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Seismic Analysis of Structures using Capacity Spectrum Method

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Abstract - *A Seismic design is aimed toward controlling the structural damage supported precise estimations of proper response parameters. Seismic design explicitly evaluates how a building is probably going to perform; given the potential hazard it's likely to experience, considering uncertainties inherent within the quantification of potential hazard and uncertainties in assessment of the particular building response. It is an interactive process that begins with the choice of performance objectives, followed by the development of a preliminary design, an assessment on whether or not the planning meets the performance objectives, and finally redesign and reassessment, if required, until the desired performance level is achieved. A performance - based design is at controlling the structural damage supported precise estimation of proper response parameter. In performance based seismic analysis evaluates how building is likely to perform. Performance based seismic design (PBSD) method is getting wide recognition as the most suitable seismic design process. PBSD is essentially a displacement based seismic design process involving the determination of performance point. The capacity spectrum method is one among the foremost established and widely accepted displacement based seismic design method which is used for performance based seismic design.*

Key Words: Seismic Analysis, Performance Based Seismic Design, Capacity Spectrum Method, Shear wall.

1. INTRODUCTION

Earthquake has always been a threat to human civilization from the day of its existence, devastating human lives, property and man-made structures. The very recent earthquake that we faced in our neighboring country Nepal has again shown nature's fury, causing such a massive destruction to the country and its people. It is such an unpredictable calamity that it is very necessary for survival to ensure the strength of the structures against seismic forces. Therefore there is continuous research work going on around the globe, revolving around development of new and better techniques that can be incorporated in structures for better seismic performance. Obviously, buildings designed with special techniques to resist damages during seismic activity have much higher cost of construction than normal buildings, but for safety against failures under seismic forces it is a prerequisite. The rapid growth of urban population and limitation of available land, scarcity and high cost of available land, the taller structures are preferable now days. As the height of structure increases then the consideration of lateral load is very much important. The concept of seismic design is to provide building structure with sufficient strength and deformation capacity to sustain seismic demands imposed by ground motion with adequate margin of safety.

One of the most widespread procedures for the assessment of building behaviour, due to earthquake, is the capacity spectrum method (CSM). The capacity spectrum method (CSM) is a procedure that can be applied to PBSD. Shear walls are usually provided between column lines, in stairs wells, lift wells, in shafts. They provide lateral force resistance by transferring horizontal forces. Shear wall is a vertical member that can resist lateral forces directed along its orientation. Shear walls are structural system consisting of braced panels, also known as Shear Panels. Concrete Shear walls are widespread in many earthquake-prone countries like Canada, Turkey, Romania, Colombia, and Russia. It has been in practice since 1960's, used in buildings ranging from medium- to high-rise structures. Shear walls should always be placed symmetrically in the structure and on each floor, including the basement. Reinforced concrete Shear walls transfer seismic forces to foundation and provide strength and stiffness.

End of the paper.

1.1 Objective

The objectives of present work are as follows:

- To analyze the building with different gorund motions, namely, IS code compatible ground motion.
- To perform dynamic analysis of the building using STAAD Pro.
- To model building with different lateral stiffness systems and study the change in response of the building.
- To compare and get a better and efficient lateral stiffness system.

1.2 Scope

- This study concerns analysis of reinforced concrete moment resisting open frame, open frame with shear walls only, using STAAD Pro program. The effect of brick infill is ignored.
- This study involves a theoretical G+10 building with normal floor loading and no infill walls.

- The comparison of fundamental period, base shear, inter-storey drift and top- storey deflection is done by using Response Spectrum Analysis, which is a linear elastic analysis method.

1.3 Relevance of the work

- The work is feasible where earthquake is dominant. It is necessary to construct a structure which can withstand all forces safely. So that there will be no danger to lives.
- It is necessary to know behavior of seismic forces before designing a structure. so that new methodologies can be used to analyze these forces.
- To design, construct and maintain structures to perform at earthquake exposure up to the expectations and in compliance with building codes.
- The central focus of the nonlinear static analysis methods is the generation of the capacity curve or pushover curve.
- The most common used non-linear static analysis procedures for the evaluation of the performance levels of structures are the capacity spectrum method, which uses the intersection of the capacity curve with a reduced response spectrum.
- Also provision of shear wall results in a huge decrease in base shear and roof displacement both symmetrical buildings and un-symmetrical buildings.

2. METHODOLOGY & INVESTIGATION

2.1 DATA COLLECTION

Various Indian standard codes were collected. The earthquakes considered in this work are time history of ground motion as per IS 1893:2002 (Part-I).

2.2 METHODOLOGY

- Analysis of bare frame.
- Analysis of the frame with shear wall.

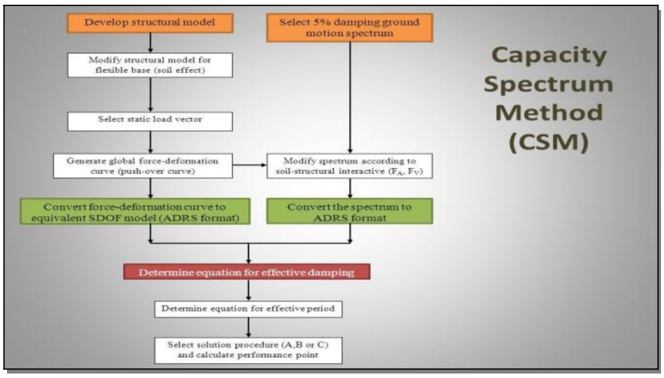


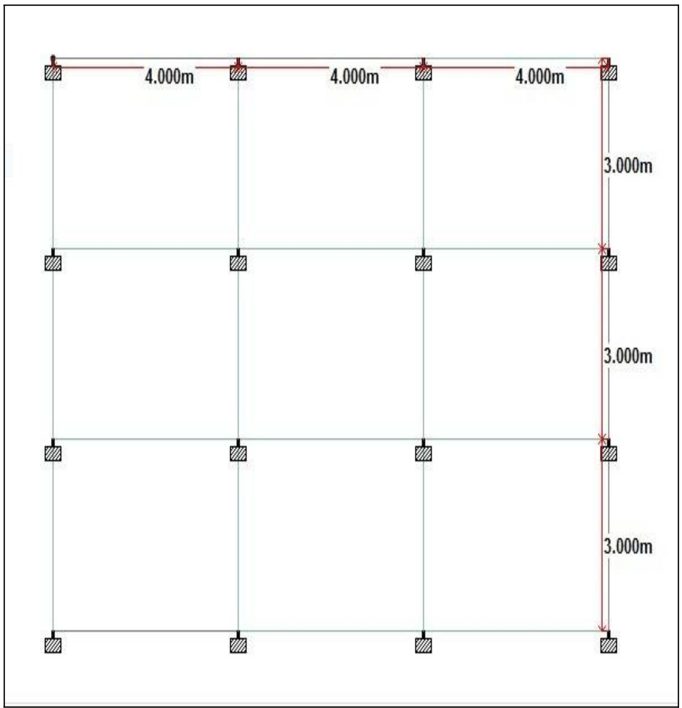
Fig 1. flow chart of CSM

For analysis an 11 stories high building is modeled in STAAD Pro as a space frame. The building is does not represent any real existing building. The building is unsymmetrical with the span more along X direction than along Z direction. The building rises up to 32.5m (including plinth) along Y direction and spans 12m along X direction and 9 m along Z direction .The building is analyzed by Response Spectrum Analysis, which is a linear dynamic analysis. Dynamic Analysis is adopted since it gives better results than static analysis. The specifications of the frame are given in Table 1. and the plan and the model of the building is shown in Fig. 4 and n and the model Fig.5 respectively. In the entire course work X and Z are taken as the horizontal axes and Y as the vertical axes.

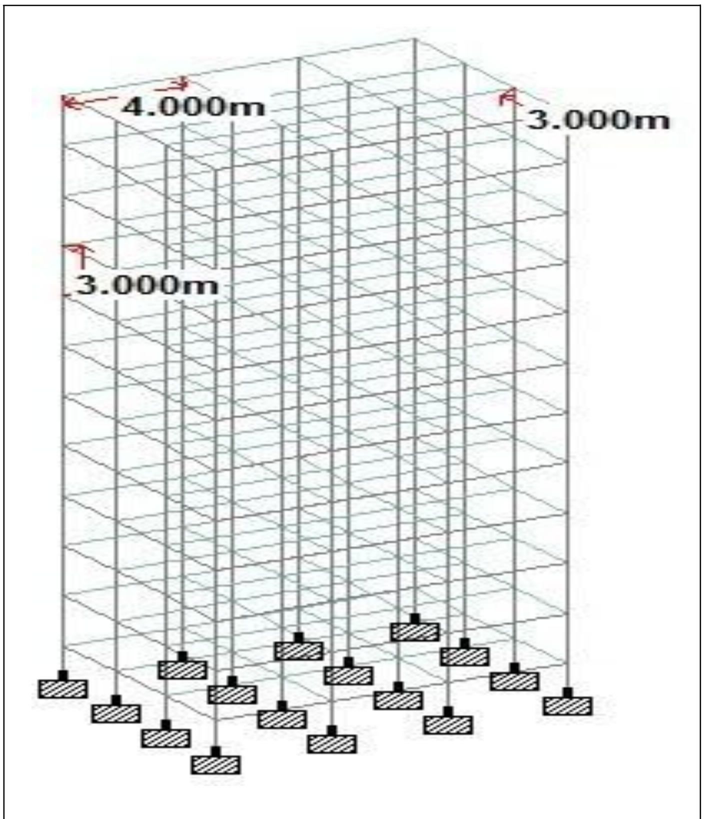
Specifications	Data	Specifications	Data
Storey Height	3m	Longitudinal Beams	0.23X 0.45
No. of bays along X direction	3	Transverse Beams	0.23 X 0.45
No. of bays along Z direction	3	Slab Thickness	0.15m
Bay Length along X direction	4m	Unit Weight of Concrete	25 KN/m3
Bay Length along Z direction	3m	Zone	IV
Concrete grade used	M20	Soil Conditions	Medium Soil
Columns	0.23 X 0.45	Damping Ratio	5%

Table -1: Specifications of building

2.3 PLAN OF BUILDING



2.4 MODEL OF BUILDING



2.2.1 Analysis

The basis of engineering seismology is the need to quantify how a given structure will respond to complex ground motions. The structure's response is determined by its mass and stiffness distributions. For example, stiff buildings will experience low accelerations relative to the ground. Tall buildings tend to accelerate away from ground motions, resulting in low absolute accelerations, where absolute acceleration is the sum of the building's movement relative to the ground and the ground acceleration.The response spectrum method (RSM) was introduced in 1932 in the doctoral dissertation of Maurice Anthony Biot at Caltech. It is an approach to finding earthquake response of structures using waves or vibrational mode shapes. The mathematical principles of oscillations in n-degree-of-freedom systems were taken largely from the theories of acoustics developed by Rayleigh. Biot stated "…[a] building…has a certain number of so called normal modes of vibration, and to each of them corresponds a certain frequency." Biot utilized the Fourier amplitude spectrum to find the maximum amplitude of motion of a system: the sum of amplitudes for each separate mode of oscillation (Trifunac and Todorovska, 2008). The concept of the "response spectrum" was applied in design requirements in the mid 20th Century, for example in building codes in the state of California (Hudson, 1956; Trifunac and Todorovska, 2008). It came into widespread use as the primary theoretical tool in earthquake engineering in the 1970s when strong-motion accelerograph data became widely available (Trifunac and Todorovska, 2008).

2.2.2 Time periods without shear wall

Storey	Time period (s)
1	2.43565
2	1.70326
3	1.61263
4	0.80336
5	0.56531
6	0.52681
7	0.46900
8	0.33653
9	0.33620
10	0.30084
11	0.26424

2.2.3 Procedure

In STAAD Pro, Response Spectrum Analysis is done as follows:-

- After preparing the bare model, seismic definition for IS 1893-2002 was created by giving the required input of time period, zone factor, R factor, etc. Then under seismic definition self-weight, floor weights and member weights of 1kN/m2 and 3.5 kN/m2 and 13.5 kN/m2 were given.
- Under Load Definition Earthquake load, Dead load, Live load and various load combinations were created.
- Under Earthquake load, after assigning self-weight, floor load and live load in X, Y and Z directions, Response Spectra was defined. For Indian Code compatible earthquake already defined IS 1893-2002 is chosen. The Sa/g is the response spectrum values that were taken from the results of MATLAB program for generating Response Spectrum from time history of ground motion of the earthquake considered.
- The load combinations that were considered were according to IS 1893-2002 (Part-1) and are as follows:

  i. 1.5(DL+LL)

  ii. 1.2 (DL+ LL+EL)

  iii. 1.2 (DL+ LL-EL)

  iv. 1.5 (DL+EL)

  v. 1.5 (DL-EL)

  vi. 0.9DL + 1.5 EL

3. RESULT AND DISCUSSION

3.1 RESULT

A. The result is based on the responses of the bare frame model and the changes in the responses after using shear wall with different position.

B. The results include changes in time periods, base shear, inter-storey drifts and top-storey deflections for ground motions along X and Z direction considered individually.

C. The results of time period, base shear, inter-storey drifts and top-storey deflection for bare frame and shear wall frame were then compared with each other and a conclusion was then drawn.

3.2 FUTURE SCOPE

A. Use of bracing for better rigidity in structural member in study can be included.

B. Pushover analysis can be done for future course of study.

C. Fly ash bricks or hollow blocks may place in infill frame in modeling.

D. Study for 30 storey or greater for future researchers due to scarcity of land

4. CONCLUSIONS

This project work was a small effort towards perceiving the how introducing a shear wall in a building can make in difference in protecting the building in earthquakes. Almost all the buildings in India are RC frame, and earthquake tremors are felt every now a then in some or the other part of the country. Hence through this project it was tried to appreciate the effectiveness and role of this small extra structural elements that can save both life and property, at least for most of the earthquakes.

The following conclusions were drawn at the end of the study:

A. There is a gradual reduction in time periods of the shear wall systems from the time period of bare frame, indicating increase in stiffness.

B. Time Period in case of Shear Wall D is the highest, hence is the most stiff and better option for strengthening the structure.

C. Shear Wall A is effective in reducing drifts along X-direction only, Shear Wall is effective in reducing drifts along Z- direction only, for all the ground motions.

D. Above all Shear Wall D is the best in all the stiffening cases considered.

E. Total displacement of the building decreases considerably when the frame building is provided with shear wall.

F. From the results it has been concluded that the case D (when shear walls are placed as a corner) shows best location of shear wall since lateral displacement and axial forces are less as compared to other models.

G. About 67% of the lateral displacement in X direction & 58% of the lateral displacement in Y Direction get reduced when shear wall is incorporated in the Bare Frame System.

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