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ESSENCE OF POUNDING GAPS IN SEISMIC ZONE IV AND V WITH & WITHOUT SHEAR WALLS

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ABSTRACT

With the advent of new technologies, design philosophies and smart materials the mitigation techniques presented in civil engineering structures have gradually been reducing the effect caused by natural disasters such as earthquake and cyclones etc. The pounding effects during the earthquakes have significantly reduced with the inception of shear walls in multistorey RC framed buildings. To ascertain the magnitude of mitigation effect with shear wall, G+10 and G+8 storey adjacent RC framed buildings in Seismic Zone IV and Zone V were simulated in ETABS software using Response spectrum analysis. Even though there is a small seismic pounding gap is required for the buildings with shear walls, the seismic code IS 1893(PartI):2016 prescribed very conservative values.

Key words: IS 4326:2016, IS 1893(Part I)2016, Response Spectrum Analysis, Seismic Pounding Separation distance, Shear wall, ETABS Software.

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1. INTRODUCTION

1.1. Seismic Separation Width

It is owing to seismic ground motion, spatial variations and different dynamic properties, adjacent buildings may vibrate laterally out-of-phase, which can lead to collisions if the separation distance between them is not large enough. Pounding between inadequately separated buildings has been observed in most previous major earthquakes. Each time when pounding occurs, building structures will be subjected to large impact force which is not specifically considered in conventional designs. These impacts usually cause damage around the pounding areas of adjacent structures and may amplify the overall dynamic responses of structures. Enormous research efforts, especially after the 1985 Mexico earthquake, have been devoted to understanding the pounding responses of adjacent structures and development of mitigation measures to reduce responses are governed by the relative structural properties and the gap size between the adjacent buildings. In this study, the structural responses of adjacent buildings of unequal height subjected to pounding were considered. It is found that pounding might amplify the responses of the taller structure over the entire building height, and de amplify those, except at the storey's in the vicinity of the pounding, of the shorter building.

The effectiveness of implementing different techniques to mitigate pounding, such as filling the gap with rubber pad or joining the adjacent structures by dampers, has been studied. All these methods have pros and cons. For example, filling the gap with rubber pad may reduce the peak impact force but increases the number of poundings; joining the two structures together is beneficial to the flexible adjacent structure but increases the responses of the stiffer building. Therefore, it is concluded that the most effective method is to increase the separation distance/width to completely preclude pounding **(**Hong Hao 2015**)[3].**

1.2. Shear Walls

The walls, in the building, which resist lateral loads originating from wind or earthquakes are known as shear walls. The use of shear walls becomes imperative in certain high rise buildings, if inter-storey deflections caused by lateral loadings are to be controlled. When acting as a vertical cantilever beam ,the behavior of this wall , which is properly reinforced for shear ,will be governed by yielding of the tension steel located near the vertical edge of the wall. The most important property of shear wall for seismic design is that it should have a good ductility under reversible and repeated overloads.

1.3. Response Spectrum Analysis

There are significant computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode using smooth design spectra is the average of several earthquake motions(Ishan Jyoti Sharma 2008)[4]**.** In particular this method is applicable to analysis of forces and deformations in multi-storey buildings due to medium intensity ground shaking, which causes a moderately large but essentially linear response in the structure. (SK Duggal 2017) [13].

The aim of this paper is to understand the seismic pounding gap requirement for Reinforced Concrete (RC) buildings with a special moment resisting frame (SMRF) with shear walls in Seismic Zone IV and V in India. For this purpose, a parametric study was conducted with response spectrum dynamic analysis in ETABS Software[17] for two adjacent RC frame buildings with G+10 storey and G+8 storey heights with an initial pounding gap of

25mm (IS 4326:2013)[7]. Comparative study of IS 1893 (Part I): 2016 Codal provisions are also epitomized [5].

2. LITTERATURE REVIEW

An investigation of past and the recent earthquake damage has illustrated several instances of pounding damage. The main reason of collisions between adjacent buildings under earthquake excitation, besides insufficient distance between structures, is the difference in stiffness and/or mass. This difference leads to the out-of-phase vibrations and finally may cause structural interactions (B Sotysik and R Jankowski 2015)[1]. The positive and negative peak displacements are essential to determine the degree of biased response of the pounding system. Therefore, seismic poundings between adjacent buildings may induce unwanted damages, even though each individual structure might have been designed properly to withstand the strike of credible earthquake events. A sudden restraint of displacement at the pounding level results in large and quick acceleration pulses in the opposite direction (Shehata E. Abdel Raheem 2006) [15].

If the fundamental time periods of adjacent buildings are equally or very close to each other, the required separation distances are very small. However, as the periods of adjacent buildings vary, the required separation distances start to increase due to out-of-phase vibrations. A larger separation distance is required for both adjacent buildings have a longer fundamental period(Jeng-Hsiang Lin 1997)[8].

In the last decade, many methods were proposed by different researchers to mitigate pounding. These include filling the gap, connecting the adjacent structures, using bumper walls and providing adequate separation distance, etc. The most straightforward method is to provide sufficient separation between structures. Many seismic codes also give recommendations on the minimum required separation distance between structures to avoid pounding (Hong Hao and Jay Shen)[14]. Many cases of structural damage due to pounding between adjacent buildings during major earthquakes have been reported over the past two decades. Some case studies of pounding were Reported by Chenna Rajaram , Ramancharla Pradeep Kumar2012)[2].

The study of different shear wall positions to influence the pounding gap effects for G+12 storey and G+9 Storey with response spectrum, time history, and equivalent static analyses concluded that the pounding gaps were greatly reduced **(**Khaja Afroz Jamal et al..,2013)[9] Parametric study for pounding gaps with the SAP 2000 software elucidated that even though the response of taller frame is more the shear walls are more effective in comparison with the bracings (Puneeth Kumar M S et al 2015)[10]

(Sathish T B, et al 2016) [12]The prevention techniques of pounding between adjacent buildings for different earthquake zones with shear walls by ETABS 9.7.4 Version Software Package, It was found that by providing the shear wall at the corners, the pounding effect was reduced significantly both in terms of displacement and storey drift.

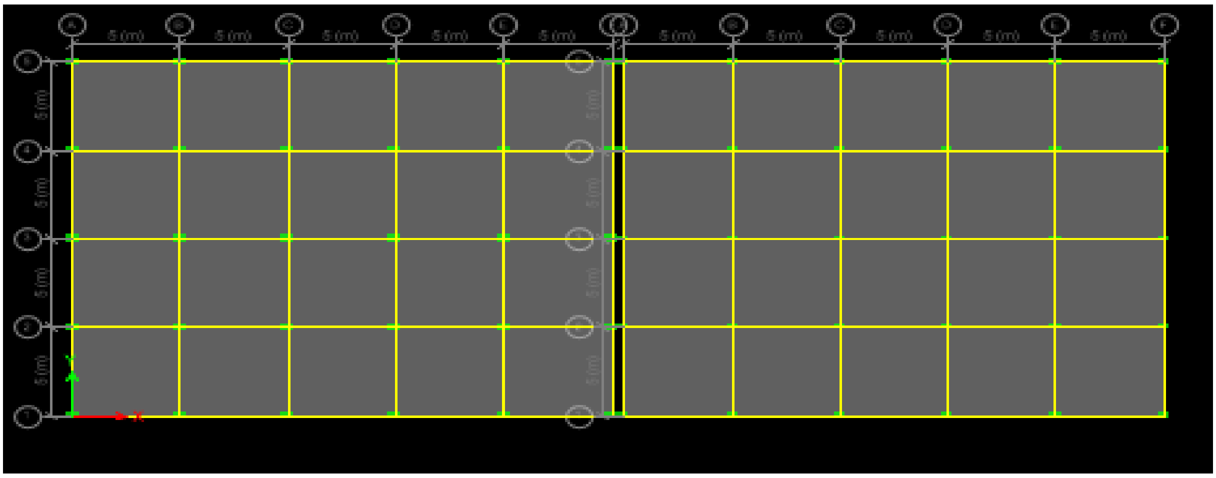

Figure 1 Plan of G+10 & G+8 Storey RC structures without shear walls

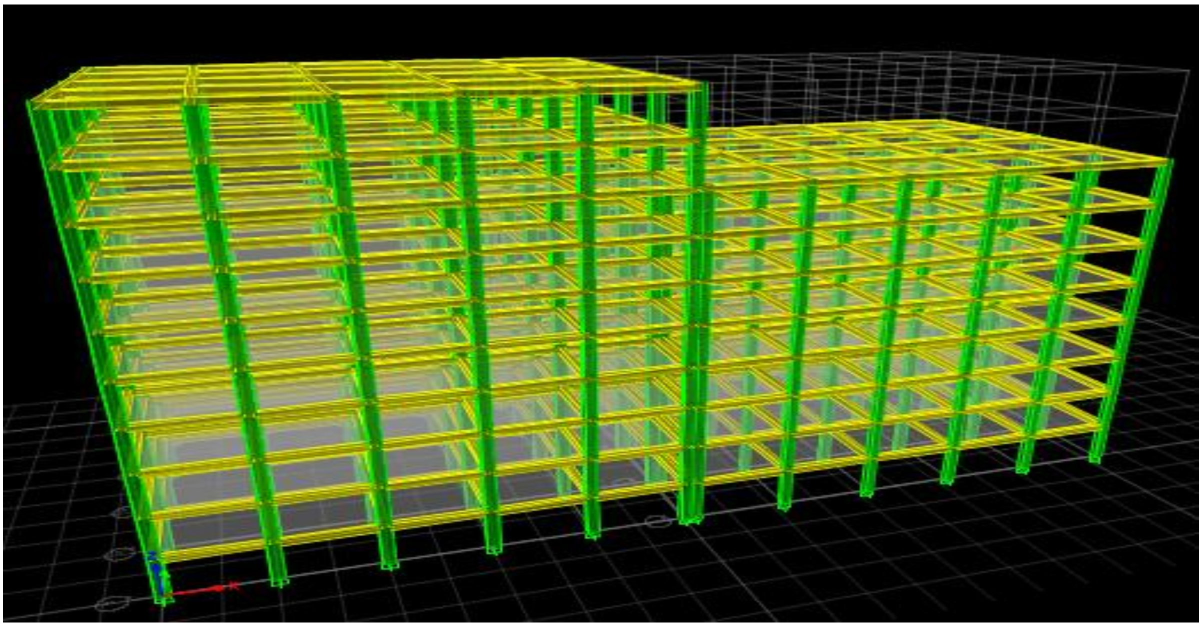

Figure 2 Elevation of G+10 and G+8 Storey RC structures without shear walls

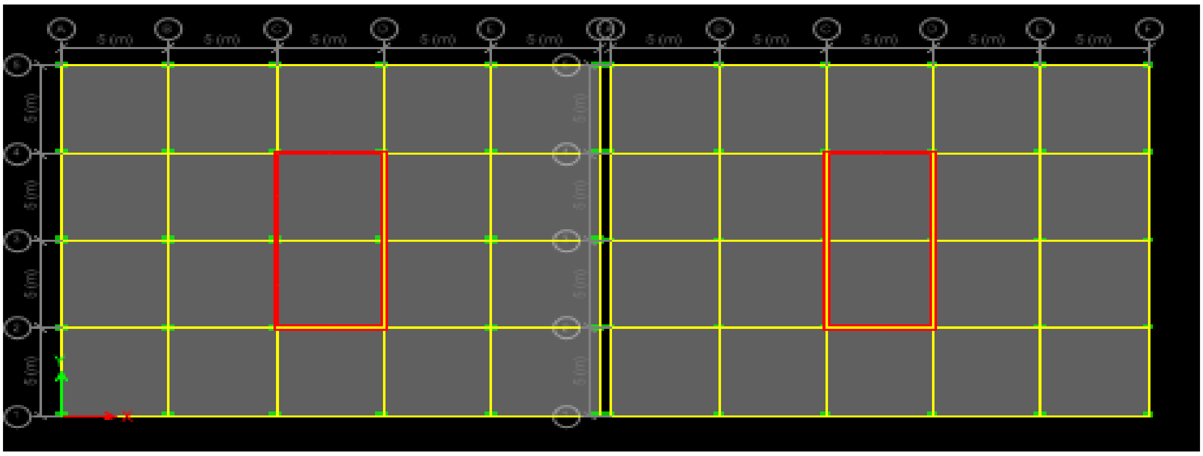

Figure 3 Plan of G+10 and G+8 Storey RC structures with shear walls

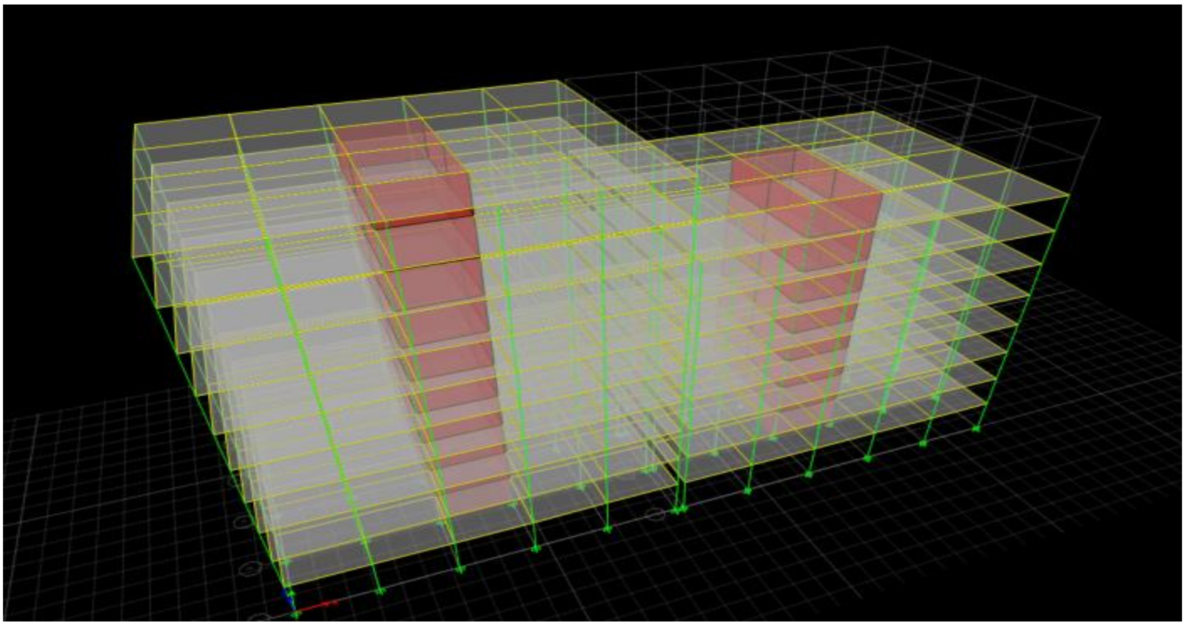

Figure 4 Elevation of G+10 & G+8 Storey RC structures with shear walls

3. METHODOLOGY

The G+10and G+8 storey buildings are analyzed as RC buildings with a special moment resisting frame considered to be situated in seismic zone IV and zone V on type II soil (medium soil) for residential purpose. These two adjacent buildings are separated by an initial pounding gap of 25mm(IS4326:2013)[7]. The design is based on IS 456 : 2000 Code [6] with ETABS Non- Linear software[17]. The relevant parameters considered in this study are depicted in table 1. The plan and elevation of simulated G+10 and G+8 Storey RC frame models with and without shear walls generated in the Etabs software[17] are shown in Figure 1 through 4. The shear walls are provided at the center of the frame from the foundation level of the frame to avoid the torsional collision. The response spectrum method has been adopted since 1) the natural time period of the frames is more than 0.4 seconds and 2) the frames are considered as RC buildings with a special moment resistance frames (SMRF). The response spectrum is corresponding to 5 percent damping only.The appendix shows 1) damaged RC framed structure due to pounding and 2)the potential pounding location of adjacent buildings.

Table 1 Parameters of RC building with SMRF frame

FRAME	Beam size mm	Column size mm	Floor slab thickness(mm)	Thickness of shear wall (mm)	Concrete grade	Live load Floor/ Roof (kN/sqm)	Floor finish (kN/sqm)
G+10 storey	450X350	600X400	150	200	M 25	3.0 /1.50	1.0
G+8 storey	450X350	500X300	150	200	M 25	3.0 /1.50	1.0

4. RESULTS AND DISCUSSION

The seismic pounding gap for G+10 and G+8 storey heights of RC buildings with SMRF frame with and without shear walls for seismic zone IV &V were examined by the response spectrum method of IS 1893(Part1):2016[5] in ETABS software[17] with IS 456-2000 Code of practice[6]. Storey wise pounding gaps(displacements) were depicted in table 2 and 3 for respective seismic zones.

Table 2 The pouding gaps in mm for seismic Zone -IV

STORY	**Without Shear wall**		**With Shear wall**	
G+10	25.1		7.6	
G+ 9	24.4		6.9	
G+ 8	23.0	21.9	6.2	4.1
G+ 7	21.2	21.0	5.4	3.7
G+ 6	18.8	19.4	4.5	3.2
G+ 5	16.1	17.1	3.7	2.6
G+4	12.9	14.2	2.8	2.1
G+3	9.4	10.7	2.0	1.5
G+ 2	5.6	6.8	1.2	0.9
G+ 1	2.0	2.7	0.5	0.4

Table 3 The pouding gaps in mm for seismic Zone -V

STOREY	**Without Shear wall**		**With Shear wall**	
G+10	37.7		21.1	
G+ 9	36.5		19.0	
G+ 8	34.6	32.8	16.7	16.2
G+ 7	31.8	31.6	14.2	14.1
G+ 6	28.3	29.1	11.7	11.9
G+ 5	24.3	25.7	9.2	9.5
G+4	19.4	21.3	6.8	7.1
G+3	14.0	16.1	4.5	4.8
G+2	8.4	10.2	2.5	2.7
G+1	3.0	4.0	0.9	1.0

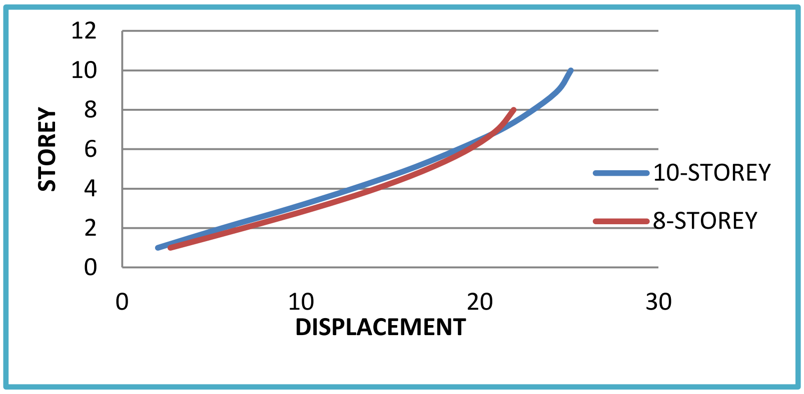

Figure 5 Pounding gaps in mm for Zone-IV without shear wall

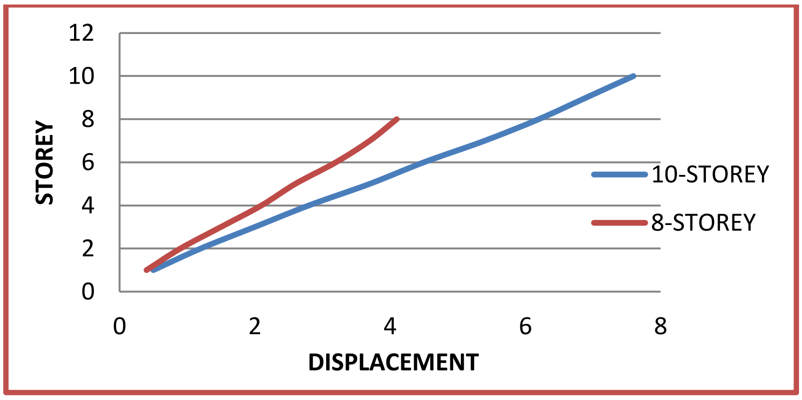

Figure 6 Pounding gaps in mm for Zone -IV with shear wall

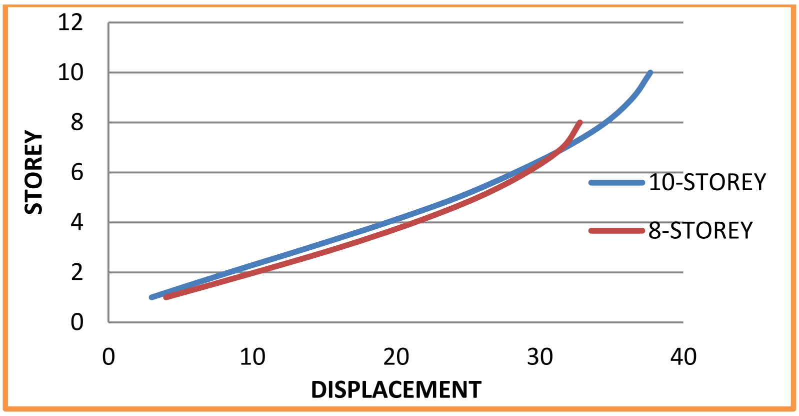

Figure 7 Pounding gap in mm in Zone-V without shear wall

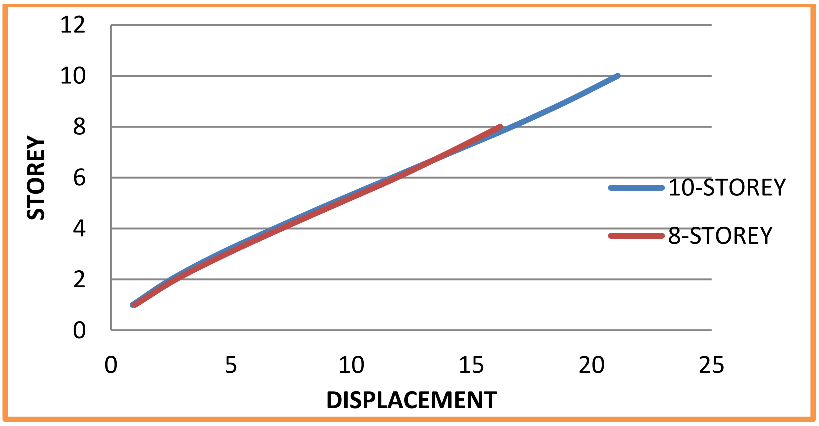

Figure 8 Pounding gap in mm in Zone-V with shear wall

5. DISCUSSION

Considering with reference to table 2 and figure 5, the calculated seismic pounding gap for Storeys up to G+3storey is less than the preliminary minimum gap requirement, but beyond the G+3 storeys the calculated seismic pounding gaps are more than the minimum requirement of the gap for the RC frame Building without Shear Wall in seismic zone IV.

Considering with reference to table 2 and figure 6,the estimated sum of pounding gaps for all storeys in G+10and G+8 buildings, is well within the preliminary pounding gap of 25 mm RC frame Building with Shear Wall in seismic zone IV

Considering with reference to table 3 and figure 7 the calculated seismic pounding gap for Storey up to G+3 is (20.10mm) less than the preliminary minimum required gap of 25mm , but beyond the G+3 storeys the calculated seismic pounding gaps are more than the minimum requirement of the gap for the RC frame Building without Shear Wall in seismic zone V.

Considering with reference to table 3and fig8 the estimated sum of maximum pounding gaps for G+10and G+8 Storeys are 10.33 mm, at the respective storey heights is well within the preliminary pounding gap of 25 mm for the RC frame Building with Shear Wall in seismic zone V.

It is attributed by the IS 1893 (Part I):2016 code that one unit change in the seismic Intensity zone, increases the Zone factor by 1.5 times. Accordingly pounding gaps for the RC Buildings with SMRF without shear walls for Zone V is 1.5 times the corresponding storey pounding gaps in zone IV.

6. CONCLUSIONS

Based on the response spectrum analysis in ETABS software[] carried out on the seismic pounding effects for G+10 and G+8 Storey of adjacent buildings for zone IV and zone V, the following conclusions have been drawn.

- According to Earthquake intensity zones the pounding gaps are varied, the high intensity zone shows the larger seismic gaps.
- The preliminary pounding gaps for G+10 and G+8 storey structures are satisfied up to G+3 storey for both the seismic zones without shear walls.
- The preliminary pounding gaps for G+10 and G+8 storey structures are satisfied for all storeys for both the seismic zones with shear walls.
- Even though the parametric study with the softwares shown the very less pounding gaps, a recent review of seismic gap analysis with shear walls of structures with the commercial softwares concluded that, due to the interaction of reinforced concrete Walls (from both directions) and floor structures, yield unrealistically low displacements. when compared to the seismic codes (Predrag Petronijević 2014)[16]. This may mislead the designers if they follow the logic that the elastic displacement of adjacent buildings multiplied by the ductility factor can be assumed as referential when designing separation joints.
- IS 1893(Part I):2016[5] prescribed the minimum seismic pounding gap is R times (Response Reduction Factor) the sum of the seismic gaps of adjacent buildings / structures is conservative.

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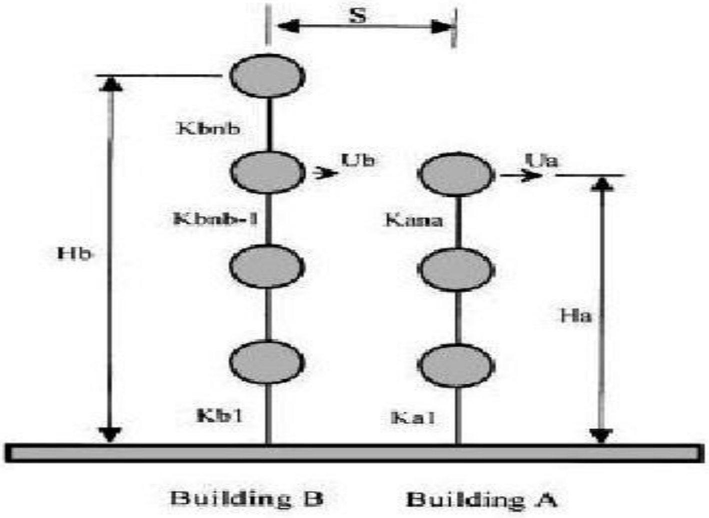
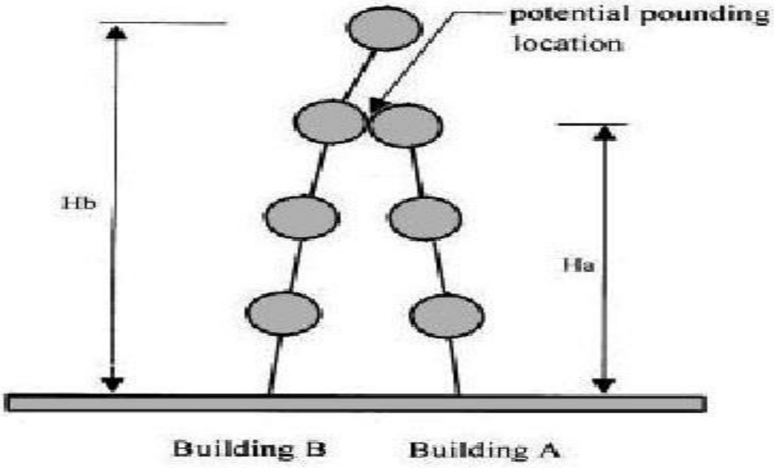
APPENDIX

Courtesy: Bipn Shrestha,2013, International Journal of Civil and Structural Engineering Volume 3, No 3, 2013



(a) Adjacent buildings at rest



(b) Adjacent buildings at pounding