Journal of Advances in Science and Technology
Vol. 18, Issue No. 2, September–2021, ISSN 2230-9659

Analyses of Seismic Structures and effect of Higher Modes on Residual Mode Method

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Abstract- In earthquake resistant design of building structures, priority is given to protection of human lives against infrequent but large earthquakes. Following the experiences of building performance from a large number of recent earthquakes all over the world, a lot of research is being carried out in this field. Based on the concept of saving human lives, in conventional seismic design, acceptable performance of a structure during earthquake ground shaking is linked to the lateral force resisting system being able to absorb and dissipate vibrational energy due to ground motions in a stable manner for a large number of cycles of motions. Energy dissipation generally occurs in specially detailed ductile plastic hinge regions of beams and column bases, which also form part of the gravity load carrying system. The proposed methodologies used and recommendations specified by seismic structure codes of training for the seismic analyses of structures, when high frequency modal responses are involved are reviewed. The effect of the damping ratio on the rigid response coefficient is studied for different earthquake ground motions.

Keywords- Earthquake, Seismic Structure, Building Structures, Residual Mode Method

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INTRODUCTION

Strong earthquakes, explosions, wind, moving loads, machinery, and enormous ocean waves have raised the need for more flexible civil engineering structures such as towering buildings & long span bridges, which are susceptible to unwanted vibration, deformation, and accelerations. Excessive vibration in structures is an undesired phenomena that causes human discomfort, energy loss, partial collapse of structural sections, transmits unneeded stresses, and poses a threat to structural safety, leading to collapse in some cases. It is vital to understand the behaviour & response of structural systems subjected to dynamic loads such as earthquakes and wind loads in order to eliminate the negative impacts of vibrations in structures. The creation of creative design concepts to safeguard civil engineering structures from harm, including material contents and human occupants, from the hazards of strong winds and earthquakes is one of the key difficulties facing structural engineers in the current decade. To survive under extreme dynamic loading and blast loads, structural structures have traditionally depended on their inherent strength and capacity to dissipate energy. Inelastic cycle deformations at the extremely detailed plastic hinge areas of structural elements may cause energy dissipation in such systems. This produces localised structural damage since the structure must absorb much of the input energy from dynamic forces, which has a significant repair cost. Hospitals, police stations, and fire stations, on the other hand, must stay operational even after an earthquake. The traditional design technique is ineffective for keeping a structure functional after an earthquake since it allows for significant damage.

LITERATURE REVIEW

Chandurkar & Pajgade (2013). Structural walls are an efficient bracing system with a lot of lateral load resistance capability. Because the seismic reaction of these seismic shear walls dominates the response of the buildings, it is critical to assess the seismic response of the walls adequately. Four separate models were used to investigate the effectiveness of shear walls. The first model is a bare-frame structural system, whereas the other three are dual-type structural systems. A ten-story building in zone II, zone III, zone IV, or zone V is subjected to an earthquake load. In both scenarios, when a column is replaced with a shear wall, parameters such as lateral displacement, storey drift, and total cost required for the ground floor are estimated.

The building's detailed seismic performance from a local perspective is being investigated by (Chang, H. Y. & Chiu, C. K. 2011). Test data and reaction analysis were used to analyse the BRBs' capacity & demands. A confidence parameter has been utilised to link with the likelihood that a structure will meet a certain hazard's performance objective. The level of confidence was then calculated in relation to the risk of BRB yielding, buckling, & fracture failure. The results reveal that BRBs can provide a high level of assurance, ensuring that the building meets its immediate occupancy & life safety performance targets. When the building approach the instantaneous occupancy (IO) limit state, it is obvious that the BRBs have sufficient capacity to prevent buckling failures. When the building reaches the LS limit state, it is also discovered that the BRBs have a considerable capacity against fracture failures.

Experimental study on controlling dynamic response of a building model using two types of bracings, namely, Concentric- and Eccentric bracing is done by (Dhara Panchal & Sharad Purohit 2012). A building model is fabricated using aluminum flats and plates and bracings are fabricated using linear springs of moderate stiffness. A model represented as Single Degree of Freedom (SDOF) system is subjected to sinusoidal excitations of various frequencies through small scale shake table. Acceleration response of an uncontrolled building model (model without bracings) is obtained using accelerometers and Data Acquisition System (DAQ) – Lab VIEW 8.0.It is found that natural time period and damping ratio of a controlled building model is increased as compared to the uncontrolled system due to stiffness addition. Displacement and Acceleration response is reduced appropriately for the controlled system as compared to the uncontrolled system.

A comparison of knee braced steel frame with other types of bracings had been done by (Anitha M & Divya K.K 2015) this study provides data on the seismic effect of different types of steel bracings. The performance of each frame had been studied using non-linear static analysis and non-linear time history analysis. Various parameters such as displacement and stiffness were studied. A single story frame of span 3 m and height 2 m is selected in this study. In a non-linear static analysis performed, steel frames with double knee bracings showed very good behavior during a seismic activity. Double knee bracings showed more lateral stiffness compared to another type of bracings. In time history analysis the maximum displacement observed for double knee bracings was 90.5% more than without braced frame and 50% more than the eccentrically braced frame.

From the study of the geological properties of the earth’s crust, it has been found that the igneous rocks are the most common types of rocks in the crust (NGS, 2018). They are also the most optimal material for constructing the tunnels since they have denser interlocking and slight differences in the features of the rock. Hence, the problems faced to drill the tunnels in these rocks are less. On the other hand, sedimentary rocks are softer and have bedding planes and weak links between the connections. This difference in the structure, features and the strength causes heterogenity while constructing the tunnels when compared to other rocks like igneous and metamorphic. Additionally, some sedimentary rocks like mud rocks that are vulnerable to shrinking and swelling do not remain stable for a long period of time (Wright & Catlow, 1999). Metamorphic rocks are harder and have more strength, different structure and contents. Their properties and orientations are considered to be anisotropy. Hence, it is difficult to construct the tunnels in these types of rocks.

METHODOLOGY

Methodology is the systematic, theoretical analysis of the methods applied to a field of study. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge. Typically, it encompasses concepts such as paradigm, theoretical model, phases and quantitative or qualitative techniques.

The proposed methodologies used and recommendations specified by seismic structure codes of training for the seismic analyses of structures, when high frequency modal responses are involved are reviewed. The effect of the damping ratio on the rigid response coefficient is studied for different earthquake ground motions. Regression analysis is conducted using the ground motion data and empirical relationships are derived for evaluating a rigid response coefficient. The expressions are validated by comparing with the numerically derived rigid response coefficient.

The 90% modal mass criteria in the numeral of modes deliberated for exploration are studied with the help of numerical examples. The variation of mass throughout the structure when higher modes are truncated is studied. Intense studies are conducted by using of statistical examples to study the contributions of the rigid and periodic parts of the response and modal mass corresponding to the residual mode, by varying the frequencies and mass contribution of the truncated higher modes. The residual mode method is suitably modified to approximate the contributions of truncated higher modes.

The modified residual mode method is used for developing a simplified procedure for the design of structures with vertical mass and stiffness irregularity. The method is validated using numerical examples. The examples are taken from the literature and suitably modified to impart the irregularity. The error is calculated by comparing the calculated responses using the modified residual mode method with the responses calculated using all modes.

OBJECTIVES

1. To explore the impact of the damping ratio on the rigid response coefficient in a set of modal responses
2. To study the effect of truncation of higher modes

RESULTS AND ANALYSIS

USNRC 1.92, rev3 (2012) recommends the Gupta strategy for the modal set of the responses which contains a rigid and damped periodic part. The empirical expressions for rigid response coefficient are constructed on a straight-line fit amongst a key frequency *f1* & a rigid frequency which is independent of damping. In previous studies, the effect of damping on the rigid response coefficient is expressed as parabolic variation from the straight-line fit. Recent studies show that rigid frequency also varies according to the damping ratio. In this work, an attempt is made to evolve empirical expressions for the rigid response coefficient for dissimilar damping ratios. The expressions are validated by comparing the values with the numerically derived rigid response coefficient.

EFFECT OF DAMPING ON RIGID RESPONSE COEFFICIENT

Damping and Rigid Frequency

The response spectrum, disparity of rigid response coefficient by frequencies and the variation of rigid frequency with damping ratios for El Centro (1940) ground motion are presented in

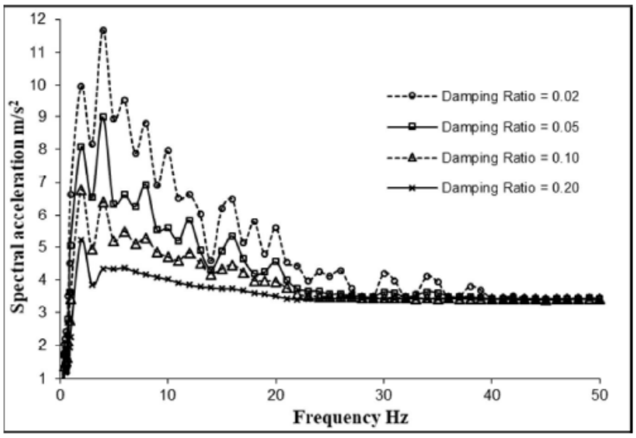

Figure 1: Response spectrum for El Centro (1940)

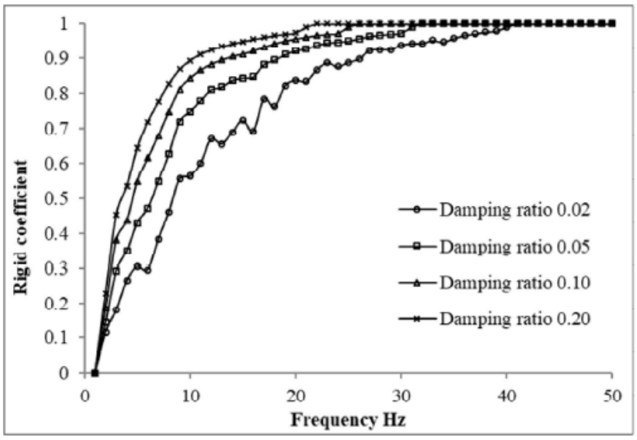

Figure 2: Variation of rigid response coefficient for dissimilar damping ratios in the mid-frequency zone of El Centro (1940) spectrum

Rigid Response Coefficient

To incorporate the effect of damping on the rigid frequency it is proposed to use different rigid coefficients corresponding to different damping ratios given by,

$$\alpha_{i\varsigma} = \frac{\ln f_i / f_1}{\ln f^r_\varsigma / f_1} \quad , \qquad 0 \le \alpha_i \le 1 \tag{1}$$

In order to incorporate the deviation of the rigid response coefficient from the straight-line idealization due to the effect of damping the proposed expression for $\alpha_{i\varsigma}$ is modified as,

$$\alpha_{i\zeta} = \alpha_{i\zeta o} + \alpha_{i\zeta o}(1 - \alpha_{i\zeta o})\Delta\alpha^a \tag{2}$$

Where $\alpha_{i\zeta o} = \alpha_{i\zeta}$ given by Equation (1), and $\Delta\alpha^a$ is given by, The values *a* and *b* taken from the previous studies based on 12 earthquakes are 2.12 and 0.6 respectively. The key frequency *f1,* and the rigid frequency f^r_ζ used in Equation (2) for 6 earthquakes corresponding to different damping ratios are shown in Table 4.1. The expressions are compared with the numerically derived values of the rigid response coefficient for 2%, 5%, 10%, and 20 % damping.

Table 1: Damped rigid frequency, f_{ζ}^{r} Hz & key frequency, *f1,* Hz

No	Earthquake	Damped rigid frequency, f_{ζ}^{r} (Hz)				Key frequency f_1, Hz			
		Damping Ratios, ζ				Damping Ratio, ζ			
		0.02	0.05	0.10	0.20	0.02	0.05	0.10	0.20
1	El Centro (1940)	38.00	31.00	25.00	21.00	1.50	1.47	1.43	1.39
2	Kern County (1952)	18.00	16.00	14.00	12.00	1.44	1.16	0.32	0.70
3	Kocaeli (1999)	5.00	5.00	4.00	4.00	0.69	0.76	0.82	0.89
4	Little Skull (1992)	30.00	28.00	25.00	21.00	5.00	5.00	4.75	4.58
5	Borrego Mt. (1968)	15.00	13.00	11.00	10.00	0.62	0.72	0.73	0.82
6	Friuli (1976)	38	34	31.00	30.00	3.8	3.32	3.78	3.57

The frequency at which a spectral curve with a given damping ratio converges with a spectral curve with a higher damping ratio and the spectral acceleration equals zero period acceleration is considered as the value of f_{ζ}^{r} for a spectral curve. For an earthquake, the maximum values of the spectral acceleration and spectral velocity are calculated using the MATLAB program. The value of *f1* is calculated using these values from Equation , using pseudo acceleration and pseudo velocity spectrum (Gupta and Chen, 1984). For each frequency $\alpha_{i\zeta}$ is calculated using these values and Equations. For each frequency α_i is also calculated as per the USNRC recommendation. USNRC recommends the Gupta method using *f2= fr*, where *fr* for an earthquake is calculated based on the conventional definition of rigid frequency. The conventional rigid frequency is constant for an earthquake irrespective of damping.

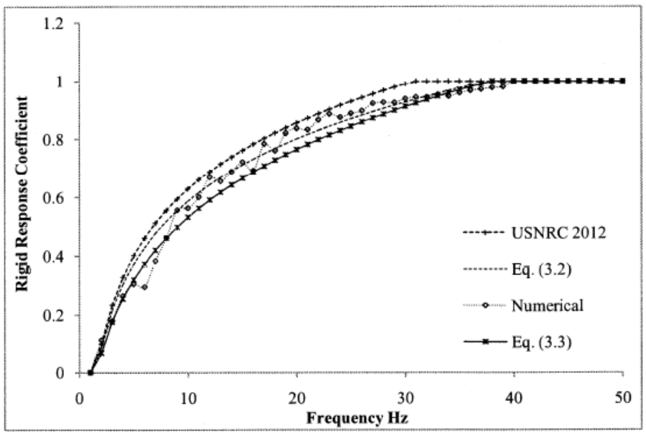

Figure 3: Rigid response coefficient for El Centro (1940), 2% damping

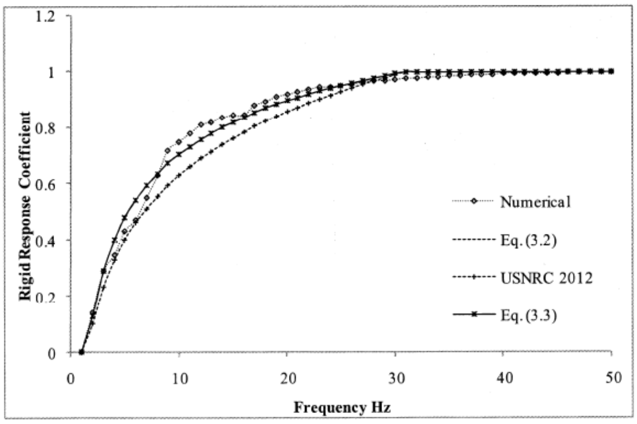

Figure 4: Rigid response coefficient for El Centro (1940), 5% damping

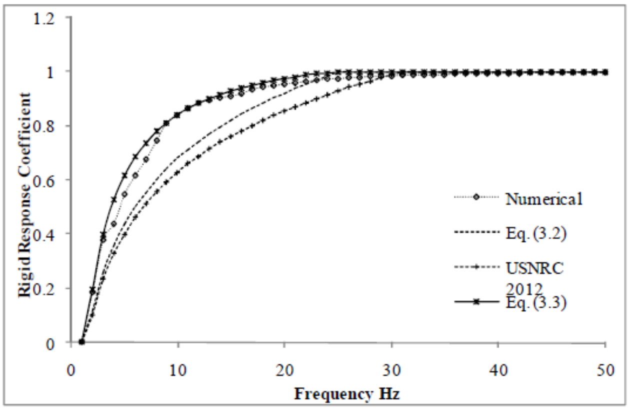

Figure 5: Rigid response coefficient for El Centro (1940), 10% damping

EFFECT OF HIGHER MODES ON RESIDUAL MODE METHOD

International seismic building codes recommend that the number of modes to be used in the analysis should be such that the sum total of modal masses of all modes considered is at least 90 percent of the total seismic mass. The 90 percent structural mass involvement in the number of modes utilised in the research does not guarantee 90 percent structural mass participation at all mass points, particularly in irregular structures. For the seismic analysis of irregular structures, the contribution of all modes up to rigid frequency must be included, as well as "missing mass" correction for the truncated high frequency modes beyond rigid frequency, in estimating correct responses in all structural components. Until reaching the stiff frequency, numerous modes must be examined for a big system with many degrees of freedom. In this paper, an attempt is made to design a simplified method that considers the residual mode's ability to approximate the periodic part of the response in order to account for the response contributions of truncated modes and to expand the suggested method to pushover evaluation of structures.

METHOD OF MODIFIED RESIDUAL MODE

The residual mode's ability to resemble the periodic part of the response is evaluated using the 2 degrees of freedom (DOF) system depicted in Figure In Table 2, the modal features are listed.

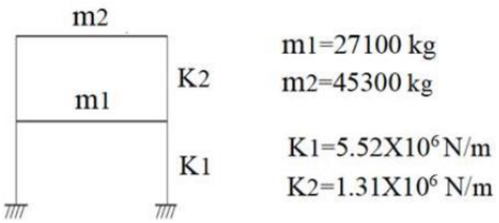

Figure 6: Two DOF system properties

Table 2: Modal property of a two-DOF system

Modal Properties			
Mode Number	Natural Frequency (Hz)	Damping ratio %	Mass participation %
1	0.97	5	69.76
2	2.05	5	30.24

The ground motion response spectrum of El Centro (1940) is used to examine the structure. The key frequency, f1, is 1.47Hz, while the stiff frequency, 31.0Hz, corresponds to 5% damping. The first mode is used to analyse the structure, whereas the second mode is truncated. The second mode has a frequency of 2.05Hz, which is lower than the stiff frequency but close to the key frequency f1, indicating that the majority of the response is damped periodic.

For analyzing the two degrees of freedom system, a program is written in MATLAB. The eigenvalues and vectors for the two degrees of freedom system are evaluated using MATLAB. The exact method developed by Nigam and Jennings (1969) is used for evaluating the corresponding spectral displacements. Modal response combination rules based on correlation coefficient & rigid response coefficient are used to combine the modal responses.

The modal expansion of Ub, which corresponds to the second mode, is computed. Equation is used to build the equation of motion, and the term ω_o^2 is scaled out. The resulting equation is solved, yielding a vector ϕ_o, which is normalised to provide $\phi_o \ {}^T M\phi_o = 1$. It is calculated the fictional frequency 20 that corresponds to the residual vector. The residual mode's modal participation factor, mass participation factor, and modal response are determined in the same way as the other modes. Modal response combination rules are used to combine the residual response with the other modal responses.

For the truncation of the second mode, a residual mode correction is used, and the residual response is mixed with the other modal response using modal response combination rules. The residual mode's natural frequency is 2.05Hz, and its mode structure is identical to that of the second mode. Table 3 summarises the findings of the study. The error in the response is determined in relation to the response in each mode. The residual mode calculates the responses exactly, despite the fact that its frequency is 2.05Hz, which is much lower than the rigid frequency, as shown in Table 3. This demonstrates that the residual mode approximates both the damped periodic and stiff parts of the response and can be combined using Equation's modal response combination rule. As a result, the residual mode technique can be thought of as an approximation dynamic correction. Even though its frequency is 2.05Hz, which is significantly less than the stiff frequency and close to the key frequency f₁, this example indicates that the residual mode accurately calculates the responses. Figure 4.49 shows that the residual mode shape is identical to the second mode form.

Table 3: Error in spring force for 2 DOF system

Analysis	Spring Force	
	Element 1 (N)	Element 2 (N)
Modal Analysis (all modes)	$3.05x10^5$	$1.79 x10^5$
First Mode alone (Error % w.r.t all modes)	$2.45x10^5$ (-19.67)	$1.69x10^5$ (-5.13)
First Mode +Residual Mode (Error % w.r.t all modes)	$3.05x10^5$ (0.00)	$1.79 x10^5$ (0.00)

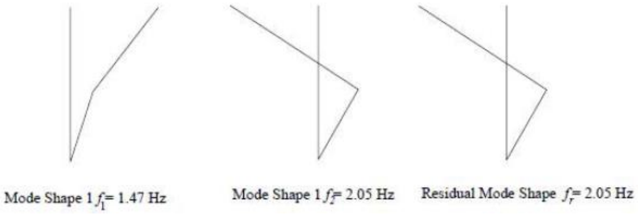

Figure 7: Mode shapes for the 2 DOF system

Consider the 5 DOF system as shown in Figure. The system has a damping ratio of 5% and the natural frequencies are 0.39 Hz, 1.14 Hz, 1.80 Hz, 2.32 Hz, 2.64 Hz and their modal mass participation are 88%, 8.7%, 2.4%, 0.75% and 0.15% respectively. The modal mass participation in the first mode is nearly 90 percent of the total mass. The structure is analyzed using response spectrum of El Centro (1940) ground motion. MATLAB Program developed is utilized for the analysis. Table shows the error in calculating storey shear utilizing only the first mode in comparison to storey shear utilising all modes. In the top level, the maximum inaccuracy is 33.06 percent.

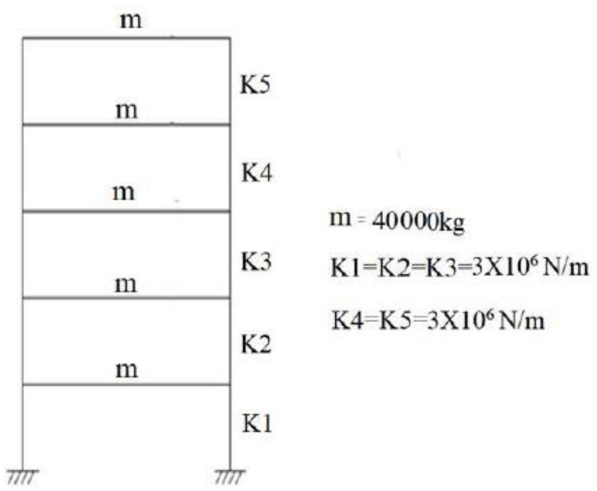

Figure 8: Five DOF system properties

The residual mode approach is used to adjust for the shortened upper modes. The modal expansion of **U**$_b$ corresponding to the truncated modes is calculated is formulated. The term μ_g is scaled out and the subsequent comparison yields a vector ϕ_o**o** , that regularized as $\phi_o \; ^T M\phi_o = 1$. The frequency of the residual mode is 1.42 Hz. The storey shear corresponding to the residual mode is combined with the storey shear of the first mode using modal response combination rule given by Equation. The results are shown in Table and the maximum error is observed to be 30.64% in the top storey. The shape of the second mode shape and the residual mode shape are shown in Figure. Unlike the previous case, there is a difference in the mode shape. The parameters which contribute to the modal response as seen from Equation are mode participation factor, mode shape, and spectral displacement. The residual mode takes into account the mode participation factor of the shortened upper modes. The residual mode corresponds to a mass participation factor of 12 percent. From bottom to top, the mass involved at each mass point corresponding to the residual mode is 25749.14kg, 12652.8kg, 1771.97kg, -6011.85kg, & -10068.10kg. The damped periodic part of the truncated modal response is approximated by the residual response, which takes the stiff part of the truncated modal response. The mode shape is the third parameter that influences the response. As a result, the residual mode shape is changed to the second mode form, or the matching response is computed.

The results are shown in Table , from which it is observed that the maximum error is reduced to 13.38% in the top storey and the error in other stories are negligible. It can be seen from Table 4.10 that the error due to first mode alone is 33.06% and due to the first mode and residual mode is 30.64%. The proposed method is simple and reduces the maximum error to 13.38%. This may be due to the modal response combination of the first mode and the modified residual mode.

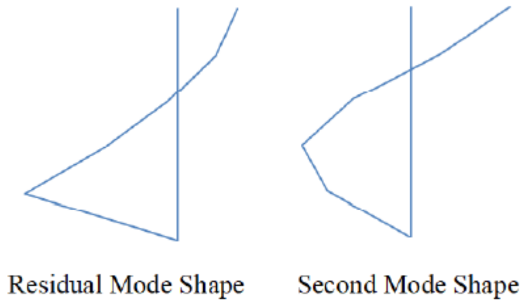

Figure 9: Residual mode shape and second mode shape for the 5 DOF system

Table 4: Error in storey shear force for 5 DOF system

Analysis	Storey Shear (N)				
	Storey 1	Storey 2	Storey 3	Storey 4	Storey 5
Modal Analysis (all modes)	3.15×10^5	2.73×10^5	2.35×10^5	1.89×10^5	1.24×10^5
First Mode (90% Modal Mass) (Error % w.r.t all modes)	2.92×10^5 (-7.3)	2.68×10^5 (-1.8)	2.23×10^5 (-1.83)	1.59×10^5 (-15.8)	0.83×10^5 (-33.06)
Residual Mode Method (Error % w.r.t all modes)	3.29×10^5 (4.44)	2.77×10^5 (1.46)	2.30×10^5 (-2.12)	1.65×10^5 (-12.69)	0.86×10^5 (-30.64)
Proposed Method (Error % w.r.t all modes)	3.01×10^5 (-4.44)	2.69×10^5 (-1.46)	2.29×10^5 (-2.55)	1.83×10^5 (-3.17)	1.07×10^5 (-13.38)

It is proposed to calculate the contribution of the higher modes other than the fundamental mode using a residual mode and an equation is developed as shown in Equation, from which the corresponding response can be calculated.

$$\mathbf{U}_i = \Gamma_r \phi_2 S_{Dr}$$

Where Γ*r* is the modal participating factor of the residual mode, $\phi_2$is the additional mode shape and *SDr* is the spectral displacement corresponding to the residual mode. Rather than considering most of the modes, the structure's reaction can be estimated using first mode, with the residual mode adjusted using Equation. The suggested method makes seismic performance of structures with considerable contributions from higher modes much easier. Six case study are provided to demonstrate the validity of the derived equation.

CONCLUSION

The effect of damping on rigid response coefficient is studied. Expressions are derived to calculate the effect of damping on rigid response coefficient. It is observed from the Figures that the proposed expression gives better values for rigid response coefficient for the various damping ratios considered. In the lower region near to the low frequency region, the numerically calculated rigid response coefficient is not showing any trends in some of the earthquakes. The value of rigid response coefficient in this region is negligible. It is observed that converges to USNRC method for 5% damping. In the cases studied, the present criteria result in an underestimating of storey shear in the top and bottom storeys. According to a novel method proposed, the response is approximated using the first mode or a modified residual mode to account for the contributions of truncated upper modes. As indicated by the instances examined, the proposed technique produces reasonable results in the estimated response. The proposed method is extended to structural lateral loads, allowing higher modes other than the beginning mode's contributions to be analysed elastically.

REFERENCES

1. Gopen, P &Pankaj, A 2012, 'Experimental Verification of Seismic Evaluation of RC Frame Building Designed as per previous IS Codes before and after Retrofitting by Using Steel Bracing', Asian Journal of Civil Engineering (Building and Housing), vol. 13, no. 2, pp. 165-179

2. Guney, D & Kuruscu, AO 2011, 'Optimization of the configuration of infill walls in order to increase seismic resistance of building structures', International Journal of Physical sciences, vol. 6, no. 4, pp. 698-706.

3. Malu Girish & Murnal Pranesh, 2013, 'Sliding isolation system: State of the art review', International Journal of Mechanical and Civil engineeringISSN 2278-1684. vol. 02, no.6, pp. 30-35.

4. Mehmet, B & Tugrul, T 2011, 'Experimental study on seismic strengthening of reinforced concrete Frames by precast concrete panels', ACI Structural Journal, Title no. 108-S23, pp. 227-237.

5. Mehmet, I & Hayri, BO 2006, 'Effect of Plastic Hinge Properties in Nonlinear Analysis of Reinforced Concrete Buildings, Engineering Structures, pp. 1494-1502,

6. Min KW, Hyoung-Seop Kim, Sang-Hyun Lee, Hongjin Kim, & Sang Kyung Ahn 2005, 'Performance evaluation of tuned liquid column dampers for response control of a 76-story benchmark building', Engineering Structures, vol. 27, pp. 1101–1112.

7. Mohammed Nauman, & Nazrul Islam 2014, 'Behaviors of RCC multistoried structure with and without infill walls', vol.3, no. 1, pp. 8455-8465.

8. Moti Perets. 2014, 'Literature Review & Survey of Spherical Bearing Patents', International Journal of Scientific & Engineering Research, vol. 5, no. 7.

9. Mulgund, GV & Kulkurni, AB2011, 'Seismic assessment of RC frame buildings with brick masonry infills', International Journal of advanced engineering sciences and technologies, vol. 2, no. 2, pp. 140-147.

10. Murnal Pranesh & Sinha Ravi 2004, 'Behavior of structures isolated using VFPI during near-source ground motions', Proc. 13th World Conference on Earthquake Engineering, pp. 3105.

11. Murty, CVR & Das, D 2000, 'Beneficial Effects of Brick Masonry In Fills In Seismic Design of RC Frame buildings', Engineering Structures Journal, vol. 21, no. 4, pp. 617-627.

12. NEHRP 2009, Recommended Seismic Provisions FEMA-P 751 (2012), 450 National earthquake hazards reduction program.

13. Nikita Gupta, Dipali Sharma & Poonam 2014, 'State Of Art Review-Base Isolation for Structures', International Journal of Scientific & Engineering Research, vol. 5, no. 5. 225 36.NZS 1170

14. Nilupa Herath, Priyan Mendis, Tuan Ngo & Nicholas Haritos H 2010, 'Seismic Performance of Super Tall Buildings',Proceedings of International Conference on Sustainable Built Environment (ICSBE2010), Kandy.

15. Nitendra, GM & Raijiwala, DB 2011, 'Seismic response control of a building installed with passive dampers', International Journal of Advanced Engineering Technology, vol. 2, no. 3, pp. 246-256.

16. Nivedita, NR & Swati, DA 2013, 'Pushover Analysis of Multistoried Building', Global Journal of Researches in Engineering Civil and Structural Engineering, vol. 13,no.4, version 1.

17. NZS 1170.5:2004 Supplementary - Structural design actions Part 5: Earthquake actions - New Zealand.

18. Ohtori, Y, Christenson, RE & Spencer, BF 2004, 'Benchmark Control Problems for Seismically Excited Nonlinear Buildings', Journal of Engineering Mechanics, vol. 130, no.4, pp. 366-385.

19. OSHPD 1994, 'Office of Statewide Health Planning and Development', Division of Facility Development Structural Engineering Section.

20. Panchal, DR & Marathe, PM 2011, 'Comparative Study of RCC, Steel and Composite (G+30 Storey) Building',

Proceedings of the International conference on current trends in technology - 'NUiCONE – 2011', Institute of technology, Nirma university, Ahmedabad.

21. Patil, S.J & Reddy, G.R. 2012, 'State of art review-Base Isolation System for Structures', International journal of emerging technology and advanced engineering, vol.2, no. 7.

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