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COMPARATIVE STUDY OF CODAL PROVISIONS IN IS 1893 (PART 1): 2002 & IS 1893 (PART 1): 2016

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ABSTRACT

The clauses provided in seismic code guide the designers to improve the behaviour of structures during an earthquake & withstand against it without significant loss of life & property. For India, Indian Standard Criteria for Earthquake Resistant Design of Structures (IS 1893 Part 1) provides the required clauses to structural designers for designing earthquake resistant buildings. As a result of continuous research, gained knowledge & experiences, the IS 1893 Part 1 has been revised whenever required. The comparative study of codal provisions is required to be made whenever the code is revised. This paper contains the comparative study of an IS 1893 (Part 1):2002 & IS 1893 (Part 1):2016. The paper mainly focuses on the revised codal provisions in IS 1893 (Part 1):2016.

Keywords: Earthquake Resistant Design, Irregularity, Revised clauses, Seismic Analysis

I. INTRODUCTION

The seismic codes are prepared with consideration of seismology of country, accepted level of seismic risk, properties of construction materials, construction methods, and structure typologies etc. Furthermore, the provisions given in seismic codes are based on the observations, experiments & analytical case studies made during past earthquakes in particular region. In India, IS 1893 (Part1) Criteria for Earthquake Resistant Design of Structures is used as code of practice for analysis & designing of earthquake resistant buildings. In the last decade, the detailed & advanced research, damage survey was carried out by the Earthquake Engineering Sectional Committee of Bureau of Indian Standards. As a result, the huge data regarding behaviour of various types of structures during earthquake was collected which gained the knowledge. This continuous effort has resulted in revision of IS 1893 (Part 1): 2002 [1]. Hence the sixth revision of IS 1893 (Part 1) was published in 2016. To implement the latest code in practice, it is necessary to understand the revised codal provisions in IS 1893 (Part 1):2016 [2] with respect to IS 1893:2002. The paper aims to give brief idea about the revised clauses in latest seismic code.

II. LITERATURE REVIEW

IS 1893 (Part 1): 2002 [1] have mentioned the methods, parameters which are required in analysing & designing of earthquake resistant structures, especially buildings.

IS 1893 (Part 1): 2016 [2] have mentioned general provisions, terminologies, analysis methods & designing parameters for earthquake resistant buildings.

S.K. Ahirwar, S.K. Jain & M.M. Pande [3] presented a comparative study of seismic loads on four multi-storey RC framed buildings (3 storey, 5 storey, 7 storey & 9 storey) as per IS 1893- 1984 & IS 1893- 2002 codal recommendations. In this paper seismic coefficient, response spectrum & modal analysis methods were adopted to compute the seismic forces on these buildings. The conclusion includes comparison of lateral load & base shear for each building calculated as per both mentioned IS codes.

K. Rama Raju, A. Cinitha & Nagesh R. Iyer [4] carried out a non linear seismic analysis of 6 storey building frame in SAP 2000. The building was constructed as per past code of practice. The four load cases given in IS 456 & IS 1893 were used for pushover analysis. The study of distribution of lateral forces for each load case, comparison of base shear & roof displacement is carried out. Authors observed a significant variation in base shear capacities and hinge formation mechanisms for four design cases.

Azhar Bagadia [5] compared the response of industrial structure as per IS 1893-1984 with IS 1893 Part 4 -2005. The model of composite structure of RC framed building with steel roof truss was analysed in STAAD Pro software as per both mentioned codal provisions. The results showed that the displacement & base shear values given by analysis as per IS 1893 part 4-2005 are much less than that given by analysis as per IS 1893-1984.

Dr. H. Sudarsana Rao [6] compared lateral forces calculated as per the provisions of IS 1893- 1984 & IS 1893-2002 for two buildings, one is of 12 stories in area which was in zone I but later on upgraded to zone II, & another building is of 11 stories situated in zone II. The STAAD Pro software was used for analysis of both case studies. Author concluded that the forces calculated as per IS 1893-2002 gave higher values than the previous version of building in zone I upgraded to zone II. The observation made that the base shear value as per revised IS 1893-2002 is higher for structures in zone II.

III. OBJECTIVES

1) To study the clauses provided in IS 1893 (Part1): 2016, & compare them with clauses provided in IS 1893 (Part1): 2002.

2) To highlight the revised clauses in IS 1893 (Part1): 2016 which will help designers to understand new code in simple & quick manner.

3) To motivate the designers to use latest seismic codes so as to generate valuable data for research regarding provisions made in new seismic codes.

4) To motivate faculties to teach the respective subjects with revised seismic codes & latest practical knowledge.

IV. METHODOLOGY

The comparison of clauses given in IS 1893:2002 [1] & IS 1893:2016 [6] simply give the revised & newly added clauses in latest code. The present study focuses on the revised & newly added provisions in IS 1893:2016 regarding general principles & design criteria.

V. REVISIONS IN IS 1893 (PART 1) 2016

As per the clause 1.2 & 1.3, the parking structures, security cabins, ancillary structures, scaffolding, temporary excavations are need to be designed for seismic forces.

The clause 6.1.3 expects to design the structures for at least the minimum design lateral force specified in Table 7 of standard, which is newly added in latest version of code. The clause 6.3.1.1 from latest code expects to adopt provisions for earthquake resistant design, ductile detailing & construction related to seismic conditions as per the standard even when load combinations that do not contain seismic effects but indicate larger demand than combinations including the seismic effects.

As per the clause 6.3.3.1, the structures located in seismic zone IV or V, structures which has plan or vertical irregularity, structures founded on soft soils, bridges, structures with long spans or with large lateral overhangs of structural members are required to consider the effects due to vertical earthquake shaking in load combinations. The load combinations for three directional earthquake ground shaking are mentioned in clause 6.3.4.

When seismic forces are considered, net bearing pressure in soils can be increased, depending upon type of foundation & type of soil. To determine the type of soil for this purpose, soils are divided into four types which are mentioned in Table 2 of the new standard.

In IS 1893 (Part1): 2016, the design spectra are defined for natural period up to 6 seconds & separate for equivalent static method & for response spectrum method. The Fig. 2 in the standard shows these graphs of design acceleration coefficient corresponding to 5% damping. Hence, the clause 6.4.2 mentions the expressions for determination of design acceleration coefficient (S_a /g) for use in equivalent static method as well as use in response spectrum method. The table 4 in new standard deals with the classification of type of soil on which structure can be founded. It is used to be in the determination of correct spectrum, to calculate the S_a/g.

As per the clause 6.4.3.1, for structural analysis, the moment of inertia shall be taken as 70% of gross moment of inertia of columns & 35% of gross moment of inertia of beams in case for RC & masonry structures. The gross moment of inertia can be considered for columns & beams in case of steel structures.

The Table 5 in the standard deals with the definitions of plan irregularities with respect to clause 7.1. This table states the limits on irregularities for seismic zone III, IV & V. According to this, the building is said to be torsionally irregular when the ratio of maximum lateral displacement at one end & the minimum lateral displacement at other end is in the range of 1.5 to 2. If it is more than 2 the building configuration shall be revised. The code states to carry out three dimensional dynamic analysis for buildings with re-entrant corners. In buildings with Out of Plane Offsets in vertical elements, the lateral drift shall be less than 0.2% in the storey having the offset & in the storey below.

The Table 6 in the standard deals with the definitions of vertical irregularities with respect to clause 7.1. According to this, the soft storey is a storey whose lateral stiffness is less than that of the storey above. Also when the seismic weight of any floor is more than 150% of that of the floors below, the mass irregularity shall be considered to exist. The vertical geometric irregularity considered to exist when the horizontal dimension of lateral load resisting system in any storey is more than 125% of the storey below. The In-plane discontinuity in vertical elements resisting lateral load shall be considered to exist when in-plane offset of lateral force resisting elements is more than 20% of the plan length of those elements. The buildings with in-plane discontinuity are not permitted in seismic zone III, IV & V. The code states that features like floating columns & stub columns are undesirable & prohibited if it is the part of primary lateral load resisting system.

The code expect to ensure that the first 3 modes together contribute at least 65% mass participation factor in each principal plan direction & the fundamental natural periods of the building in the two principal plan directions are away from each other by at least 10% of the larger value, to avoid the irregular modes of oscillation in two principal plan directions.

In IS 1893 (Part1): 2016, Table 8 enlists the values of Importance factor depending upon the use, occupancy & service provided by the structures. The important factor value "1.2" is introduced for residential or commercial buildings with occupancy more than 200 people.

The Table 9 in code deals with Response Reduction factor R for various lateral load resisting systems. Five types of lateral load resisting system & their respective R values are mentioned in the table which are, Moment Frame systems, Braced Frame Systems, Structural Wall systems, Dual systems, and Flat slab – structural wall systems. According to the code, followings are the revised & newly added types of load resisting systems & their respective R values.

Steel Buildings with OMRF – 3.0

Steel Buildings with SMRF – 5.0

Buildings with ordinary braced frame having concentric braces – 4.0

Buildings with special braced frame having concentric braces – 4.5

Buildings with special braced frame having eccentric braces – 5.0

Unreinforced masonry with horizontal RC seismic bands – 2.0

Unreinforced masonry with horizontal RC seismic bands & vertical reinforcing bars at corners of rooms & jambs of opening (with reinforcement as per IS 4326) – 2.5

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Confined masonry – 3.0

Buildings with ductile RC structural walls with RC OMRFs – 4.0

Flat Slab- Structural Wall - 3.0

The clause 7.3.5 & 7.3.6 states that, in regions of severe snow loads & sand storms exceeding intensity of 1.5 kN /m^2, 20% of uniform design snow load or sand load shall be included in the estimation of seismic weight. In buildings with interior partitions, the weight of these partitions on floors shall be included in the estimation of seismic weight & this value shall not be less than 0.5 kN /m^2. In case the minimum values of seismic weights corresponding to snow loads or sand storms or partitions given in IS 875 are higher, the higher values shall be used.

The clause 7.6.2 gives newly added equations for calculation of approximate fundamental natural period,

For Bare steel MRF building, $T_a = 0.085\, h^{0.75}$ (1)

For Building with RC Structural Walls, $T_a = 0.075\, h^{0.75} \div \sqrt{Aw} \quad > 0.09\, h \div \sqrt{d}$ (2)

Where *h* is the height of building as defined in clause 7.6.2, in meters, *d* is base dimension of building at plinth along considered direction of seismic, in meters. A_w is total effective area in m^2 of walls in first storey of building which is given by, $A_w = \sum_{i=1}^{Nw} \left[Awi \left\{ 0.2 + \left(\frac{Lwi}{h}\right) 2 \right\} \right]$ (3)

But the above formula is revised in Amendment No. 1 September 2017 to IS 1893 (Part 1): 2016, as follows

$$A_w = \sum_{i=1}^{Nw} \left[Awi \left\{ 0.2 + \left(\frac{Lwi}{h}\right) \right\}^2 \right] \quad (4)$$

Where A_{wi} is effective cross sectional area of wall *i* in first storey of building in m^2, L_{wi} is length of structural wall *i* in the first storey in the considered direction of seismic force in meters, N_w is number of walls in the considered direction of seismic force. The value of L_w / h to be used in the equation shall not exceed 0.9.

In the IS 1893: 2016, Fig. 5 explains the definition of Height & Base width of buildings, which is newly introduced.

As per the clause 7.6.4, a floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape at any point of diaphragm is more than 1.2 times average displacement of the entire diaphragm.

The clause 7.7.1 expects to perform linear dynamic analysis to obtain design seismic base shear & its distribution at different levels along height of building, for all buildings other than regular buildings lower than 15 m in seismic zone II.

The newly added recommendations regarding RC frame buildings with unreinforced masonry infill walls are given as clause 7.9. These provisions are made to estimate the in-plane stiffness & strength of URM infill walls in the structures. Also the design equations are provided along with the clauses.

The clause 7.10.3 states that RC structural walls must be designed so as the lateral stiffness in open storey is more than 80% of that in the storey above & lateral strength in open storey is more than 90% of that in the storey above & RC structural wall must not increase torsional irregularity in plan than that already present in the building.

As per the clause 7.12.3, the compound walls shall be designed for design horizontal coefficient A_h of 1.25Z, that is, with I =1, R =1, & S_a /g = 2.5.

The Annex F in IS 1893:2016 deals with simplified procedure for evaluation of liquefaction potential which is newly added.

VI. CONLCUSIONS

1. In IS 1893:2016, clauses are framed slightly well than the IS 1893:2002, which helps to understand it.
2. The temporary structures, excavations are required to be designed as per IS 1893:2016, which will improve behaviour of structures under construction or excavations during earthquake.
3. In IS 1893:2002, the design spectra are given up to 4 seconds of time period. But in the latest code, design spectra are given for natural time period up to 6 seconds which may help designers to design structures which will have time period more than 4 seconds without any confusion.
4. In IS 1893:2016, the importance factor for intermediate importance category is introduced which may help designers to consider this value for required building without any doubt. Also if required, the code gives freedom to the designers to consider any other value of important factor more than the values mentioned in code.
5. In latest code, a provision is made which ensures that all the buildings are designed for at least minimum seismic force, which may improve the performance of buildings during an earthquake resulting comparatively less loss of lives & properties.
6. In the latest standard, flat slab & structural wall system, braced systems are considered as lateral load resisting system.
7. The new code brings the additional clarification regarding the irregularities in the buildings.
8. The effects of masonry infill walls are included in analysis & design of frame buildings.
9. Even the new code does not have any solved examples regarding analysis & design of earthquake resistant structures. Also for numbers of time it is mentioned that to refer the specialists literatures.
10. The exact process of analysis & design of earthquake resistant structures with standard software is not given in the codes which sometime lead to confusion due to lack of expertise.
11. In the preparation of IS 1893:2016, an attempt has been made to coordinate with standards & practices prevailing in different countries & assistance has been taken from various well prepared standards of

developed countries & also from various revised codes in India. Hence it can be said that the Indian Standard Seismic codes are on the path of development & the design, analysis processes, criterions will be very realistic & improved in future.

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