CHAPTER 6

SEISMIC ACCELERATION AMPLIFICATION FACTOR FOR PIN SUPPORTED MOMENT RESISTING RC FRAME STRUCTURES: AN EXAMPLE OF CHI-CHI EARTHQUAKE

This chapter considers five different RC moment-resisting frame models as 2,4,6,8 and 10 stories, with pin support conditions. The linear time history method is used to analyse all RC frame models with different ground motion data ranges (0.01g to 0.32g). The acceleration amplification factor for all these models and compared with the previous models. It is observed that no previous model gave satisfactory results. Therefore, propose the amplification model, which not only depends on the height of the building, natural period of the building but also depends on the range of the peak ground acceleration (PGA). The proposed model is compared with the previous renowned models; it is observed that the proposed model gives better results with respect to other models.

6.1 CURRENT MODEL EQUATIONS

For determine the acceleration amplification factor of the structures, UBC and ASCE code and IITK-GSDM gave some guidelines based on the height of the structures. However, Akhalghi and Fathali observed that it also depends on the natural period of the structures. All these models were explained in chapter 3, respectively.

6.2 PROPOSED MATHEMATICAL MODEL

The IITK model is based only on the normalized height of the structures and is not dependent on the fundamental period of the structures or the intensity of the seismic motion. UBC 1997 formula for amplification factor gave obscure results when the height of the building increased. ASCE model is also based on the normalized height of the structures only. The Fathali and Akhlaghi models show that the amplification factor not only depends on the normalized height of the building but also depends on the intensity of ground motions and the fundamental period of the structures. But sometimes, its results were observed to be conservative when the range of the ground motion changes. So based on these factors, the amplification factor model is proposed in this study. In this study, five-moment resisting RC frame structures with different heights are considered, and it is observed that no single maximum structural period is found to satisfy the actual amplification factor. To find the realistic amplification factor, two steps have been followed. Firstly, the ground acceleration has been divided into three ranges viz. 0.01-0.067g, 0.067-0.2g and 0.2-0.32g. Secondly, each acceleration range is divided into three zone based on the natural period of the structures. About 90 simulation studies have been carried out to arrive at the Tmax values. The proposed models based on observed results are represented as:

$$\Omega = \frac{PFA}{PGA} = \left(1 + \frac{\mathrm{Tmax} - \mathrm{T}}{a * T}\frac{z}{h}\right) \tag{6.1}$$

where T_{max} is the maximum structural period, and its value is recommended as 2.5 seconds [134]. T is the period of supporting structure when the peak roof acceleration is not less than PGA. Constant “a” not only depends the period of the supporting structures but also depends on the nature of the ground motion, its values given in table 3.

Table 6.1 Values of “a” based on ground motion range and period of supporting structure

Ground motion acceleration	**“a”**	**Period of supporting structure**
$PGA=0.04S_{DS} <0.067g$	1.2	0<T<0.70sec
	0.61	0.7sec≤T<1.2sec
	0.35	1.2sec≤T<1.5sec
$0.067g \le PGA=0.04S_{DS} <0.2g$	1.00	0<T<0.70sec
	0.75	0.7sec≤T<1.2sec
	0.49	1.2sec≤T<1.5sec
$0.2g \le PGA=0.04S_{DS} <0.31g$	1.25	0<T<0.70sec
	0.70	0.7sec≤T<1.2sec
	0.43	1.2sec≤T<1.5sec

6.3 CONFIGURATION OF BUILDINGS

For the analysis in this paper, five different RC frame building models as two, four, six, eight, and ten storeys are considered. All these models are pin supported in hard rock strata. From the base to the first storey, the height is 4m, and for the above storey height of 3.4m is considered. The 2D model of the pin supports is shown in figure 5.2. The size of the beam and column are presented in table 3.1. The damping ratio and the fundamental period of the structures are considered as 5% and up to 1.5 sec, respectively.

6.4 SELECTION OF TIME HISTORY DATA

The previous researchers worked with the higher range of the ground motion (0.3g to 0.8g), but most of the structures are damaged below the ground motion's low range. So, in this study, considering the low range of the acceleration data, the analysis of RC frame structure, seismic data has been taken in the range of 0.01g to 0.31g. These data are divided based on the Fathali, and lizundia [139] approached (0.01g to 0.067g, 0.067g to 0.02g and higher than 0.2g). The selection of ground acceleration was obtained from the strong ground motion virtual data centre [140]. For the study of these models, different ranges of time history data (28 recorded ground motion data between 0.01g to 0.067g, 29 ground motion data in the range of 0.067g to 0.2g, and 24 ground motion data between 0.2g to 0.32g) are considered. Details of the ground motion data are given in Tables 5,6, and 7 as below.

6.5 RESULTS AND DISCUSSION

6.5.1 Floor Spectra Curve

For obtaining the spectral acceleration of the structures in each storey, different ground motion data on the structures is applied. Figure 6.1 express the mean spectral acceleration of the building for the ground motion ranges as 0.2g to 0.32g, respectively. For the analysis of all these models, hard rock-type soil is considered. It is noticed that when the fundamental period of the structures increases, the floor spectral acceleration of the structures decreases i.e. when the height of the building is less, the amplification value is maximum. Furthermore, the fundamental period of the structure increases to 1.5 sec, the floor spectra value decreases to 25% with respect to the low natural period of the structure.

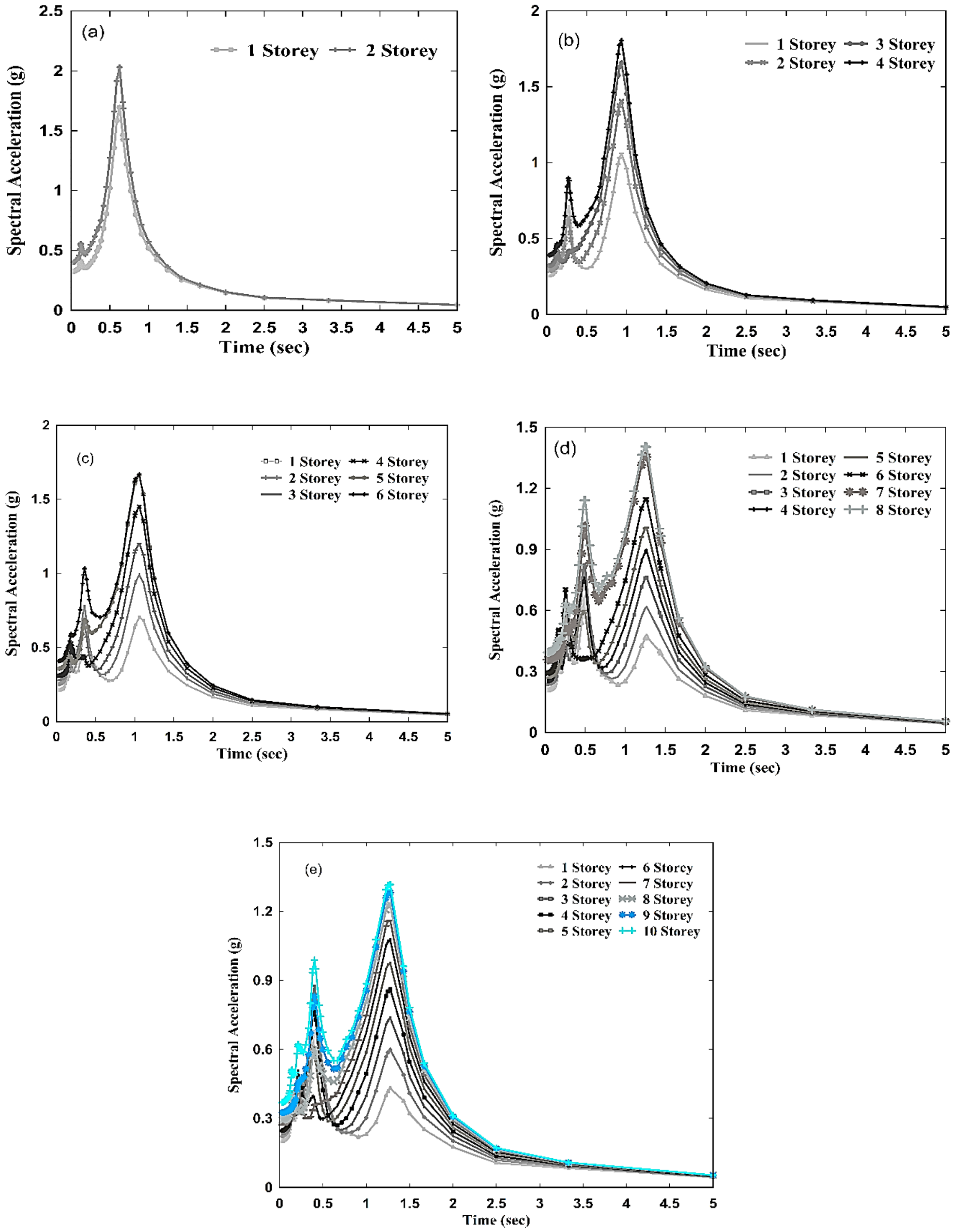


Figure 6.1 Floor Spectral Acceleration of different model for hinge support condition

6.5.2 Compared to peak floor acceleration compared with respect to seismic ground acceleration

The comparison of peak floor acceleration of all models with respect to seismic ground acceleration is shown in Figures 6.2 to 6.4, respectively.

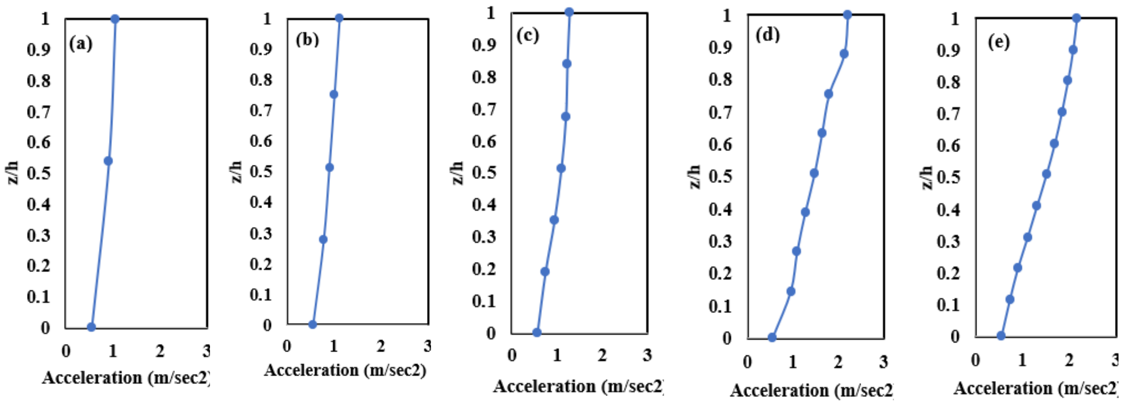


Figure 6.2 Behaviour of peak floor acceleration with respect to normalised hight when the chi-chi earthquake 0.06g for (a) 2 Storey (b) 4 Storey (c) 6 Storey (d) 8 Storey (e) 10 Storey

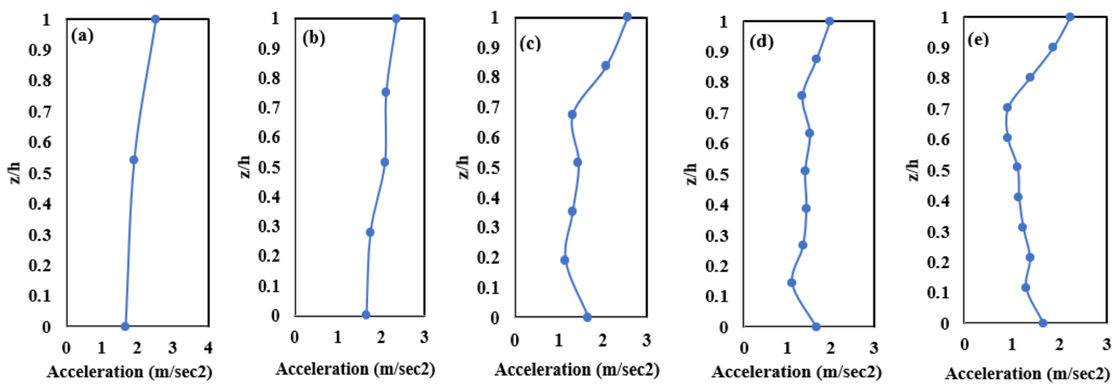


Figure 6.3 Behaviour of peak floor acceleration with respect to normalised hight when the chi-chi earthquake 0.17g for (a) 2 Storey (b) 4 Storey (c) 6 Storey (d) 8 Storey (e) 10 Storey

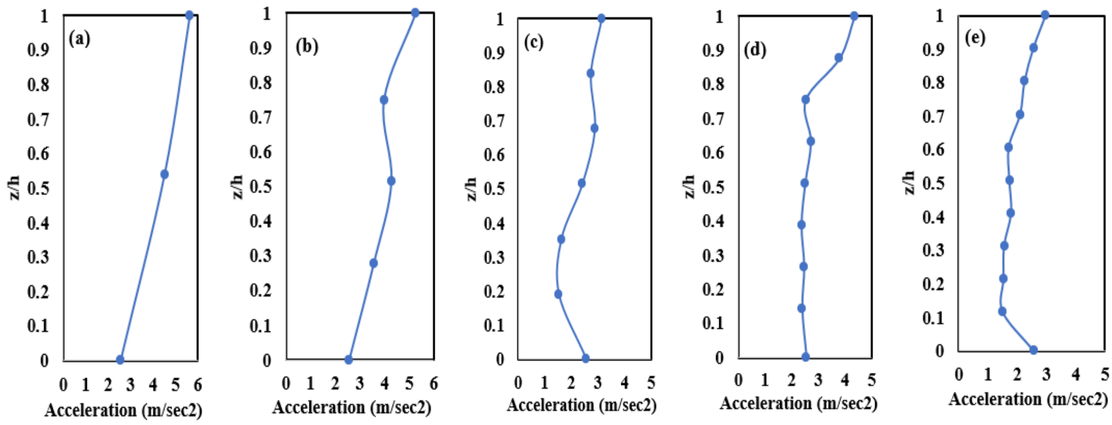


Figure 6.4 Behaviour of peak floor acceleration with respect to normalised hight when the chi-chi earthquake 0.26g for (a) 2 Storey (b) 4 Storey (c) 6 Storey (d) 8 Storey (e) 10 Storey

Figure 6.2-6.4 present the peak floor acceleration in five building models to those recorded during the Chi-Chi earthquake. The peak floor acceleration is approximately four times, 1.5 times and two times higher than the building base for .01g to .067g, 0.067g to 0.2g and 0.2g to 0.31g acceleration. The amplification values are significantly higher when the natural period of the structure is less than 1 sec. The shape of peak floor acceleration performed non-linear as the seismic motion increases.

6.5.3 Compared to the mean +sd acceleration amplification factor with previous models

To compare all models with the proposed model is shown in Figures 6.5, 6.6 and 6.7, respectively.

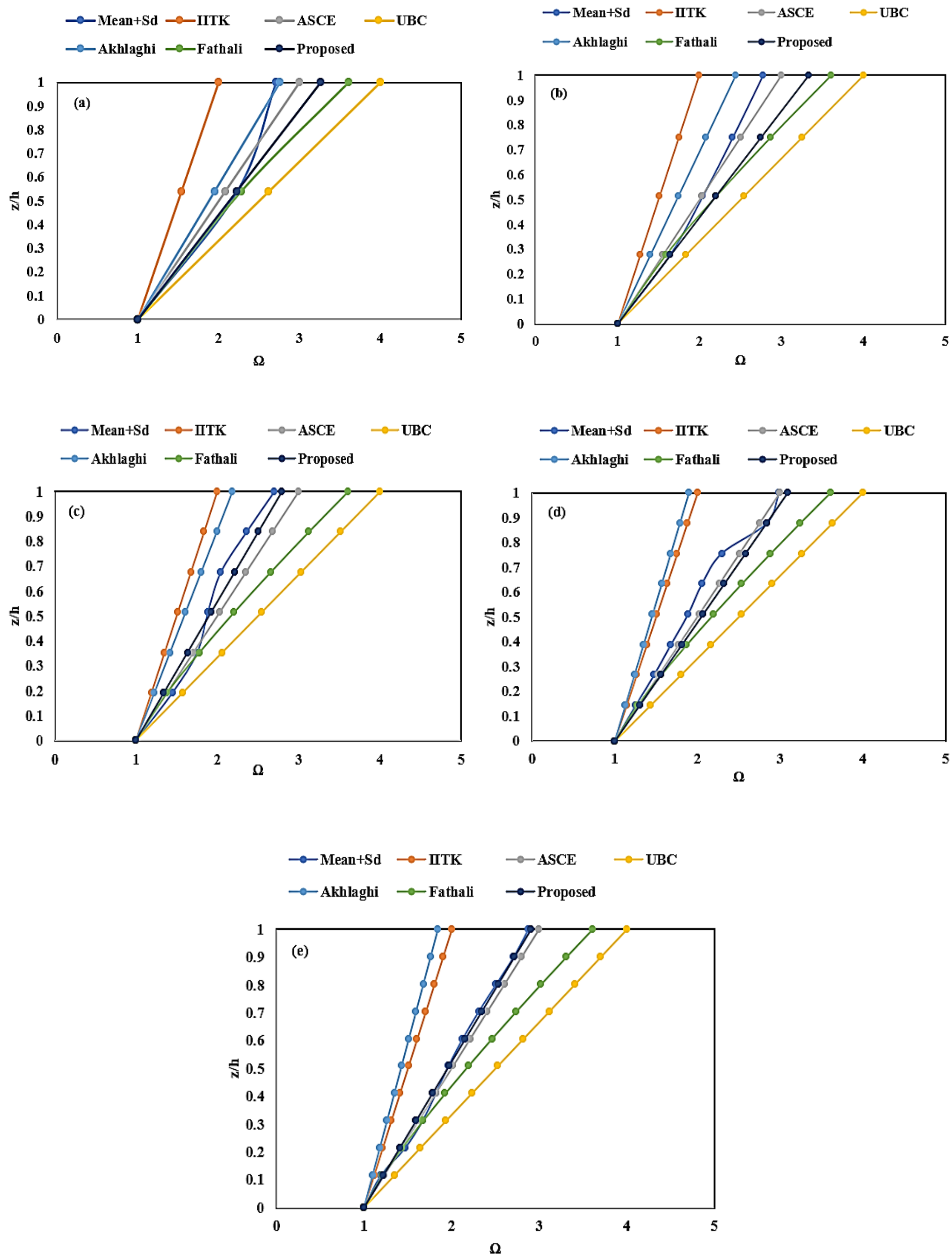
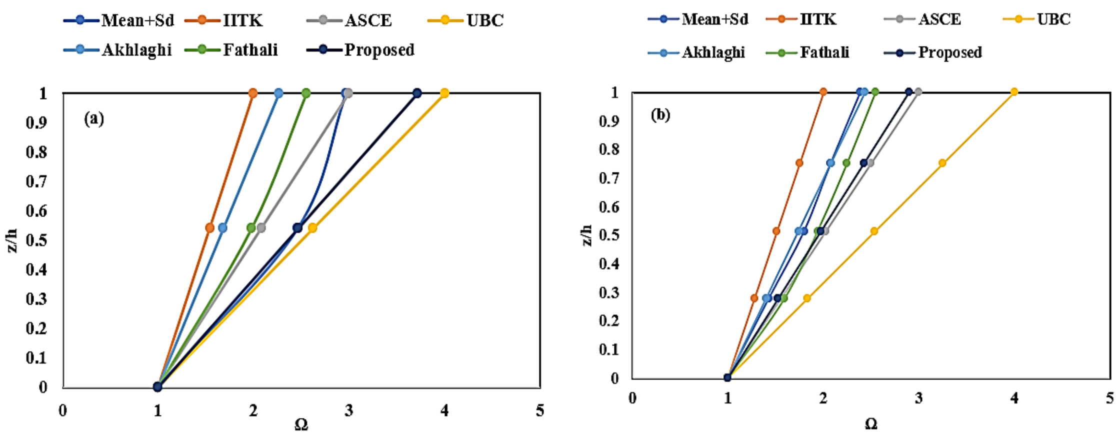


Figure 6.5 Comparison of the models with the seismic range 0.01g to 0.067g (a) 2 (b) 4 (c) 6 (d) 8 and (e) 10 Stories.

In Figure 6.5, the behaviour of acceleration amplification factors is non-linear as the height of the building increases. IITK model gave a conservative result for all the building models when the ground motion range is 0.01g to 0.067g. UBC code gave safe results on an approximate basis. It was 48% high than the mean+sd results. ASCE model gives the linear relation between the amplification factor and the normalized height of the structures. ASCE model obtained obscure results for the natural period of the structure less than 0.7 sec.; after that, it performed satisfactorily. In Akhlaghi model, better results are observed when the natural period of the structure is less than 1.0 sec but for a higher period, it reacts obscure results, and its values are approximately 35% higher than mean+sd results. Fathali model is a non-linear model; its results are 34% higher than the mean+sd results. The proposed amplification model values are nearly 20% higher than the mean+sd amplification factor value for the natural period of the structure less than 0.7 sec. However, the proposed model results are much close to the mean+sd results when the natural period of the structure is higher than 0.7 sec, and its values are nearly 10% higher than the mean+sd results.



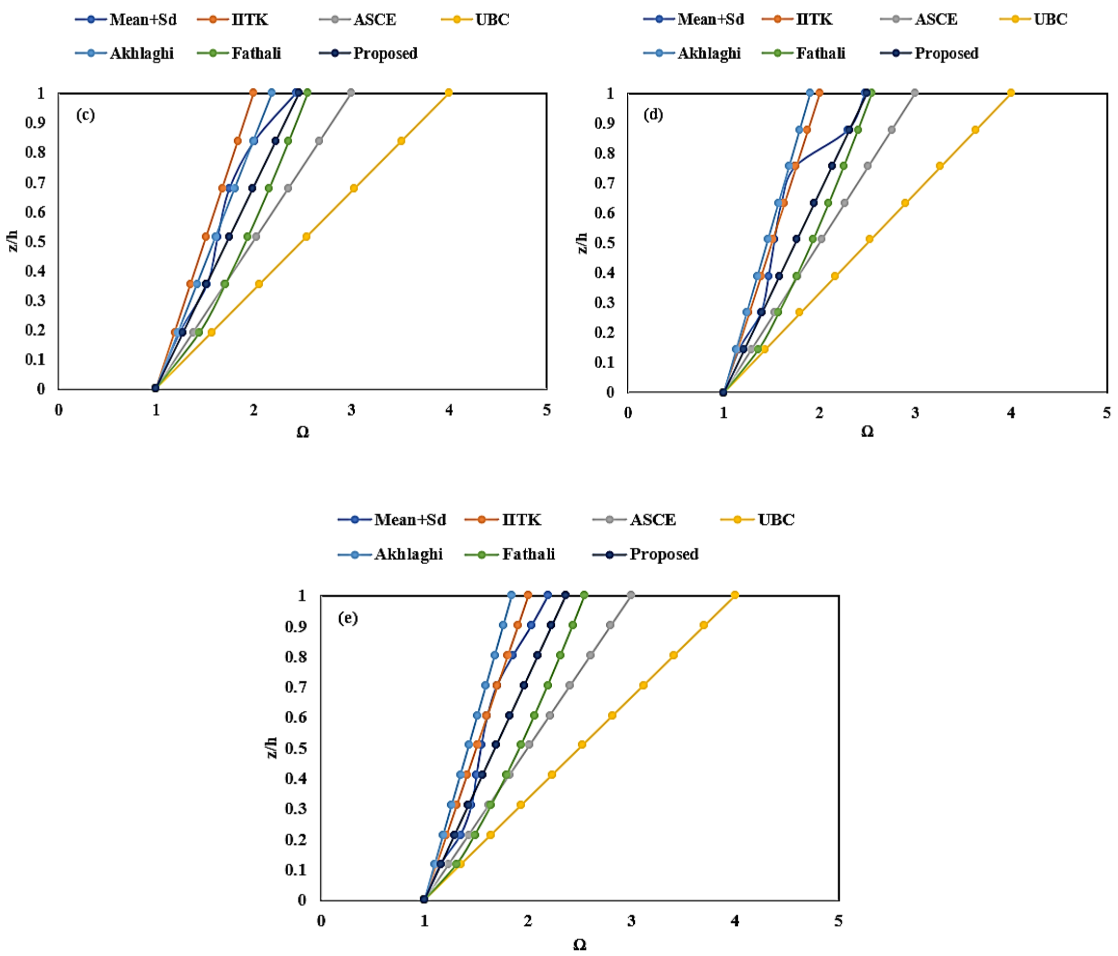
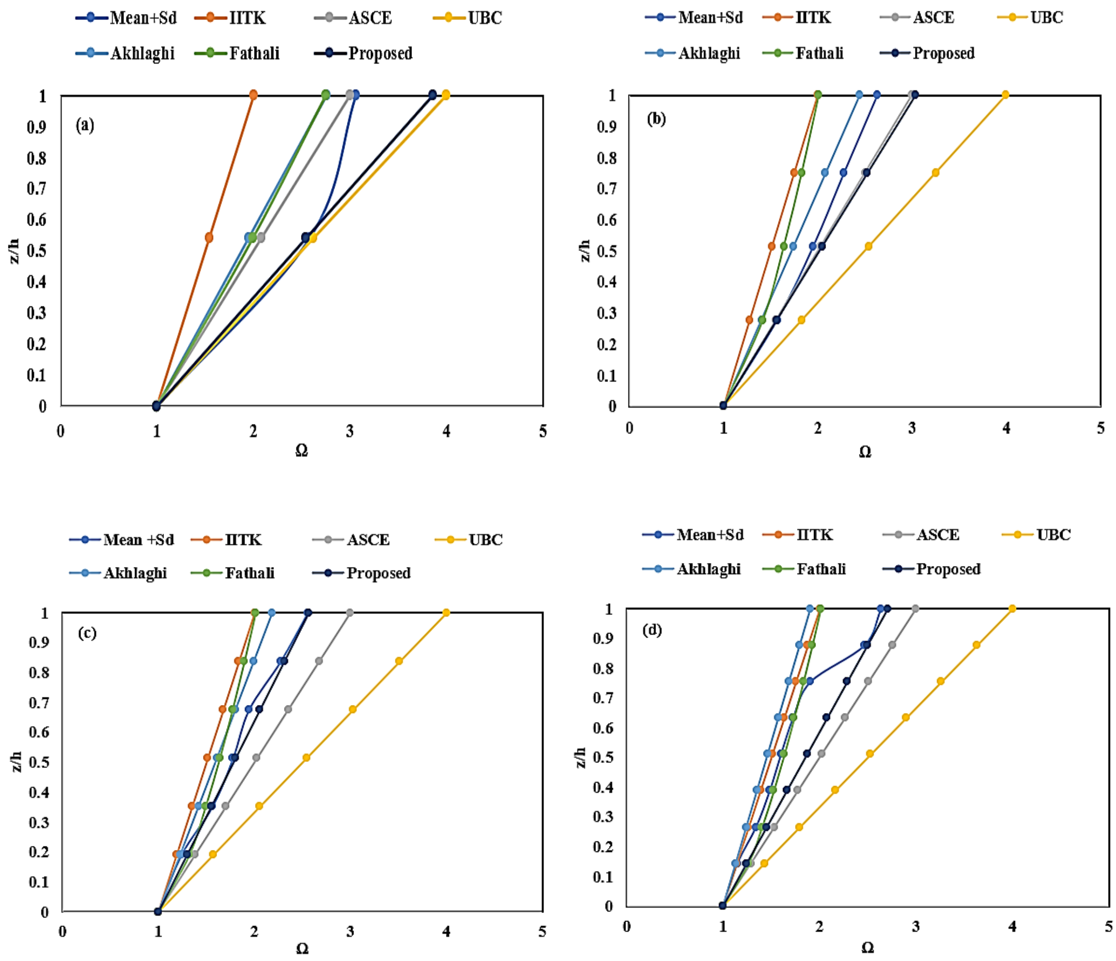


Figure 6.6 Comparison of the models with the seismic range 0.067g to 0.2g (a) 2 (b) 4 (c) 6 (d) 8 and (e) 10 Stories.

In Figure 6.6, IITK and Akhlaghi models gave lower value with respect to mean+sd results for all the fundamental period of the structures. UBC code observed better results compare to the IITK model, and it is approximately 38% higher than the mean+sd results for the natural period of the structure up to 0.7 sec. For the higher natural period of the structure, gaping of amplification values are increased related to mean+sd results. The Fathali model results are obscure when the natural period of the structures is less than 0.7 sec. However, its results are satisfactory when the period of the structure higher than 0.7 sec, and the amplification factor for this model is approximately 29% higher than the mean+sd results. When the natural period of the structures is less than 0.7 sec, only one model (UBC code) gives truthful results as compared to the other model, and the amplification values of this model are around 40% higher than the mean+sd amplification value. However, the proposed model value amplifies approximately 22% higher than the mean+sd results. The fundamental period of the structures increases from 1 to 1.5 sec where some models performed unclear results (IITK and Akhalghi model), however ASCE, UBC, and Faithli models amplification values 42%, 84%, and 30% higher than the mean+sd amplification results. The amplification value obtained by the proposed model is almost 18% higher than the mean+sd amplification results for the natural period of the structure is 1.0 to 1.5 sec and the seismic range of ground motion is 0.067g to 0.2g, respectively.



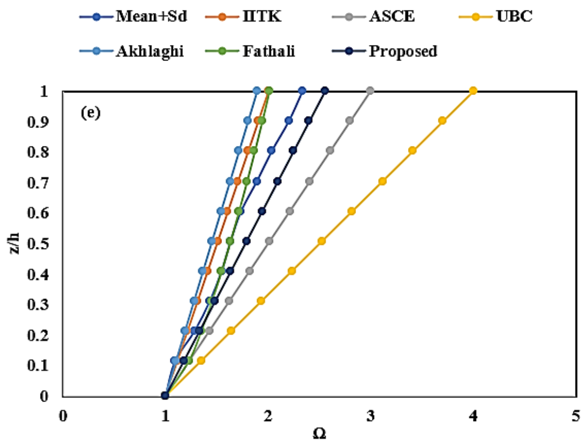


Figure 6.7 Comparison of the models with the seismic range 0.2g to 0.31g (a) 2 (b) 4 (c) 6 (d) 8 and (e) 10 Stories.

In Figure 6.7, When the ground motion range between 0.2g to 0.31g, the UBC model gives better results and is nearly 30% higher than the mean+sd results, although the natural period of the structures is up to 0.7 sec. For a higher natural period, the UBC model gives obscure results, and the amplification factor values are approximately 72% higher than the mean+sd amplification factor results. In contrast, the amplification value of the proposed model is 20% higher than the mean+sd amplification results for the fundamental period of the structure up to 1.0 sec. As the natural period of the structures increases from 1.0 sec to 1.5 sec, IITK and Faithli model does not observe reasonable results, whereas ASCE and UBC model observed 30% and 72% higher than the mean+sd amplification results. The amplification values of the proposed model are approximately 15% higher than the mean+sd amplification value for the period of structure lying between 1.0 sec to 1.5 sec and the seismic range are 0.2g to 0.31g, respectively.

6.6 CONCLUDING REMARKS

In this Chapter, five different models as, 2, 4, 6, 8, and 10 stories have been considered. The support condition of all these models is the pin and linear time history method used for the analysis of these models. A range of time history data, 0.01g to 0.32g, is considered. To determine the acceleration amplification factor and comparison with the previously proposed models is done. For acceleration amplification values, no single model is performing to give satisfactory results for pin support conditions. To this overcome, the proposed acceleration amplification model is given and compared with the previous renowned models. The conclusions are summarised as:

- For pin support condition and the different range of seismic motion, IITK-GSDM model do not perform to give satisfactory results.
- UBC code formula performed to give better results when the natural period of the structures is less than 0.7 sec.; after that, its results are conservative.
- Akhlaghi model depends on the fundamental period of the structures, but this model does not perform to give truthful results when the support condition has pined.
- ASCE model is not given an adequate result when the fundamental period of the structures is less than 0.7 sec for all the different ranges of seismic ground motion.
- When the natural period of the structure is higher than 0.7 sec, the ASCE model gives better results for the ground motion range of 0.01g to 0.067g. But for other ranges as 0.067g to 0.2g and 0.2g to 0.32g, its results are found to be conservative.
- Fathali model observed satisfactory results when the ground motion range is 0.067g to 0.2g. But on the higher seismic range, its results performed inadequately.
- The acceleration amplification factor of the non-structural components is not only dependent on the height of the building, but it also depends on the fundamental period of the structures and the intensity of the ground motion.

The proposed model gave satisfactory results with respect to the previously renowned models for the different ranges of ground motion with pin support conditions. This research is focused on the pin-supported RC frame Structures: hence the results and conclusion derived herewith may not present the shear wall or braced frame structures.