mechanical splices. They shall be used except for the following location:

- Distance = twice the depth of member from the member face.
- Locations where there are chances of yielding of reinforcement.

Provision of not greater than 50% of the area of bars being spliced at a section is applied here too.

The code does not allow the welding of links, ties, inserts or other similar elements to vertical reinforcement bars for any seismic zone. This has been done to prevent any local brittle failure of weld.

**Transverse reinforcement**

The term 'hoops' in the earlier code has now been replaced with the term 'links'. Some slight modifications have been made. The minimum diameter of the link has been increased from 6 mm to 8 mm regardless of span of beam. The extension of $135^o$ hook is now 6d ( $\geq$ 65 mm) in place of 10d ($\geq$75 mm), where d is diameter of bar. The end of cross ties has been modified to $90^o$ hook of length 6d ( $\geq$ 65 mm) on one side and $135^o$ bend at the other.

The calculations of design shear force demand and design shear force capacity are the same as earlier version of code. The earlier notation of $M_{u,lim}$ is replaced by $M_u$ (ultimate moment) in consistence with IS: 456 – 2000. The provisions for spacing of links are also the same.

## X. REVISION IN PROVISIONS FOR COLUMNS AND INCLINED MEMBERS

The term 'inclined members' have been added in this clause to make it more widely applicable. This section of code governs those earthquake resisting columns and inclined members which are subjected to factored axial compressive stress $\geq$ 0.08 $f_{ck}$, due to gravity and earthquake loading. This value was earlier 0.1 $f_{ck}$. The maximum axial compressive stress due to all load combinations shall be 0.4 $f_{ck}$.

The code also clarifies that these provisions are applicable to rectangular and circular columns only. Specialist literature needs to be referred for columns of other shapes like T, X etc.

 

**Dimensions of Column**

The requirements for minimum dimensions of column have been made more stringent now. The minimum dimension was 200 mm earlier. Less column width leads to less moment capacity of column section and less space for anchorage of beam bars. Hence the minimum dimension has now been increased to greater of 300 mm and 20 $d_b$ where $d_b$ is diameter of largest longitudinal beam bar anchoring into the column at the joint.

The ratio of the smaller to the larger dimension of cross-section of column or inclined member should be atleast equal to 0.45. Earlier this value was 0.4. Larger aspect ratio leads to better confinement of concrete.

**Relative Strength of Beams and Columns at a Joint**

This provision has been added in the new code to incorporate the strong column weak beam concept so that the failure of building occurs by beam mechanism and not by storey mechanism. Storey mechanism causes early failure of columns which creates more damage in the building. Hence the columns need to be designed stronger than beams meeting at any joint.

To incorporate this concept, the code has given a provision that the sum of the nominal design strength of columns meeting at a beam column joint along each principal plane should be atleast 1.4 times the sum of nominal design strength of beams meeting at that joint in the same plane. The nominal strength of column must be calculated for the factored axial load in the direction of the lateral force under consideration so that the least column nominal design strength is obtained.

The code also mentions that the design moment of resistance of any beam should be calculated considering the limit state theory and as per IS 456. The design moment of resistance of any column should be calculated as for beams corresponding to zero axial force on the load – moment (P – M) interaction curve for column. Also the design moments of resistance in all the beams meeting at the joint should be considered in the same direction while the design moments of resistance of columns at that joint should be considered in the direction opposite to that of the moments in the beams.

If this above provision is not satisfied at a particular joint then the columns meeting at that joint will be considered as gravity columns and not considered as a part of the lateral load resisting system.

This check has to be made at each joint for both positive and negative directions of shaking in the plane considered.

If the building has more than 4 storeys, then this check is not required at all joints at roof level only. Also this check is not required for flat slab structures.

**Longitudinal reinforcement**

The code IS 456 used for design of RC structures suggests minimum 6 bars for circular columns. The same clause had been added to the new code. This ensures better confinement of concrete.

**Lap splicing**

There are many modifications and additions in this part of the section. The term ‘links’ has replaced the term ‘hooks’ for columns also in the new code. They were to be provided over the entire splice length at a maximum spacing of 150 mm centre to centre. This maximum spacing has been reduced in the new code to 100mm centre to centre. Also the new code requires the lap length to be atleast equal to the development length of the largest longitudinal bar in tension.

The code has also added that the lap splices should not be provided within a joint or within a distance of 2 times the effective depth of the beam from the face of the beam. Also lap splicing can be done for maximum 32 mm diameter bars. Above this diameter, mechanical splicing should be used.

**Mechanical Couplers**

The provisions for mechanical couplers are similar to those mentioned for beams. The mechanical splices should conform to IS 16172. Only those mechanical splices are permitted which would be able to develop strength equal to the specified tensile strength of the spliced bars. They shall be provided for the locations where there are chances of yielding of reinforcement and within a distance equal to twice the depth of member from the face of the column.

**Welded Splices**

The provisions for welded splices in columns are exactly similar to those mentioned for beams. The code now clarifies the use of mechanical splices. They shall be used except for the following location:

- Distance = twice the depth of member from the member face
- Locations where there are chances of yielding of reinforcement.

Provision of not greater than 50% of the area of bars being spliced at a section is applied here too.

The code does not permit the welding of links, ties, inserts or other similar elements to vertical reinforcement bars for any seismic zone. This has been done to prevent any local brittle failure of weld.

**Transverse Reinforcement**

The extension of the $135^o$ link has been reduced to 6 times the diameter of bar and not less than 65 mm, at each end, in the new code, in place of 10 times the diameter of the bar (not less than 75 mm) in the earlier version of the code.

The clause for minimum diameter of transverse reinforcement bar has been added in the new code for rectangular links. The minimum diameter of transverse reinforcement bar is 8mm for longitudinal bars $\leq$ 32 mm and 10 mm for

longitudinal bars > 32mm. The provisions for maximum permissible spacing of these bars and of the parallel legs of the links are the same as in the earlier version of the code.

The diameter of bars forming cross ties should be less than or equal to the diameter of bars forming the links.

## XI. CONCLUSIONS

The revision of codes is a periodic process which results from continuous and systemic research in the related field. IS: 13920-2016 is the first revision of the code on ductile detailing of RC structures subject to seismic forces. The first revision has added some design aspects also along with detailing. The provisions of earlier code have been suitably modified keeping in view more strength and stiffness and enhanced energy dissipation in the event of an earthquake along with ductility for seismic resistance of structures. The revised code will lead to major modifications in beam-column design owing to the inclusion of strong column-weak beam theory.

## XII. REFERENCES

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