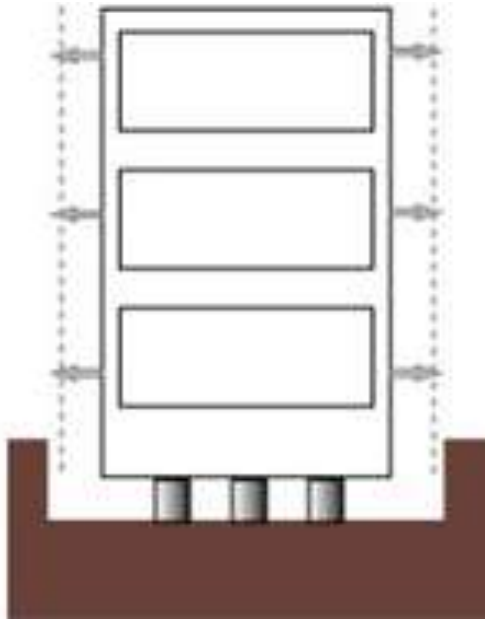
A Comparative Study of Base Isolation Devices in Light Rail Transit Structure featured with Lead Rubber Bearing and Friction Pendulum System

By:
Santi Nuraini, ST
Dr. Asdam Tambusay, ST
Prof. Priyo Suprobo, MS., Ph.D

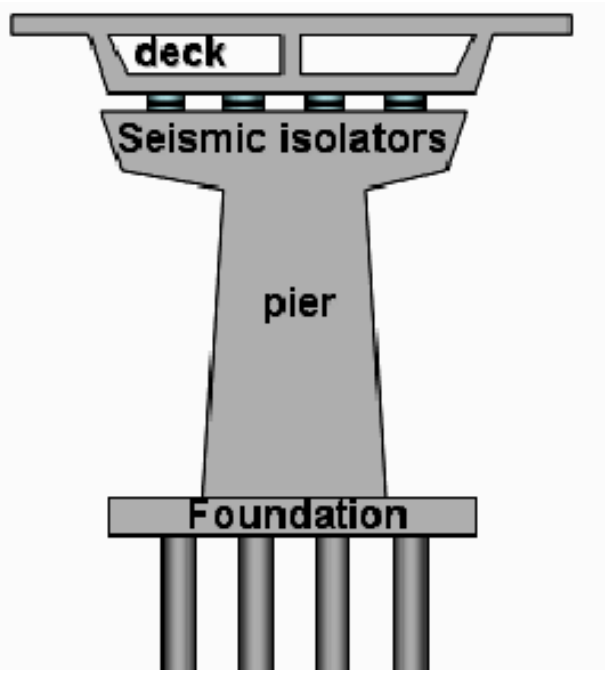
BASE ISOLATION SYSTEM

1. extend the natural period of a structure as a means of providing additional damping and energy dissipation
2. preventing the structure to undergo severe damage under a major earthquake

Buildings



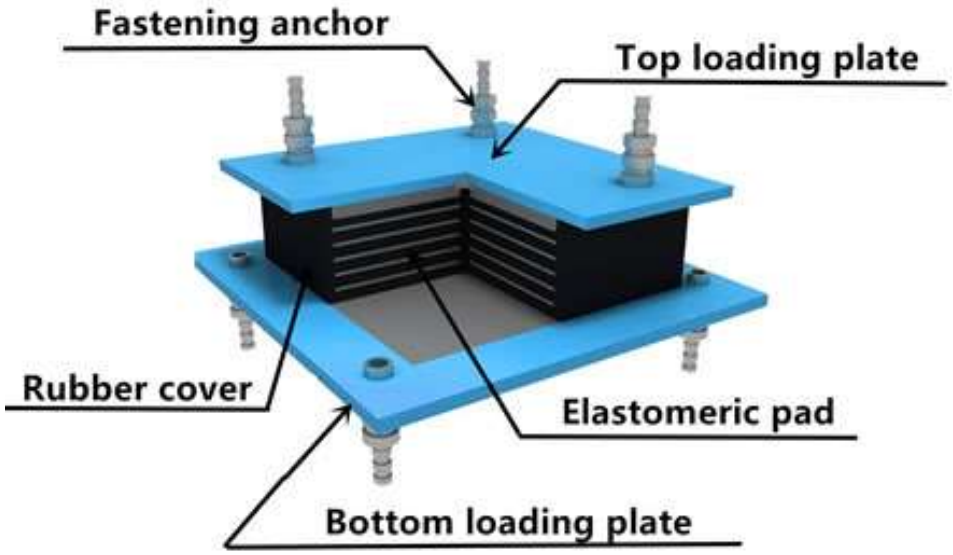
Bridge



TYPE OF BASE ISOLATION

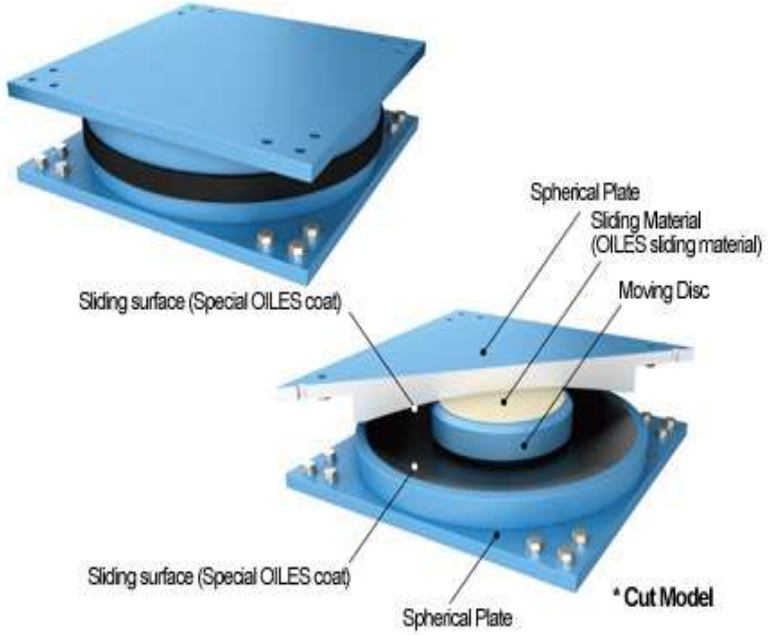
LRB

(Lead Rubber Bearing)

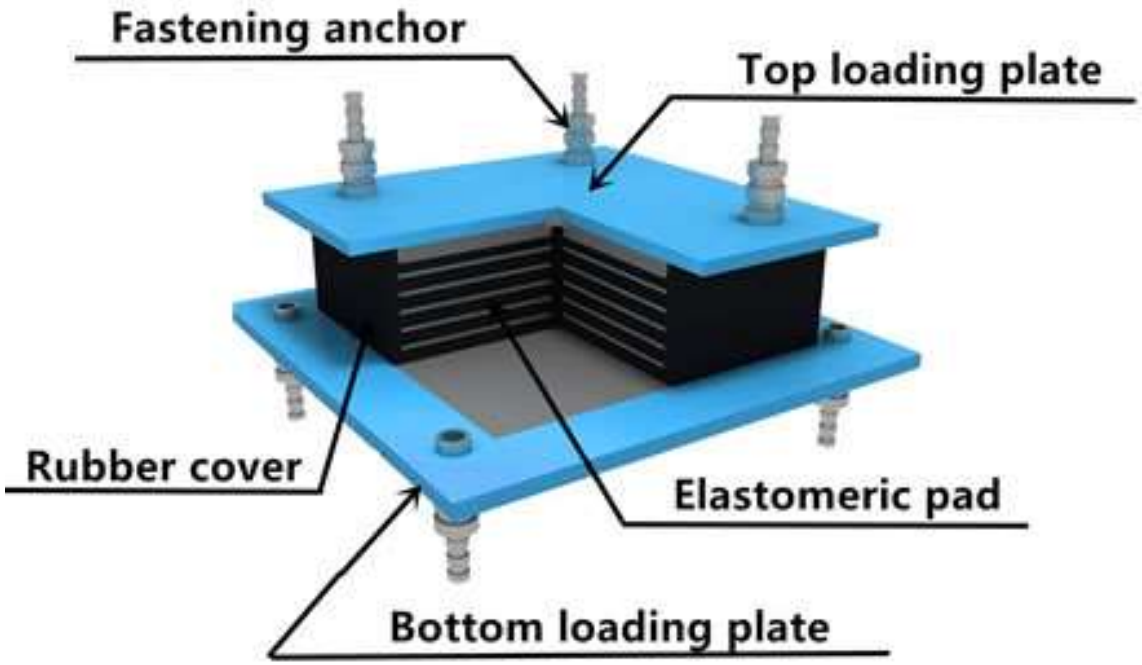


FPS

(Friction Pendulum System)

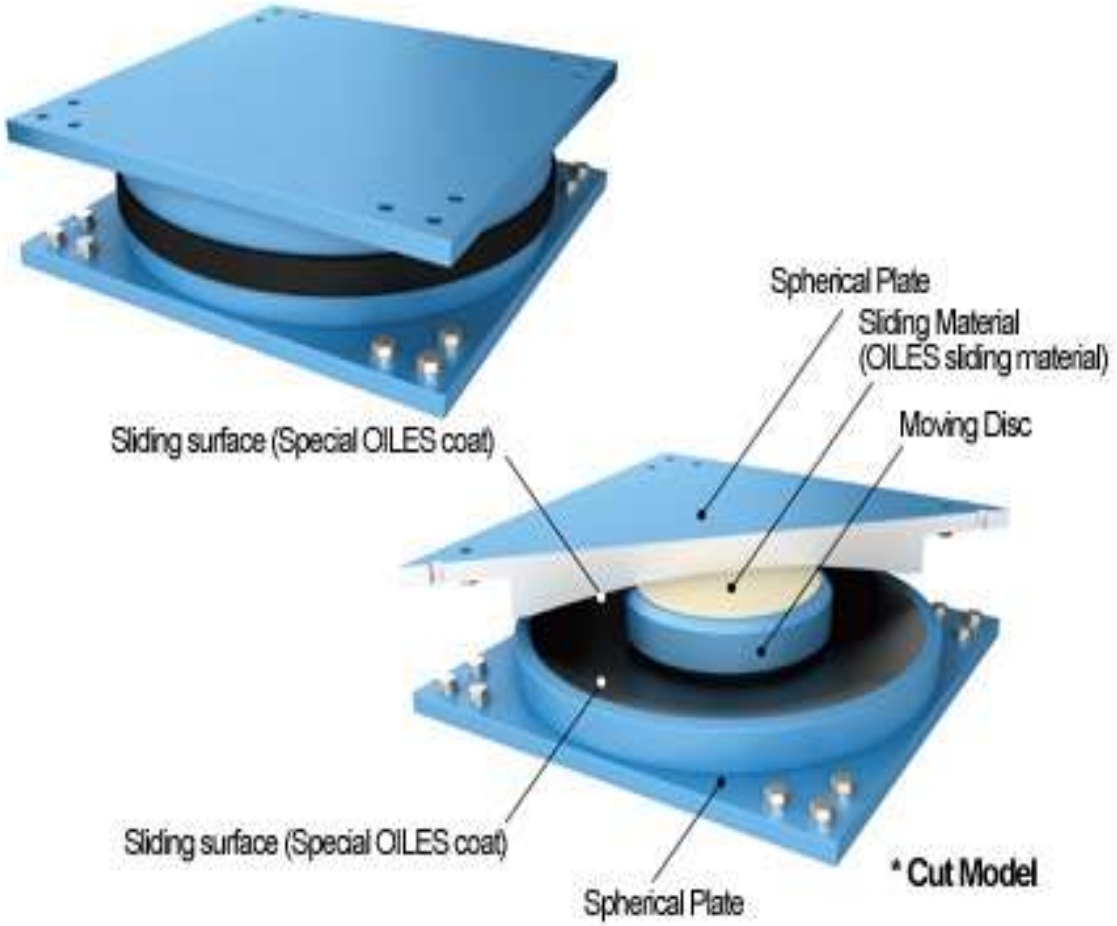


LRB (Lead Rubber Bearing)



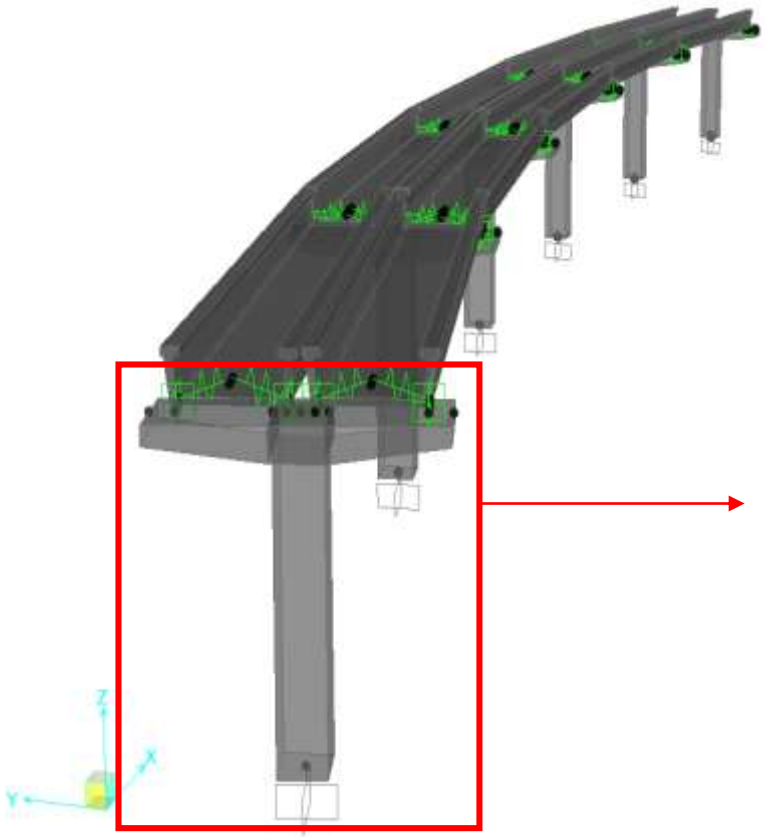
This bearing includes a lead plug embedded at the centre of a laminated natural rubber structure, where the rubber incorporates the spring capability and the lead plug provides the damping capability. Generally, a separate damper is not required making it a good choice for areas with space constraints. Its hysteresis resembles elasto-plastic materials. The

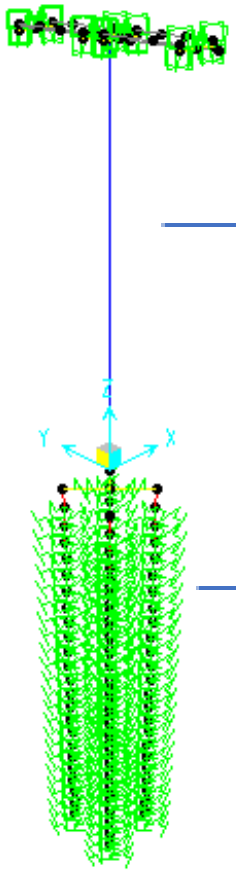
FPS (Friction Pendulum System)



The FPS consists of a spherical sliding surface and an articulated slider which is faced with a high pressure capacity bearing material. The bearing, which realize a pendulum system, may be installed also upside-down with the spherical surface facing down rather than up. In both installation methods the behavior is identical

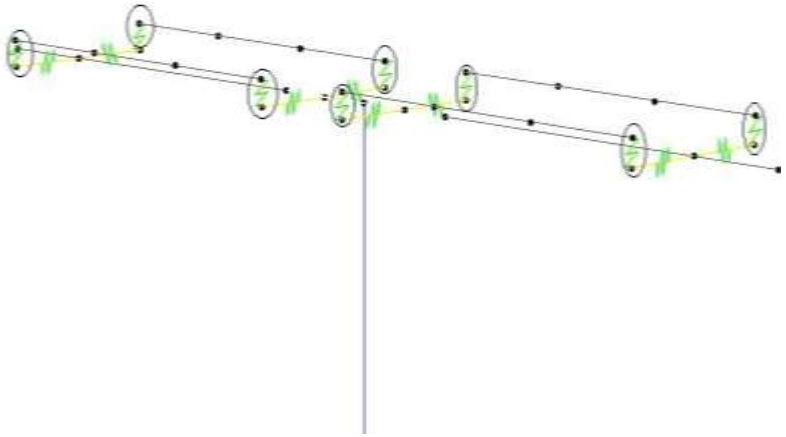
STRUCTURE MODEL





Bearing

Pier



Spring
Foundation

Pier Dimension : 2 x 2 m
Pile Cap : 2 x 2 x 5 m
Pier Height : 16 m

SEISMIC DESIGN

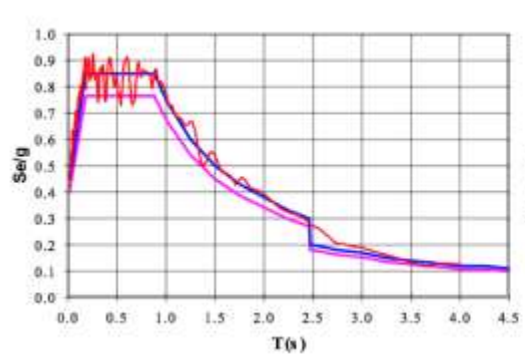
Design of seismic ground motion is determined based on the Indonesia earthquake provision SNI 1726:2012 [14] (drafted largely based on ASCE/SEI 7-10.

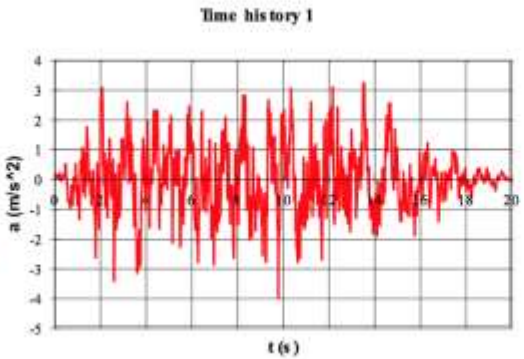
(*PGA*) = 0.325*g* mapped MCER

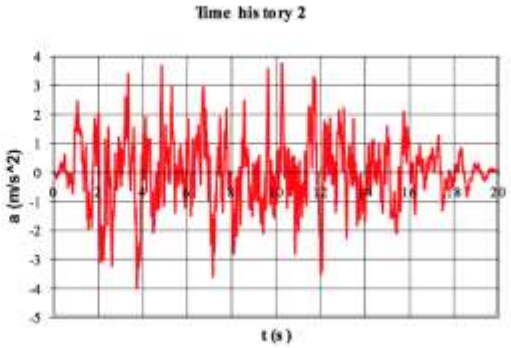
0.2 (*SS*) = 0.50g

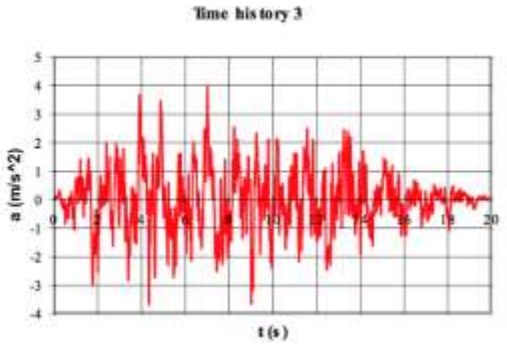
Damping = 5%

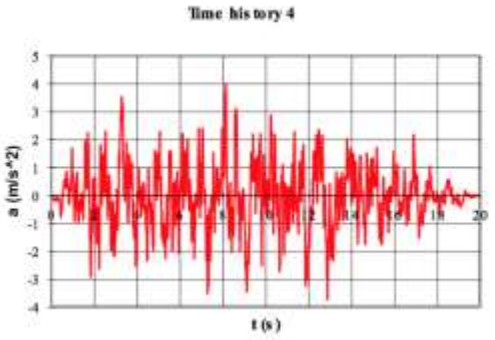
1 (*S1*) = 0.25g

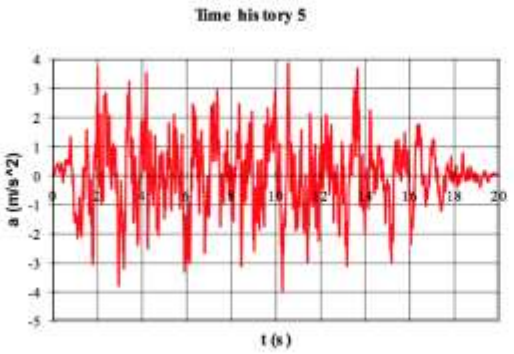


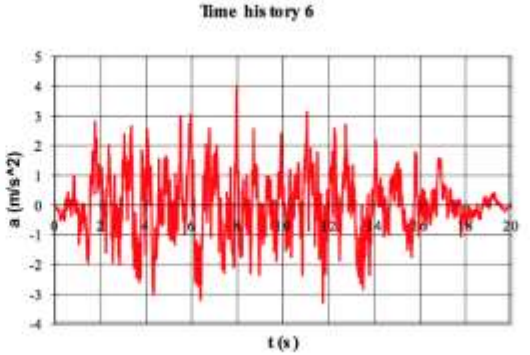


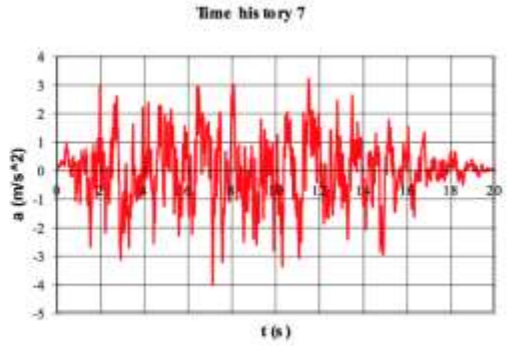




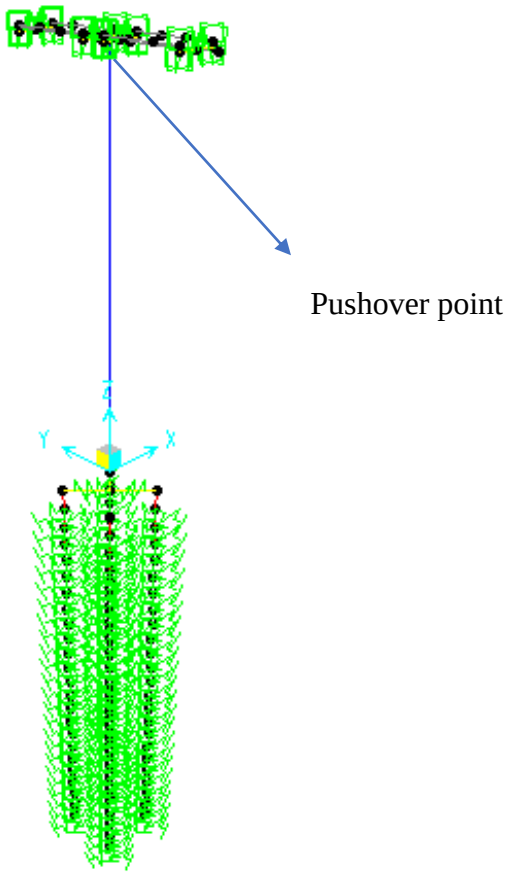








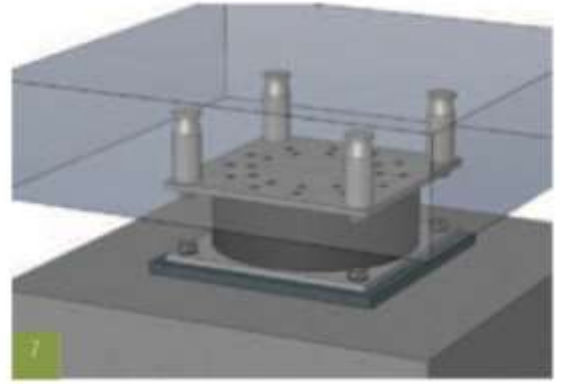
PUSHOVER ANALYSIS

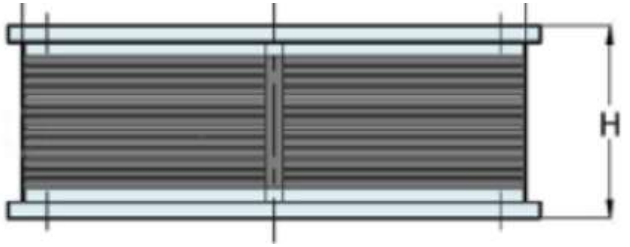


Pushover analysis was performed using nonlinear static displacement control. Only the self-weight of the structure was considered in this simulation. The column tip was pushed up to one metre to foresee the nonlinear plateau of the structure and thereby allowing one to obtain the level of performance during plastic hinge mechanisms.

MATERIAL PROPERTIES

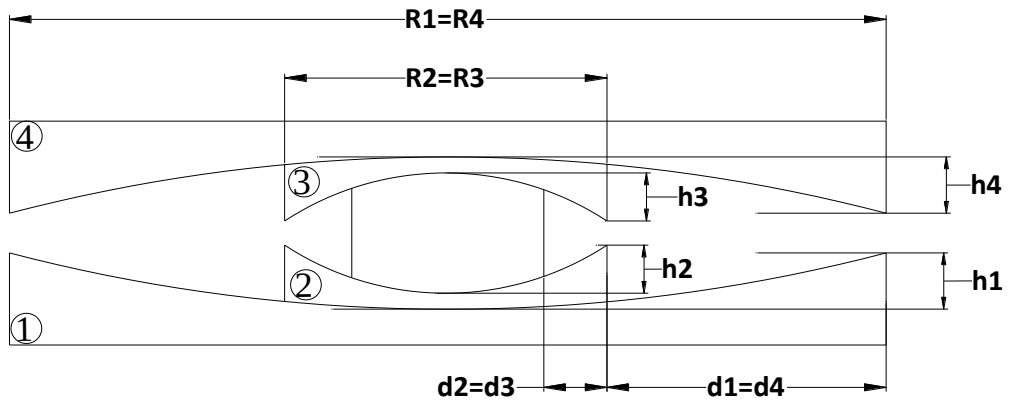
Properties	LRB Type 1	LRB Type 2	LRB Type 3
Allowable bearing displacement	315 mm	315 mm	315 mm
Stiffness	4,3 kN/mm	5,53 kN/mm	3,15 kN/mm
Yield strength	80 kN	80 kN	80 kN
Height	252 mm	298 mm	356 mm





MATERIAL PROPERTIES

Properties	Type 1	Type 2	Type 3
$R1_{eff} = R4_{eff}$ (mm)	2133	3395	6934
$R2_{eff} = R3_{eff}$ (mm)	330	526	1074
$d1^* = d4^*$ (mm)	339.8	540.4	1103.48
$d2^* = d3^*$ (mm)	41.5	65.9	30.85
$\mu1 = \mu4$ (lower bound)	0.071	0.078	0.093
$\mu2 = \mu3$ (lower bound)	0.053	0066	0.093
μ (lower bound)	0.068	0.076	0.093
$\mu1 = \mu4$ (upper bound)	0.085	0.094	0.112
$\mu1 = \mu4$ (lower bound)	0.064	0.079	0.111
μ (upper bound)	0.082	0.092	0.112



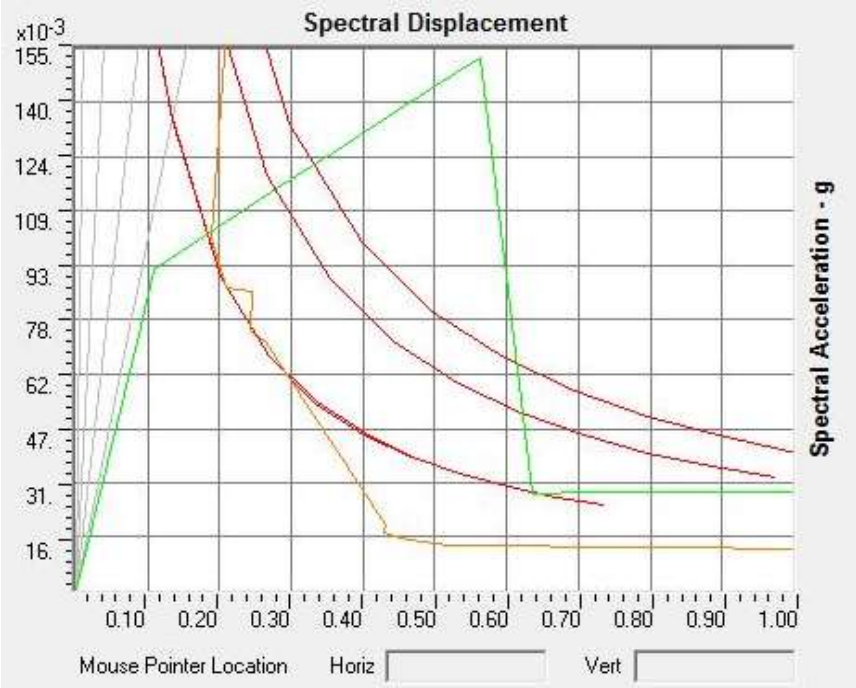
PERFORMANCE LEVEL

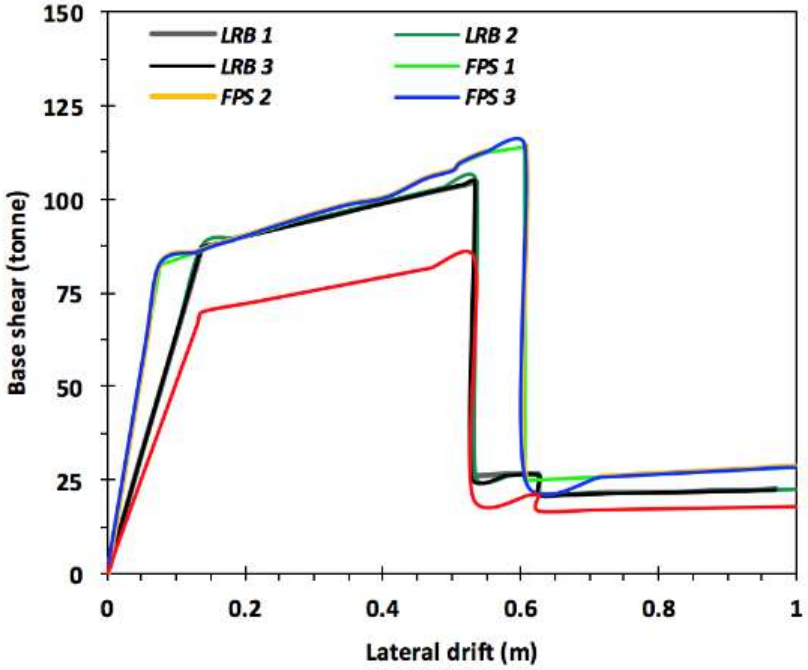
Base shear and displacement of LRB

Pushover analysis			Time history analysis	
LRB	Drift (m)	Base Shear (ton)	Drift *x* (m)	Drift y (m)
1	0.183	89.551	0.162	0.050
2	0.180	89.189	0.149	0.044
3	0.178	89.086	0.145	0.042

Base shear and displacement of FPS

Pushover analysis			Time history analysis	
FPS	Drift (m)	Base Shear (ton)	Drift *x* (m)	Drift *y* (m)
1	0.116	70.457	0.137	0.045
2	0.102	70.345	0.136	0.053
3	0.082	70.031	0.134	0.043



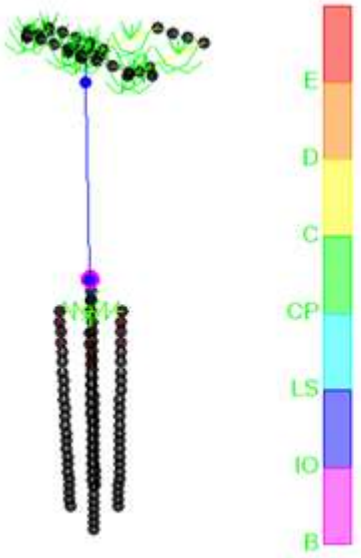


ENERGY DISSIPATION

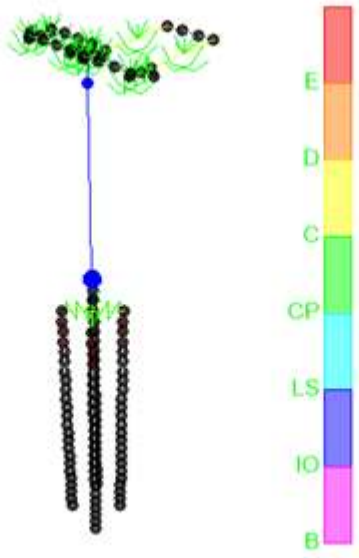
In this current work, the improvement of energy dissipation controlled by seismic isolation system is inspected by the ratio of the structure without isolator (RL) and with isolators (FPS and LRB). According to Table, it is apparent that both seismic isolation devices stipulate higher energy dissipation with average improvement over 15%.

Type	Ratio FPS/RL	Ratio of LRB/RL
1	1.084	1.177
2	1.141	1.180
3	1.165	1.181

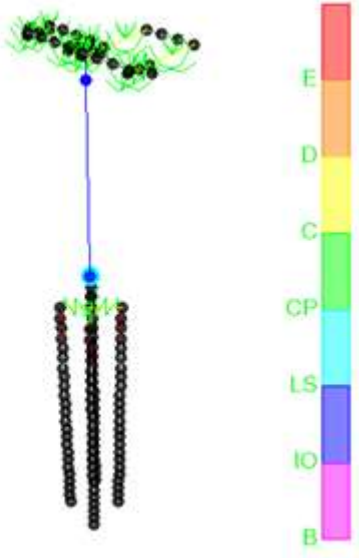
PLASTIC HINGE MECANISM



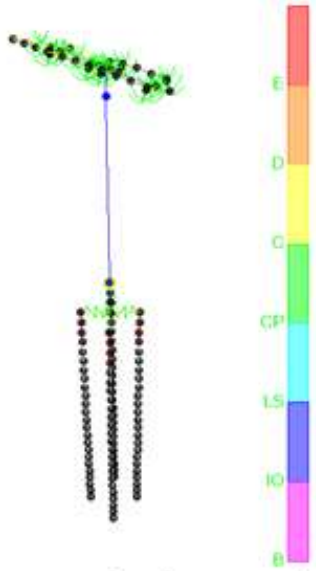
Step 1 *(Drift 57mm)*



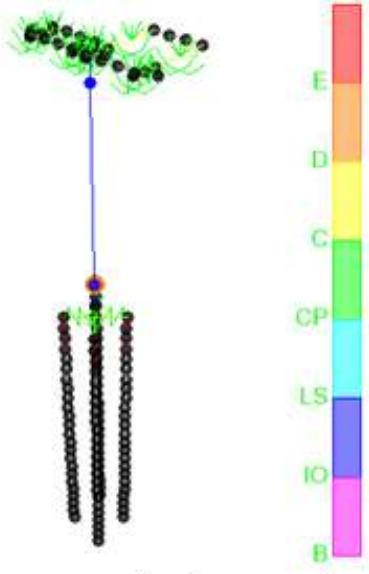
Step 2 *(Drift 183mm)*



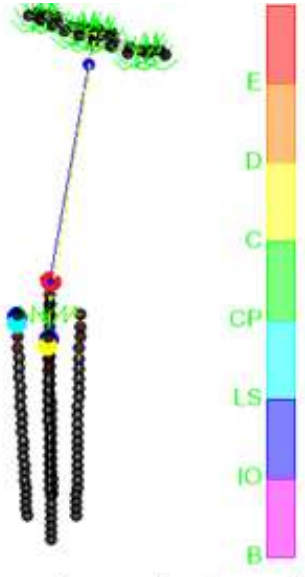
Step 3 *(Drift 424mm)*



Step 4 *(Drift 444mm)*

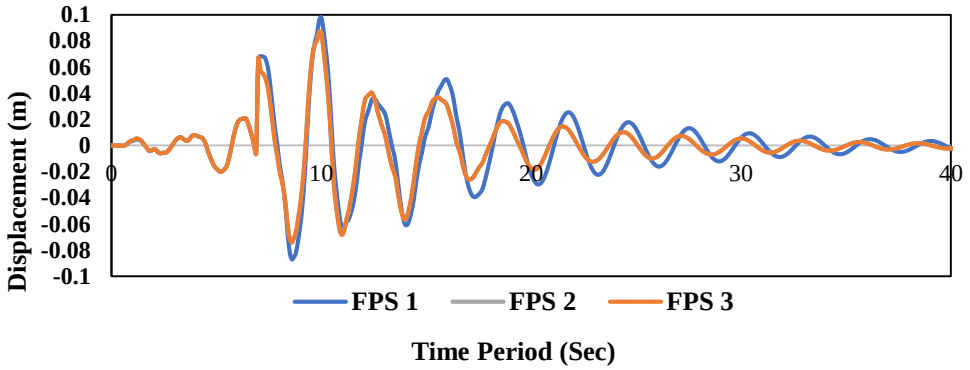


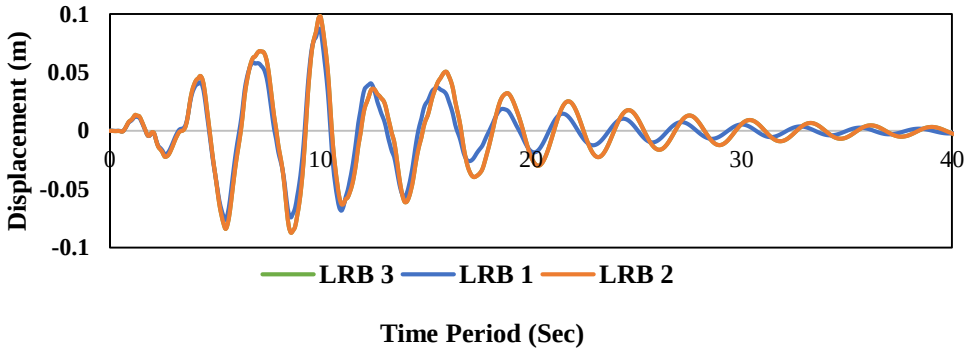
Step 5 *(Drift 446mm)*

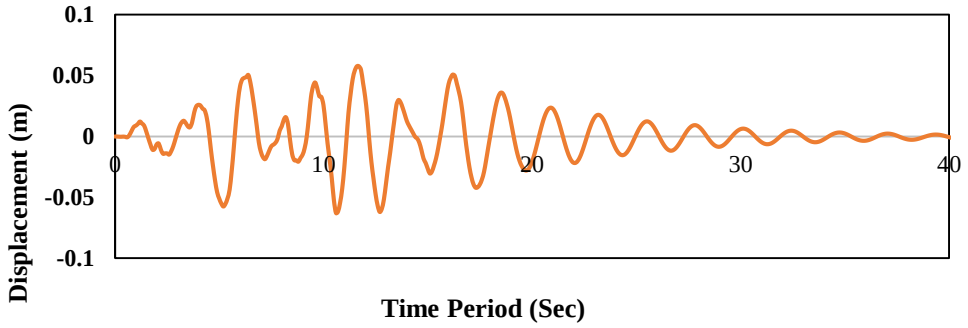


Final step *(Drift 1m)*

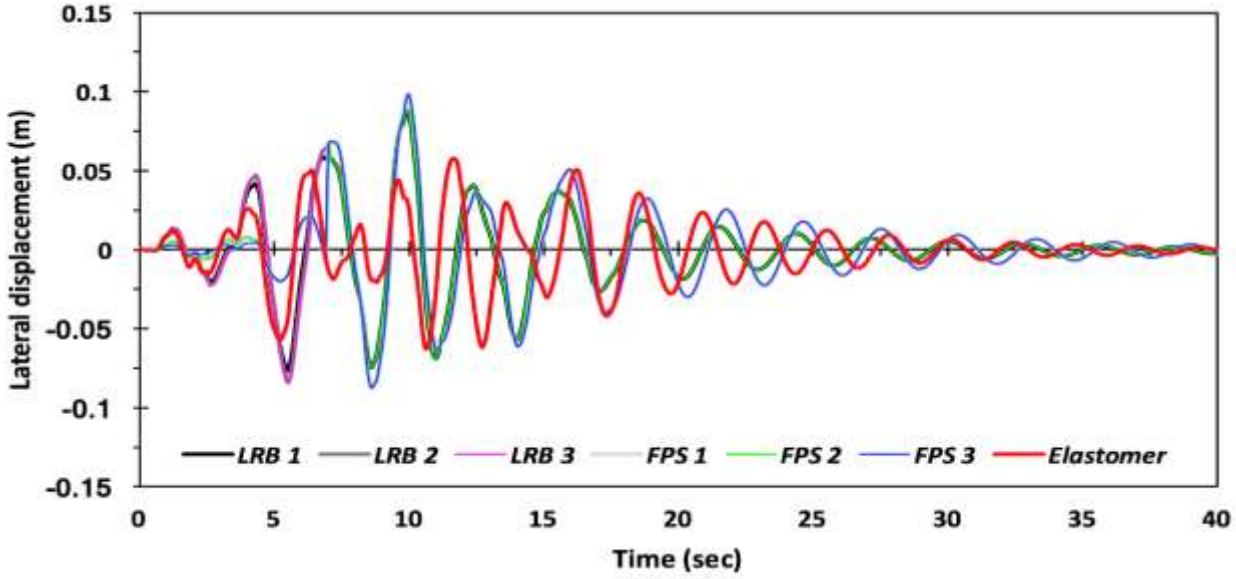
Respon Struktur







The result obtained indicates that structure with elastomer engenders frequent peak facet without significant displacement reduction over time. Whilst in structures with seismic isolation devices, peak facet is found to be relatively diverse with the displacement reduced over time, signifying that seismic isolators provide adequate damping on isolating seismic forces prior to transferring to the column and thereby leading to alleviation of base shear at the column.



CONCLUSIONS

1. The application of seismic bearings is found to be helpful in safeguarding the level of performance point of the structure within the range of IO-LS.
2. It is now understood that the use of pendulum bearings indeed provides more ductile response than that of lead rubber bearing. It can also be associated with higher energy dissipation maintained by pendulum bearings.
3. Design of LRT structure has proven to meet the general conception of an earthquake-resistant structure where the development of plastic hinge occurs initially at the column and propagate toward the first two metres of bored pile foundations.
4. It is found that pendulum bearings provides as better response in terms of isolating the seismic force, leading to a decrease of magnitude of base shear at the column base adjacent to the pile cap.

THANKYOU