International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 03 | Mar -2017 www.irjet.net p-ISSN: 2395-0072

EVALUATION OF RESPONSE REDUCTION FACTOR FOR MOMENT RESISTING STEEL FRAMES- A REVIEW

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Abstract - *Moment resisting frames are an assemblage of columns and beams that are rigidly connected thus providing sufficient strength and lateral stiffness. They are commonly used a dominant model of lateral resistance system in seismic regions. Damage levels of buildings structures under a design Earthquake are closely related to certain assigned values of response reduction factor. The poor performance of Ordinary Moment Resisting Frame (OMRF) in past earthquakes suggested special design and detailing to warrant a ductile behaviour in seismic zones of high earthquakes. So when a large earthquake occurs, Special Moment Resisting Frame (SMRF) which is specially detailed with a response reduction factor is expected to have superior ductility. The objective of my study is to evaluate the response reduction factors for steel frames through a non linear modeling. The purpose of study in steel frames is that steel has ability to undergo seismic excitation. In this study steel framing systems are investigated and seismic response modification factors of individual systems are analyzed. Numerous load resisting layouts, such as different bracing systems and unbraced moment resisting frames with various bay and story configurations are designed and evaluated in a parametric fashion. The structure is analysed in SAP2000 and the R values so obtained from the analysis is compared with codal requirements considering the various areas of seismicity and different sets of ground motion of various intensities and frequencies. Method of analysis, design and evaluation data are presented in detail. Previous studies in literature and the theory of response reduction factor is also presented.*

***Key Words*:** response modification factors, steel frames, non-linear static analysis, seismic performance.

1.INTRODUCTION

There are many natural hazards in the world but earthquakes are one of the most destructive natural hazards that can result is severe social and economic impact. The devastating potential of an earthquake can have major consequences on infrastructures and lifelines. During the last two decades, some devastating earthquakes have occurred throughout the world .A large number of structures which were designed and built according to the actual seismic codes were subjected to strong ground motions, exceeding the levels for which they were designed. A great number of high and mid rise buildings have steel moment resisting frames on primary lateral load resisting system. This type of construction was considered the safest one to be able to sustain large plastic deformation in bending and shear. In general it can be stated that the behavior of steel buildings during such earthquakes was satisfactory.

However, damage with local failures in the steel elements or in the beam-to-column joints was observed. This proves that steel structures are vulnerable to seismic excitation and the importance of improving design rules for buildings in seismic zones was evident. These rules should take into account the real structural behaviour, the ductility demand under cyclic loading and damage due to the plastic deformation that should not exceed limits related to the local and global ductility of the structure. Although steel structures, performed well during recent earthquakes from a life safety perspective ,economic loss and business interruptions were high .Hence, damage control has become more important, particularly when the performance based seismic design philosophy was developed. This is a general philosophy in which design criteria and structural systems are chosen on the basis of a specified level of reliability so that the structure will not be damaged beyond certain limits. Some recent seismic design codes are based on force-controlled design or capacity design. In order to develop simple design rules for steel structures in seismic zones it is important to characterize the behaviour of steel members and beam-to-column joints under cyclic reversal loading, and to focus on the damage caused by plastic deformations and low cycle fatigue. Theoretically, when considered at a material level steel can develop a large ductility as obtainable by a tensile test but in practice, the global inelastic behaviour of steel structures , local buckling and low-cycle fatigue influences both in the steel members and their connections

1.1 Response Reduction Factor

The response modification factor, R, represents the ratio of the maximum lateral force, Ve, which would develop in a structure, responding linearly elastic under the specified ground motion, to the lateral force, Vd, for which it has been designed to withstand. The ratio R, expressed by the equation:

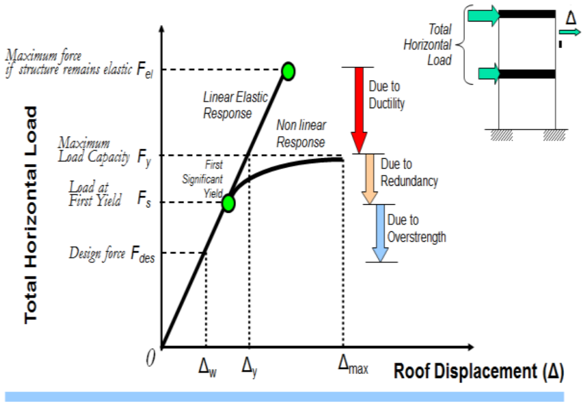
$$R = Ve/Vd$$

The response reduction factor is expressed in terms of over-strength, redundancy ductility, and damping of structure. Mathematically it can be written as:

$$R = Rs*R\mu*R\xi*Rr$$

Where Rs is overstrength factor, Rμ is ductility factor, Rξ is damping factor and Rr is redundancy factor. Many design procedures depends upon elastic analysis of structure. They do not consider nonlinear behavior of structure that due to material as well as geometry. Most of the codes used for seismic design of buildings use the concept of response reduction to account for the nonlinear response of the structure subjected to a high intensity earthquake. The response reduction factor , "R" factor is first introduced in 1978, inorder to reduce the base shear force (Ve) calculated by elastic analysis using a 5% damped acceleration response spectrum for the purpose of calculating a design base shear (Vd). R factors are integrated into the static elastic analysis of structures to account for the inelastic response. Major static analysis routines are Equivalent Lateral Force Method and Response Spectrum Method where R factors are utilized to calculate the design base shear

The response modification factors (R) have been the subjects of investigations by various researches and was found that the response modification factors decreased when the number of stories increased. For 3-, 6- and 15-stories braced frame, the response modification factors was investigated. The effects of some parameters influencing the value of R factor, including the height of the frame, share of bracing system from the applied load and the type of bracing system were investigated. They found that the addition of steel X and knee braces significantly increase the response modification factor; hence the number of stories appeared to be the predominant variable. Seismic codes have long relied upon the concept of inelastic spectrum for specifying design forces to be used for elastic analysis of structures which are expected to respond inelastically to the design earthquakes. Thus, the design base shear is calculated by dividing the base shear for elastic response by the response modification factor (R).



$$\text{Response Reduction Factor} = \frac{\text{Maximum Elastic Force } (F_{el})}{\text{Design Force } (F_{des})}$$

The concept of response modification factor (R) was proposed based on the premise that well-detailed seismic framing systems could sustain large inelastic deformations without collapse and develop lateral strengths exceeding their design strength. The response modification factor (R) was assumed to represent the ratio of forces that would develop under the specified ground motion if the framing system were to behave entirely elastically with respect to the prescribed design forces at the strength level. The response modification factor (R) specified in seismic design codes mostly depend on committee consensus based on the performance based past earthquake. The response modification factors (R) have been the subjects of investigations by various researches and was found that the response modification factors decreased when the number of stories increased. For 3-, 6- and 15-stories braced frame, the response modification factors was investigated. The effects of some parameters influencing the value of R factor, including the height of the frame, share of bracing system from the applied load and the type of bracing system were investigated. They found that the addition of steel X and knee braces significantly increase the response modification factor; hence the number of stories appeared to be the predominant variable.

To utilize inelastic behavior in design, first of all, effects of earthquake induced motion on the structure must be examined. Current engineering practice is capable of making close approximations of the structural properties and properly put them into operation of computer aided finite element analysis (formulation of the problem into a set of mathematical equations). Such as the mass, stiffness and damping properties moreover gravity loading conditions may be modeled. On the contrary the earthquake characteristics are unique. The ground motion is unpredictable and irregular in direction, magnitude and duration. Therefore past ground motion records serve as a starting point to form a basic understanding of characteristics of the excitation such as the displacements, velocities, and accelerations.

1.2 Method of Analysis

Modeling and analysis of frame is done by using SAP 2000, which is a structural analysis program for static and dynamic analysis of structure. The R values obtained from the analysis is compared with codal requirements considering the various areas of seismicity and different sets of ground motion of various intensities and frequencies. Thus, seismic evaluation of the structures provides a frame of reference for the estimation of seismic demands for typical steel frame structures, and provides basic information for issues to be addressed in current seismic design procedures for improving the performance of new structures. Brief information and every modeling property data are presented in every section with the intention of providing all details to be benefited, in future investigations or possible extensions of this study.

1.3 Pushover Analysis

Pushover analysis is a nonlinear static procedure to analyse the seismic performance of a building where the computer model of the structure is laterally pushed until a specified displacement is attained or a collapse mechanism has occurred .The loading is increased in increments with a specific predefined pattern such as uniform or inverted triangular pattern. The gravity load is kept constant during the analysis. The structure is pushed until sufficient hinges are formed such that a curve of base shear versus corresponding roof displacement can be developed and this curve is known as pushover curve. The maximum base shear the structure can resist and its corresponding lateral drift can be found out from the Pushover curve.

2. LITERATURE SURVEY

An extensive literature review was carried out prior to the project. The survey of literature includes , Non linear analysis in steel frames, classification of RC framed buildings, steel frame buildings, SMRF and OMRF, response reduction factor, various stress strain models and pushover analysis.

[1] Sadjadi et al. (2006), conducted an analytical study for assessing the seismic performance of RC frames using non-linear time history analysis and push-over analysis. A typical 5-story frame was designed as ductile, nominally ductile and GLD structures. Most of the RC frame structures built before 1970 and located in areas prone to seismic actions were designed only for gravity loads without taking into account the lateral loads. These structures were referred to as Gravity Load Designed (GLD) frames. The lack of seismic considerations in GLD structures resulted in non-ductile behavior in which the lateral load resistance may be insufficient for even moderate earthquakes. It was concluded that both the ductile and the nominally ductile frames behaved well under the considered earthquake, while the seismic performance of the GLD structure was not satisfactory. The seismic performance was improved after the damaged GLD frame was retrofitted.

[2]Walid AAttia and Masood M M Irheem - Design of the structures to resist seismic force depends on the theory of dissipation in elastic energy that already exists in response modification factor . The main problem is codes gives a constant value for *R*-factor, since change in boundary conditions of building changes the behavior of braced steel frame structures and that effects on *R*-factor. This study is an attempt to assess overstrength, ductility and response modification factor of X-braced steel frame under change in boundary conditions, as change in the direction of strong axis of column and connection support type of column besides variation in storey and bays. These frames were analyzed by using nonlinear static pushover analysis. Minimum value of R is close to code value . That is code is more conservative in suggesting of *R*-factor and gives a large factor of safety. Change in the location of bracing gives change in value of *R*-factor for all boundary conditions. Change in direction of strong axis of columns and support type didn't give change in value of fundamental period, all boundary conditions.

[3] M Fathi, F Daneshooj , R E Melches- In this paper, firstly, existing methods for determining the behaviour factor of moment-resisting steel frames and their range of applicability for multi-degree-of-freedom frames are reviewed. Modifications of this factor for multi-degree-of-freedom moment-resisting steel frames are then indicated. Necessary modifications in determining the behaviour factor of frames involve the period and the base shear distribution factor for a given earthquake loading code. The effects of storeys, spans and connections of frames on the behaviour factor were considered over ranges of values for these factors for frames with semi-rigid connections up to five spans and ten storeys. On the basis of the results, new relationships for the period and the behaviour factor of moment-resisting steel frames with semi-rigid connections as a function of the main geometric parameters of the frame are presented.

[4] A.S.Khatavkar , A.P.Ghadi PG , Prof.P.R.Barbude - Damage levels of building structure under a design earthquake are closely related to the assigned values of response reduction factors. The present study focuses on comparison of estimating the seismic Response reduction factor for a RC frame and steel frame. In the investigation, nonlinear static analysis of analytical model of eight story RC frame and steel frame is conducted for local seismic conditions. The analysis revealed that the four major factors Strength factor, Ductility factor, Redundancy factor and Damping factor affect the actual value of the response reduction factor and therefore they must be taken into consideration while determining the appropriate response reduction factor to be used during the seismic design process. Pushover analysis is an advanced tool to carry out static nonlinear analysis of framed structures. It is used to evaluate non linear behavior and gives the sequence and mechanism of plastic hinge formation. Here displacement controlled pushover analysis is used to apply the earthquake forces at C.G. of structure. The pushover curve which is a plot of base shear versus roof displacement, gives the actual capacity of the structure in the non linear range

[5] Cheol-Kyu Kang and Byong-Jeong Choi- The design force levels currently specified by most seismic codes are calculated by dividing the base shear for elastic response by the response modification factor (R). This is based on the fact that the structures possess significant reserve strength, redundancy, damping and capacity to dissipate energy. This paper proposed the evaluation methodology and procedure of the response modification factors for steel moment resisting frames. The response modification factors are evaluated by multiplying ductility factor ($R\mu$) for SDOF systems, MDOF modification factor (RM) and strength factor (RS) together. The proposed rules were applied to existing steel moment resisting frames. The nonlinear static pushover analysis was performed to estimate the ductility ($R\mu$), MDOF modification (RM) and strength factors (RS). The results showed that the response modification factors (R) have different values with various design parameters such as design base shear coefficient (V/W), failure mechanism, framing system and number of stories.

[5] P. Pravin Kumar Venkat Rao1 and L. M. Gupta- Seismic over strength for steel moment resisting frames has been determined by performing the seismic non-linear static pushover analysis on 3, 5, and 7 story steel frames. The building frames were designed for seismic zones 2, 3, 4, and 5 according to IS 1893 (Part-1):2002 and IS 800:2007. In this paper, the effects of building height and seismic zones on over strength factor of steel frames were investigated. It has been seen that over strength factor varies with number of storeys and seismic zones. The buildings which are having high level of ductility, they are showing higher reserve strength. The over strength factor decreases as the number of story increased. These observations are very much significant for building seismic provision codes, which at present not taking into consideration the variation of response reduction factor, R.

3. CONCLUSIONS

This chapter dealt with the numerous numbers of papers and journals that has been found helpful for carrying out the work. An extensive literature review is done and the inference is noted down. It was noted that response modification factors (R) have different values with various design parameters such as design base shear coefficient (V/W), failure mechanism and framing system. over strength factor varies with number of storeys and seismic zones. The buildings which are having high level of ductility, they are showing higher reserve strength. The over strength factor decreases as the number of story increased. Change in the location of bracing gives change in value of *R*-factor for all boundary conditions. Change in direction of strong axis of columns and support type didn't give change in value of fundamental period, all boundary conditions

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