A COMPARITIVE STUDY ON POUNDING EFFECT ON MULTI STORIED BUILDING WITH AND WITHOUT SHEAR WALL

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Abstract

Dynamic actions are caused on the buildings due to wind loads and earthquake loads.During a short duration of time, reversal of stresses due to wind loads is minimum whereas reversal of stresses due to earthquake loads are maximum. The damage to life andpropertyonesucheffectis**pounding**.

Now-a-days as the urbanization is growing in many of the earthquake prone areas thestructures are being constructed very close to each other without providing minimumseparationbetween adjacentstructures.During theearthquakecollision between theadjacentbuildingstakesplaceandthatcollisionistermedaspounding.Poundingphenomenon causes adjacent buildings to vibrate out of phase leading to severe damageto life and property. Due to increase in cost of land providing large **separation distance**forbuildingsisbecomingproblem.Thereforeinsteadofkeepinghugeseparationdistance mitigation measure like **Shear walls**, dampers, bracings which reduce poundingeffectareadopted.

Pounding variation is also seen with different **heights** of buildings. In this present studyfour different heights of multi-storied buildings (G+22),(G+18),(G+14) and (G+10) withplan areas of 24mx24m for all buildings in two seismic zones Z-III and Z-V are modeledand analyzed using ETABS 2016 software. The buildings are modeled by consideringwith pounding and without pounding condition, with shear wall and without shear wallcondition.Toanalyzethestructuredynamicanalysismethod(Responsespectrummethod) is used. From analysis it is concluded that pounding phenomenon increases thedisplacements of buildings (G+22)(G+18), (G+22)(G+14) and (G+22)(G+10) by 16.5%,29.5% and 34.8% respectively when compared to (G+22) building without pounding, bythe use of shear wall the displacements for (G+22)SW(G+18), (G+22)SW(G+14) and(G+22)SW(G+10)are64.3%,27.5%and32.3%respectivelywhencomparedto(G+22)SWbuildingwithoutshearwall.

Keywords: Pounding,Separationdistance,Shearwall,Height

1.1General

Earthquakes are the Earth's herbal approach of releasing stress. When the Earth's platesmove in opposition to every other, stress is put on the higher mantle (lithosphere). When this stressis great sufficient, the lithosphere breaks or shifts. As the Earth's plates circulate they putforces on themselves and every other. When the force is huge enough, the crust is forcedto damage. When the wreck takes place, the stressis launched as power which actions throughthe Earthintheformofwaves thataretermedasearthquake.

A narrow Zone Rock breakage is referred to as faulting and it causes a launch of electricity whenstored stress is suddenly converted to movement. Vibrations known as seismic waves areproduced - they travel outwards in all directions and upto 14 kilometers per second. Atthese speeds,it would take the fastest waves only 20 minutes to reach the other side oftheEarthbygoingstraightthroughitscentre-that'sadistanceofalmost13,000kilometers. The waves distort the rock they pass through,but the rock returns to itsoriginal shape afterwards. The epicenter is the point on the Earth's surface directly abovethe source of the earthquake.Earthquakesdo not occur deeper than thisbecause rocksare no longer rigid atvery high pressures andtemperatures- they can'tstore stressbecause they behave plastically. Smaller events occur more frequently - in fact, mostearthquakes cause little or no damage. A very large earthquake can be followed by aseries of smaller aftershocks whileminor faulting occurs during an adjustmentperiodthatmaylastforseveralmonths.

1.2 Occurrenceofearthquakes

No a part of the earth's floor is safe against earthquake. But a few regions enjoy ahigher importance of earthquakes than others and additionally of extra frequently than others.Earthquakes are most commonplace at plate boundaries, in which one of a kind tectonic plates meet.The biggest events generally occur in which plates are colliding - this is in which largeamounts of strain can building up hastily. About eighty percentage of all recorded earthquakesoccur at the circum-Pacific seismic belt. Intraplate earthquakes arise less typically.Theytakeplaceintherelativelystableinteriorofcontinents,awayfromplateboundaries.Thistypeofearthquakegenerallyoriginatesatmoreshallowlevels.

1.3Pounding

Pounding is the phenomena of collision among adjacentbuilding or distinctive elements ofthe equal building during robust vibrations. It may additionally motive both architectural or structuraldamageandmay leadtopartial oreven completecollapseofthestructure. Jointlyseparated constructing structures may be a severe risk in seismically lively regions. Earthquakeconvey on pounding among carefully spaced shape is one of the highest reason ofseismic susceptibility as it could reason severe disturbance to non structural and structuralmembersandevenassignedtostructuralcollapseThedifferenceinthedynamiccharacteristics of adjoining constructing structures results in an out-of-segment vibration of thestructureswhensubjectedtoearthquake.

.1.4 Poundingdamageinstructures

1) Adjacentbuildingwithsameheightsandsamefloorlevels.
2) Adjacent buildingwithequalflooring levelsbutdifferentheights.
3) Adjacentbuildingwithdistincttotalelevationabovethegroundandvarioussurfacelevels
4) Structureareestablishedin line
5) Adjacent structurewithdistinctdynamiccharacteristics.
6) Adjacent buildingwithunequalheights,poundingmayjustarisein columns.
7) Adjacentbuildingwithunequaldistributionofmassorstiffness.

2.MATERIAL PROPERTIES

2.1 Shearwall

A shear wall is a vertical structural element that resists lateral forces in the plane of thewallthroughshearand bending.Shearwallsaregenerallyusedin high-risebuildings

subject to lateral wind and seismic forces. Shear wall acts as a beam cantilevered out ofthe foundation and just as with a beam, part of its strength derives from its depth. MostReinforcedconcretebuildingswithshearwallsalsohavecolumnsthesecolumnsprimarily carry gravity loads (i.e., those due to self-weight and contents of building).Shear walls provide large strength and stiffness to buildings in the direction of theirorientation, which significantly reduces lateral sway of the building and thereby reducesdamage to structure. Since shearwallscarry large horizontal earthquakeforces, theoverturningeffectsonthemarelarge.

Shear walls in buildings must be symmetrically located in plan to reduce ill-effects oftwist in buildings. They could be placed symmetrically along one or both directions inplan.Shearwallsaremoreeffectivewhenlocatedalongexteriorperimeterofthebuilding–

suchalayoutincreasesresistance ofthe buildingtotwisting.

2.2 Forceson shearwalls

Shear wallbasicallyhastwotypesofforces

a) ShearForces

Shear forces are generated in stationary buildings by accelerations resulting from groundmovement and by external forces like wind and waves. This action creates shear forcesthroughoutthe heightofthewallbetweenthe topandbottomshearwallconnections.

b) Upliftforces

Uplift forces exist on shear walls because the horizontal forces are applied to the top ofthe wall. These uplift forces try to lift up one end of the wall and push the other enddown. In some cases, the uplift force is large enough to tip the wall over.Upliftforcesaregreaterontallshortwallsandlessonlowlongwalls.

2.3 ClassificationofShearwalls

- Simplerectangulartypeand flangedwalls
- Coupledshearwalls
- Rigidframeshearwalls
- Framedwallswithinfillframes
- Columnsupportedshearwalls
- Coretypeshearwalls

2.3.1Rectangulartypeandflangedwalls

These are most commonly used kind of shear walls. Rectangular shear partitions range basedon the width to depth ratio and shear partitions meeting each different at right angles result inflanged configurations and are known as flanged walls. In such cases, a part of theintersecting wall can be treated as a flange of the shear wall e.G. As an I-phase or a T-segment. Such partitions are usually required to resist earthquake forces in each principaldirectionsofthebuilding.

2.3.2 Coupled shearwalls

When two or more shear walls are combined they are termed as coupled shear walls.These are vertically oriented wide beams, behaves as a slender cantilever beam underlateral loads that is resisting external loads by forming a couple at the base. By couplingindividualflexuralwallsoverturningmomentsareresistedpartiallybyanaxialcompression -tension couple across the wall system rather than by the individual flexuralaction of the walls. When a coupled shear wall system is pushed from left to right underlateral loads the coupling beams are subjected to double curvature and resulting sheardemands are transferred to the wall piers as axial tension and compression loads in leftand rightwall piers respectively. The couplingof these axial forces provide resistingbase moment thatis additive with the moments at the base of each pier resulting in alargeflexuralresistance.

2.3.3 Rigid frameshearwalls

A rigid vertical diaphragm is capable of transferring lateral forces from exterior walls,floors, and roofs to the ground foundation in a direction parallel to their planes are calledrigid frame shear walls. Lateral forces caused by wind, earthquake and uneven settlementloads, in addition to the weight of structure and occupants, create powerful twistingforces. These forces can literally shear a building apart. Reinforcing a frame by attachingor placing a rigid wall inside it maintains the shape of the frame and prevents rotation atthe joints.

2.3.4Coretypeshearwalls

Astructureofshearwallsin thecenterofalarge building oftenencasing anelevatorshaft

orstairwell formashearcoreandthatisknownascoretypeshearwall.

3. Modelling &Analysis

3.1Buildingdata

In this four multi- storied buildings (G+22), (G+18), (G+14) and (G+10) of symmetricalsections are taken. The plan areas of all buildings are (24mx24m). These structures areanalyzedusingETABS2016Software inResponse spectrumanalysis.

3.2 Designloads

a) Deadloads

b) Liveloads

c) Earthquakeloads

d) Windloads

3.3 Modelingofstructure

In this four buildings of (G+22),(G+18),(G+14) and (G+10) are modeled using ETABSSoftware in different zones of earthquake (i.e.,) Z-III and Z-V under medium soil conditionby performing Response spectrum analysis. Initially 24 storeyed building is modeled withandwithoutshearwallcaseseparately.

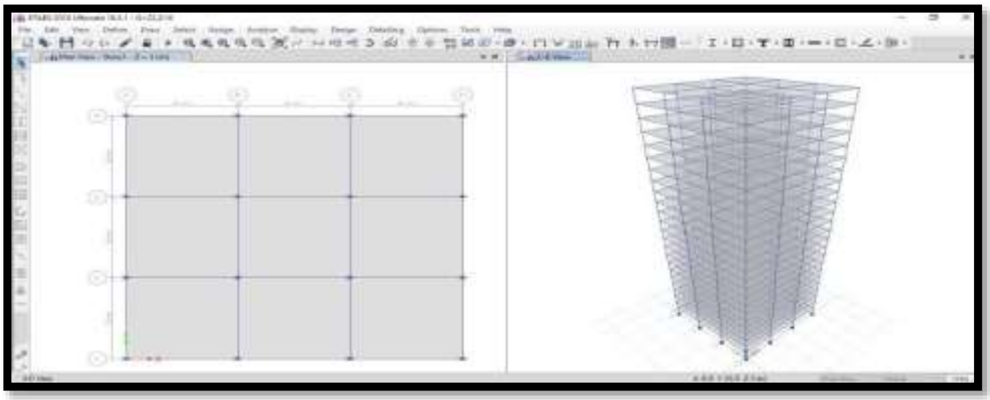


Fig.3.1Planand3Dviewof(G+22)building without shearwallcase

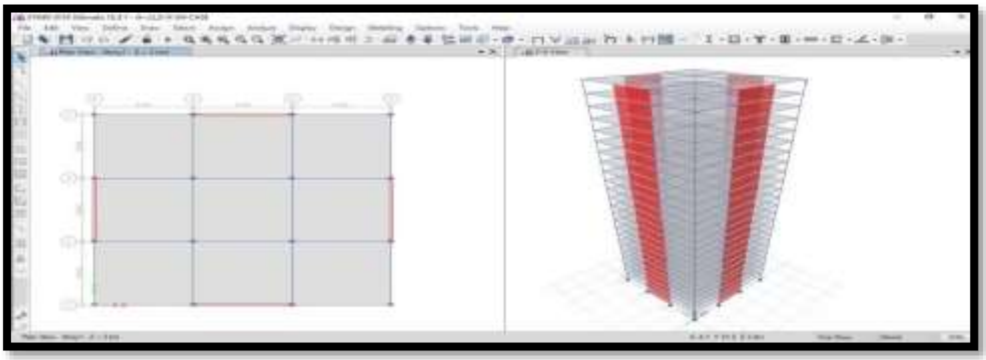
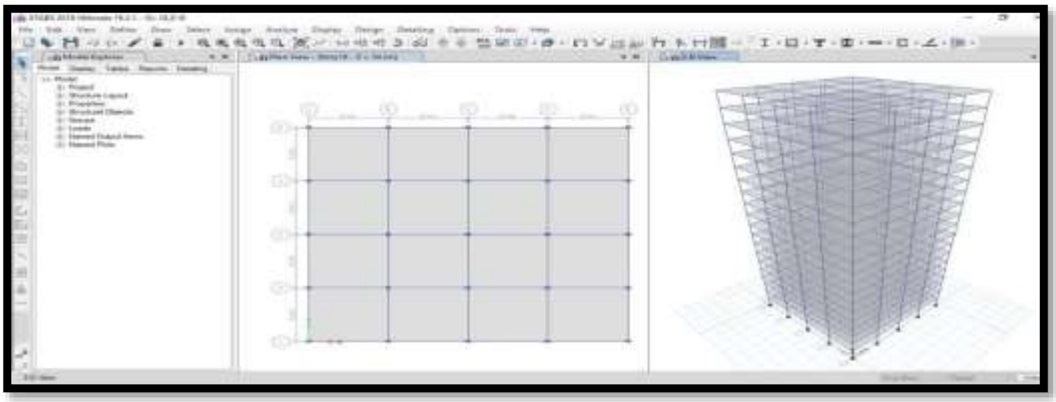


Fig.3.2 Planand3Dview of(G+22)building withshearwallcase



Inthesecondcase(G+18),(G+14)and(G+10)aremodeledwithoutshearwallconsideration.

Fig.3.3 Plan and3Dviewof(G+18)building

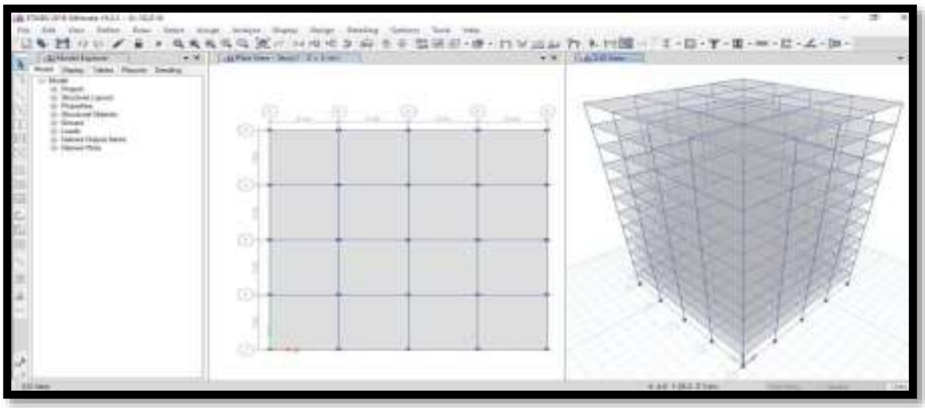


Fig.3.4Planand3Dviewof(G+10)building

In the third stage two buildings of different heights are modeled simultaneously toobservetheeffectofpoundingcausedduetoearthquakes. Someofthecasesarelistedbelow.

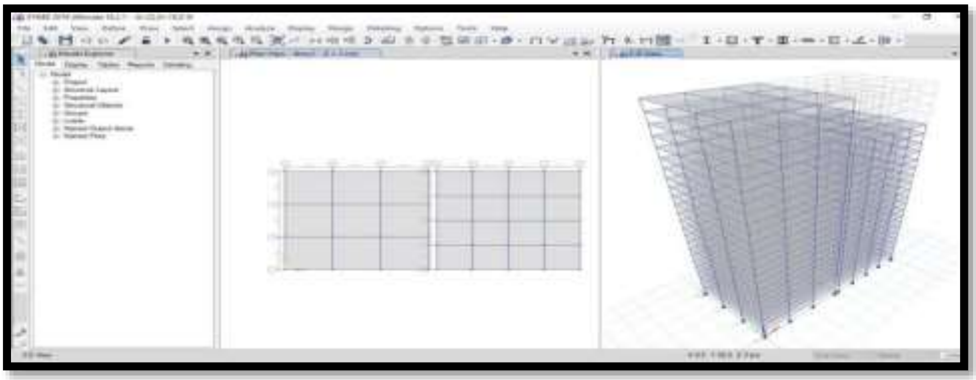


Fig.3.5Planand 3Dviewof (G+22)(G+18)buildingswithoutshearwallcase

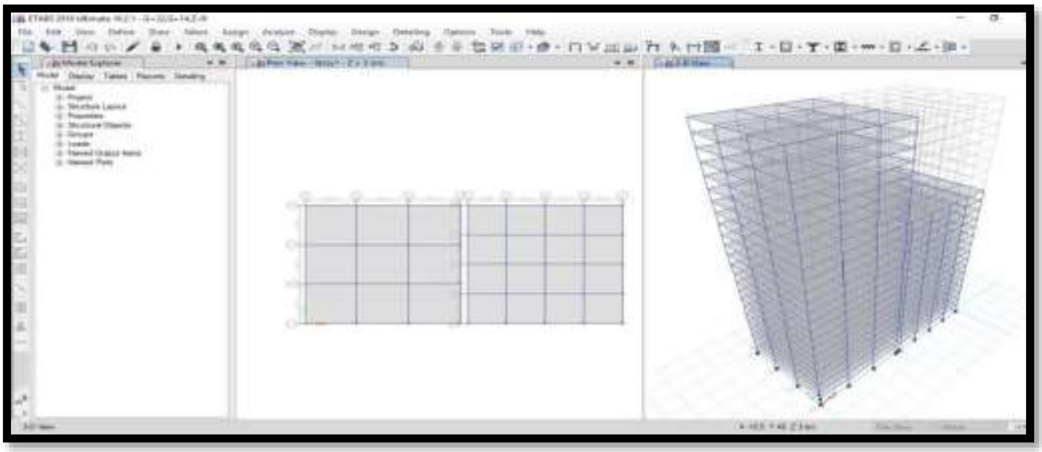


Fig.3.6Planand3Dviewof(G+22)(G+14)buildingswithoutshearwallcase

In the final stage two buildings of different heights are modeled simultaneously with shearwall case to observe the pounding effect caused due to earthquakes. Some of them are listedbelow.

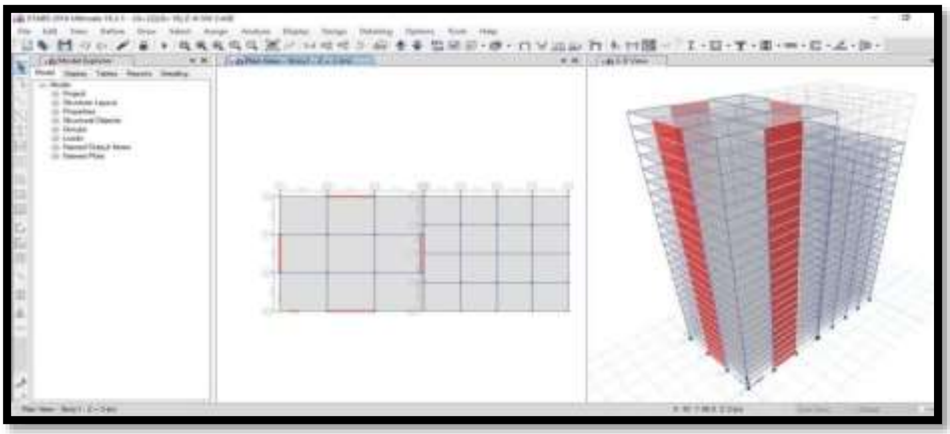


Fig.3.7 Plan and 3dviewof(G+22)(G+18)buildingswith shearwallcase

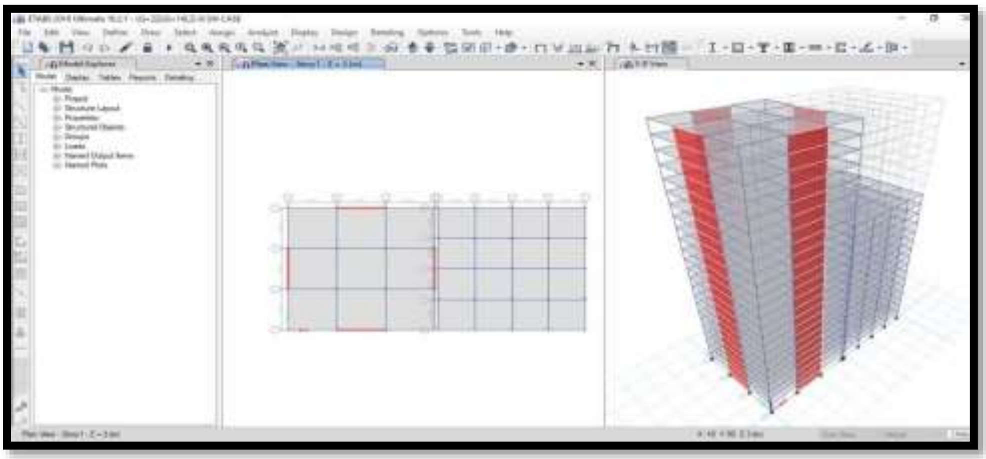


Fig.3.8Planand3Dviewof(G+22)(G+14)buildingswithshearwallcase

1. <u>RESULTS</u>

General

The seismic analysis of (G+22),(G+18),(G+14) and (G+10) are performed using ETABSSoftwarewithandwithoutpoundingeffect,withandwithoutshearwallcasein twodifferentzones of earthquakes Z-III andZ-V undermedium soil condition andtheresultsaregiveninthefollowingsections.Theparametersstudiedarebaseshear,storeydisplacementsandstoreydrifts.

<u>4.1 Withoutpoundingeffect</u>

1.(G+22)storeybuildingwithoutshearwall

Storeydisplacement

It is the total displacement of the i^{th} with respect to the ground. In this since the building issymmetrical the displacements are considered only in one direction (i.e.,) X-direction. Thestorey displacements of (G+22) storey building without shear wall in two seismic zones aretabulatedbelow andtheirvariationsisseeninFig4.1

Storey	Zone-III	Zone-V
	X-displacement(mm)	X-displacement(mm)
24	414.816	933.336
23	410.502	923.631
22	403.974	908.941
21	395.077	888.924
20	383.921	863.823
19	370.842	834.395
18	355.977	800.947

17	339.586	764.067
16	322.135	724.803
15	303.818	683.59
14	284.537	640.209
13	264.359	594.808
12	243.393	547.635
11	222.635	500.929
10	201.402	453.155
9	179.756	404.451
8	157.778	355
7	135.55	304.988
6	113.159	254.608
5	90.705	204.086
4	68.349	153.784
3	46.528	104.688
2	25.893	58.26
1	8.507	19.14
Base	0	0

2. (G+22)building withshearwall

Storeydisplacement

Thestoreydisplacementsforthe(G+22) buildingwithshear wallinX-directionfortwodifferentseismiczonesaretabulatedbelowandtheir variationsisseen inFig4.2

Table.4.2Storeydisplacementof (G+22)withSW

Storey	Zone-III	Zone-V
	X-displacement(mm)	X-displacement(mm)
24	73.485	165.342
23	69.412	156.176
22	65.323	146.977
21	61.227	137.76
20	57.126	128.534
19	53.03	119.318
18	48.949	110.136
17	44.897	101.018
16	40.889	92
15	36.942	83.12
14	33.075	74.42
13	29.309	65.946
12	25.666	57.748
11	22.165	49.871
10	18.825	42.357
9	15.672	35.262
8	12.73	28.643
7	10.025	22.557
6	7.584	17.065
5	5.434	12.227
4	3.604	8.108

3	2.117	4.764
2	1.002	2.254
1	0.285	0.64
Base	0	0

3.Storeydrifts

The storey drifts for the (G+22) building with shear wall in X-direction for two differentseismiczonesare tabulatedbelow andtheirvariationsisseeninFig4.3

Table.4.3Storey driftsof(G+22)withSW

Storey	**Zone-III**	**Zone-V**
	X-drift	**X-drift**
24	0.001358	0.003055
23	0.001363	0.003066
22	0.001366	0.003072
21	0.001367	0.003075
20	0.001365	0.003072
19	0.00136	0.003061
18	0.001351	0.003039
17	0.001336	0.003006
16	0.001316	0.00296
15	0.001289	0.0029
14	0.001255	0.002824
13	0.001215	0.002733
12	0.001167	0.002626
11	0.001113	0.002504
10	0.001051	0.002365
9	0.000981	0.002206
8	0.000902	0.002029
7	0.000814	0.001831
6	0.000717	0.001612
5	0.00061	0.001373
4	0.000495	0.001115
3	0.000372	0.000837
2	0.000239	0.000538
1	0.000095	0.000213
Base	0	0

4 .(G+10)buildingwithout shearwall

Storeydisplacement

In this the building is symmetrical so displacements are considered only in one direction(i.e.,) along X-direction.thestorey displacements of (G+10) storey building without shearwall intwoseismiczonesaretabulatedbelowandtheirvariationsisseen inFig 4.4

Table.4.4Storeydisplacementsof(G+10)withoutSW

Storey	Zone-III	Zone-V
	X-displacement(mm)	X-displacement(mm)
12	58.144	132.752
11	56.389	128.734
10	53.55	122.241
9	49.683	113.405
8	44.955	102.602
7	39.538	90.232
6	33.593	76.662
5	27.267	62.22
4	20.697	47.228
3	14.4	32.859
2	8.253	18.833
1	2.835	6.473
Base	0	0

Storeydrifts

The storey drifts for (G+10) building without shear wall for different seismic zones Zone-IIIand Zone-V are tabulatedbelow andtheirvariationsare seeninFig4.5

Table.4.5Storeydriftsof(G+10) without SW

Storey	Zone-III	Zone-V
	X-drift	X-drift
12	0.000585	0.00133
11	0.000946	0.00216
10	0.001289	0.00294
9	0.001576	0.003601
8	0.001806	0.004123
7	0.001981	0.004524
6	0.002109	0.004814
5	0.00219	0.004997
4	0.002099	0.00479
3	0.002049	0.004675
2	0.001806	0.00412
1	0.000945	0.002158
Base	0	0

5.Poundingphenomenon[withoutshear wall]

Z-IIIstoreydisplacements

(G+22) and (G+18) buildings are placed side by side with a minimum separation distanceasperIS1893-2002.Thestoreydisplacementsofseparatebuildingsandcombinedbuildingsare tabulatedbelow andtheirvariationsare seeninFig4.6

Table.4.6+Storeydisplacementsof(G+22),(G+18),(G+22)(G+18)buildingwithout SW inZone-III

Storey	(G+22) Disp:X mm	(G+22)(G+18) Disp:X mm	Storey	(G+18) Disp:X mm
24	414.816	483.286	20	148.316
23	410.502	478.26	19	146.224
22	403.974	470.654	18	142.984
21	395.077	460.289	17	138.593
20	383.921	447.292	16	133.248
19	370.842	432.054	15	127.083
18	355.977	414.734	14	120.137
17	339.586	395.638	13	112.496
16	322.135	375.307	12	104.249
15	303.818	353.966	11	95.962
14	284.537	331.503	10	87.306
13	264.359	307.995	9	78.332
12	243.393	283.568	8	69.1
11	222.635	259.383	7	59.671
10	201.402	234.646	6	50.101
9	179.756	209.426	5	40.443
8	157.778	183.821	4	30.765
7	135.55	157.924	3	21.247
6	113.159	131.837	2	12.09
5	90.705	105.677	1	4.119
4	68.349	79.63	Base	0
3	46.528	54.208		
2	25.893	30.168		
1	8.507	9.911		
Base	0	0		

Zone-VStoreydrifts

(G+22) and (G+18) buildings are placed side by side with a minimum separation distanceas per IS 1893-2002. The storey drifts of separate buildings and combined buildings aretabulatedbelow andtheirvariations are seeninFig4.7

Table.4.7Storeydriftsof(G+22),(G+18),(G+22)(G+18)building

withoutSW inZ-V

Storey	(G+22) Drift:X Nounits	(G+22)(G+18) Drift:X Nounits	Storey	(G+18) Drift:X Nounits
24	0.003235	0.003769	20	0.001569
23	0.004897	0.005705	19	0.00243
22	0.006672	0.007774	18	0.003293
21	0.008367	0.009748	17	0.004009
20	0.009809	0.011429	16	0.004624
19	0.011149	0.01299	15	0.005209
18	0.012293	0.014322	14	0.005731
17	0.013088	0.015248	13	0.006185
16	0.013738	0.016005	12	0.006215
15	0.01446	0.016847	11	0.006492
14	0.015134	0.017632	10	0.006731
13	0.015724	0.01832	9	0.006924
12	0.015569	0.018138	8	0.007072
11	0.015925	0.018553	7	0.007178
10	0.016235	0.018914	6	0.007243
9	0.016484	0.019204	5	0.007259
8	0.01667	0.019422	4	0.007139
7	0.016793	0.019565	3	0.006868
6	0.016841	0.01962	2	0.005978
5	0.016767	0.019535	1	0.003089
4	0.016366	0.019067	Base	0
3	0.015476	0.01803		
2	0.01304	0.015193		
1	0.00638	0.007433		
Base	0	0		

5.CONCLUSIONS

5.1General

Inthepreviouschapter,theseismicbehaviorofthemodeledstructuresi.e.storydisplacement, story drifts, base shear and natural time period in all seismic zones III and Vare discussed and comparison is made between the structures with and without poundingeffect, pounding effect with varying heights, pounding effect in presence of shear wall. Inthischapter,theconclusionsoftheobtainedresultshave beendiscussedindetail.

5.2 Withoutshearwall

1. Themaximumstoreydisplacementsinzone-IIIandzone-Vforthreecases(G+22)(G+18),(G+22)(G+14) and(G+22)(G+10) buildings with pounding increased by 16.5%,29.5% and 34.8%respectivelywhencomparedto(G+22) buildingwithoutpounding.

2. The maximum storey drifts in zone-III and zone-V for three cases (G+22)(G+18), (G+22)(G+14)and (G+22)(G+10) buildings with pounding increased by 16.48%,29.5% and 34.8% respectivelywhencomparedto(G+22) buildingwithoutpounding.

3. Incaseof buildingswithpoundingthedisplacementsandstoreydriftsincreaseswhencomparedtonopoundingbuildingsbecauseof increase inrelativedisplacements.

With shearwall

4. The maximum storey displacements in zone-III and zone-V for three cases (G+22)SW(G+18),(G+22)SW(G+14) and(G+22)SW(G+10) buildings with pounding increased by 64.3%,27.5% and32.3%respectivelywhencomparedto(G+22)SWbuildingwithoutpounding.
5. Themaximumstoreydriftsinzone-IIIandzone-Vforthreecases(G+22)SW(G+18),(G+22)SW(G+14) and(G+22)SW(G+10) buildings with pounding increased by 64.3%,27.6% and32.3%respectivelywhen comparedto(G+22)SWbuildingwithoutpounding.

6. Shearwallismitigationmeasuretoreducepoundingbydecreasingdisplacementsofbuildings.

5.3 Withvariationinheights

1. The maximum storey displacements in zone-III and zone-V of (G+22)(G+14) when comparedwith(G+22)(G+18)increasedby11.1% and7.27%respectively.

2.The maximum storey displacements in zone-III and zone-V of (G+22)(G+10) when comparedwith(G+22)(G+14)increasedby4% and8%respectively.

2. The maximum storey displacements in zone-III and zone-V of (G+22)(G+10) when comparedwith(G+22)(G+18)increasedby15.7%.

The maximum storey displacements in zone-III and zone-V of (G+22) SW (G+14) when comparedwith(G+22)SW (G+18)decreasedby22.3%.

3.In general as the height of buildings decreases the stiffness increases so minimum displacements isseen in that case. But in case of pounding, smaller building experiences more displacements andliabletogreaterdamagethanlargerbuilding.Thereasonisthatintheshortbuilding,bothdisplacements and story shears are decreased on all floors on the pounding side but increased on theno-pounding side. The short building is prevented from moving on the pounding side, but is pushedaway on the no-pounding side, which produces not only larger displacements but also larger relativedisplacements,andconsequentlylargerstoryshearsonitspoundingside.

5.4 Scopeforfutureresearchwork

Pounding response of adjacent buildings with different kinds of dampers and bracings byvarying heights of buildings can be studied by performing Response spectrum analysis andTime-historyanalysis.

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