IARJSET

ISSN (Online) 2393-8021
ISSN (Print) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Vol. 8, Issue 4, April 2021

DOI: 10.17148/IARJSET.2021.8453

Analysis of Seismic Pounding Between RC Buildings with Non-aligned slabs

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Abstract: Building pounding is one of the most common and dangerous causes of structural damage and even collapse during earthquakes. When two adjacent buildings are separated by a small gap, this phenomenon happens. It is critical to investigate the consequences of earthquake damage. The pounding phenomenon occurs during strong earthquakes due to different–phase oscillations of buildings with improper distances. Intensive effects result from earthquakes with acceleration history of repeated directions changes with greater acceleration.

Keywords: Seismic pounding, Impact force, SAP 2000, Time history analysis, Gap element.

I. INTRODUCTION

Pounding happens when neighbouring buildings begin vibrating out of phase during seismic activity, causing the adjacent structures to collide. The massive forces produced during the collision significantly alter the dynamic behaviour of adjacent buildings, making collision between them a relevant issue during high seismic events. The impact effect can be beneficial in some situations, particularly when it comes to inter-storey drift; however, pounding can be detrimental in many situations, especially when it comes to absolute acceleration. The resulting change in demand loads can lead to a disastrous demolition of one and both structures when two adjacent buildings collide. Building collapses and non-structural damage have been recorded as a result of seismic pounding. Collision damage depends on the dynamic properties of both structures when the collision occurs.

Buildings with 6 stories with same height but impact at different level were modelled using the GAP joint element, and nonlinear time–history analyses for El centro, and Northridge accelerographs were performed using SAP 2000 software. A parametric study on buildings pounding response were conducted. The parameters such as impact force, absolute acceleration responses, impact velocity, displacement responses, acceleration responses of un-aligned slabs were compared with aligned slabs. There are various dynamic responses, and therefore various responses are caused by pounding, depending on the accelerograph.

II. BUILDING GEOMETRY

The analysis considers two adjacent building namely Tower A & Tower B. Plan is symmetrical for both the towers. As shown in Fig. 1, two number of bays are considered in X- direction as well as in Y- direction.

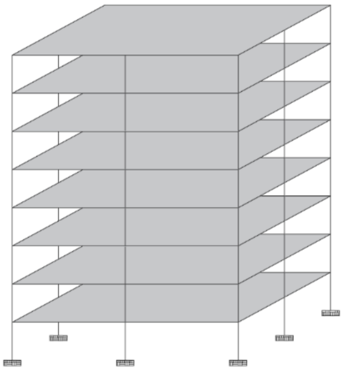

Fig. 1 Geometry of six storey 2 bay building

Total number of storey considered are 7 including the ground storey. All storey has similar height, which is 3 m. Span length for both the tower are 5 m considered in X- direction as well as in Y- direction. Size of column for Tower A is 300 mm×550 mm, while for Tower B is 300 mm×600 mm. Depth of slab for Tower A (left building) is 125 mm, while for Tower B (right building) is 150 mm. Total height of both the nearby building is 21 m. Foundation is not taken into consideration. Support condition for both towers is taken as fixed support.

III. GROUND MOTION CHARACTERISTICS

In this section, to study the different parameters two different earthquake have chosen namely el centro and northridge. Fig. 2, shows acceleration vs. time graph for selected input parameter.

Earthquakes generate complex loading with motion components that cover a wide frequency range. The frequency content explains how ground motion amplitude is spread across various frequencies. The frequency content of an earthquake motion would have a significant impact on structure motion.

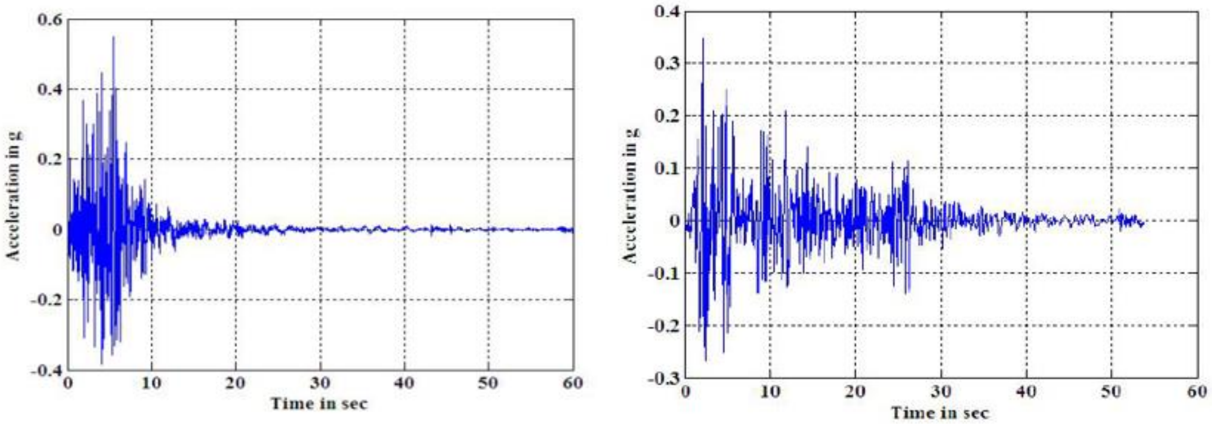

Fig. 2 (a) El centro ground motion record (b) Northridge ground motion record

IV. IMPACT MODELS

The following impact models are used to compare the parametric results:

a. Impact at L
b. Impact at L/2
c. Impact at L/4

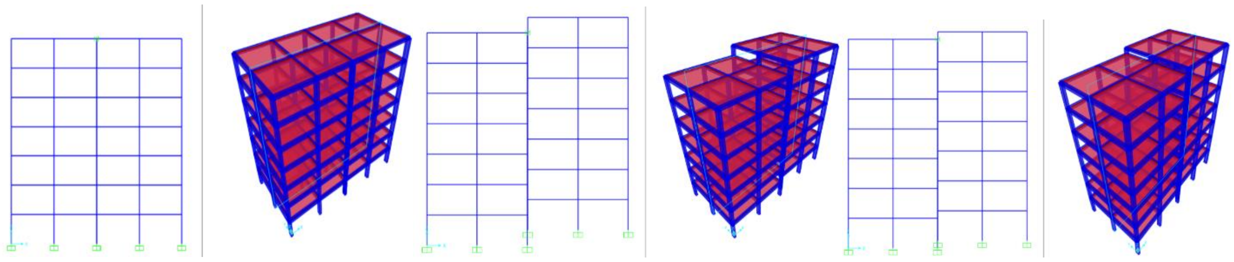

Fig. 3 (a) Impact at L (b) Impact at L/2 (c) Impact at L/4

V. SELECTED MODELS

1. Models for un-aligned slab level.

- Model – 1: Impact at L/2 level, d = 2 cm. Considered Earthquake – El centro.
- Model – 2: Impact at L/2 level, d = 2 cm. Considered Earthquake – Northridge.
- Model – 3: Impact at L/4 level, d = 2 cm. Considered Earthquake – El centro.
- Model – 4: Impact at L/4 level, d = 2 cm. Considered Earthquake – Northridge.
- Model – 5: Impact at L/2 level, d = 4 cm. Considered Earthquake – El centro.
- Model – 6: Impact at L/2 level, d = 4 cm. Considered Earthquake – Northridge.
- Model – 7: Impact at L/4 level, d = 4 cm. Considered Earthquake – El centro.
- Model – 8: Impact at L/4 level, d = 4 cm. Considered Earthquake – Northridge.

2. Models for aligned slab level.

- Model – 9: Impact at equal slab level, d = 2 cm. Considered Earthquake – El centro.
- Model – 10: Impact at equal slab level, d = 2 cm. Considered Earthquake – Northridge.
- Model – 11: Impact at equal slab level, d = 4 cm. Considered Earthquake – El centro.
- Model – 12: Impact at equal slab level, d = 4 cm. Considered Earthquake – Northridge.

VI. RESULTS

In this case, analysis is carried out for model – 1 and model – 3 and results are compared. In this comparison separation distance d is taken as 2 cm for both models, while the slab level varies. In model – 1 impact is occurring at L/2, while in case of model – 3 the impact is occurring at L/4.

Discussion on impact force time history.

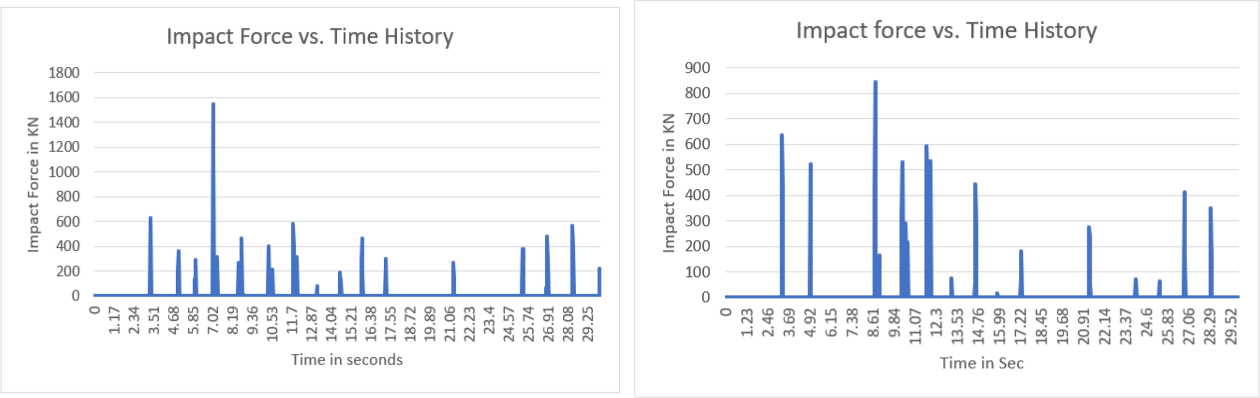

Fig. 4 (a) Impact force vs Time history for Model – 1 (b) Impact force vs Time history for Model – 3

The calculated maximum impact force in case of model - 1 between tower A & tower B are 1546.7 KN. While in case of model – 3 the impact force for tower A & tower B is 846.58 KN. This actively demonstrates that, for same separation distance collision values are higher when impact is at L/2.

Discussion on acceleration response.

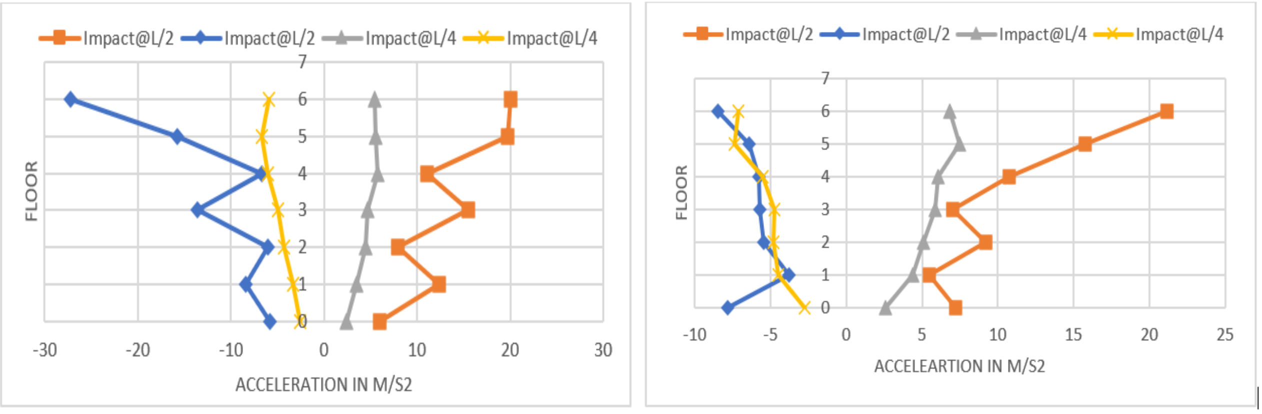

Fig. 5 (a) Acceleration response for Model – 1 & 3, Tower A (b) Acceleration response for Model – 1 & 3, Tower B

In this section, acceleration responses at each floor level are presented. The acceleration responses are shown in Fig. 5, Acceleration response is more amplified when impact is at mid height.

Discussion on velocity response.

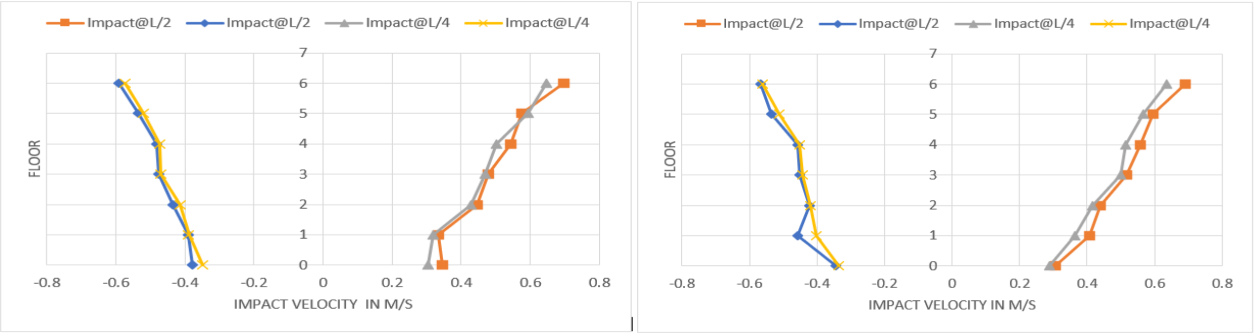

Fig. 6 (a) Velocity response for Model - 1 & 3, Tower A (b) Velocity response for Model - 1 & 3, Tower B

The maximum impact velocity is not significantly affected by the pounding.

Discussion on displacement response.

In this section, displacement results at each floor level are presented. The displacement responses are shown in Fig.7,

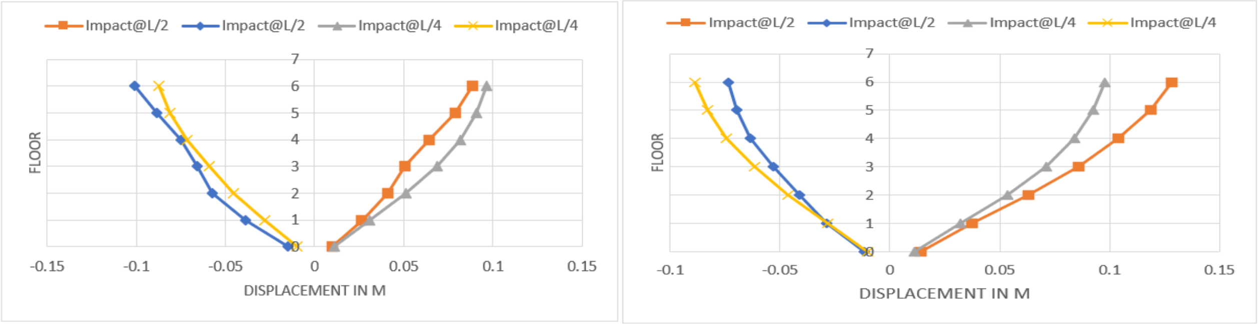

Fig. 7 (a) Displacement response for Model - 1 & 3, Tower A (b) Displacement response for Model - 1 & 3, Tower B

The influence of the displacement response is relevant, but no clear trend is observed. Outward displacement at each storey is higher when impact is at mid height.

TABLE I IMPACT WHEN SEPARATION DISTANCE IS SAME BUT SLAB LEVEL VARY.

Case no.	Description	Model No.	Earthquake	d cm	Impact @	Pounding Force KN	Acceleration Response m/s^2		Displacement Response m		Velocity Response m/s	
							Tower A	Tower B	Tower A	Tower B	Tower A	Tower B
1	Impact when separation distance is same but slab level vary.	1	Elcentro	2	L/2	**1546.7**	**27.27**	**21.14**	**0.10**	**0.12**	0.68	0.69
		3			L/4	846.58	6.71	7.50	0.09	0.09	0.64	0.64
2		2	Northridge		L/2	**2917.42**	**48.48**	**24.61**	**0.13**	**0.16**	1.18	1.37
		4			L/4	1938.08	12.73	14.32	0.10	0.12	1.16	1.35
3		5	Elcentro	4	L/2	**989.93**	**9.57**	**6.67**	**0.09**	**0.09**	0.59	0.73
		7			L/4	751.94	7.76	6.12	0.09	0.09	0.59	0.73
4		6	Northridge		L/2	**1982.23**	**15.35**	**12.71**	0.08	**0.14**	1.30	1.33
		8			L/4	1775.63	11.83	9.68	**0.10**	0.12	1.22	1.38

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TABLE III IMPACT WHEN SEPARATION DISTANCE VARY

Case no.	**Description**	**Model No.**	**Earthquake**	**Impact @**	**d cm**	**Pounding Force KN**	**Acceleration Response m/s²**		**Displacement Response m**		**Velocity Response m/s**	
							Tower A	**Tower B**	**Tower A**	**Tower B**	**Tower A**	**Tower B**
5	Impact when separation distance vary	1	Elcentro	L/2	2	**1546.7**	**27.27**	**21.14**	**0.10**	**0.12**	0.68	0.70
		3			4	989.93	9.57	6.67	0.09	0.09	0.60	0.72
6		2	Northridge		2	**2917.42**	**48.48**	**24.61**	**0.13**	**0.16**	1.20	1.37
		4			4	1982.23	15.35	12.71	0.08	0.14	1.30	1.33
7		5	Elcentro	L/4	2	**846.58**	**6.71**	**7.50**	**0.09**	**0.09**	0.63	0.70
		7			4	751.94	7.76	6.12	0.09	0.09	0.60	0.73
8		6	Northridge		2	**1938.08**	**12.73**	**14.32**	**0.10**	**0.12**	1.16	1.35
		8			4	1775.63	11.83	9.68	0.10	0.12	1.21	1.38

TABLE IIIII COMPARISON OF RESULT BETWEEN ALIGNED & UN-ALIGNED SLAB

Case no.	**Description**	**Model No.**	**Earthquake**	**d cm**	**Impact @**	**Pounding Force KN**	**Acceleration Response m/s²**		**Displacement Response m**	
							Tower A	**Tower B**	**Tower A**	**Tower B**
9	Comparison of result between aligned & un-aligned slab	9	Elcentro	2	L	709.8355	5.71	5.23	0.05	0.10
		1			L/2	**1546.7**	**27.27**	**21.14**	**0.10**	**0.12**
10		9			L	709.8355	5.71	5.23	0.05	0.10
		3			L/4	**1938.082**	**6.71**	**7.50**	**0.09**	**0.10**
11		10	Northridge		L	1182.698	7.56	8.45	0.07	0.10
		2			L/2	**2917.422**	**48.48**	**24.61**	**0.13**	**0.16**
12		10			L	1182.698	7.56	8.45	0.07	0.10
		4			L/4	**1938.082**	**12.73**	**14.32**	**0.10**	**0.12**
13		11	Elcentro	4	L	612.8178	5.30	5.44	0.09	0.09
		5			L/2	**989.9324**	**9.57**	**6.67**	**0.09**	**0.09**
14		11			L	612.8178	5.30	5.44	0.09	0.09
		7			L/4	**751.9434**	**7.76**	**6.12**	**0.09**	**0.09**
15		12	Northridge		L	709.8355	13.96	9.20	**0.10**	0.12
		6			L/2	**1982.23**	**15.35**	**12.71**	0.08	**0.14**
16		12			L	709.8355	13.96	9.20	0.10	0.12
		8			L/4	**1775.639**	**20.13**	**12.81**	**0.10**	**0.12**

VII. CONCLUSION

When slab of adjacent building is at mid height collision force increases as compared to any other slab level. In Table I, for case 1 to 4 separation distance are kept same but slab level varies. From the obtained results it can be seen that impact force in case of L/2 is **44.12%** high as compared to impact when L/4.

In Table II, shows for case 5 to 8 slab level kept same but comparison made on different separation distance. From the analysis it can concluded that collision force decreases as the separation distance increases. Separation distance has greater influence on collision force. This is because of the fact that, as the gap distance is more, structures are less susceptible to pounding and impact force also reduces which reduces the moment transfer. From the obtained results it

DOI: 10.17148/IARJSET.2021.8453

can be seen that impact force in case of d = 2 cm is **31.28%** high as compared to impact when separation distance is at 4 cm.

In Table III, shows for case 9 to 16, results of impact force of non-aligned slabs were compared with aligned slabs. From the results it can be concluded that collision force increases when slabs are non-aligned. As compared to impact at L Collision forces are **126.33**% higher when impact is at L/2. As compared to impact at L collision forces are **102.42**% higher when impact is at L/4.

Acceleration response

For cases 1 to 4, separation distance kept same and different impact level were selected. From the obtained results it can be concluded that for impact at L/2 acceleration values are more amplified than impact at L/4.

For cases 5 to 8, impact level kept as same but separation distance is different. From the obtained results it can be concluded that for d = 2 cm acceleration values are more amplified than d = 4 cm.

For cases 9 to 16, acceleration values are more amplified in case of unaligned slabs as compared to aligned slab level.

Impact velocity

Globally speaking, the maximum impact velocity is not significantly affected by the pounding. In a considerable number of cases, the velocity response differs by very small amount.

Displacement Response

The influence of the displacement response is relevant, but no clear trend is observed. In considerable number of cases, when slabs are kept at different level, outward displacement are generally higher or nearly same.

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