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A Study of Effect of Earthquake Ground Motion on Analysis of Structures

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Abstract - The effect of the earthquake on a building depends not only on the peak value of ground acceleration, but also on the size and shape of the building, the arrangement of structural elements, and the presence of mass and stiffness irregularities. Dynamic analysis needs to be performed for knowing the performance of the structure under earthquake loading. The dynamic analysis can be linear or non-linear. Linear analysis is performed using response spectrum method. Non-linear analysis can be performed using time history analysis. There is advancement in computing techniques with the arrival of more powerful computers. Advanced computer programmes and applications are developed for seismic analysis of the structures. In present study a programme is written in MathCADsoftware and the output is validated for with professional software STAAD.Pro for different configurations of the structures.The modal response is compared for evaluating natural frequency, fundamental time period, modal frequency, mode shape coefficients.

Keywords - Earthquakes, Buildings, Seismic Analysis, Damping Ratio,Modal frequency, Mode shape coefficients

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1. INTRODUCTION

High-rise buildings and long-span bridges need to be more flexible in order to withstand significant earthquakes, blasts, wind, moving loads, machineries (and enormous ocean waves), which cause undesired vibrations, deformations and accelerations. When structures are subjected to excessive vibration, it can lead to a variety of negative effects on people and the environment, including human discomfort, energy waste, structural part failure, & transmission of harmful forces and, in the worst case scenario, a collapse. Structures susceptible to dynamic loads, such as earthquakes and wind, must be studied in detail in order to eliminate the harmful consequences of vibrations. There's a lot of work to be done by structural engineers today to develop creative design concepts that protect civil engineering structures and their contents & human inhabitants from the dangers of high winds & earthquakes. Structures traditionally depended on their inherent strength to withstand extreme dynamic loading & blast loads, but this is no longer the case. Inelastic cyclic deformations at structural elements' intricately detailed plastic hinge areas may be a source of energy loss in such systems. The structure itself must absorb much of the input energy from dynamic forces, resulting in substantial maintenance costs and localized damage. A major earthquake does not have to shut down lifesaving facilities like hospitals, police stations, and fire stations. This strategy, which allows for significant structural damage, is ineffective for buildings that must withstand an earthquake and still function as intended. As a result, towering buildings require more advanced methods and procedures for their study and design than other structures. There is also a lack of attention paid to tall buildings, which make up just a small percentage of the development activity in most places. Consequently, structural engineers & researchers who are interested in better understanding the design & performance of modern megacity icons such as skyscrapers need to be familiar with modern methods to seismic analysis & design of tall buildings. Recent years have seen a rise in the use of novel methods to improve structural functionality and safety against dynamic loads. In order to reduce the impact of dynamic loadings, additional energy absorption & dissipation devices can be included in structures. A portion of the energy that would otherwise be transmitted to the structure is absorbed and/or reflected by these systems. Vibration control systems could be passive, active, semi-active, or hybrid, depending on how they function to regulate vibrations.

Acceleration is Critical for the structures which have Short Natural period of vibration (Low

HightStructures), Velocity is Critical for the structures having Medium Natural period of vibration (Med HeightStructures), Displacement is Critical for the structures with Long Natural period of vibration (Tall Structures).

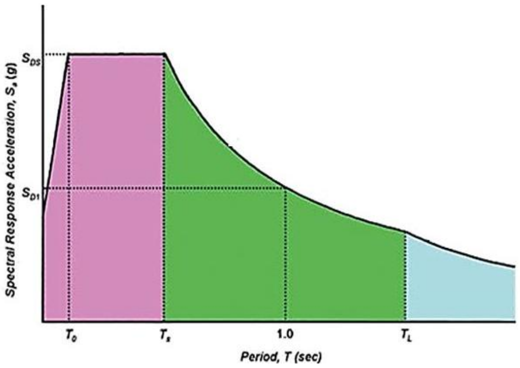


Figure 1: Response of structures with different time periods

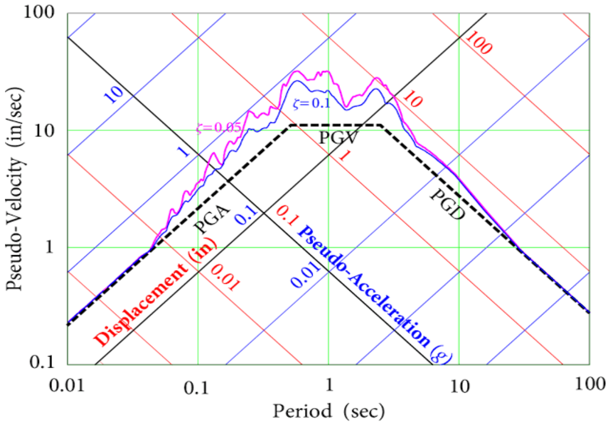


Figure 2: Tripartite Plot

A mode of the structure in an oscillating system, in which all parts of the structure are oscillating with the same frequency. The sum of mass participation in structure vibrations calculated in the modal analysis increases as the number of modes increases. However, to obtain 90-percent mass participation required by codes, it is necessary to consider contribution of large number of eigenmodes, which lengthencalculations and analysisresults.

The seismic response of vibration consists of two combinations of two different motions, which are referred in structural dynamics as the damped-periodic motion (also called as simply "periodic") response and the "rigid" response. (In the theory of vibrations, these two parts of motion are referred to as "transientresponse" and "steady-state response" respectively). The periodic responses have the frequencies of the oscillators (or individual modes), and the rigid responses have the frequencies of the input motion.

2. RESEARCH METHODOLOGY

In present study a programme is written in MATHCAD software and the output is validated with professional software STAAD. Pro for different configurations of the structures. The modal response is compared for evaluating natural frequency, fundamental time period, modal frequency, mode shape coefficients. The effect of the different mass, height, stiffness is studied and compared.

- **Selection of Programing Tool: Math CAD**

MathCAD is easy to use and have combined benefits of mathematical expressions, geometry, graphs as well as word and excel sheets.

- **Selection of Analysis Software: STAAD.PRO**

STAAD.PRO is well validated and globally recognized and used application software for structural analysis.

- **Validation of Math CAD Programme:**

Code is developed in MathCAD for Dynamic Analysis using established methods of dynamic analysis.The output is compared with standard database for validation.Output Result of MathCADProgrammeis validated withmathematical output of standard database as well as output of the STAAD.PRO.

MathCAD Code is developed for Capacity Calculation and Design of RC Beams and Column Sections as per IS456-2000 and for Capacity Calculation and Design of steel Beams and Columns as per IS800-2007.For RC columns customized Moment Interaction curve can be plotted.The output is compared with standard database of moment interaction curve.

Selection of structural data: The structure is selected from the standard database having output results available for validation. The variation is done in regular to irregular structural configuration by inducing irregularity in mass, stiffness and height of the structure.

Structural analysis: Dynamic analysis of the structure is carried out by modal analysis method using code developed in MATHCAD, Professional software STAAD.Pro. The load carrying capacity is also evaluated by both the programmes.

3. RESULTS:

3.1 SDoF Damped Forced Vibrations: MathCAD code is developed for evaluating response with following data.

Input:

$m := 100$ $k := 2000$ $c := 200$ $v0 := 0.1$

$F0 := 15$ $\omega := 10$

Math CAD Programme Output:

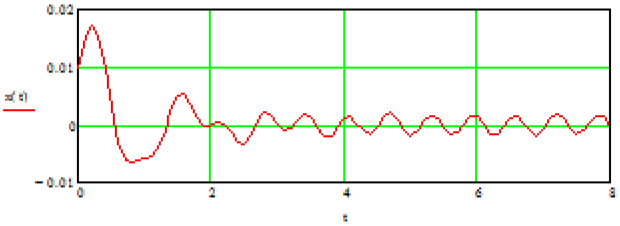


Figure 3: Transient and Steady State Response

3.2 Eigen Value Problems:

A 5-Storey plane frame is analyzed by writing code in MathCAD. The same structure is also modelled and analyzed in STAAD.Pro and the output results are compared and validated.

The same frame is analyzed for irregularity in mass, stiffness and for both mass and stiffness together.

3.2.1 Frame withMass Irregularity:

The frame has following data-

Width of frame = 5m, Material = Concrete, Floor to floor height = 4m,Total height = 20m, Size of all beams = 0.3m x 2 m (To act as rigid diaphragm action), Size of columns= 0.3m x 0.3m, Weight on each floor = 50kN/m x 4m = 200kN

$m1 := 122324\text{kg}$ $m2 := 122324\text{kg}$ $m3 := 81550\text{kg}$

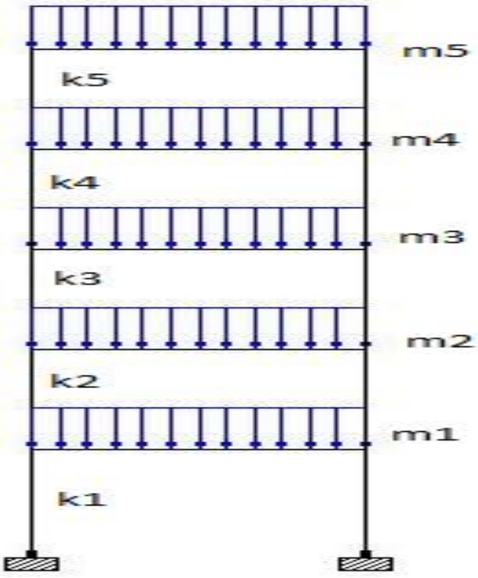
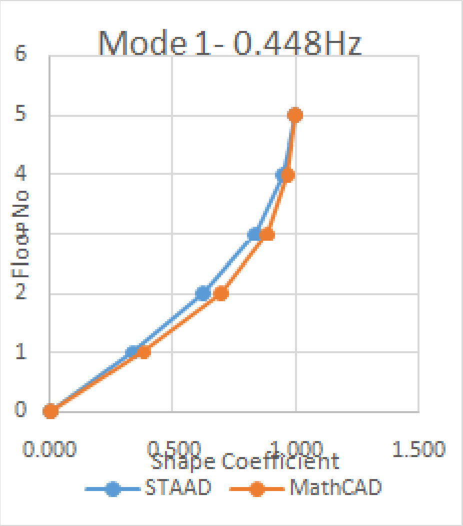


Figure 4: Five Storey Frame

Output:

	Mode 1		Mode 2		Mode 3		Mode 4		Mode 5	
Floor	STAAD	MathCAD	STAAD	MathCAD	STAAD	MathCAD	STAAD	MathCAD	STAAD	MathCAD
5	1.000	1.000	-1.000	-1.000	-1.000	-1.000	-0.951	-1.000	1.000	1.000
4	0.948	0.971	-0.728	-0.795	-0.455	-0.546	-0.121	-0.282	-0.792	-0.759
3	0.837	0.885	-0.152	-0.261	0.524	0.404	0.888	0.841	0.172	0.154
2	0.624	0.694	0.541	0.486	0.463	0.620	-1.000	-0.448	-0.034	-0.018
1	0.338	0.381	0.757	0.635	-0.516	-0.854	0.347	0.195	0.006	0.002
0	0	0	0	0	0	0	0	0	0	0



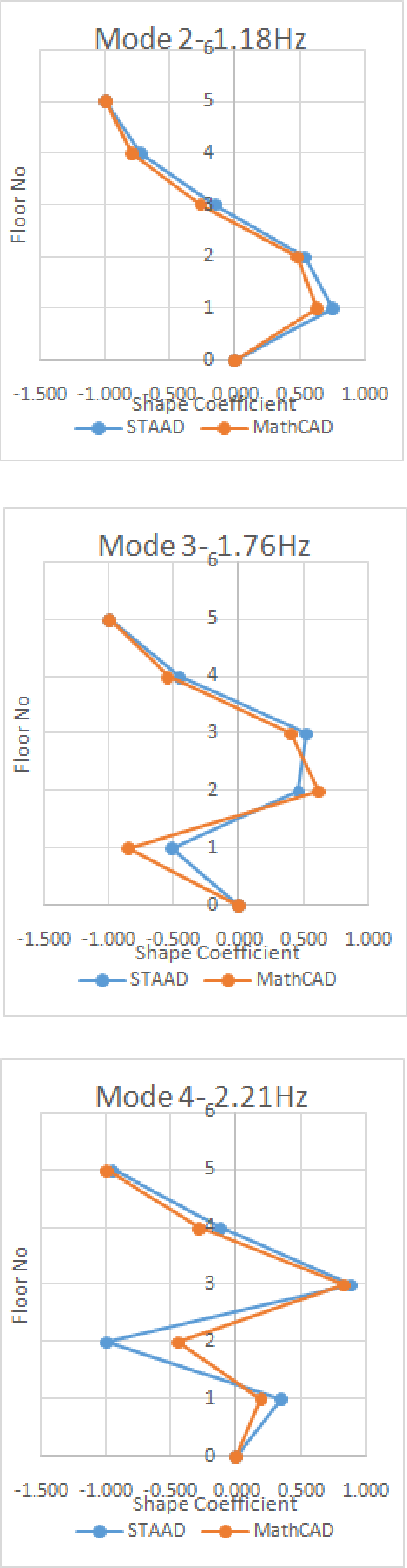


Figure 5: Mode shapes with Mass Irregularity

3.2.3 Frame with Stiffness Irregularity:

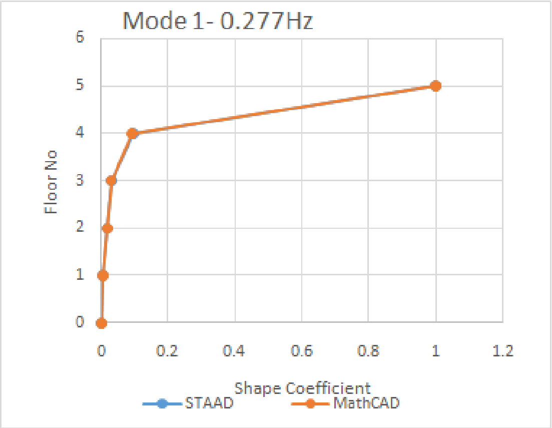
The size of Columns is changed floor wise as below-

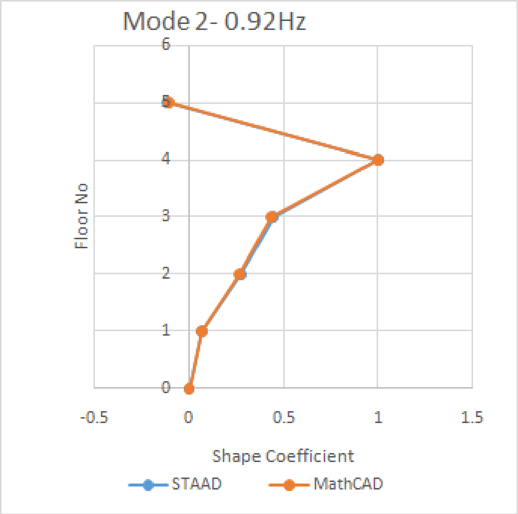
First Floor-300 x 300 mm Second floor = 300 x 300 mm

Third Floor-200 x 200 mm Fourth floor = 100 x 100 mm

Fifth Floor-50 x 50 mm

Output:





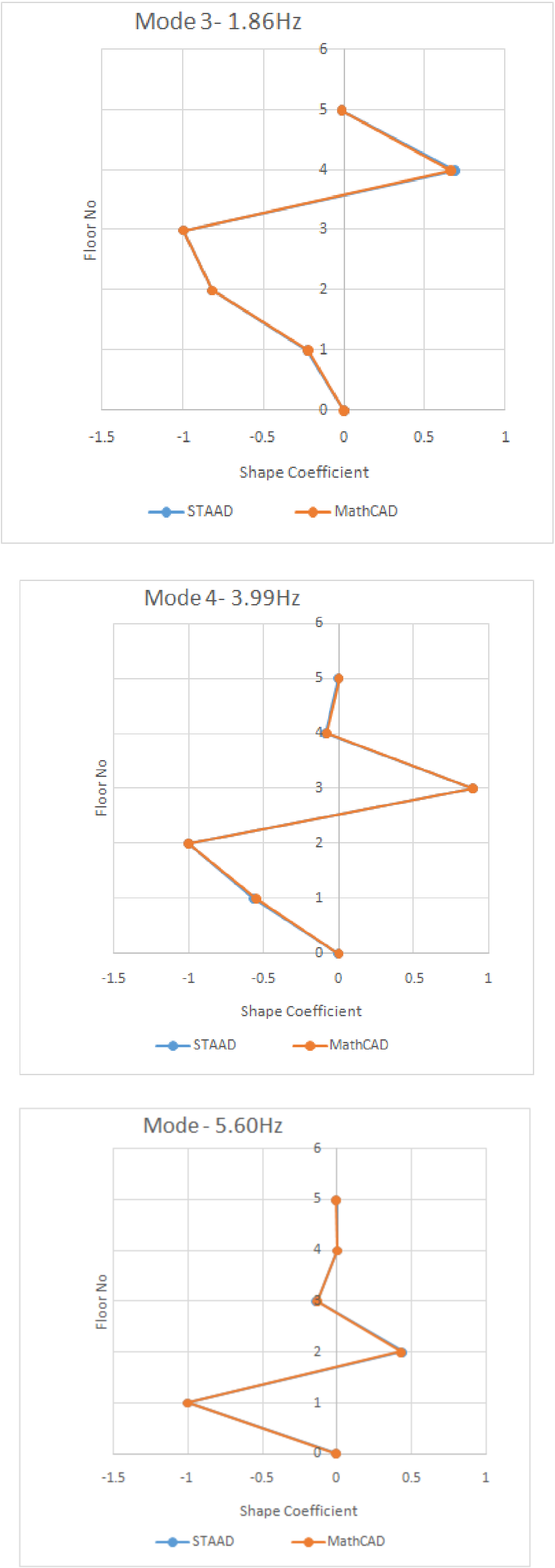
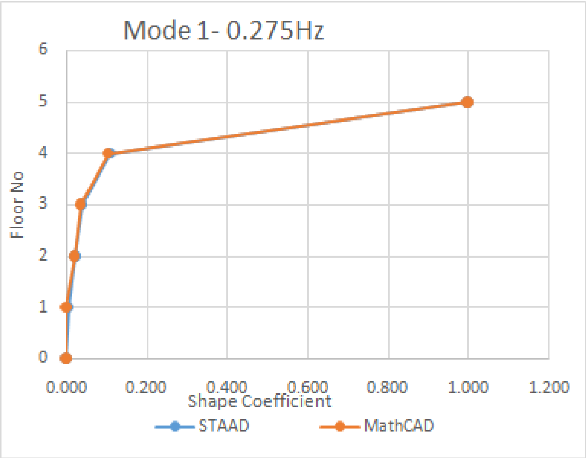


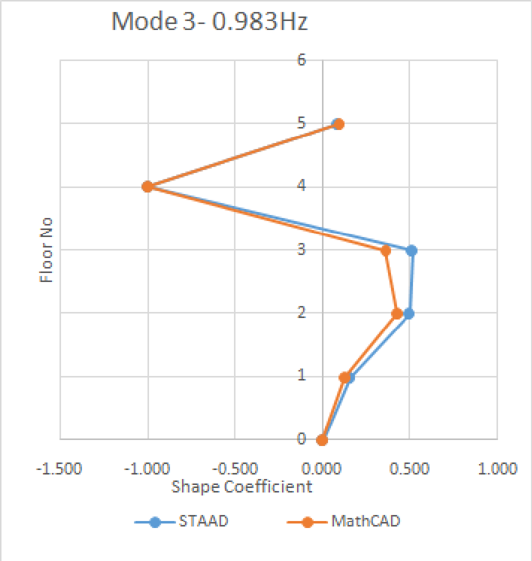
Figure 6: Mode shapes with Stiffness Irregularity

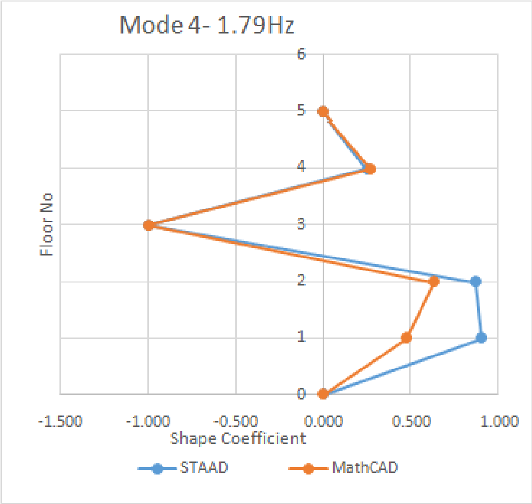
3.2.4 Frame with Mass & Stiffness Irregularity:

In this model both Mass and stiffness irregularities combined

Output:







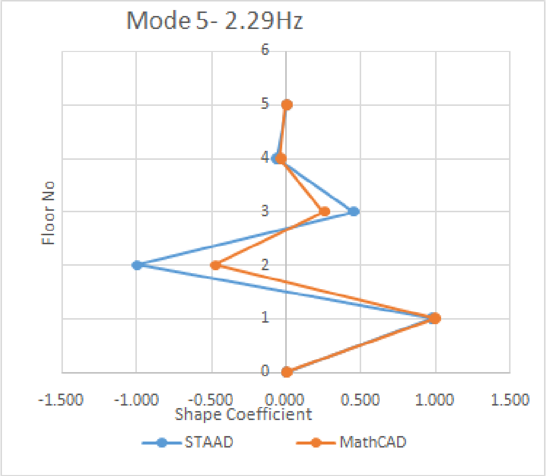


Figure 7: Mode shapes with Mass & Stiffness Irregularity

3.3 Moment Capacity of RC Column Section:

The code is written in MathCAD to find out capacity calculation and for the design of RC beam and columns. This is useful for doing modelling in FEM software like STAAD or ETABS.

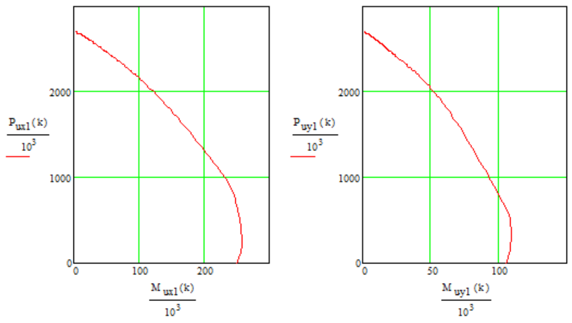


Figure 8: Column Moment Capacity Interaction Diagram

4. CONCLUSIONS

It is not simply a function of peak ground acceleration that determines an earthquake's impact on a building, but also of the structure itself, its layout, and any mass or stiffness abnormalities. The spectrum acceleration will be nearly identical to the peak ground acceleration in buildings with a short time period (high frequency). In contrast to the building's stiffness, the building's mass influences seismic design, as earthquake inertia forces are directly proportional to the building's mass. The economic viability of a project could be jeopardized if buildings are designed to withstand earthquakes with minimal damage. As a result, the structure may need to be damaged to release the energy it receives from the earthquake. It is common for the structures to be neither totally rigid nor flexible. This structure is mostly in the mid-range frequency band, which corresponds to the response spectrum's velocity sensitive zone, which is smoothed down as a constant speed region. Because of this, their response is both inflexible and sluggish. Extremely rigid structures have only the rigid response, whereas flexible structures only have the damped periodic response. Rigid and damped periodic responses are blended by taking the square root of sum of squares for each segment of the response.

- ➢ Structures with irregular configuration, participation of higher frequency modes are more significant. Effect of higher modes could not be ignored for irregular structural configuration.

- ➢ To obtain 90-percent mass participation required by codes, it is necessary to calculate a large number of eigenmodes, lengthening calculations. Residue Mode consideration is useful without increasing the number modes.

- ➢ At lower frequencies response of structure is mainly periodic. Higher frequencies consist of 'periodic' response and the 'rigid' response.

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