CHAPTER V

CONCLUSION AND RECCOMENDATION

5.1 Conclusion

Based on comparison of analysis output from time history analysis between base isolation structure with fixed base structure, Base Isolation Structure achieved a total of 70.9% of increase in total displacement in the structure. Most of displacement occur in the base, that have displaced 21.63 cm from initial point. As the result, the inter story drift of the structure is decrease by average of 70.4 %. The displacement makes the natural period of the structure increased to 2.34 s from 1.007 s. This lead to decrease of acceleration in top-story by 70.3% and decrease of story shear force by average 68.4 %. From the analysis data, it can be concluded that the use of base isolation system will have significant impact on response of the structure.

5.2 Recommendations

As Yogyakarta is one of the most earthquake prone regions in the Indonesia, special attention towards improving the resistance of structures toward earthquake should be done. By implementing Base Isolation System, the effect of ground motion on the building can be significantly reduced with little or no damaged on the building. This can significantly reduce the cost of repair and maintenance.

However, the use of base isolator system is not yet popular in Indonesia. This is mainly because the technology is still new and expensive in Indonesia. More studies regarding base isolation economic performance compared to normal structure is needed to assess the feasibility of base isolation system on a structure. If the economic benefit of base isolation in earthquake prone area can be proven, the use of base isolation can be viable choice of solution for Indonesian Civil Engineers.

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APPENDIXES

Appendix A: Building ETABS Model

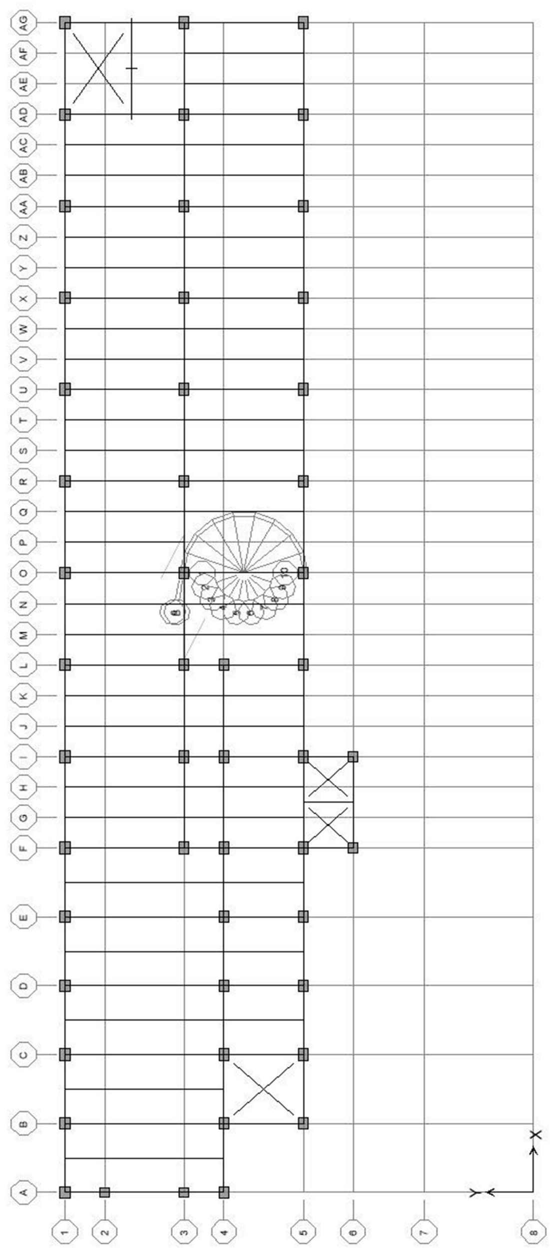

Fig.1. Typical Building Plan

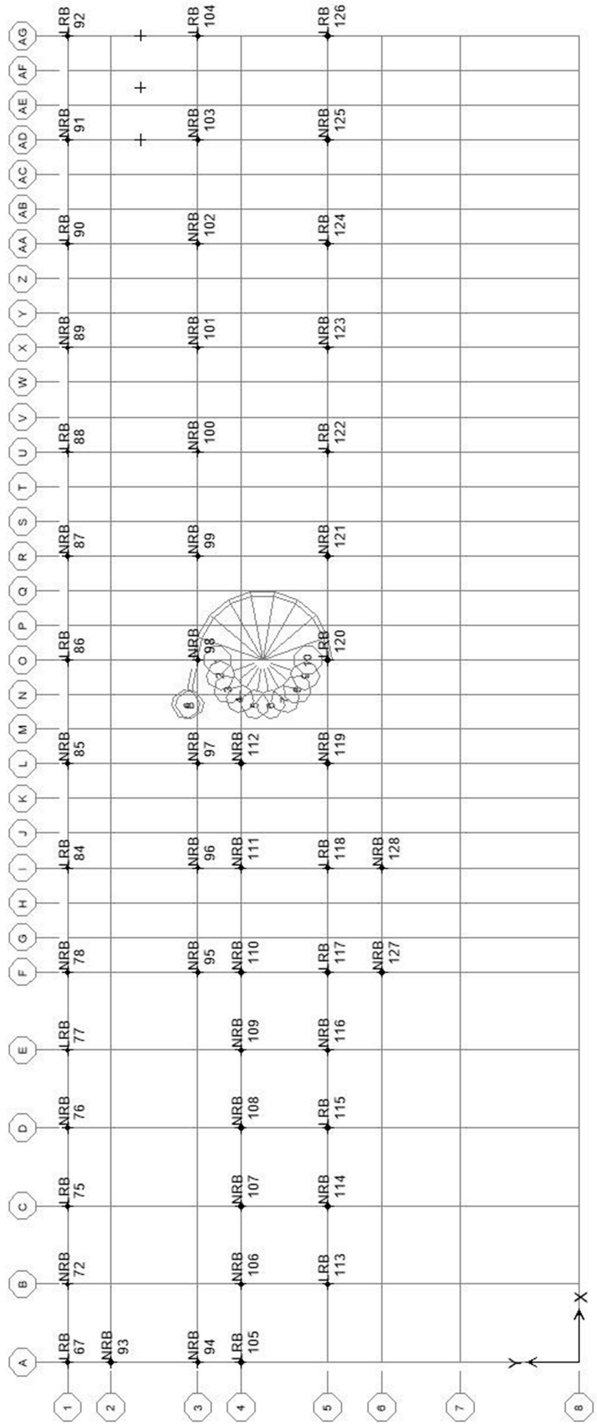

Fig.2. Building Isolator Configuration

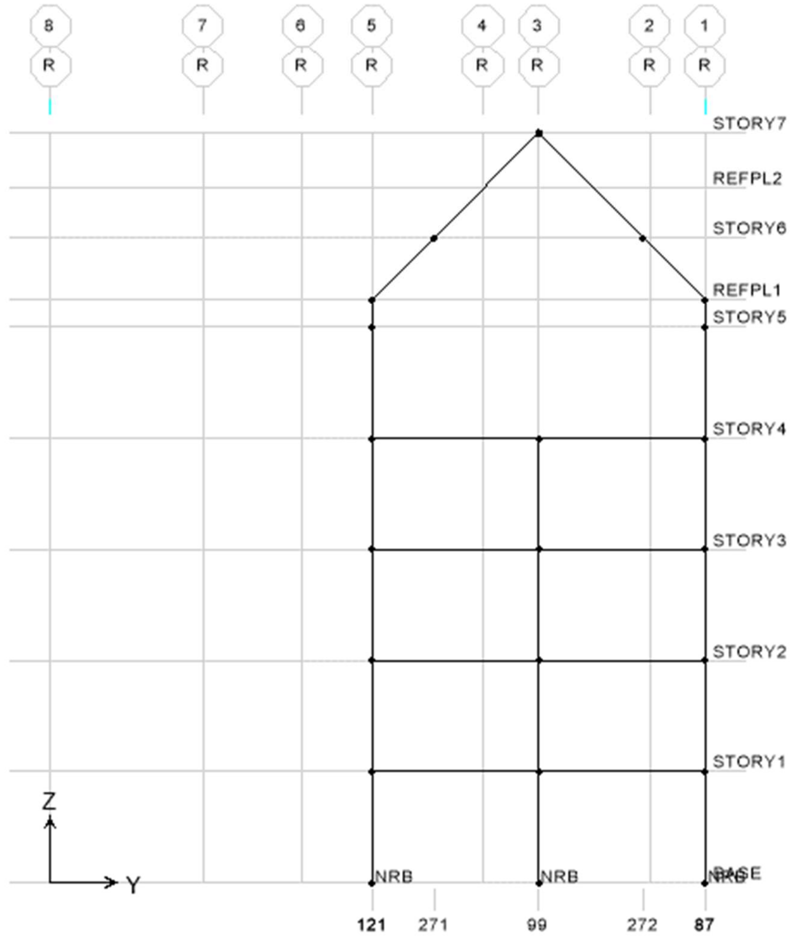

Fig.3. Typical Building Section

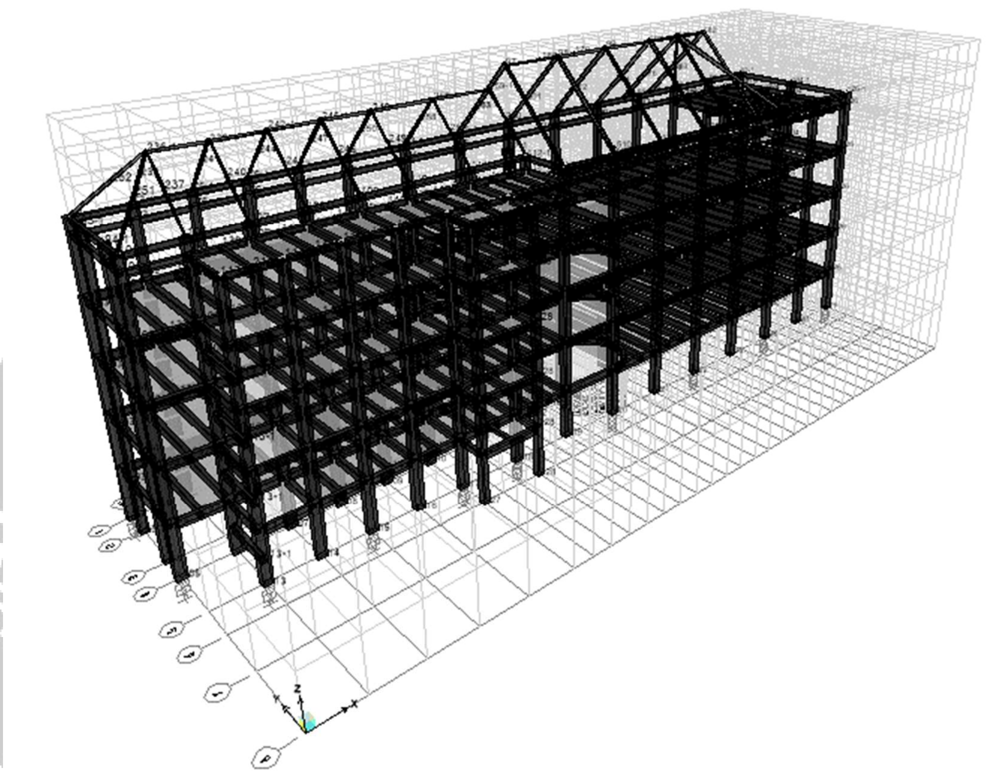

Fig.4. 3D Model of the Building

Appendix B: Isolator Properties

LL-Series (Total Rabber Thickness 160mm)

Code

Designation	Compound	Shear Modulus (N/mm²)
G4	G0.40	0.385

	Characteristics	LL060G4					LL065G4					LL070G4					LL075G4				
		C	B	A	G	H	C	B	A	G	H	C	B	A	G	H	C	B	A	G	H
Physical Dimensions	Outer Diameter (mm)	600					650					700					750				
	Inner diameter (mm)	100	110	120	130	140	110	120	130	140	150	120	130	140	150	160	130	140	150	160	170
	Effective Plane Area (× 10²mm²)	2749	2732	2714	2695	2673	3223	3205	3186	3164	3142	3735	3716	3695	3672	3647	4285	4264	4241	4217	4191
	Thickness of One Rubber Layer (mm)	3.95					4.4					4.9					4.85				
	Number of Rubber Layers (–)	41					37					34					34				
	Total Rubber Thickness (mm)	162					163					167					165				
	First Shape Factor(–)	38.0					36.9					35.7					38.7				
	Second Shape Factor (–)	3.70					3.99					4.20					4.55				
	Diameter of Flange (mm)	900					950					1000					1100				
	Thickness of Flange (mm)	22/28					22/28					22/28					22/28				
	Diameter of Bolt Center (mm)	775					825					875					950				
	Diameter (Number) of Fixing bolts (mm)	φ33×12					φ33×12					φ33×12					φ33×12				
	Supposed Bolt (–)	M30					M30					M30					M30				
	Thickness of One Reinforcing Steel Plate (mm)	3.1					3.1					3.1					3.1				
	Height (mm)	342.0					330.4					324.9					323.2				
	Total Weight (KN)	5.9	5.9	6.0	6.0	6.1	6.5	6.5	6.6	6.6	6.7	7.1	7.2	7.2	7.3	7.3	8.3	8.3	8.4	8.4	8.5
Compression Properties	Critical Stress (N/mm²) $\gamma=0$ σ_c	(41.0)					(48.4)					(53.7)					(66.5)				
	Ultimate Compressive Stress (N/mm²) (γ_0, σ_0)	(0.00,41.0)					(0.00,48.4)					(0.00,53.7)					(0.00,60.0)				
	Ultimate Compressive Stress (N/mm²) (γ_1, σ_1)	–					–					–					(0.50,60.0)				
	Ultimate Compressive Stress (N/mm²) (γ_2, σ_2)	(3.70,4.10)					(3.99,4.84)					(4.00,7.69)					(4.00,13.9)				
	Compressive Stiffness (× 10³kN/m)	2070					2400					2680					3200				
	Nominal Long Term Compressive Stress(N/mm²)	$9.2^{+1.4}_{-2.1}$					$10.5^{+1.6}_{-2.4}$					$11.4^{+1.7}_{-2.6}$					$13.0^{+2.0}_{-3.0}$				
	Nominal Long Term Column Load (kN)	2530	2510	2500	2480	2460	3380	3370	3340	3320	3300	4260	4240	4210	4190	4160	5570	5540	5510	5480	5450
	Allowable Tensile Stress (γ =100%) (N/mm²)	1.0					1.0					1.0					1.0				
Shear Properties (γ=100%)	Initial Stiffness (× 10³kN/m)	8.86	8.89	8.92	8.95	8.98	10.4	10.4	10.4	10.4	10.5	11.7	11.8	11.8	11.8	11.9	13.6	13.6	13.7	13.7	13.8
	Post Yield Stiffness (γ =100%)(× 10³kN/m)	0.682	0.684	0.686	0.688	0.691	0.796	0.798	0.801	0.803	0.806	0.903	0.905	0.908	0.910	0.913	1.05	1.05	1.05	1.06	1.06
	Characteristic Strength (kN)	63	76	90	106	123	76	90	106	123	141	90	106	123	141	160	106	123	141	160	181
	Equivalent shear stiffness(× 10³kN/m)	1.07	1.15	1.24	1.34	1.45	1.26	1.35	1.45	1.56	1.67	1.44	1.54	1.64	1.76	1.87	1.69	1.79	1.91	2.03	2.16
	Equivalent Damping Ratio (–)	0.219	0.244	0.266	0.285	0.302	0.223	0.246	0.266	0.284	0.300	0.227	0.247	0.266	0.283	0.298	0.229	0.248	0.266	0.282	0.296

Fig.5. LRB Properties

● NS-Series (S_2 = 5type)

Code

Designation	Compound	Shear Modulus (N/mm²)
G4	G0.40	0.392

Characteristics			NS060G4	NS065G4	NS070G4	NS075G4	NS080G4	NS085G4	NS090G4	NS095G4	NS100G4	NS110G4	NS120G4	NS130G4	NS140G4	NU150G4
Physical Dimensions	Outer Diameter (mm)		600	650	700	750	800	850	900	950	1000	1100	1200	1300	1400	1500
	Inner Diameter (mm)		15	15	15	15	20	20	20	20	25	25	25	30	30	40
	Effective Plane Area (× 10²mm²)		2826	3317	3847	4416	5023	5671	6359	7085	7849	9498	11305	13266	15387	17659
	Thickness of One Rubber Layer (mm)		4.0	4.4	4.7	5.0	5.4	5.7	6.0	6.4	6.7	7.4	8.0	8.7	9.3	8.5
	Number of Rubber Layers (–)		30	30	30	30	30	30	30	30	30	30	30	30	30	35
	Total Rubber Thickness (mm)		120	132	141	150	162	171	180	192	201	222	240	261	279	298
	First Shape Factor (–)		36.6	36.1	36.4	36.8	36.1	36.4	36.7	36.3	36.4	36.3	36.7	36.5	36.8	42.9
	Second Shape Factor (–)		5.00	4.92	4.96	5.00	4.94	4.97	5.00	4.95	4.98	4.95	5.00	4.98	5.02	5.04
	Diameter of Flange (mm)		900	950	1000	1100	1150	1200	1250	1300	1400	1500	1600	1700	1800	1900
	Thickness of Flange (mm)		22/28	22/28	22/28	22/28	24/32	24/32	28/36	28/36	28/36	30/38	32/40	32/40	37/45	50/100
	Diameter of Bolt Center (mm)		775	825	875	950	1000	1050	1100	1150	1250	1350	1450	1550	1650	1700
	Diameter (Number) of Fixing bolts (mm)		ϕ33×12	ϕ33×12	ϕ33×12	ϕ33×12	ϕ33×12	ϕ33×12	ϕ33×12	ϕ33×12	ϕ39×12	ϕ39×12	ϕ39×12	ϕ39×12	ϕ42×12	ϕ42×12
	Supposed Bolt (–)		M30	M30	M30	M30	M30	M30	M30	M30	M36	M36	M36	M36	M39	M39
	Thickness of One Reinforcing Steel Plate (mm)		3.1	3.1	3.1	3.1	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	5.8	5.8
	Height (mm)		265.9	277.9	286.9	295.9	353.6	362.6	379.6	391.6	400.6	425.6	447.6	468.6	537.2	694.7
	Total Weight (KN)		4.8	5.6	6.4	7.5	10.5	11.7	13.8	15.3	17.3	21.3	25.8	30.1	41.6	69.2
Compression Properties	Critical Stress (N/mm²)	$\gamma=0$ σ_{cr}	65	63	64	65	63	64	65	64	64	64	65	65	65	70
	Ultimate Compressive Stress (N/mm²)	(γ_0, σ_0)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)	(0,60)
		(γ_1, σ_1)	(0.5,60)	(0.3,60)	(0.4,60)	(0.5,60)	(0.3,60)	(0.4,60)	(0.5,60)	(0.4,60)	(0.4,60)	(0.4,60)	(0.5,60)	(0.5,60)	(0.5,60)	(0.9,60)
		(γ_2, σ_2)	(4.0,25)	(4.0,24)	(4.0,25)	(4.0,26)	(4.0,24)	(4.0,25)	(4.0,25)	(4.0,24)	(4.0,25)	(4.0,24)	(4.0,26)	(4.0,25)	(4.0,26)	(4.0,28)
	Compressive Stiffness (× 10³kN/m)		2280	2420	2640	2850	2990	3200	3420	3560	3770	4130	4570	4920	5350	6070
	Nominal Long Term Compressive Stress (N/mm²)		$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$	$15.0^{+0.0}_{-5.0}$
	Nominal Long Term Column Load (kN)		4240	4970	5770	6620	7540	8510	9540	10600	11800	14200	17000	19900	23100	26500
	Allowable Tensile Stress (γ =100%) (N/mm²)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Shear Properties	Shear Stiffness (× 10³kN/m) (critical stress : γ = ± 100%)		0.923	0.985	1.07	1.15	1.22	1.30	1.38	1.45	1.53	1.68	1.85	1.99	2.16	2.33

Fig.6. NRB Properties

Appendix C: Fixed building output

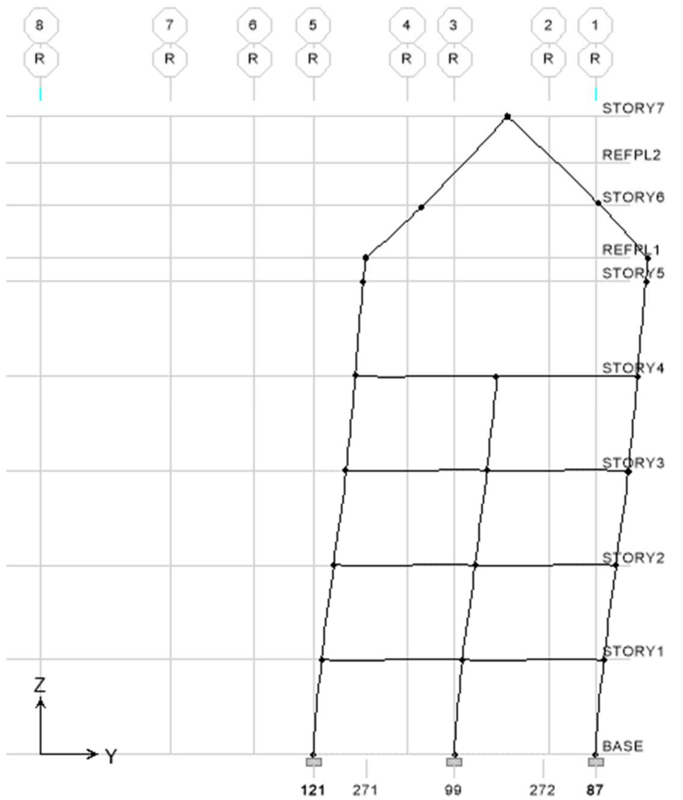

Fig.7. Displacement on Section AG

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 92

File

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
STORY7	0.000000	0.000000	0.000000	0.000000
STORY6	0.000000	0.000000	0.000000	0.000000
STORY5	0.024019	0.155744	0.000145	0.005357
STORY4	0.023436	0.134183	0.000803	0.007297
STORY3	0.020203	0.104813	0.001550	0.009655
STORY2	0.013962	0.065952	0.002034	0.009922
STORY1	0.005775	0.026014	0.001435	0.006463

Fig.8. Maximum Displacement and Story Drift Ratio

Story Shears

Edit View

Story Shears

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY5	HIST1 MAX	Top	0.00	11047.52	10115.77	535320.695	1011.728	1877.682
STORY5	HIST1 MAX	Bottom	0.00	11047.52	10115.77	535320.695	42521.285	46343.938
STORY5	HIST1 MIN	Top	0.00	-11063.64	-10312.93	-504674.328	-1019.294	-1895.444
STORY5	HIST1 MIN	Bottom	0.00	-11063.64	-10312.93	-504674.328	-41735.257	-46426.595
STORY4	HIST1 MAX	Top	0.00	19285.15	20333.60	1007850.920	42521.285	46343.938
STORY4	HIST1 MAX	Bottom	0.00	19285.15	20333.60	1007850.920	129676.229	119252.176
STORY4	HIST1 MIN	Top	0.00	-18162.97	-21653.40	-954133.246	-41735.257	-46426.595
STORY4	HIST1 MIN	Bottom	0.00	-18162.97	-21653.40	-954133.246	-123067.849	-119532.547
STORY3	HIST1 MAX	Top	0.00	17443.64	23533.19	1062154.200	129676.229	119252.176
STORY3	HIST1 MAX	Bottom	0.00	17443.64	23533.19	1062154.200	217863.531	188588.934
STORY3	HIST1 MIN	Top	0.00	-17471.58	-23874.65	-1015745.039	-123067.849	-119532.547
STORY3	HIST1 MIN	Bottom	0.00	-17471.58	-23874.65	-1015745.039	-210402.595	-180156.258
STORY2	HIST1 MAX	Top	0.00	20438.41	28910.79	1295204.992	217863.531	188588.934
STORY2	HIST1 MAX	Bottom	0.00	20438.41	28910.79	1295204.992	303886.613	230609.810
STORY2	HIST1 MIN	Top	0.00	-21650.24	-28657.71	-1313422.715	-210402.595	-180156.258
STORY2	HIST1 MIN	Bottom	0.00	-21650.24	-28657.71	-1313422.715	-291483.418	-228862.143
STORY1	HIST1 MAX	Top	0.00	27172.26	33141.14	1489673.127	303886.613	230609.810
STORY1	HIST1 MAX	Bottom	0.00	27172.26	33141.14	1489673.127	408608.058	254852.914
STORY1	HIST1 MIN	Top	0.00	-28998.65	-35230.31	-1601676.175	-291483.418	-228862.143
STORY1	HIST1 MIN	Bottom	0.00	-28998.65	-35230.31	-1601676.175	-416177.504	-263340.268

OK

Fig.9. Story shears

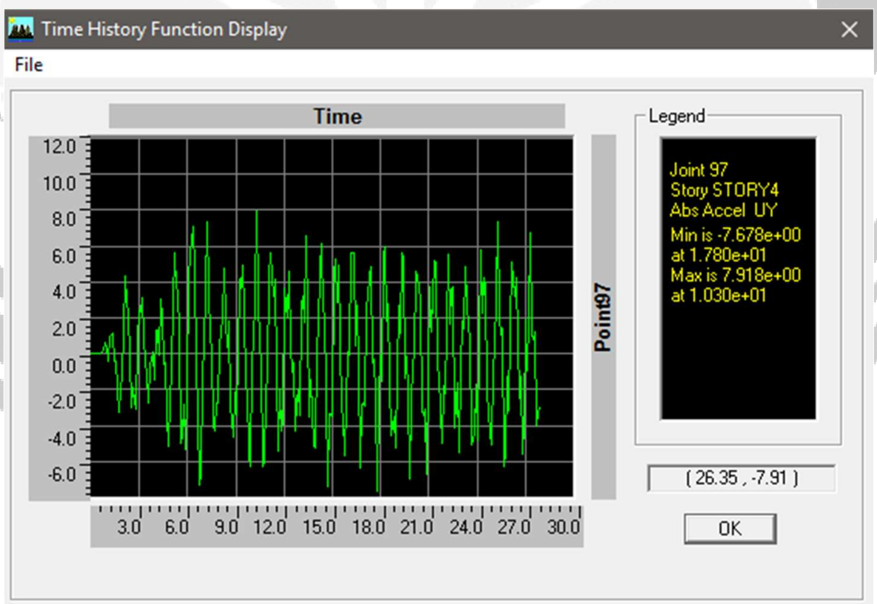

Fig.10. Story acceleration on joint 97 at 4th floor

Appendix D: Base Isolator building output

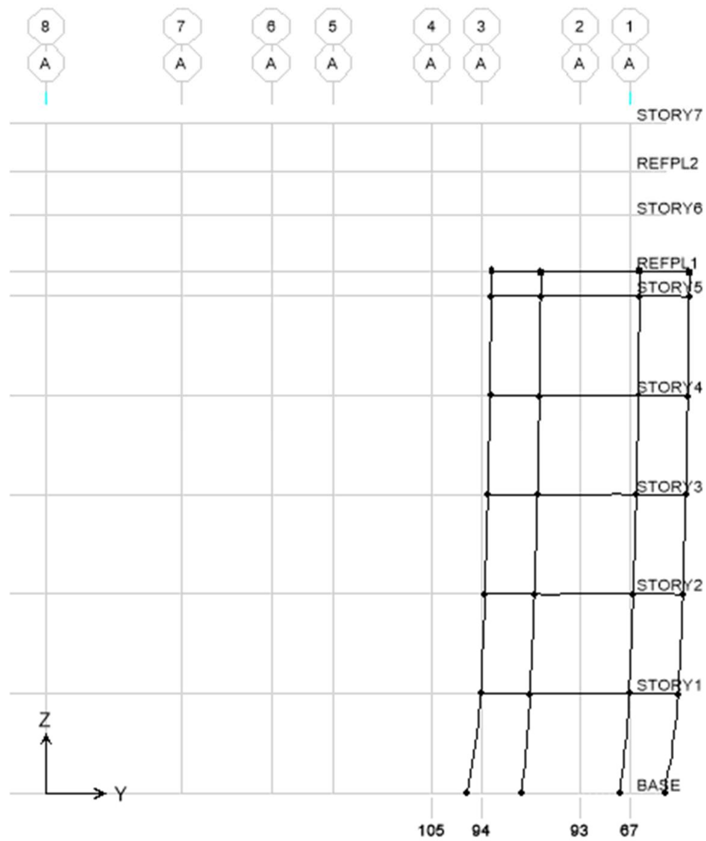

Fig.11. Displacement on Section A

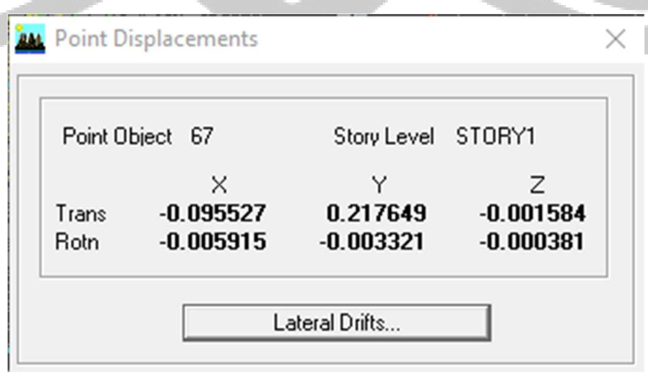

Fig.12. Maximum Displacement at Base

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 67

File

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
STORY7	0.000000	0.000000	0.000000	0.000000
STORY6	0.000000	0.000000	0.000000	0.000000
STORY5	-0.120179	0.266101	0.000670	0.001482
STORY4	-0.117484	0.260134	0.001278	0.002264
STORY3	-0.112339	0.251019	0.001802	0.003307
STORY2	-0.105087	0.237708	0.002375	0.004984
STORY1	-0.095527	0.217649	0.005823	0.015318

Fig.13. Maximum Displacement and Story Drift Ratio

Story Shears

Edit View

Story Shears

Story	Load	Loc	P	VX	VY	T	MX	MY
STORY5	HIST2 MAX	Top	0.00	2592.49	3342.90	78142.440	320.454	489.755
STORY5	HIST2 MAX	Bottom	0.00	2592.49	3342.90	78142.440	12682.578	10924.518
STORY5	HIST2 MIN	Top	0.00	-2803.71	-3071.34	-95860.315	-335.232	-532.905
STORY5	HIST2 MIN	Bottom	0.00	-2803.71	-3071.34	-95860.315	-13790.402	-11816.050
STORY4	HIST2 MAX	Top	0.00	5950.33	7129.70	120740.810	12682.578	10924.518
STORY4	HIST2 MAX	Bottom	0.00	5950.33	7129.70	120740.810	32983.055	33139.675
STORY4	HIST2 MIN	Top	0.00	-6251.42	-5190.19	-164027.177	-13790.402	-11816.050
STORY4	HIST2 MIN	Bottom	0.00	-6251.42	-5190.19	-164027.177	-42487.434	-35848.815
STORY3	HIST2 MAX	Top	0.00	8966.86	7815.47	201920.274	32983.055	33139.675
STORY3	HIST2 MAX	Bottom	0.00	8966.86	7815.47	201920.274	57656.102	67645.385
STORY3	HIST2 MIN	Top	0.00	-8927.36	-6908.43	-152698.619	-42487.434	-35848.815
STORY3	HIST2 MIN	Bottom	0.00	-8927.36	-6908.43	-152698.619	-73944.709	-69647.013
STORY2	HIST2 MAX	Top	0.00	10181.30	8314.88	227196.655	57656.102	67645.385
STORY2	HIST2 MAX	Bottom	0.00	10181.30	8314.88	227196.655	92422.675	107459.179
STORY2	HIST2 MIN	Top	0.00	-11219.63	-8637.66	-169173.360	-73944.709	-69647.013
STORY2	HIST2 MIN	Bottom	0.00	-11219.63	-8637.66	-169173.360	-101216.427	-114806.019
STORY1	HIST2 MAX	Top	0.00	10029.17	8596.90	167385.128	92422.675	107459.179
STORY1	HIST2 MAX	Bottom	0.00	10029.17	8596.90	167385.128	139191.525	141443.941
STORY1	HIST2 MIN	Top	0.00	-13590.71	-11619.59	-187093.133	-101216.427	-114806.019
STORY1	HIST2 MIN	Bottom	0.00	-13590.71	-11619.59	-187093.133	-124610.681	-169508.643

OK

Fig.14. Story shears

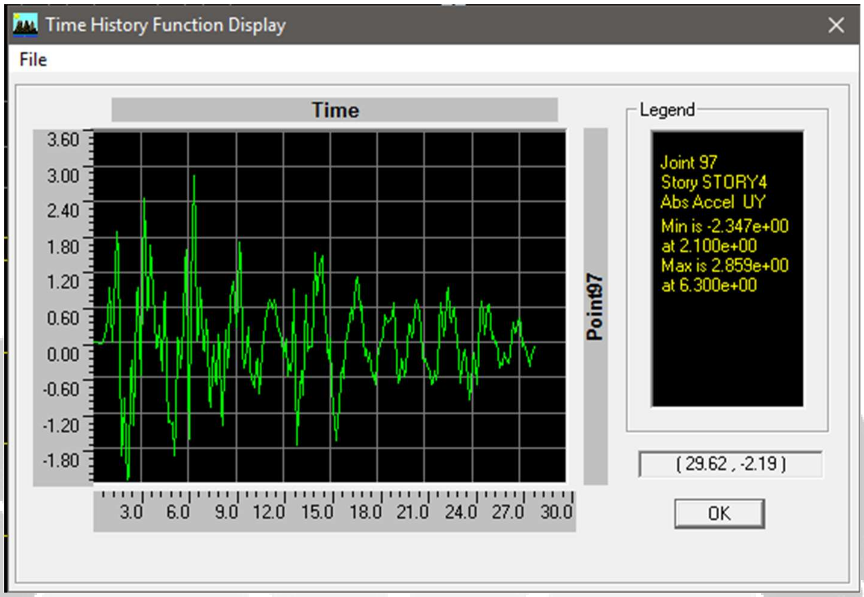

Fig.15. Story acceleration on joint 97 at 4th floor