RESEARCH ARTICLE OPEN ACCESS

General Concepts to be Followed in Earthquake Resistant Design as a Safety Measures for Economic Construction

Vedant Mishra*, Dr. M.P. Mishra **
**(M-Tech Structural Engineering, RGPV University, Bhopal, M.P.*
*** (Assistant Engineer MPHID Board, Bhopal, M.P.*

ABSTRACT
It is seen that reinforced concrete (RC) frame buildings are commonly found constructions in urban India, on which several types of forces are subjected during their lifetime, such as static forces due to dead and live loads and dynamic forces due to the wind and earthquake. It has been confirmed from different studies that unlike static forces, direction and locations of dynamic forces, amplitude, especially the earthquakes, vary significantly with time, which cause considerable inertia effects on the buildings. Under dynamic forces behaviour of buildings depends on the dynamic characteristics of buildings which are controlled by both their stiffness and mass properties of the buildings, whereas the static behaviour is solely dependent upon the stiffness characteristics. Hence buildings performance largely dependents on the deformability and strength of constituent members, additionally, linked to members internal design forces. The internal design forces in turn depend upon the accuracy of the method employed in their analytical determination.
Keywords – Earthquake, Seismic analysis, Bare frame, Framed structure, Dual system.

Date of Submission: 07-04-2020 Date of Acceptance: 22-04-2020

I. INTRODUCTION

During an earthquake, ground motion occurs in a random fashion both horizontally and vertically, in all directions radiating from the epicentre. The ground accelerations cause structures to vibrate and induce inertial forces on them. Hence structures in such need to be suitably designed and detailed to ensure stability, strength and serviceability with acceptable levels of safety under seismic effects.

The resultant inertial force at any floor level depends on the mass at that floor and also the height above the foundation. The inertial forces usually follow a parabolic distribution in regular multi-storey buildings with maximum values at the top floor levels. In regions of high seismic intensity, it is desirable to minimize the weights at various floor levels, especially the roofs and upper stories. Also, it is desirable to avoid discontinuities in mass or stiffness in plan and elevation.

The criteria adopted by codes IS 1893 (Part 1): 2002 and 2016 states in clause 6.1.3 for fixing the level of design seismic loading are generally as follows.

- Structures should be able to resist minor earthquakes without damage.
- Structures should be able to resist moderate earthquakes without significant
- Structural damage but with some structural damage and
- Structures should be able to resist major earthquakes without collapse, but with some structural and non-structural damage.

The magnitude of the forces induced in a structure due to given ground acceleration or given intensity of earthquake will depend amongst other things on the mass of the structure, the material, and type of construction, the damping, ductility, and energy dissipation capacity of the structure. By enhancing ductility, and energy dissipation capacity in the structure, the induced seismic forces can be reduced and a more economical structure obtained or alternatively, the probability of collapse reduced.

In general, reinforced concrete structure will have a load displacement response under seismic forces; the structures are subjected to several cycles of reversed cyclic loading. Thus, under seismic loading for a given energy input, elasto-plastic response differs from elastic response in the following ways.

- The energy gets dissipated.
- The induced force is less and
- The maximum deflection is more.

Thus, while ductility helps in reducing induced forces and in dissipating some of the input energy it also demands larger deformations to be accommodated by the structure. Since reinforced concrete is less ductile in compression and shear, so dissipation of seismic energy is best achieved by flexural yielding. Hence weakness in compression and Shear in relation to flexure should be avoided. In the structure composed of ductile moment-resisting frames and/or shear (flexural) walls, the desired inelastic (ductile) response is developed by the formation of plastic hinges (flexural yielding) in the member.

It is desirable to design the frame such that the plastic hinges form in the beams and not the columns so that,

- Plastic hinges in beams have larger rotation capacities than in columns.
- Mechanisms involving beam hinges have larger energy absorptive capacity on account of the larger number of beam hinges possible.
- Eventual collapse of a beam generally results in a localized failure, whereas collapse of a column may lead to a global failure and
- Columns are more difficult to strengthen and repair than beams in event of residual deformation and damage.

The objective of the special design and detailing provisions in IS-13920 is to ensure adequate toughness and ductility for individual members such as beams, columns and walls and their connections and to prevent other non-ductile type failure. Hence in order to maintain over all ductile behaviour of the structure with nominal damage it becomes necessary to achieve following combinations.

- Strong foundations and weak superstructure.
- Members stronger in shear than in flexure and
- Strong columns, and beams with little over strength.

Under severe earthquake, it is expected that in a structure designed to resist seismic forces in a ductile manner, large deformations and oscillations will be induced, resulting in the development of reversible plastic hinges at various locations in the ductile frames. The structural system should be so designed as to ensure that formation of plastic hinges at suitable locations, at worst, result in the failure of individual elements but will not lead to instability or progressive collapse.

In addition to the requirements of ductility for stability and strength to resist seismic forces that structure must have sufficient stiffness to limit the lateral deflection or drift. It is suggested that the anticipated drift due to seismic forces may be taken as three times the lateral deflection obtained from the elastic analysis under equivalent static loads.

It should also to ensure that the foundation of a structure does not fail prior to the possible failure of the superstructure. Plastic deformations are permitted to occur at suitable locations in the superstructure under a severe earthquake. The maximum seismic forces transmitted to the foundation will be governed by the lateral loads at which actual yielding take place in the structural elements transferring the lateral loads to the foundation. Thus, corresponding moments, shear forces and axial forces transferred from the frames and walls to the foundation system should be resisted by the foundation system with the usual margin of safety in order to ensure a combination of a relatively stronger foundation and weaker superstructure. Such a design concept is necessary to provide for ductile behaviour of the superstructure without serious damage to the foundation.

In the analysis of multi-storey buildings, the contribution of masonry infill walls is ignored, and the frame analysis is based on the bare RC frame. The mass of the Masonry infill is considered but the stiffness and strength contributions of the masonry infill are neglected. However, the infill frame has some significant effects under lateral loading.

- The infill walls significantly alter the behaviour of the frames reducing the moment resistant frame action by incorporating truss action and enhance lateral strength and stiffness of the building, reducing the lateral drift considerably.

The Infill are capable of resisting the applied lateral seismic forces through axial compression along the diagonal but there is no tensile resistance capability in other diagonal but the cracking induced in the masonry on account of this serves to dissipate energy.

II. GENERAL CONCEPTS

It is seen that structures on the earth subjected to two types of loads as static and dynamic. Static loads are constant with time while dynamic loads are time varying. In general, the majority of civil engineer structures are designed with the assumption that all applied loads are static. The effect of dynamic load is not considered because the structure is rarely subjected to dynamic loads and its consideration in the analysis makes the solution more complicated and time consuming. But this feature of neglecting the dynamic forces may sometimes become the cause of disaster particularly in case of earthquake as in Bhuj earthquake in Gujarat (India) in January-2001 and Nepal earthquake in January-2014 which leads to major life and wealth losses. So, it is essential to design structure which can withstand dynamic loads particularly, earthquake induced loads.

III. STATIC AND DYNAMIC EQUILIBRIUM

The basic equation of static equilibrium under displacement method of analysis is given by

$$F(ext.) = ky \qquad (2.a)$$

Where F(ext.) is the external applied static loads is the stiffness resistance and y are the resultant displacement and the restoring force ky resists the applied force, F(ext.). Now if the applied static force change to dynamic static force or time varying force then the static equilibrium becomes one of the dynamic equilibriums and it has the form

$F(t) = m\ddot{y} + c\dot{y} + ky$ (2.b)

If we do direct comparison of two above equation then it is clear these two additional forces that resist the applied forces with the restoring forces. These additional forces are called inertia force ($m\ddot{y}$) and damping force ($c\dot{y}$) resulting from the induced acceleration and velocities in the structure. Thus, the appearance of inertia and the damping force in the structure during a dynamic loading is the most characteristic distinction between static and dynamic loading effects.

The dynamic force may be an earthquake force resulting from rapid movement along the plane of faults within the earth crust. This sudden movement of fault releases great energy in the form of seismic waves, which are transmitted to the structure through their foundations and causes motion to the structure. These motions are complex in nature and induce abrupt horizontal and vertical oscillations in structure, which result accelerations, Velocities and displacement in structure. The induced accelerations generate inertial forces in structure which is proportional to acceleration of the mass and acting opposite to the ground motion.

The energy produced in the structure by ground motion is dissipated through internal friction within the structural and non-structural members. This dissipation of energy is called damping. The structures always possess intrinsic damping, which diminishes with time once the seismic excitation stops. These dissipative or damping forces are represented by viscous damping forces, which are proportional to the velocity induced in the structure. The constant of proportionality is called as linear viscous damping.

The restoring forces in the structure are proportional to the deformation induced in the structure during seismic excitation. The constant of proportionality is referred as stiffness of the structure. Stiffness greatly affects the structure's uptake of earthquake generated forces. Thus, on the basis of stiffness, the structure may be classified as brittle or ductile. Brittle structures having greater stiffness proves to be less durable during earthquake, while ductile structure performs well in earthquakes. Thus, behaviour of structure evokes an additional desirable characteristic called ductility.

Therefore, the equation of dynamic equilibrium for earthquake force has the form in which, inertia, damping and restoring forces balance the applied force.

$F(t) = m\ddot{y}(t) + c\dot{y}(t) + k(t) \times y(t)$ (2.c)

Where, $m\ddot{y}(t)$ is the inertia force acting in direction opposite to that of seismic motion applied to the base of the structure, whose magnitude is the mass of the structure times its acceleration. Thus, inertia forces are the most significant which depend upon the characteristic of ground motion and structural characteristic of structure. The basic characteristic of structure and ground is its fundamental and its natural period and it ranges from 0.1sec to 0.5sec up to 4 stories and between1-2 sec for tall building up to 20 stories. The natural periods of ground are usually in the range of 0.5 to 2 seconds. So, to reduce the resonance condition estimation of time period should for both structure and the site.

The value of damping in structure depends on its component, materials etc., for RCC structure its value varies up to 5 to 10 %. Similarly, $k(t) \times y(t)$ is the restoring force where $K(t)$ is stiffness or resistance (N/m) which is function of yield condition of structure. The stiffness parameter K is a potential source of discrepancy and is affected by quality of material, age, cracking, support condition, etc. And $y(t)$ is displacement in meters.

Equation 2.c is second order differential equation that's need to be solved for displacement $y(t)$. The number of displacement component required for specifying the position of the mass points which called the number of degree of freedom to obtain an adequate solution. So, depending upon the degree of freedom, number of structural models can be proposed for analysing the structure. A structure can be analysed for different model depending upon the objective of the particular analysis.

IV. LITERATURE REVIEW

Some paper which has been published showing different concepts in general design consideration are as follows.

Akira (2004) performed the study to know the effect of the sever earthquake on the entire building how they get collapse before reaching their yielding limit of stresses which causes failure of different structural system like beam column particularly in soft storey buildings. He concluded that some static cyclic loading test for moment resistant frame only shows the advantage of damage control structure and can be achieved by allowing them to yield before failure.

Kasnale and Jamkar (2008) Mostly RC framed structures are designed without regards to structural action of masonry infill walls present. Masonry infill walls are widely used as partitions. Field evidence has shown that continuous infill masonry wall can help reduce the vulnerability of a reinforced concrete structure. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. A similar soft storey effect can also appear in to position of the structure below plinth, when the ground material has removed during excoriation and refilled later. In order to study this five reinforced RC framed building with brick masonry infill were designed for the same seismic hazard, in accordance with IS code. In his paper he found that the behavior of RC frames with various arrangement of infill when subjected to dynamic earthquake loading. The result of bare frame, frame with infill, soft ground flour and soft basement are compared and conclusion are made in view of IS 1893(2002) code. It is observed that, providing infill below plinth improves earthquake resistant behavior of the structure when compared to soft basement.

The IS code methods are describing very insufficient guidelines about infill wall design procedures. Software like ETABs is used as a tool for analyzing effect of infill on the structural behavior. It is observed; ETABs provide overestimated values of fundamental period. According to relative values of all parameters, he concluded that provision of infill wall enhances the performance in terms of displacement control, storey drift and lateral stiffness.

Babu and Venkatesh (2011) he suggests many guidelines are to be reviewed for linear, non-linear analysis and also discuss about the seismic evaluation and various retrofitting techniques. Most of the researchers have been reviewed that the buildings are assumed to be placed in various zones of India, which is carried out the non-linear analysis (pushover analysis), then show the performance of the building components. Maximum base shear capacity of the structures for various zones is compared. Many papers discussed different amount of masonry infill walls are considered to investigate the effect of infill walls on earthquake response of the structures. SAP2000, ETABS and IDARC-2D software are mainly used to find the seismic evaluation and performance of the structures mainly used.

Chandurkar and Pajgade (2013) performed a study to demonstrate the effect of shear wall in multi-storey building with different models and locations to find the economy and effectiveness with respect to height. He observed that by Changing the position of shear wall will affect the attraction of forces, so that wall must be in proper position. If the dimensions of shear wall are large then major amount of horizontal forces are taken by shear wall. And Providing shear walls at adequate locations substantially reduces the displacements due to earthquake.

Aainawala and Pajgade (2014) studied and performed analysis, different model developed for the G+12, G+25, G+38 Storey building. It is found that in building with shear wall at corner location gives minimum drift and minimum displacement. His study also suggests that size of members like column can be reduced economically in case of structure with shear wall as compared to the same structure without shear wall. It is also seen that variation in column size at different floors affects the storey drift.

V. CONCLUSION

From the above it is concluded that design of buildings should be for a fraction of force that they would experience during earthquake permitting little damage. But any structure should also have sufficient initial stiffness to avoid structural damage under minor shaking. Thus, seismic design reduces cost and acceptable damage to make project viable so that cost factor can be controlled. It also found that loading imposed by earthquake shaking under the building is of displacement type and by wind and all other hazard is of force type. Thus, earthquake shaking requires building to be capable of resisting certain relative displacement within limit at its base. So, for earthquake resistant design building should generally have seismic structural configuration, lateral stiffness, lateral strength and ductility including its other aspects like aesthetic, functionality and comfort etc. These four characteristics are the need of earthquake resistant building. Influence on geometry on a building on its earthquake performance affects like shapes, size of building, location and size of structural and non-structural element.

So, for an earthquake resistant building should have good seismic configuration with no architectural choice in the form of building otherwise it will introduce complexities in the building behavior. In the same way building must possesses minimum lateral stiffness and strength in each of its plan direction so that no discomfort to the occupants with little damage during earthquakes. Above four virtues are achieved by inputs provided at all stages of the development of the building as during planning, design, construction and maintenance so to have a economical construction with safety.

REFERENCES

Journal Papers:

[1]. M.P. Mishra. And Dr. S. K. Dubey., Seismic Drift Control in soft storied RCC buildings" *International journal of Engineering Research and Applications* www.ijera.com*ISSN: 2248-9622, Vol. 5, Issue 12, (Part - 2) -December 2015, pp.41-48.*

[2]. Aainawala, M.S., and Pajgade, P.S., 2013, "Design of Multi-storied R.C.C. Buildings with and without Shear Walls." *International Journal of Engineering sciences & Research Technology*, 3(7) , 2277-9655.

[3]. Akira, Wada., 2004, "Damage Control Structures for Strong Earthquake." *Structural Engineering Research Centre, Tokyo Institute of Technology, Yokohama 226-8503, Japan.*

[4]. Babu, D. L., Vijayakumar, A., and Venkatesh., 2011, "A Survey of Methodologies for Seismic Evaluation of Building." *Canadian Journal on Environmental, Construction and Civil Engineering, 2 (5)*

[5]. Chandurkar, P.P., and Pajgade, P. S., 2013, "Seismic Analysis of RCC Building with and Without Shear Wall." *International Journal of Modern Engineering Research*, 3(3),1805-1810.

[6]. Kasnale, A. S., and Jamkar, S. S., 2008, "Study of Seismic performance for soft basement of RC framed Buildings." *IOSR Journal of Mechanical & civil*, 2278-1684, 47-51.

[7]. IS 1893 (Part I)., 2002 and 2016, "Indian Standards criteria for Earthquake Resistant Design of Structures. Part 1- General Provisions and Buildings (Fifth Revision)." *Bureau of Indian Standards,* New Delhi.

Books:

[8]. Murty, C.V.R., and Jain, S.K., 1994, "A Review of IS-1893-1984 Provisions on seismic Design of Buildings. *The Indian concrete Journal*. **ijera.editor@gmail.com**

Vedant Mishra,etal. "General Concepts to be Followed in Earthquake Resistant Design as a Safety Measures for Economic Construction." *International Journal of Engineering Research and Applications (IJERA*), vol.10 (04), 2020, pp 21-25.