CHAPTER 5

SEISMIC ACCELERATION AMPLIFICATION FACTOR FOR FIXED AND PIN SUPPORT IN RC FRAME STRUCTURES: COMPARATIVE STUDY FOR CHI-CHI EARTHQUAKE

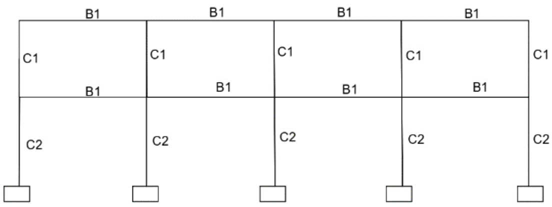
The peak horizontal floor acceleration has been used to determine the susceptibility of acceleration-sensitive non-structural elements. The force acting on the non-structural element’s such as mechanical, electrical or architectural components, is estimated because of the dynamic behaviour of the structures. The behaviour of the non-structure components' amplification factor is influenced not only by the building height but also by the structural support condition. Five distinct building models, including 2, 4, 6, 8, and 10 stories, have been studied in this article. Two different support conditions (pinned and fixed) are assigned to the base joints and the rigid NSCs linked with the main structures. The pin support condition is treated as a shallow foundation; however, the fixed support behaves as a deep foundation. The linear time history method is used for the analysis of these models considering the different ranges of the near-field directive earthquake (0.01g to 0.067g, 0.067 to 0.2g and 0.2g to 0.32g), to determine the acceleration amplification factor (Ω) (ratio between peak floor acceleration to the ground acceleration) for both support conditions. By comparing the actual acceleration amplification value for fixed and pin support conditions with the previous reported models, it is observed that some models performed satisfactorily for fixed support condition whereas some models give truthful results for pin support condition. It perceives that no such formula can be effectively used for both support conditions with different ground motion ranges.

5.1 EXISTING MODELS

The UBC code gave the provision for determine the lateral seismic design force acting on the NSCs. As per this code the maximum acceleration amplification factor is 4, act on the roof of the building. However, ASCE code define the maximum amplification factor is equal to 3. The code provision of amplification factor given by ASCE and UBC, performed the linear behaviour as the rise of the building height. In IITK-GSDM model gives the formula for determining the amplification value based on the height of the building. Similarly, Akhalghi model observed the amplification value is also depends the natural period of the structures. Based on these factors, Akhalghi proposed the amplification factor formula. However, Fathali observed that the amplification factor depends only height of the building and the range of seismic motion; based on this, Fathali proposed the amplification factor formula. All these models were depicted in chapter 3, respectively.

5.2 BUILDING CONFIGURATION

Five RC moment-resisting frame structures of two, four, six, eight, and ten stories are considered to determine the amplification factor for fixed and pin support conditions above the hard soil. For all calculations presented here, chosen first and the other storey height is 4m and 3.4m, respectively. The two-dimensional models of the fixed supports are shown in Figure 5.1. The size of the beams and columns is given in Table 3.1. The fundamental period of the structures is taken in the ranges of 0.1 to 1.5 seconds, and the damping ratio is 5%.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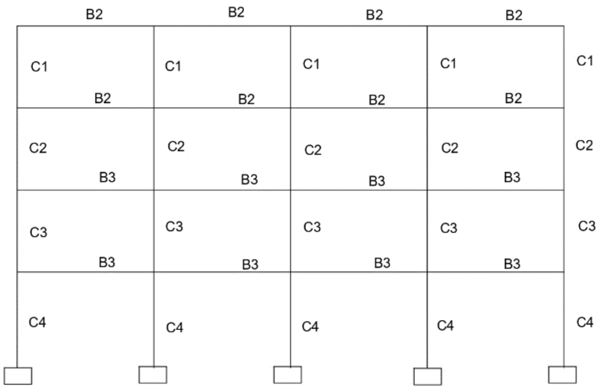
(a)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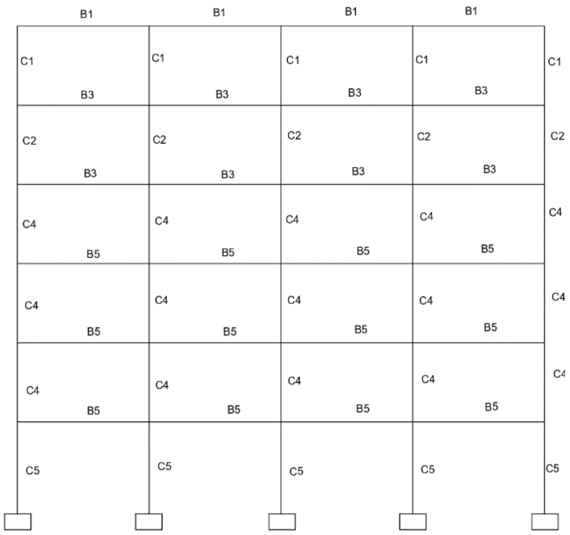
(b)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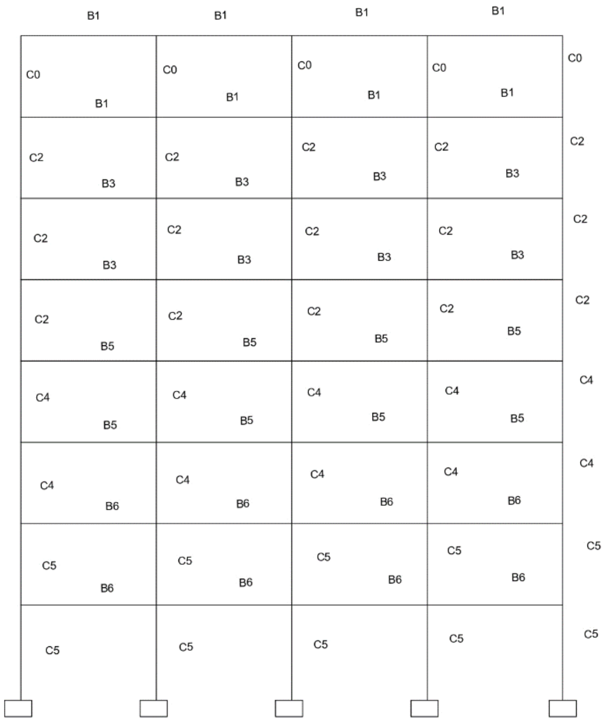
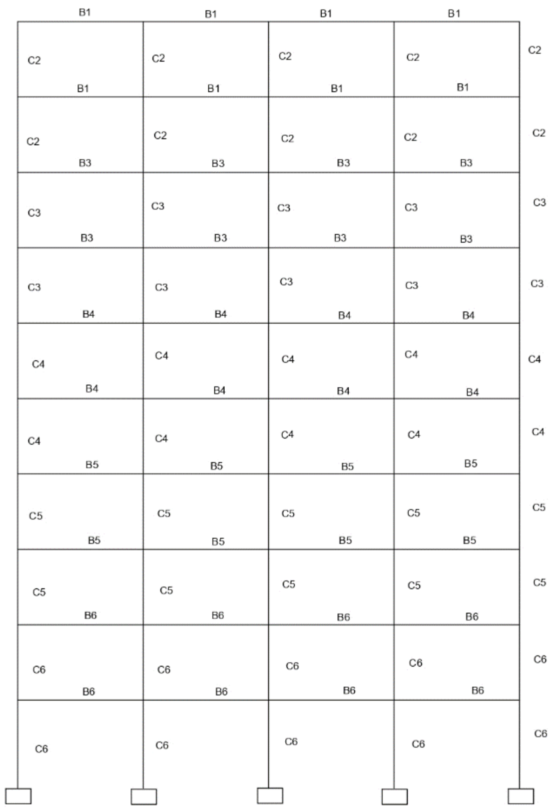
(c)

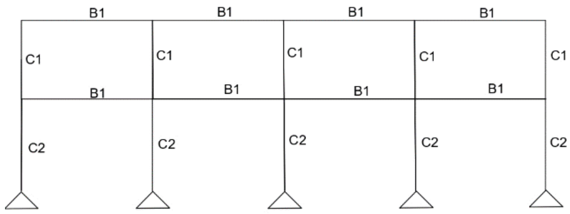


(d)

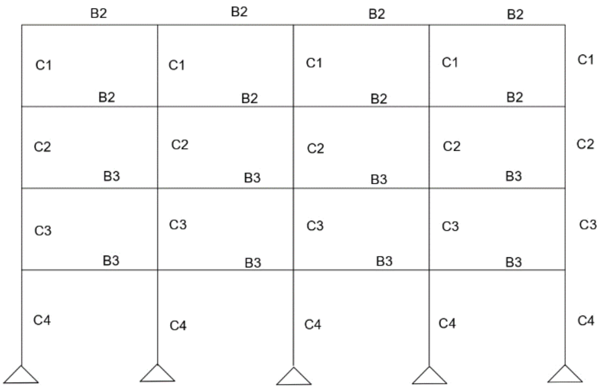


(e)

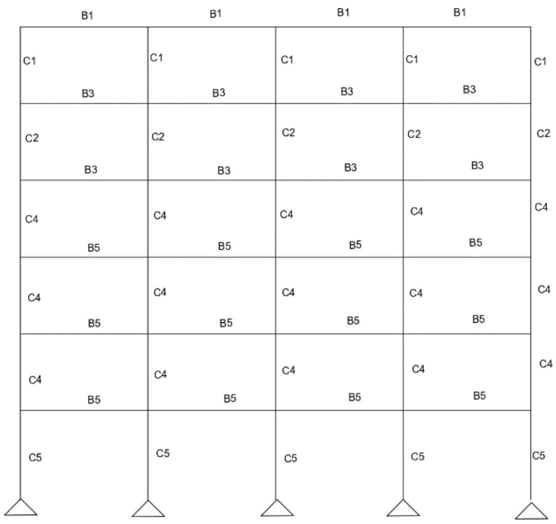
Figure 5.1 Fixed supported Moment resisting frame models (a) 2 (b) 4 (c) 6 (d) 8 and (e) 10 stories


B1 B1 B1 B1
C1 C1 C1 C1 C1
B1 B1 B1 B1
C2 C2 C2 C2 C2

(a)


B2 B2 B2 B2
C1 C1 C1 C1 C1
B2 B2 B2 B2
C2 C2 C2 C2 C2
B3 B3 B3 B3
C3 C3 C3 C3 C3
B3 B3 B3 B3
C4 C4 C4 C4 C4

(b)


B1 B1 B1 B1
C1 C1 C1 C1 C1
B3 B3 B3 B3
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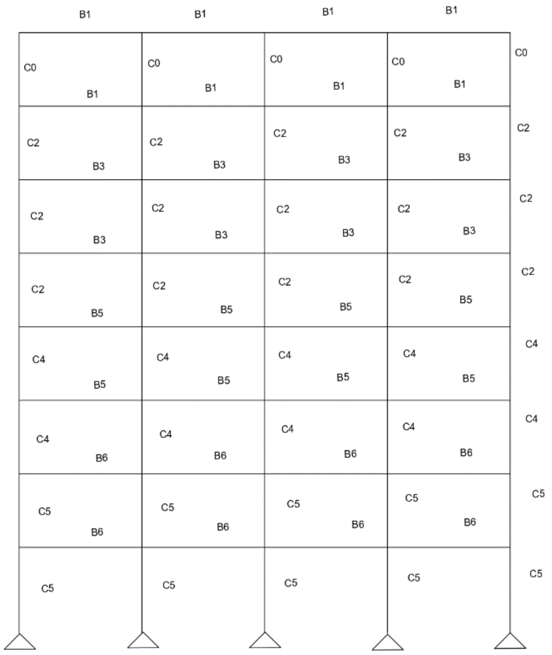
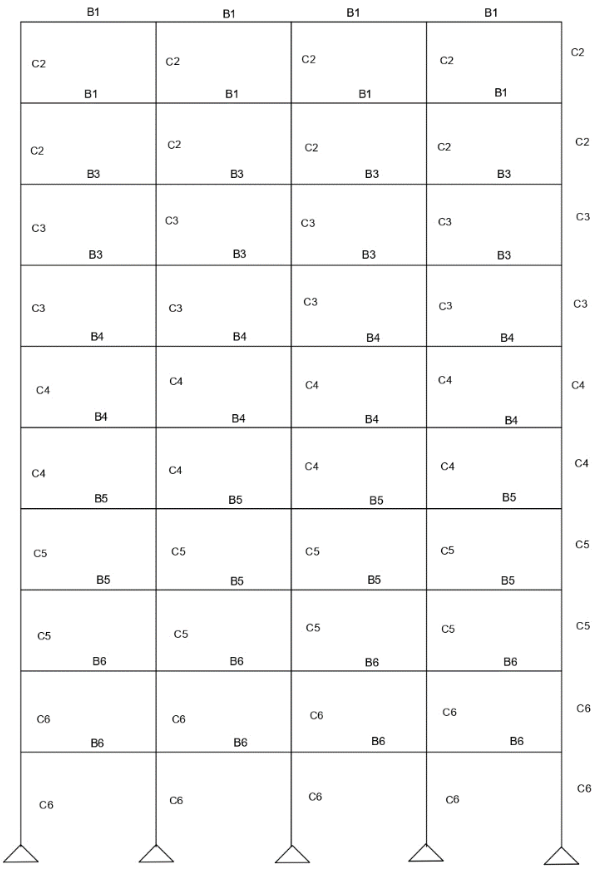
C4 C4 C4 C4 C4
B5 B5 B5 B5
C4 C4 C4 C4 C4
B5 B5 B5 B5
C4 C4 C4 C4 C4
B5 B5 B5 B5
C5 C5 C5 C5 C5

(c)



(d)



(e)

Figure 5.2 Pin supported Moment resisting frame models (a) 2 (b) 4 (c) 6 (d) 8 and (e) 10 stories

5.3 GROUND MOTION SELECTION

Many researchers have considered the ground motion intensity higher than 0.4g, but in most cases, the building collapsed in the low range of the ground acceleration. Therefore, the low range of ground motion has been considered in this study. For the analysis of the RC models, near field time history data having ranges between 0.01g to 0.32g are considered. The range of the ground motion is divided based on Fathali and lizundia [139] (0.01g to 0.067g, 0.067g to 0.2g and higher than 0.2g). The ground motion selection is obtained from the strong ground motion virtual data centre [140]. In this study, 28 recorded ground motion data is taken 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 0.3g. Details of the ground motion data are given in Tables 4.2, 4.3, and 4.4.

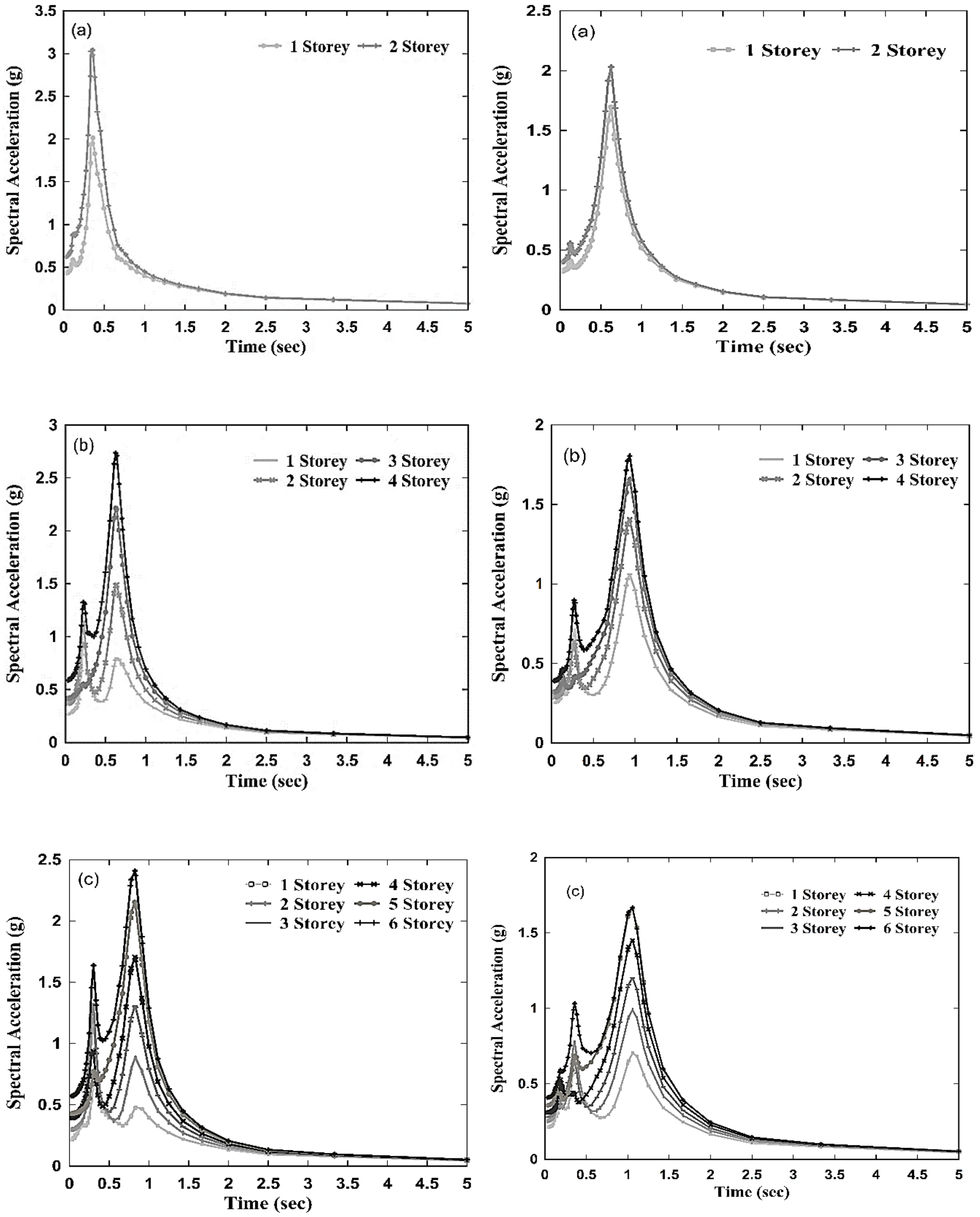
5.4 RESULTS AND DISCUSSION

5.4.1 Floor Response Spectra

To perform the dynamic analyses of the structures, the different ground motion data are applied at the model's base. In order to obtain the floor response spectra of the various models, 5 % damping ratio is considered. A mean response spectrum of the structures is plotted in figure 2 for fixed and pin support conditions with ground motion 0.2g to 0.30g. These floor spectra give information on acceleration demand and act on the NSCs which are linked with the main components having the fundamental time period T.

Figure 5.3 shows that for a two-storey model if the frequency content of the non-structural component is equal to the frequency of the main structures, the floor response exhibit up to ten times the base acceleration and its values decrease up to 6 times for ten storey model in fixed support condition. However, for pin supports, the floor spectra for a two-storey model are 7 times higher than base acceleration and decrease to 4.5 times for the ten-storey model. For comparing both support conditions, the amplification factor for fixed support is chosen higher than for the pin support condition.

Fixed Support **Pin Support**



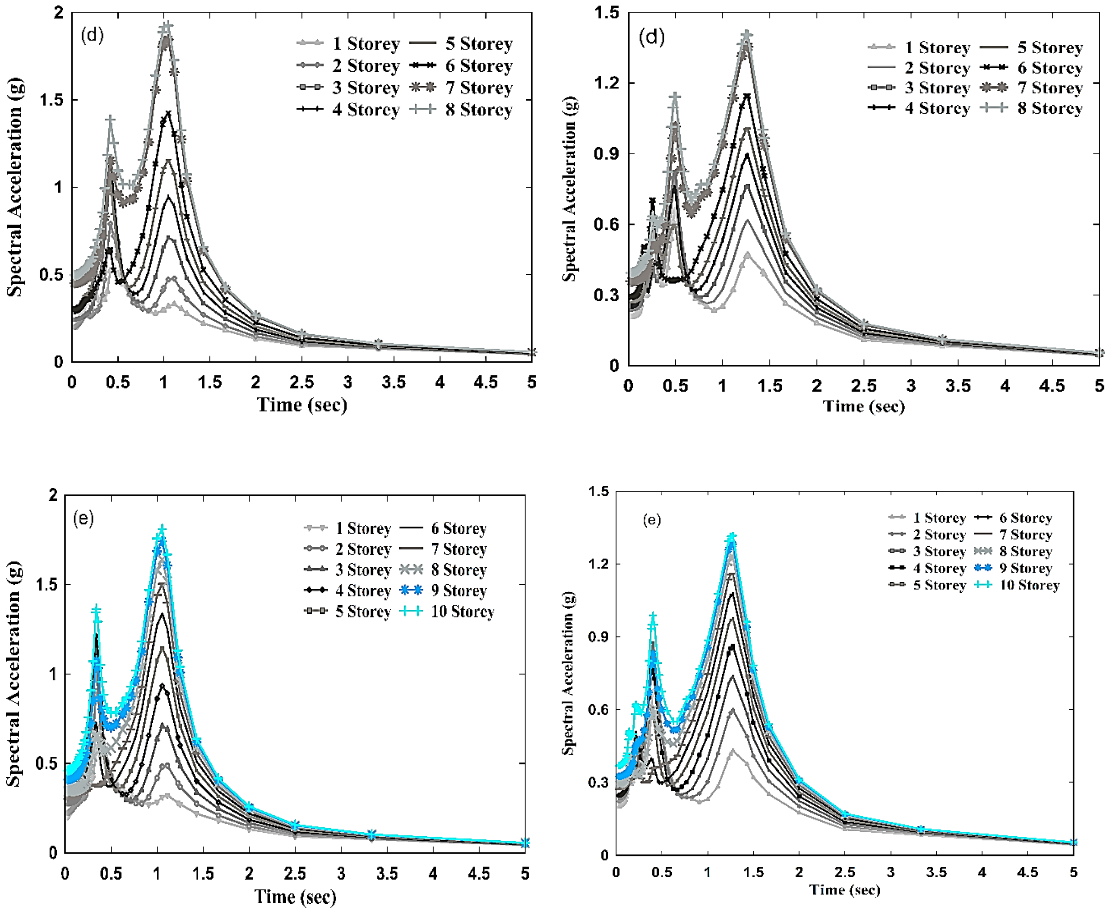


Figure 5.3 Floor response spectra of the different models for fixed and pin support condition

5.4.2 Acceleration Amplification Models

It is perceived that the amplification factor (Ω) shape is nonlinear (S-shape) as the natural period of the structure increases. For fixed support condition, acceleration amplification values decrease with respect to the height of the structures increases. For the pin support condition, as the range of the ground motion increases (0.01g to 0.31g), the amplification value decreases with regard to normalised height of the building.

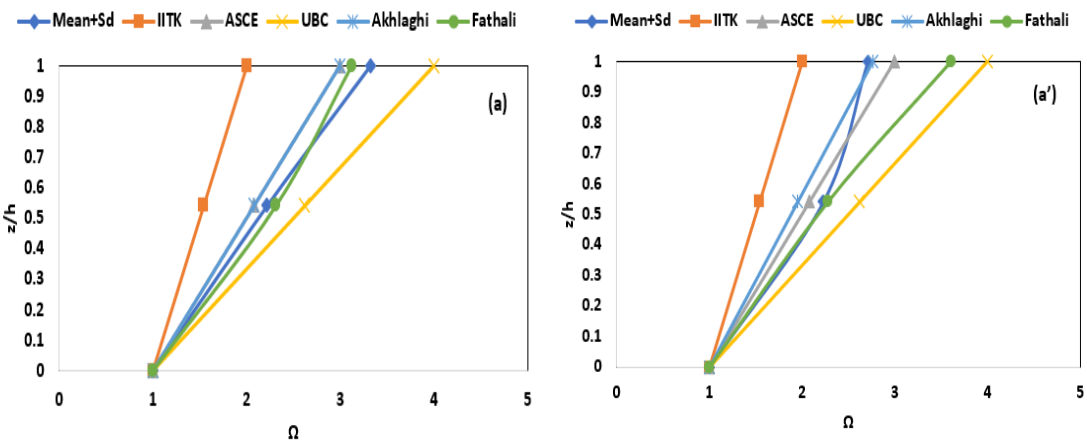
5.5 COMPARISON AND DISCUSSION

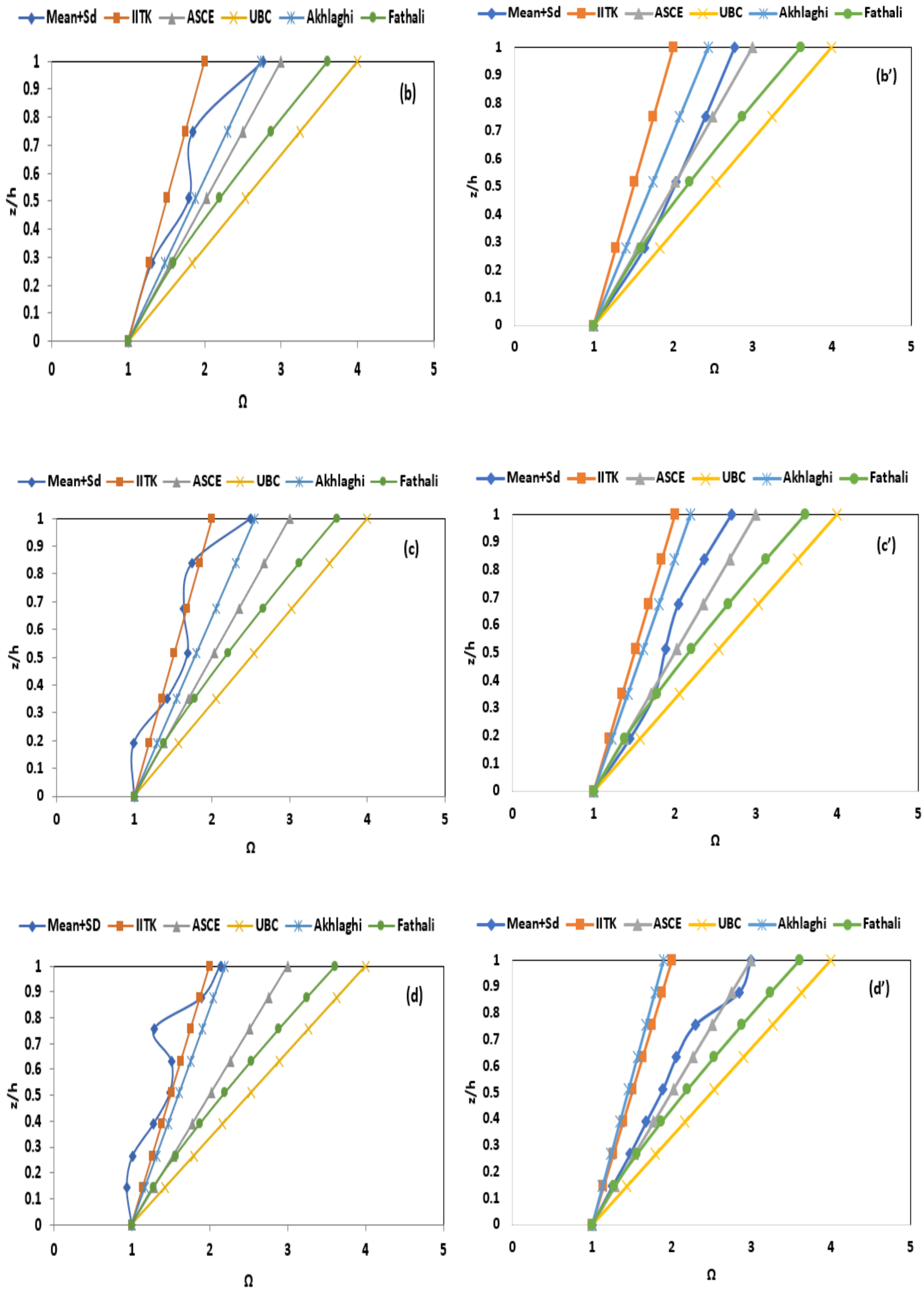
5.5.1 Comparison of Amplification models with fixed and pin support condition

The behaviour of the model with fixed and pin support condition are shown in Figures 5.4-5.6;

In Figure 5.4, the shape of the amplification factor (Ω) is non-linear with the height of the building for both support conditions. However, for fixed support condition, the non-linearity of the amplification factor is more than pin condition for the ground motion 0.01g to 0.067g, as the fundamental period of the structure increases from 1 to 1.5 sec. IITK model gave satisfactory results only for fixed support but not for the pin condition. The UBC model always gave conservative results for both support conditions. Fathali's model also gave conservative results for both support conditions with the fundamental time period of 0.5 to 1.5 sec, respectively. It should be mentioned that the ASCE codel equation produced superior results for fixed support when the fundamental period of the structure was up to 0.5 sec, but its findings after that are conservative. On the other hand, the ASCE formula gave a satisfactory result for all models with ground motions ranging from 0.01 to 0.067g and buildings with natural time periods ranging from 0.1 to 1.5 seconds. Akhlaghi model gave better results when the fundamental period of the structure is 0.10 to 1.5 sec. in fixed support condition while for pin support condition this model is not useful when the ground motion range is 0.01g to 0.067g respectively.

Fixed Support **Pin Support**





Mean+Sd IITK ASCE UBC Akhlaghi Fathali
(b)
z/h
Ω
(b')
(c)
(c')
Mean+SD
(d)
(d')

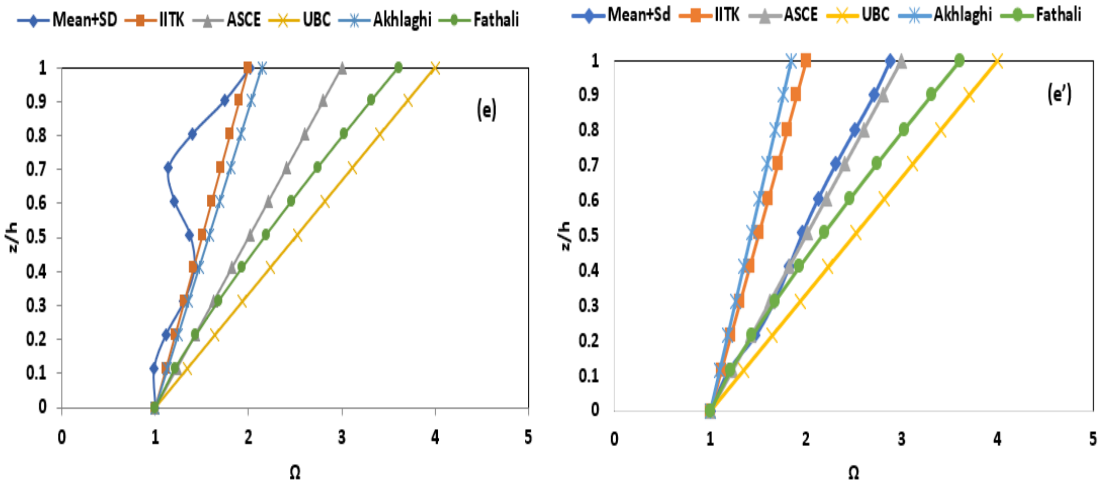
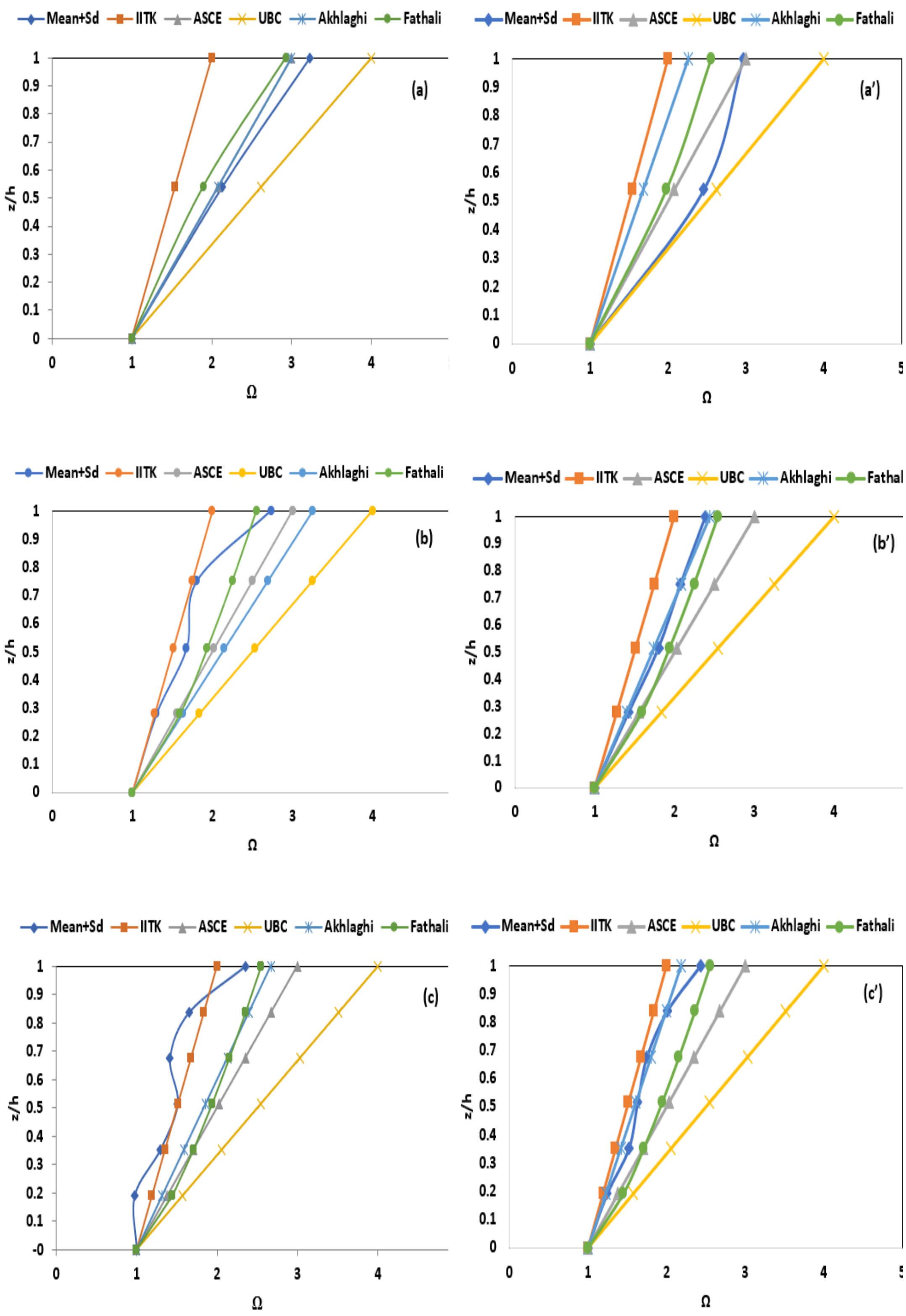


Figure 5.4 Comparison of the models for fixed and pin support condition with acceleration 0.01g to 0.067g having 2,4,6,8 and 10 stories.

When the ground motion range from 0.067g to 0.2g, the shape of the actual amplification value with respect to normalised height is non-linear. For fixed support, the amplification value decreases as the normalised height of the buildings increases, whereas, in pin support, the amplification value is approximately same at the top of the floors with an increase the normalised height of the building. The fixed support IITK model does not carry out satisfactory results for both fixed and pin support conditions. UBC model performs conservatively for both support condition when the ground motion range is 0.067g to 0.2g. ASCE code formula shows good results when the natural period of the building is less than 0.5 sec. But when the natural period of the structures is higher than 0.5 sec, its effects are conservative, for the ground motion range lies between 0.067g to 0.2g. Akhlaghi model produces satisfactory results, for the fixed support condition when the natural period of the structures is up to 1.5 sec, whereas for pin support this model is not reasonable. The Fathali's model gives unsatisfactory results for both the support conditions when the natural period of the structures less than 0.5 sec., however, as the fundamental period of the structures increases, its results are adequate for the ground acceleration ranges between 0.067g to 0.2g.

Fixed Support **Pin Support**



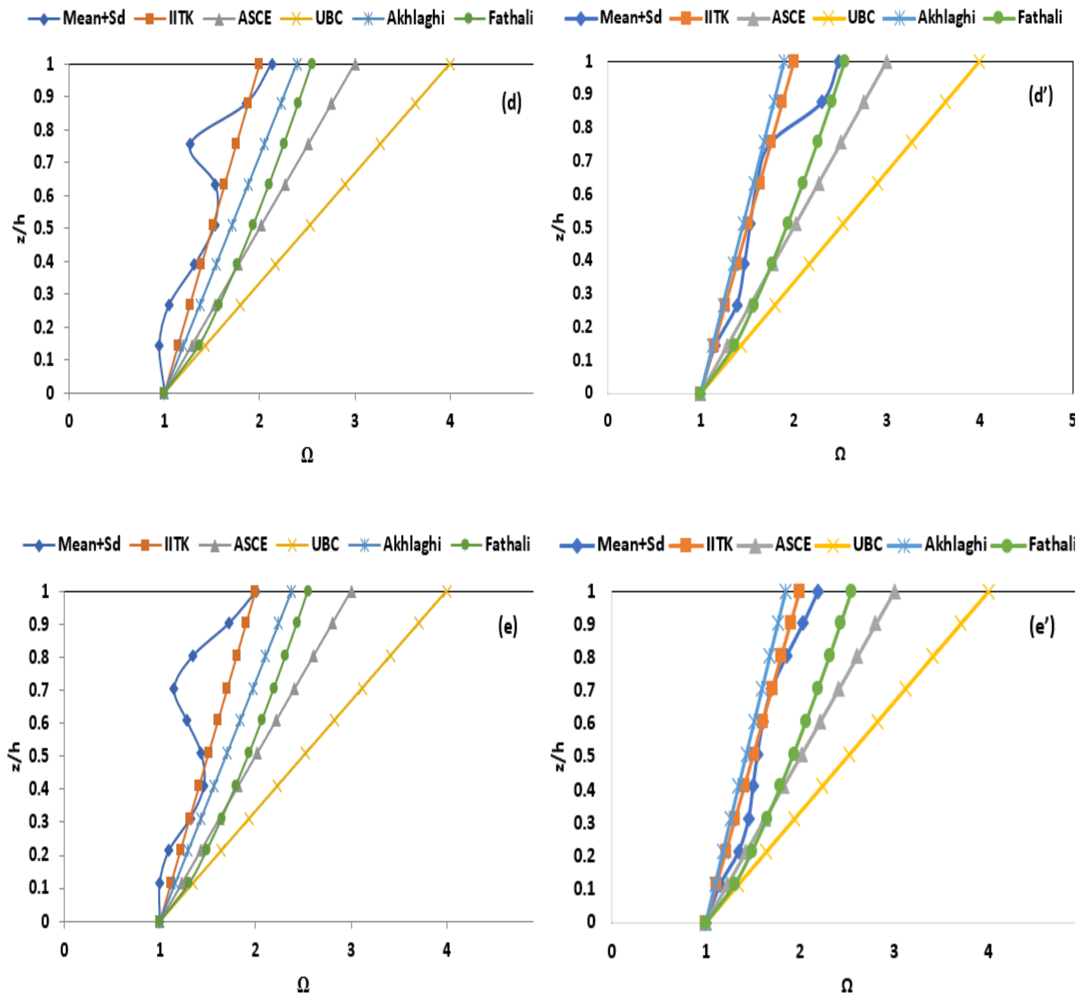
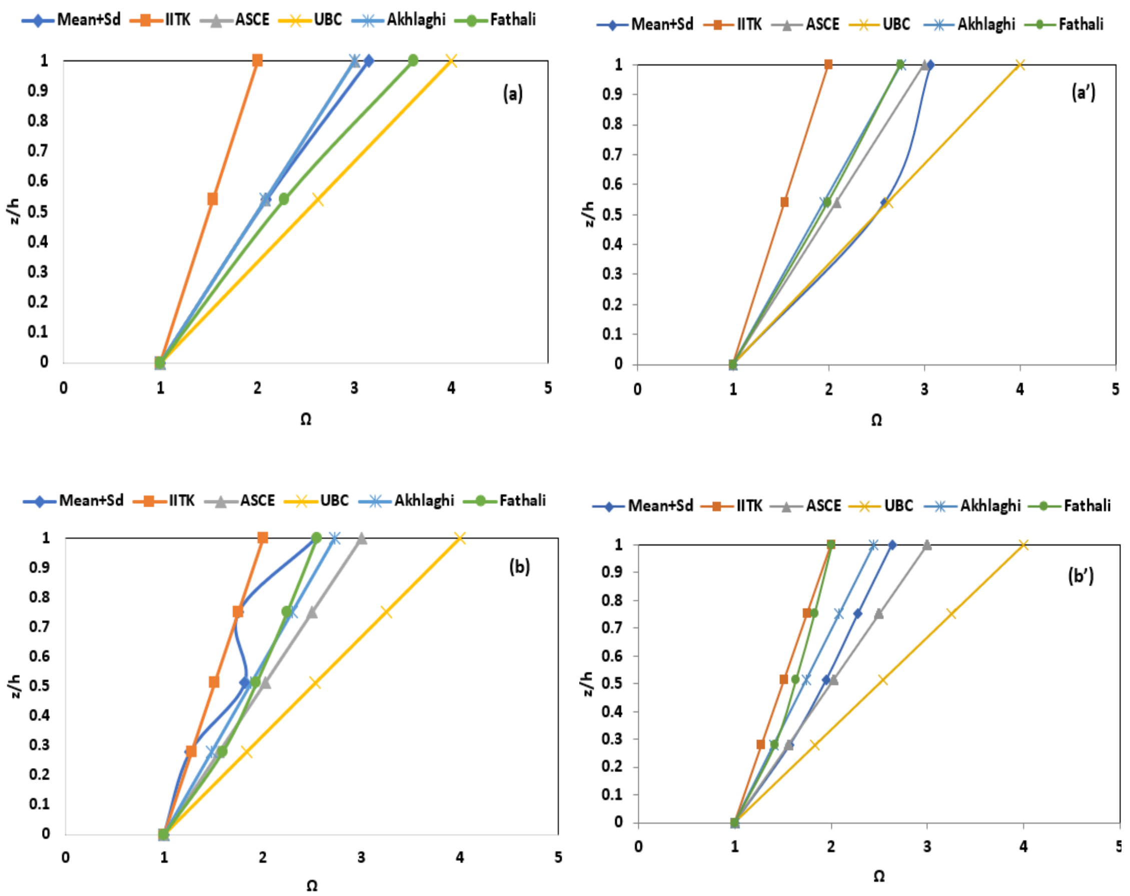


Figure 5.5 Comparison of the models for fixed and pin support condition with acceleration 0.067g to 0.2g having 2,4,6,8 and 10 stories.

For the ground motion range 0.2g to 0.3g, the IITK model for fixed support, produces the conservative results when the natural time period of the structure is up to 1 sec. After that, it produces satisfactory results. However, for pin support, IITK results are not satisfactory for all these building models. The UBC formula also showed conservative results for both support conditions. For fixed support, ASCE model observed better results when the natural time period of the structures is less than 0.5 sec. However, when the fundamental period of the structure increases, its results are conservative. On the other side, for pin support, ASCE code formula does not perform good results when the natural period of the structure is less than 0.5 sec. Still, its results are acceptable when the structure's natural period increases up to 1.5 sec. In Fixed support, the Akhlaghi model performs effective results, but for pin support, its results are not effective for the ground motion range of 0.2g to 0.30g. For a fixed support condition, Fathali’s model performed satisfactory results up to 1 sec.; after that, its results are conservative. Furthermore, it showed better results for pin support condition with respect to other renowned models for the ground motion 0.2g to 0.30g.

Fixed Support **Pin Support**



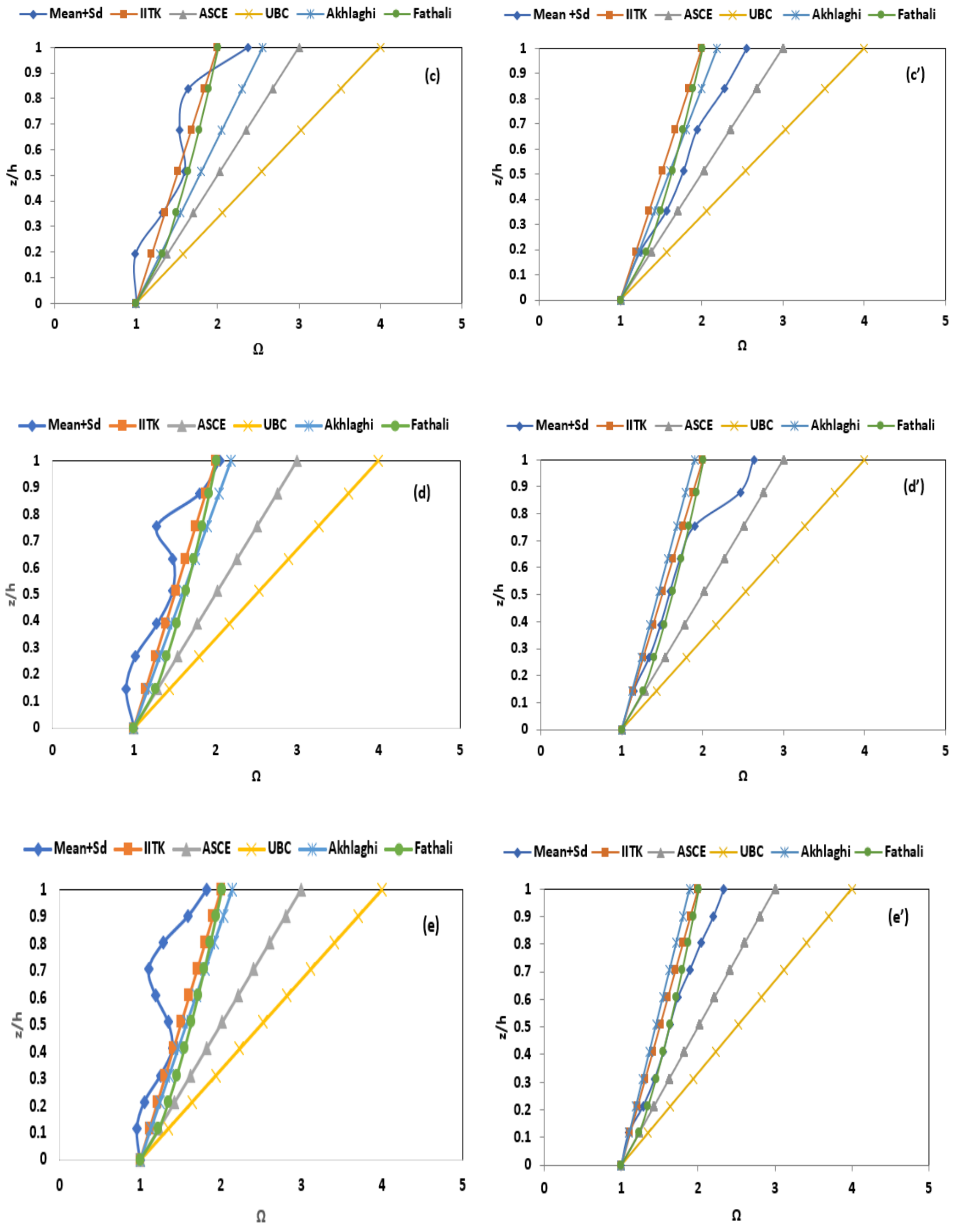


Figure 5.6 Comparison of the models for fixed and pin support condition with acceleration 0.2g to 0.31g having 2,4,6,8 and 10 stories.

5.5.2 Comparison of amplification models with respect to Mean Plus Standard deviation

From the analysis of all these buildings models with different support condition, it is observed that for pin support, when the ground acceleration is in the range of 0.01g to 0.067g and the fundamental time period of the structure is taken in between 0.5 to 1.0 sec, Akhlaghi modal gave better results. But when the fundamental period of the structure increases up to 1.5 sec. ASCE model gave better results. Overall, the acceleration amplification factor for ground motion range from 0.01 g to 0.067g the ASCE formula shows satisfactory results.

In Table 5.2, when the ground motion range lies 0.067g to 0.2g and the structures' time period is between 0.5 to 1 sec, all models are conservative except UBC code, and when the natural period lies in 1 to 1.5 sec, Fathali model gave good results. Overall, the ground motion range of 0.067g to 0.2g for pin support UBC code provided satisfactory results.

In Table 5.3, when the ground motion range is 0.2g to 0.32g and the time period 0.5 to 1 sec, UBC code gives better results with respect to other models to determine the amplification factor. On the other hand, the ASCE formula gives better results when the fundamental period increases by 1 to 1.5 sec. Overall, the acceleration amplification factor for NSCs between the ground acceleration ranges from 0.2g to 0.30g, UBC code shows satisfactory results.

For the fixed support condition, results are expressed in table 5.4, 5.5 and 5.5 for the ground motion range 0.01g to 0.30g and the fundamental natural period of the structures, 0.1 to 1.5 sec. Table 5.4 discusses the percentage of the amplification results when the seismic ground motion ranges from 0.01g to 0.067g. It is observed that Akhlaghi model performed satisfactorily with respect to another renowned model. In Table 5.5, the ground motion range lies from 0.067g to 0.2g; the UBC code observed close result with respect to mean plus standard deviation results of amplification factor for fundamental period of the structure up to 0.5 sec, after which its results are conservative with respect to other models. The structure's fundamental period is taken between 0.5 to 1.5 sec. Akhlaghi model gave satisfactory results. In table 5.6, when the ground motion is in the range of 0.2g to 0.30g Fathali model gave better results with respect to other models.

Table 5.1 Amplification factor (in %) for different models at pin support with respect to actual results when the ground motion range 0.01g to 0.067g

Fundamental Time Period (sec.)	Amplification factor with respect to actual results (in %)				
	IITK	ASCE	UBC	Faithli	Akhlaghi
T<0.5	-	-	-	-	-
0.5<T<1.0 sec	-27	11	48	33	2
1.0<T<1.5 Sec	-33	11	48	34	-37

Table 5.2 Amplification factor (in %) for different models at pin support with respect to actual results when the ground motion range 0.067g to 0.2g

Fundamental	Amplification factor with respect to actual results (in %)				
Time Period (sec.)	IITK	ASCE	UBC	Faithli	Akhlaghi
T<0.5	-	-	-	-	-
0.5<T<1.0 sec	-37	-15	35	-20	-32

1.0<T<1.5 Sec	-19	42	84	29	-24

Table 5.3 Amplification factor (in %) for different models at pin support with respect to actual results when the ground motion range 0.2g to 0.30g

Fundamental Time Period (sec.)	**Amplification factor with respect to actual results (in %)**				
	IITK	**ASCE**	**UBC**	**Faithli**	**Akhlaghi**
T<0.5	-	-	-	-	-
0.5<T<1.0 sec	-41	-20	31	-23	-25
1.0<T<1.5 Sec	-24	29	72	-24	-28

Table 5.4 Amplification factor (in %) for different models at fixed support with respect to actual results when the ground motion range 0.01g to 0.067g

Fundamental Time Period (sec.)	**Amplification factor with respect to actual results (in %)**				
	IITK	**ASCE**	**UBC**	**Faithli**	**Akhlaghi**
T<0.5	-28	35	76	55	35
0.5<T<1.0 sec	-28	54	102	79	24
1.0<T<1.5 Sec	25	111	172	140	58

Table 5.5 Amplification factor (in %) for different models at fixed support with respect to actual results when the ground motion range 0.067g to 0.2g

Fundamental Time Period (sec.)	Amplification factor with respect to actual results (in %)				
	IITK	ASCE	UBC	Faithli	Akhlaghi
T<0.5	-38	-7	24	-11	-7
0.5<T<1.0 sec	-27	66	114	52	57
1.0<T<1.5 Sec	38	110	171	91	71

Table 5.6 Amplification factor (in %) for different models at fixed support with respect to actual results when the ground motion range 0.2g to 0.30g

Fundamental Time Period (sec.)	Amplification factor with respect to actual results (in %)				
	IITK	ASCE	UBC	Faithli	Akhlaghi
T<0.5	-36	-5	27	15	-5
0.5<T<1.0 sec	-21	63	114	34	40
1.0<T<1.5 Sec	54	117	181	62	63

5.6 CONCLUDING REMARKS

This paper considers five different building models as 2, 4, 6, 8 and 10 storeys. For the analysis of the structures, different support conditions (fixed and pinned support) have been considered. These models are analysed using the time history technique. Many ground motion data ranging from 0.01g to 0.32g have been considered, and the resulting amplification factor is compared with the different models available in the literature. The conclusions of this paper are given below:

- For both support condition, the amplification value decreased as the height of the building increased. The floor spectral acceleration for the fixed support condition is found to be higher than the pin support condition.
- IITK model for acceleration amplification factor, when the fundamental period of the structures lies 1 to 1.5 sec., did not perform satisfactory results for both support condition.
- ASCE code provision gave satisfactory results for the fixed support condition with respect to the pin support. In pin support, it gave better results when the fundamental period of the structure is higher than 1.0 sec.
- In all cases, when the fundamental period of the structure is higher than 0.5 sec., UBC code showed conservative results.
- For pin support, Fathali model performed better results for the ground motion range 0.01g to 0.067g. After that, it gave conservative results.
- For fixed support, Fathali model gave the satisfactory result for ground motion range 0.01g to 0.32g with respect to other models.
- Akhlaghi model shows satisfactory results approximately for all the ground motion ranges in fixed support rather than pin support. In pin support, this model showed conservative results.
- Overall, no single model can claim to produce satisfactory acceleration amplification value for both the support condition.