MALAYSIAN RUBBER COUNCIL

INDUSTRIAL RESEARCH GRANT

اونيۏرسيتي تيكنولوݢي مارا

UNIVERSITI TEKNOLOGI MARA

TITLE OF PROJECT:
SEISMIC RESPONSE OF BASED-ISOLATED LOW-RISE BUILDINGS UNDER IN-PLANE LATERAL CYCLIC LOADING

COMPLETE PROJECT 2 (MRC INDUSTRY LINKAGE FUND)

BY:
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UNIVERSITI TEKNOLOGI MARA

DATE : 12ND SEPTEMBER 2022 (MONDAY)
TIME : 9.50 -10.30 a.m
VENUE: St Giles Garden Hotel, Kuala Lumpur

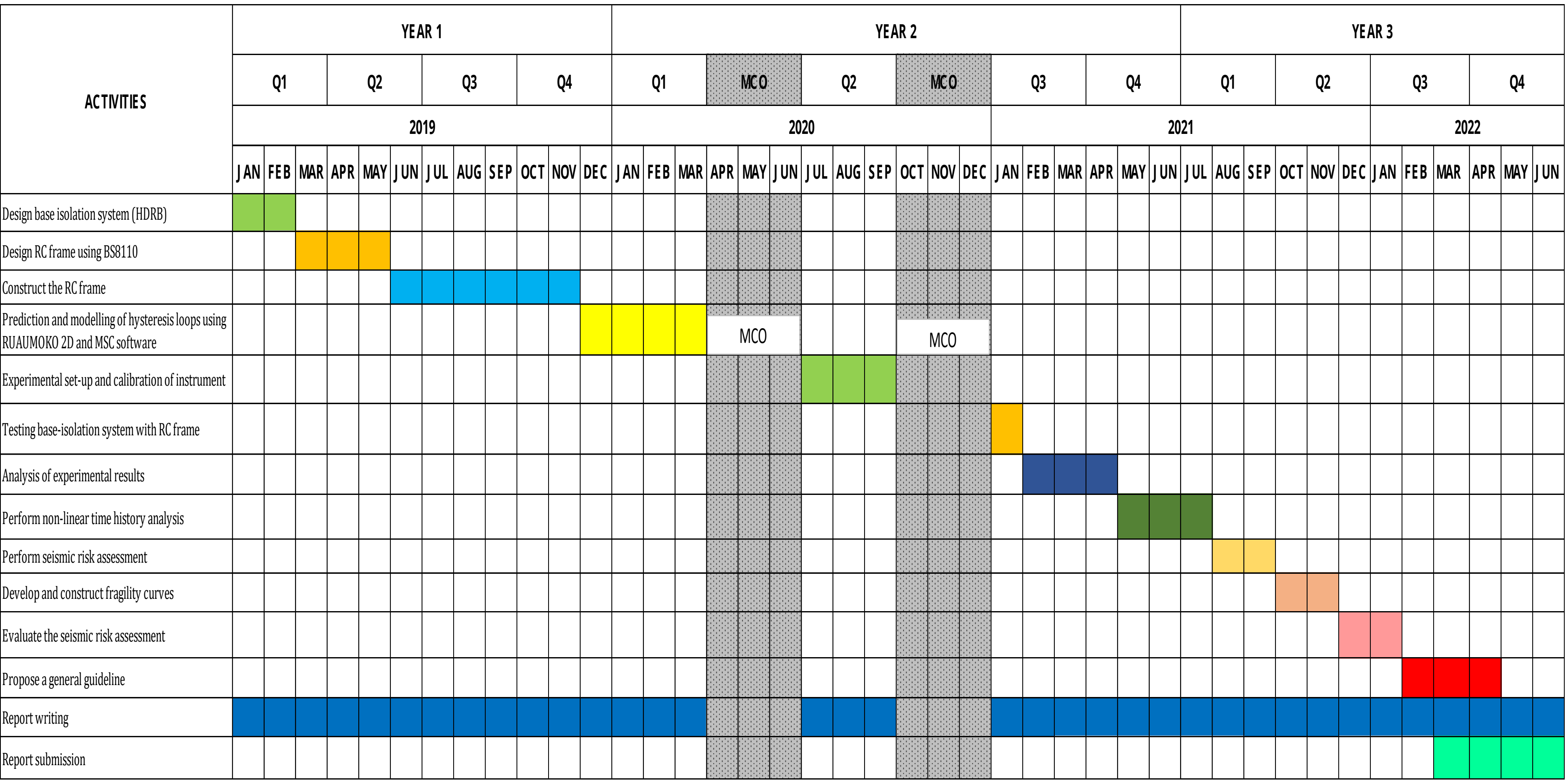
OUTLINES OF THE PRESENTATION

1. OBJECTIVES OF THE STUDY
2. PROJECT MILESTONE SCHEDULE
3. PROJECT DETAILS
4. ACHIEVEMENTS OBJECTIVE NO.1
5. ACHIEVEMENTS OBJECTIVE NO.2
6. ACHIEVEMENTS OBJECTIVE NO.3
7. ACHIEVEMENTS OBJECTIVE NO.4
8. ACHIEVEMENTS OBJECTIVE NO. 5
9. CONCLUSION AND RECOMMENDATIONS

OBJECTIVES OF THIS STUDY

1. To determine the seismic performance of two-story RC frames designed according to BS8110 with and without special base-isolation under in-plane quasi-static lateral cyclic loading.
2. To model and validate the hysteresis loops of a two-story RC frame with and without special base isolation using HYSTERES program.
3. To perform the non-linear time history analysis for a two-story RC frame with and without special base-isolation using Ruaumoko 2D under different levels of earthquake excitations.
4. To evaluate the seismic risk assessment of a two-story RC building with and without special base isolation using fragility curve.
5. To propose a proper procedure of a two-story RC building with special base isolation using Direct Displacement Based Design (DDBD).

PROJECT MILESTONE SCHEDULE



PROJECT DETAILS

This project comprises of four phases which are:

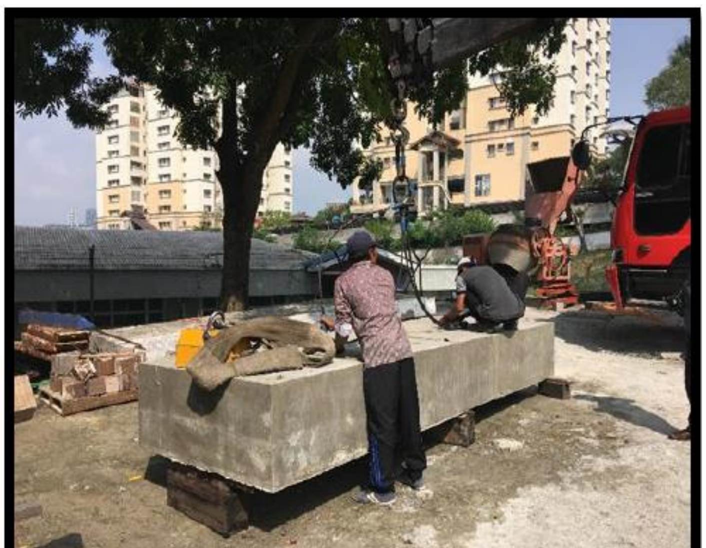
<u>PHASE 1 IS ADDRESSING OBJECTIVE 1</u> - designing special base isolation system , design RC two-story building using BS8110, construction of top concrete block, repairing foundation beam, construction of RC frame with top roof slab, experimental set-up, calibration of instruments and testing two-story RC frame with and without base isolation under in-plane lateral cyclic loading.

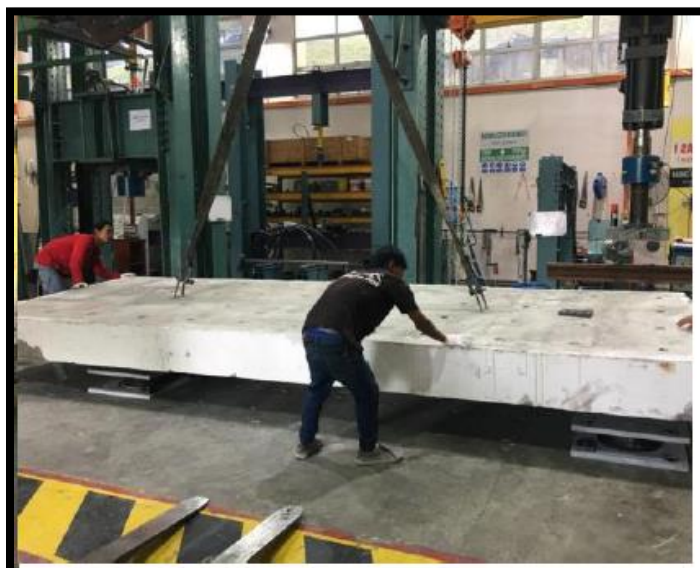
<u>PHASE 2 IS ADDRESSING OBJECTIVE 2</u> - analyzing the experimental results in term of hysteresis loops, lateral strength, stiffness, ductility, modelling and validating the hysteresis loops of two-story RC frame with and without base isolation using HYSTERES program.

<u>PHASE 3 IS ADDRESSING OBJECTIVE 3 AND OBJECTIVE 4</u> - performing nonlinear time history analysis for two-story RC frame with and without base isolation under six past selected earthquake excitation using the RUAUMOKO 2D program, performing seismic risk assessment based on the experimental data and developing fragility curve.

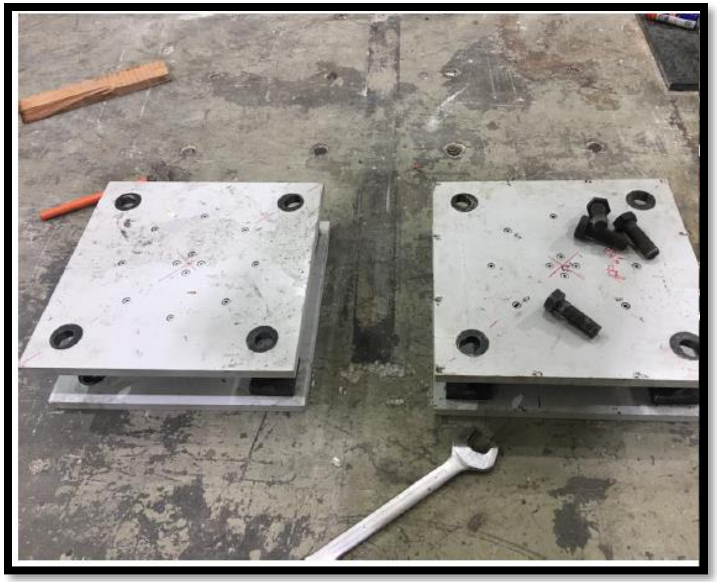
<u>PHASE 4 IS ADDRESSING OBJECTIVE 5</u> where it includes writing up the general guidelines for designing low rise RC building with special base isolation using Direct-Displacement Based Design (DDBD) approach for medium and high seismic region.

CONSTRUCTION OF TWO-STORY RC FRAME

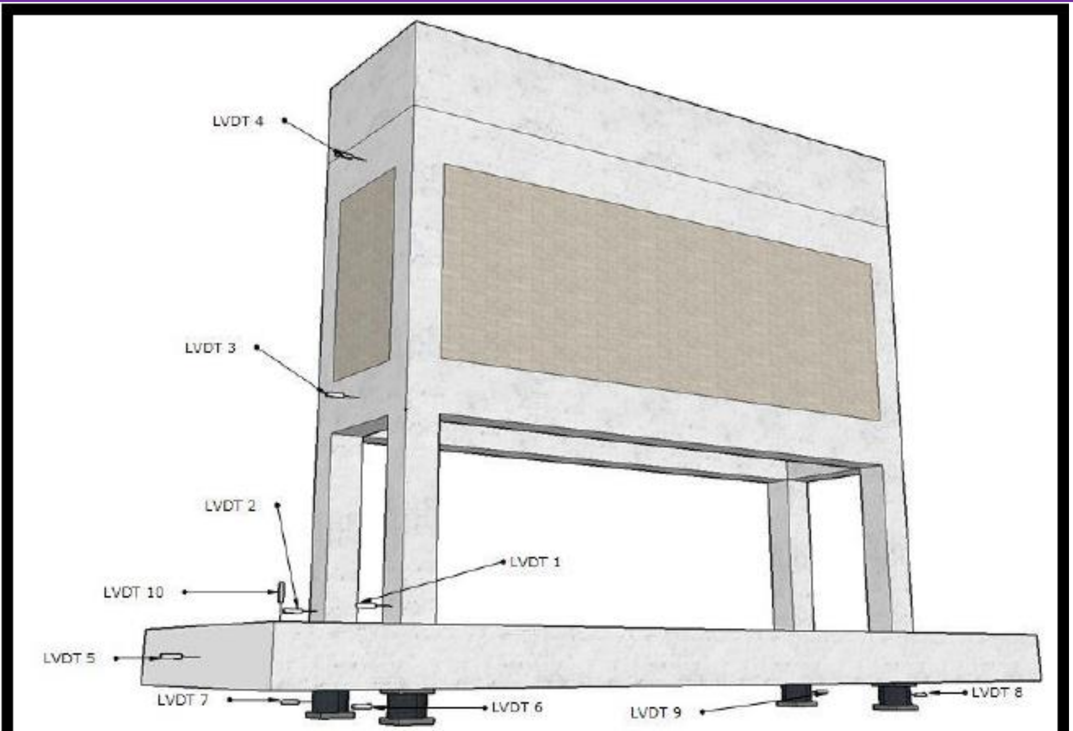


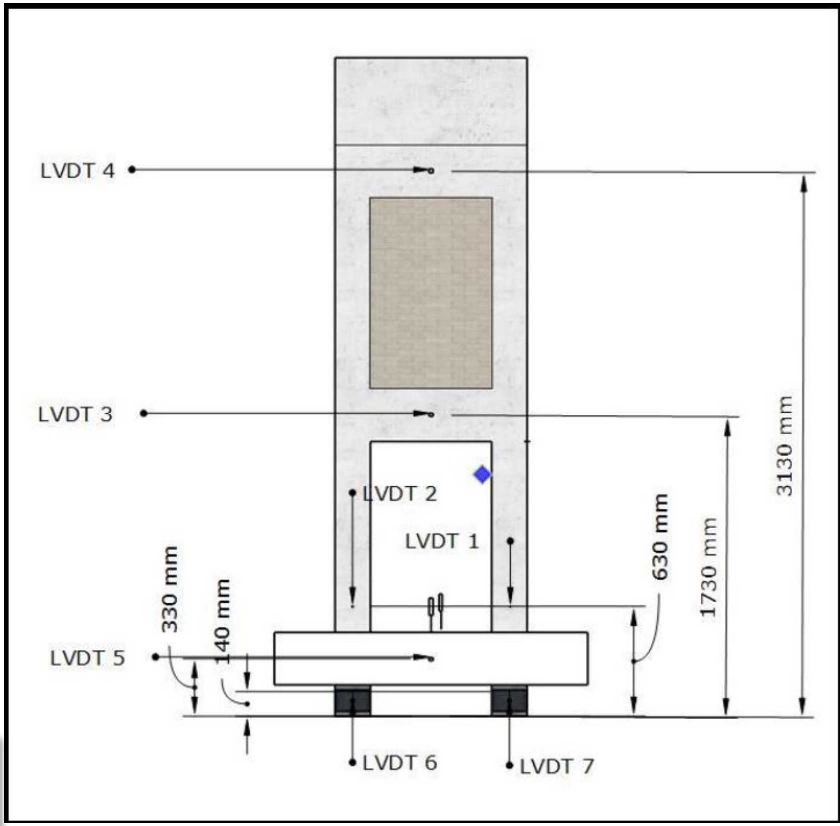


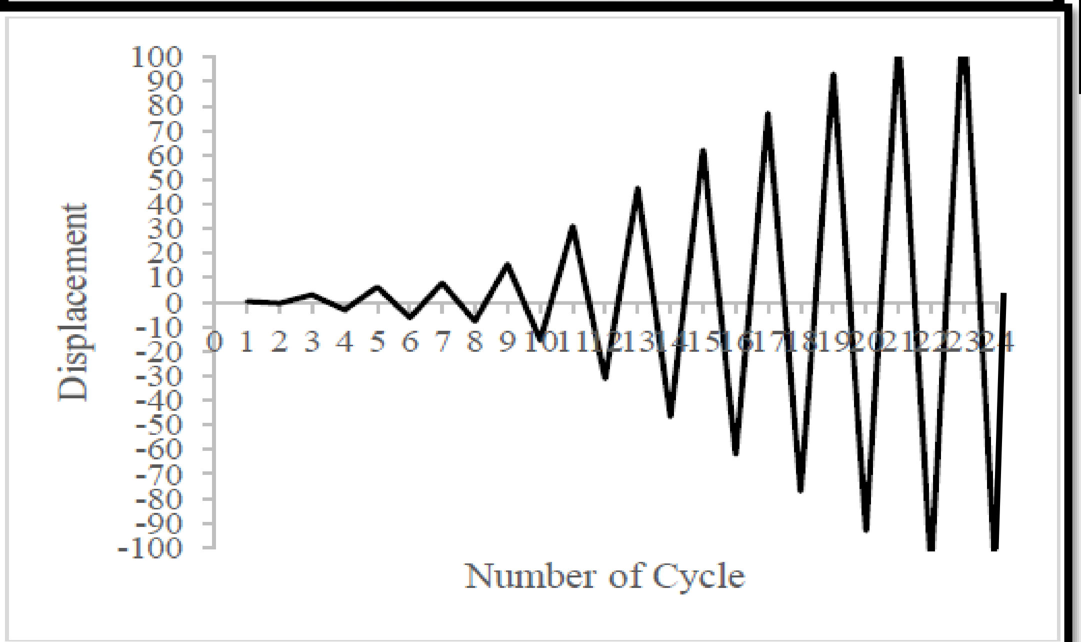
INSTALLATION OF SPECIAL BASE ISOLATION



TESTING TWO-STORY RC FRAME WITH AND WITHOUT BASE ISOLATION

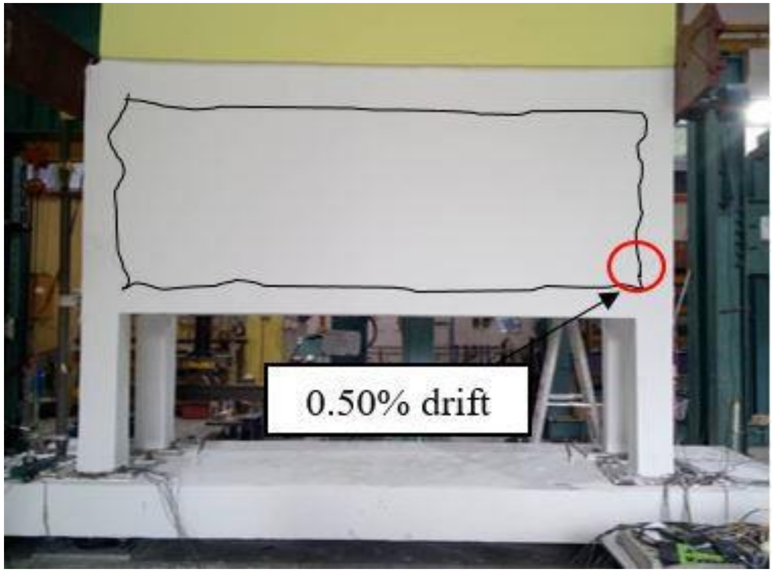


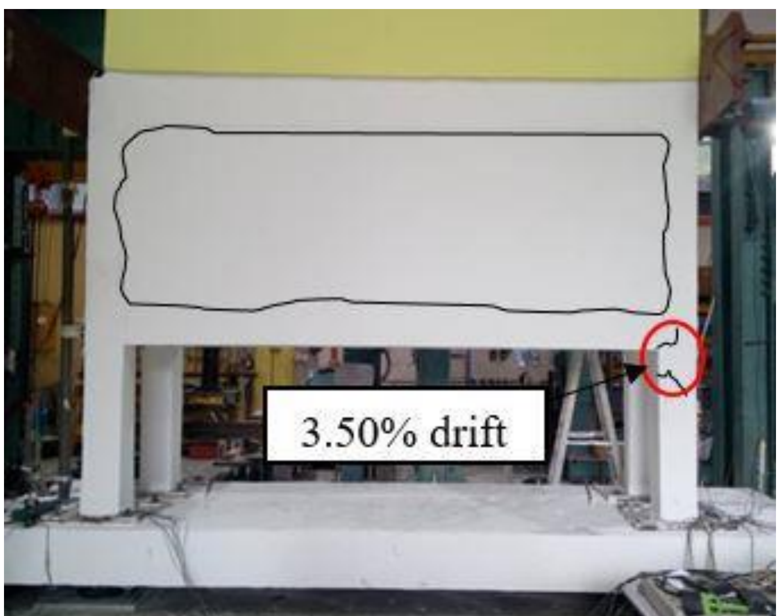


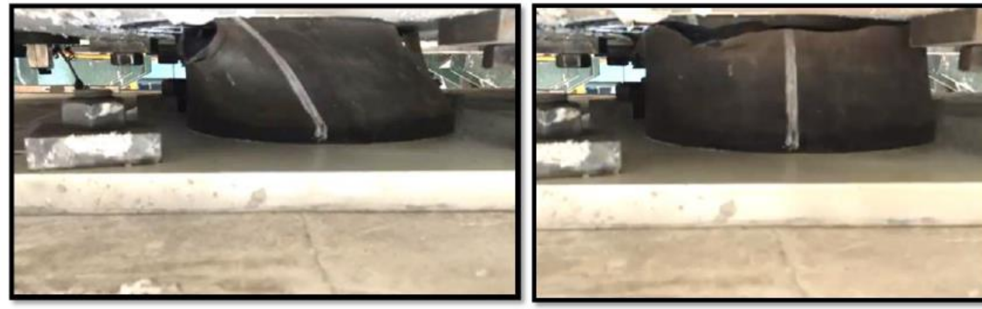


ACHIEVEMENTS OF OBJECTIVE NO. 1

1(a) VISUAL OBSERVATIONS OF TWO-STOREY RC FRAME WITH SPECIAL BASED ISOLATION





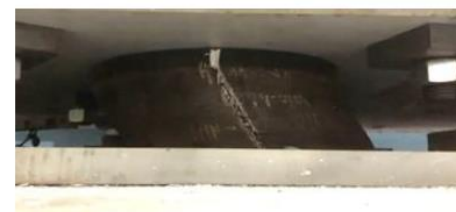


Special base Isolator No.2 and 3 tear-off at 3.75% drift

(c) at +1.00% drift

(d) at +1.50% drift

(e) at +2.00% drift

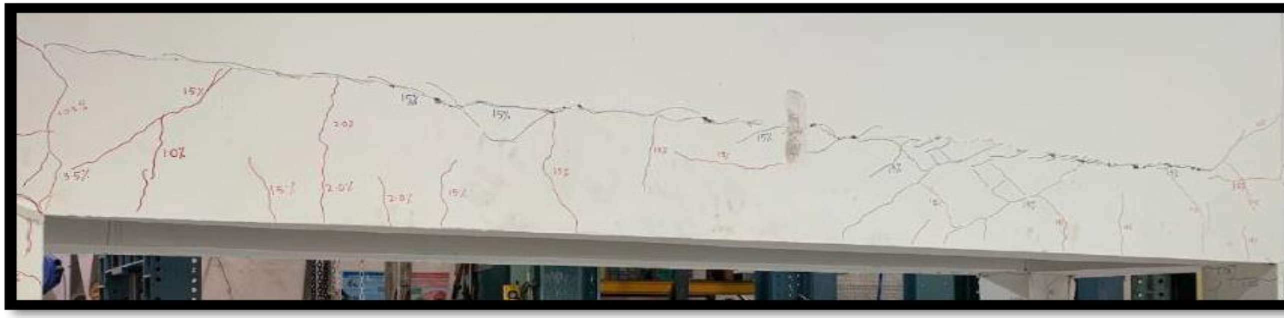


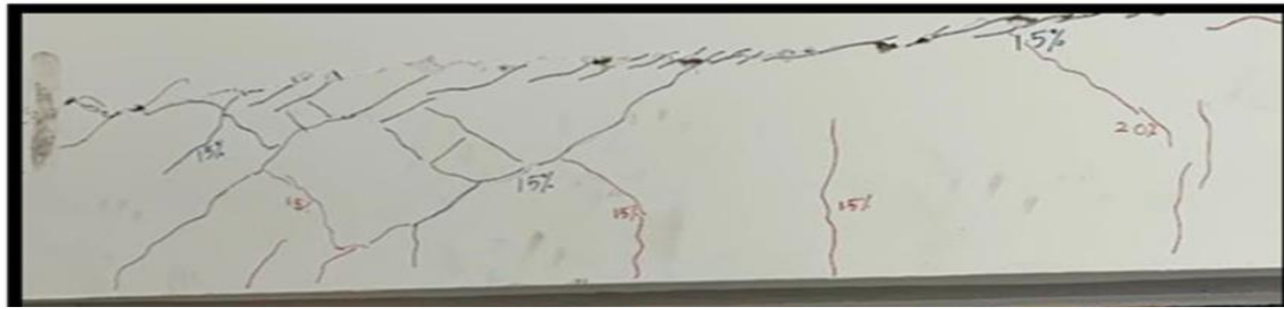
(f) at +2.50% drift

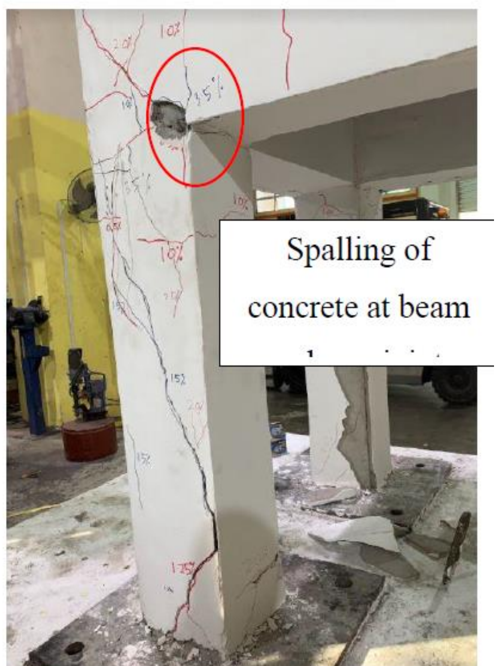
(g) at +3.00% drift

(h) at +3.50% drift

1(b) VISUAL OBSERVATIONS OF TWO-STOREY RC FRAME WITHOUT SPECIAL BASED ISOLATION

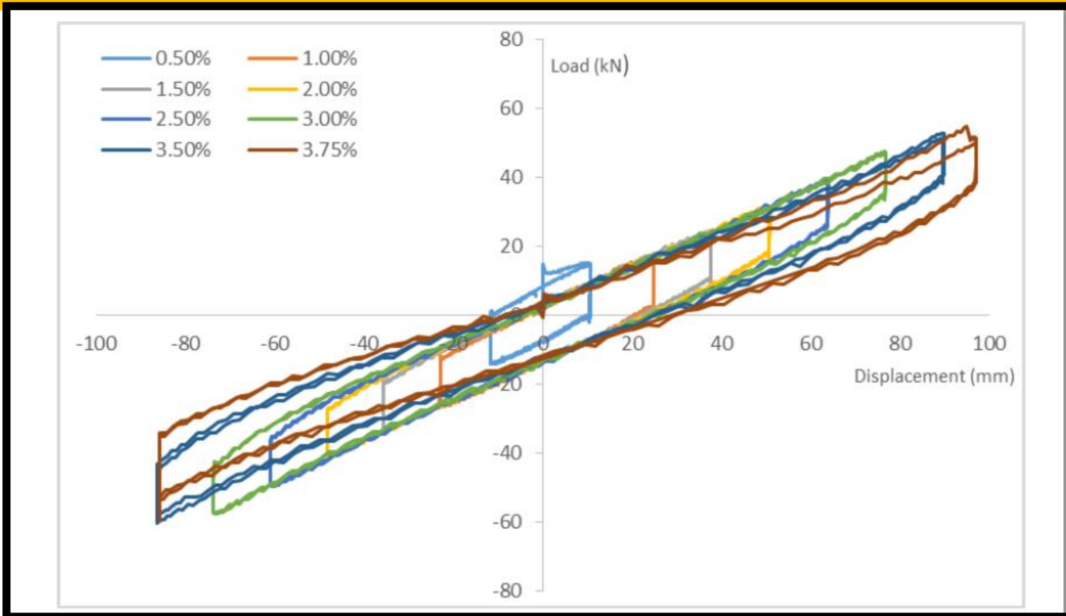




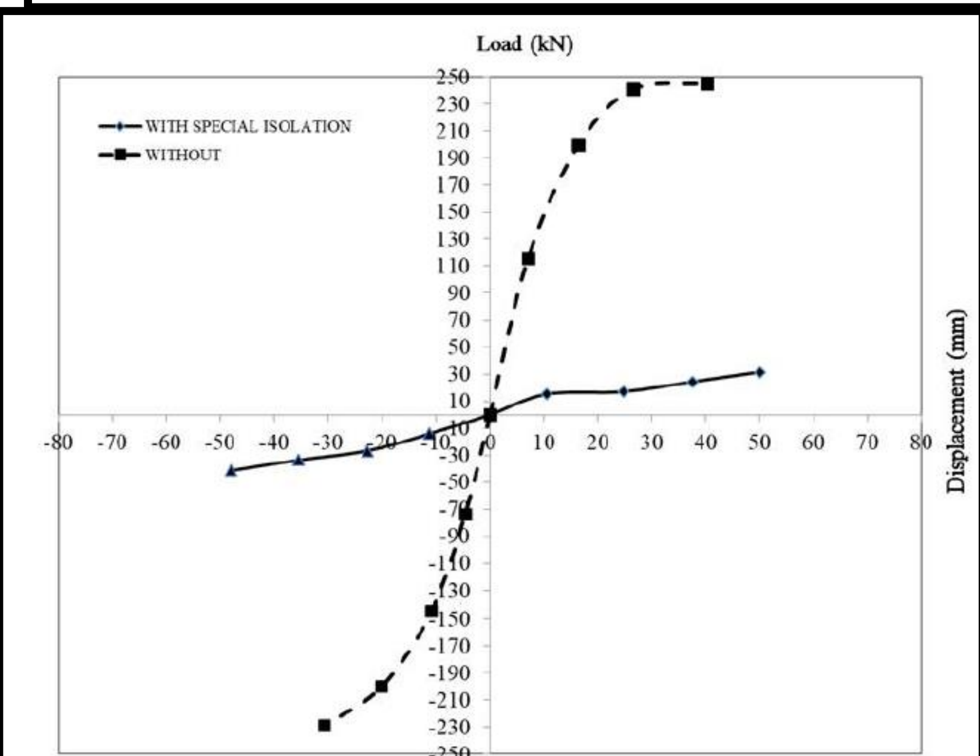


1(C) LESSON LEARNT AFTER THE 2015 RANAU EARTHQUAKE, SABAH

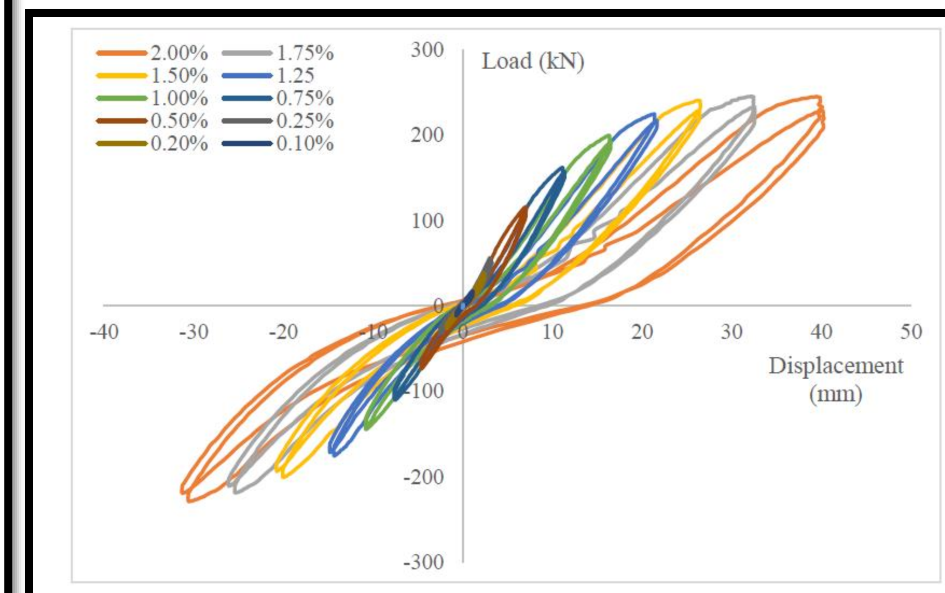
(2) HYSTERESIS LOOPS AND LATERAL STRENGTH CAPACITY



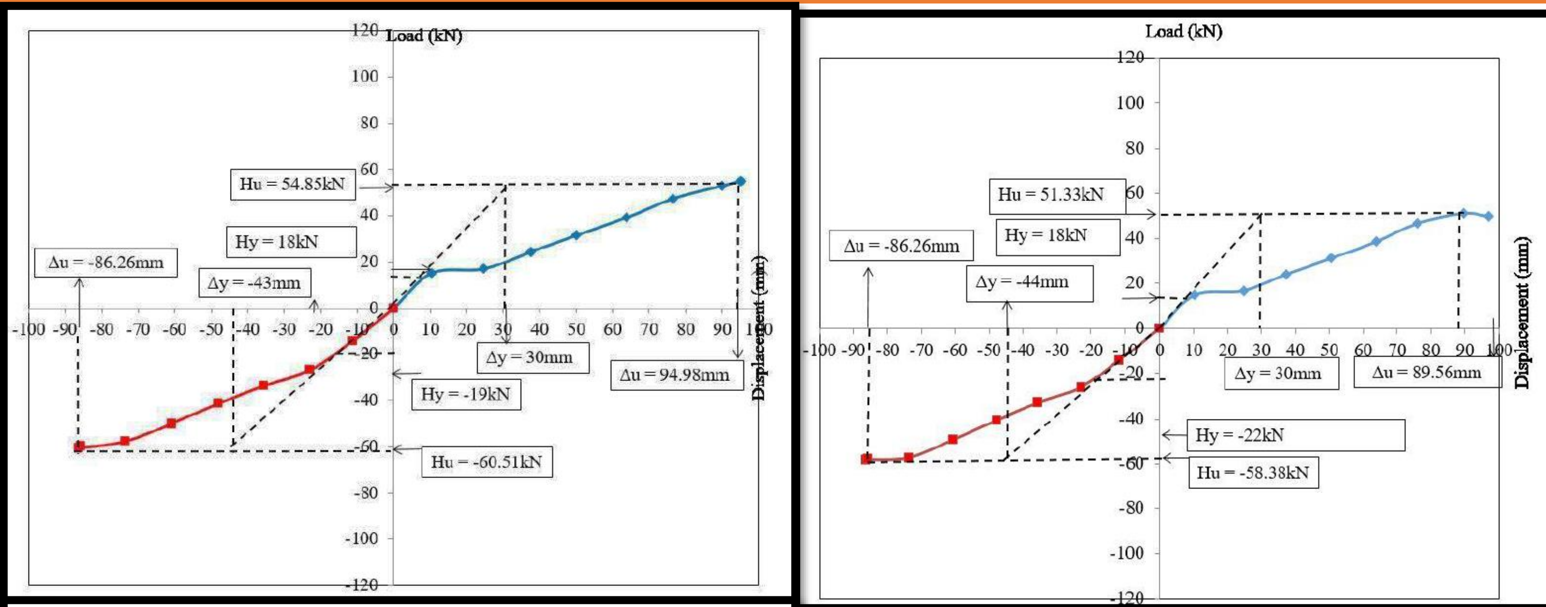
(a) Hysteresis loops of two-story RC frame with special base isolation



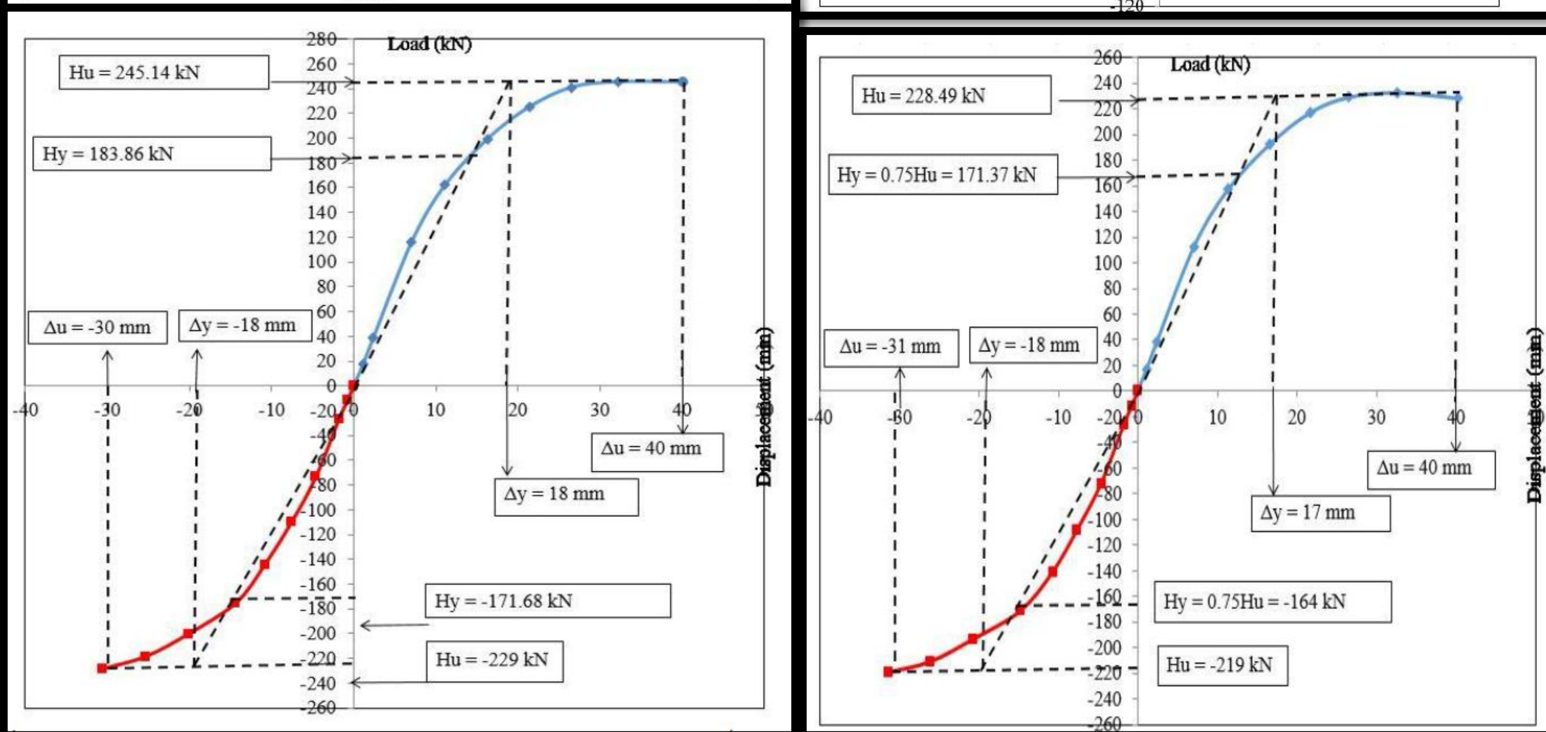
(b)Hysteresis loops of two-story RC frame without special base isolation



LATERAL STRENGTH CAPACITY

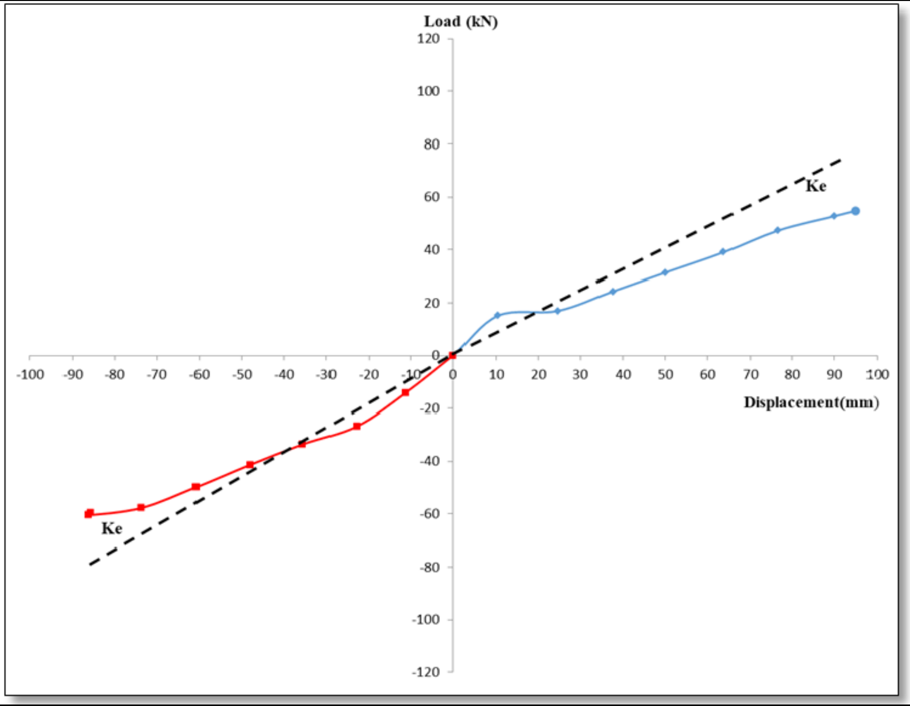


(a) Lateral strength capacity for RC Frame with special base isolation



(b) Lateral strength capacity for RC Frame without special base isolation

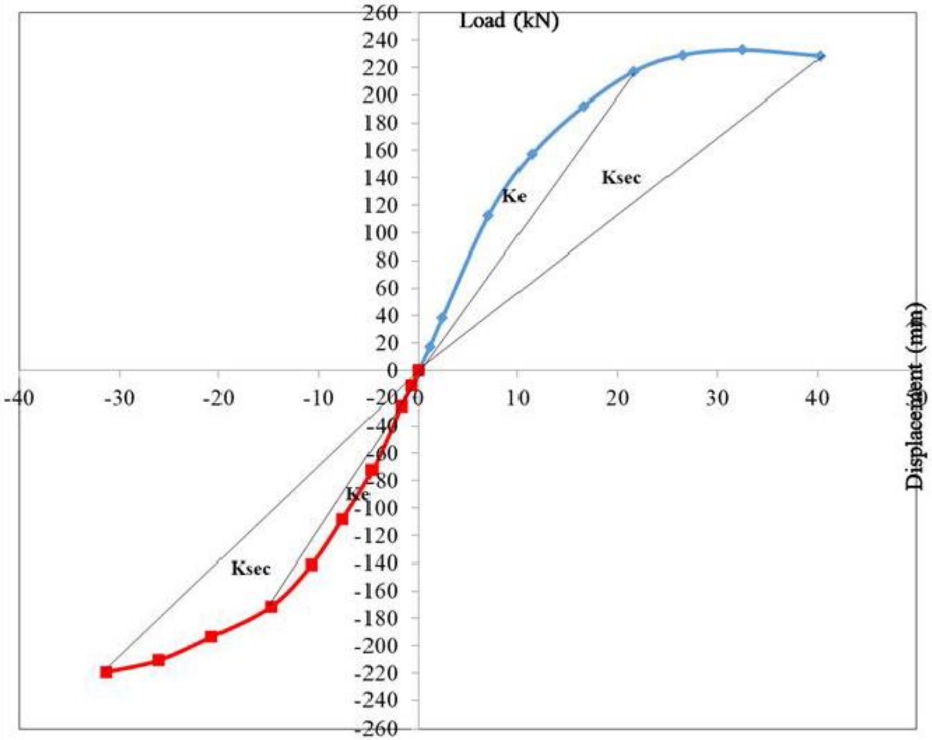
(3) Elastic and Secant Stiffness



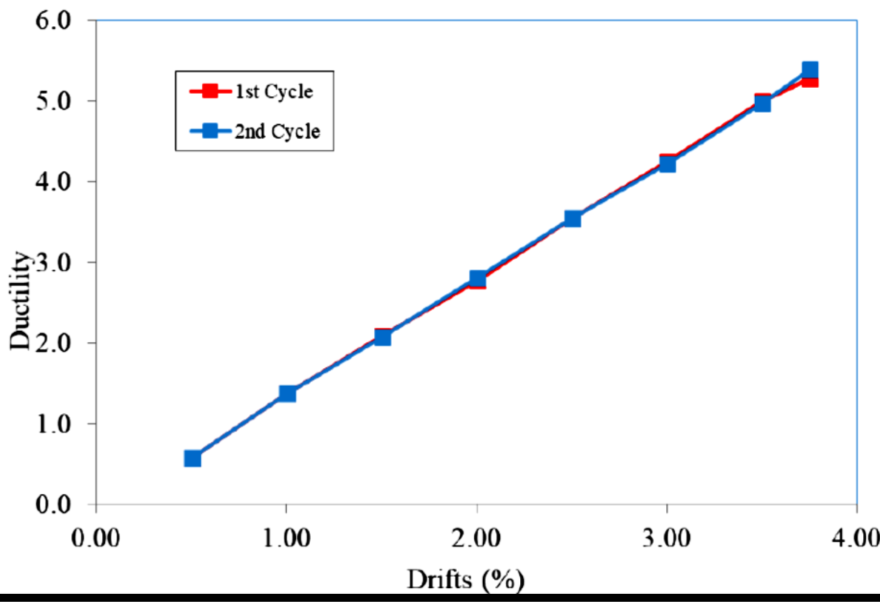
(a) Elastic Stiffness of the RC frame with special base isolation is representing a straight line:

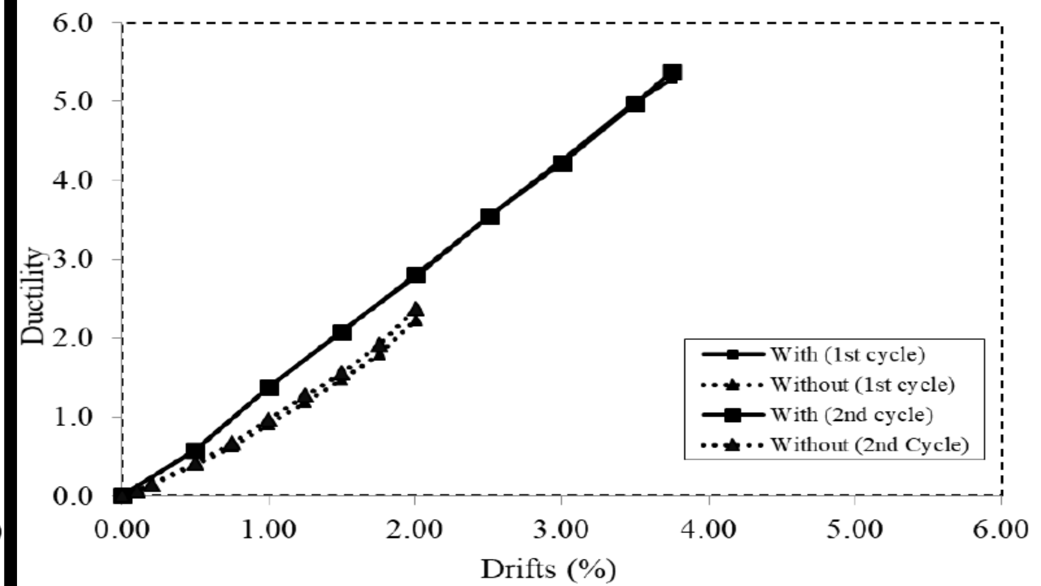
Lateral strength = 0.75 x lateral displacement

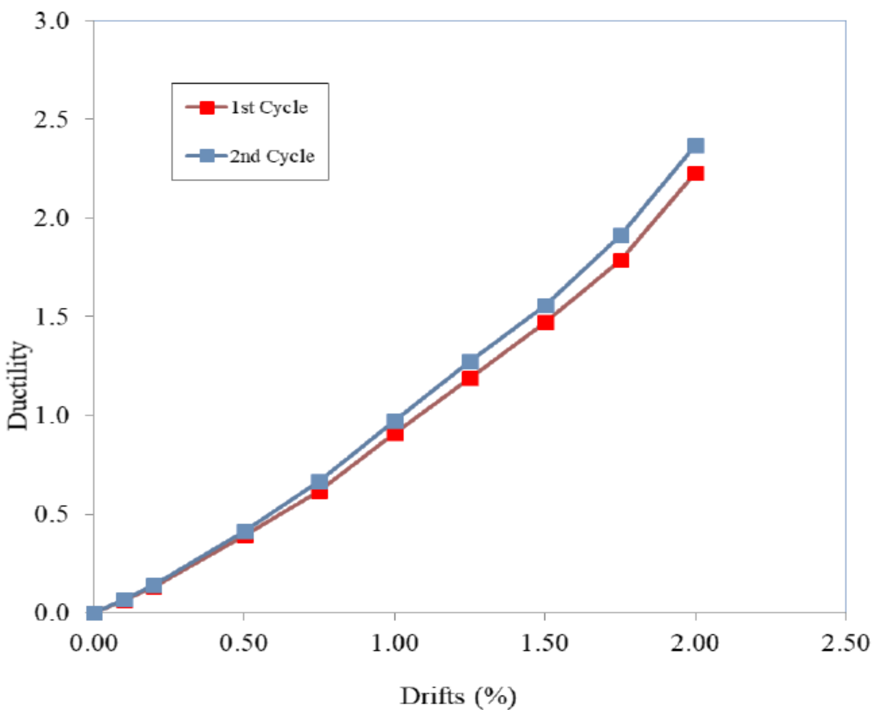
(b) Elastic and Effective Stiffness for RC Frame without special base isolation which can be represented by a curve line.



(4) COMPARISON OF DUCTILITY





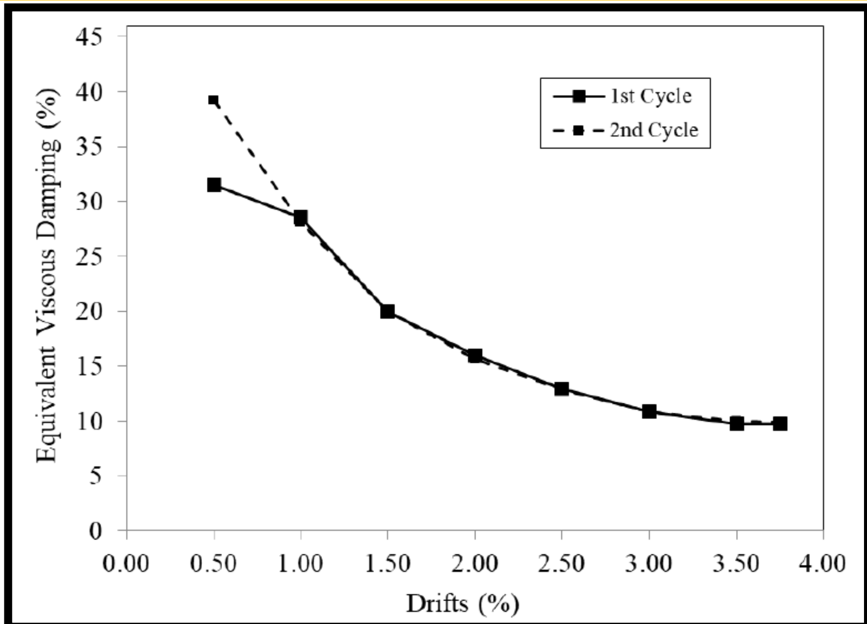


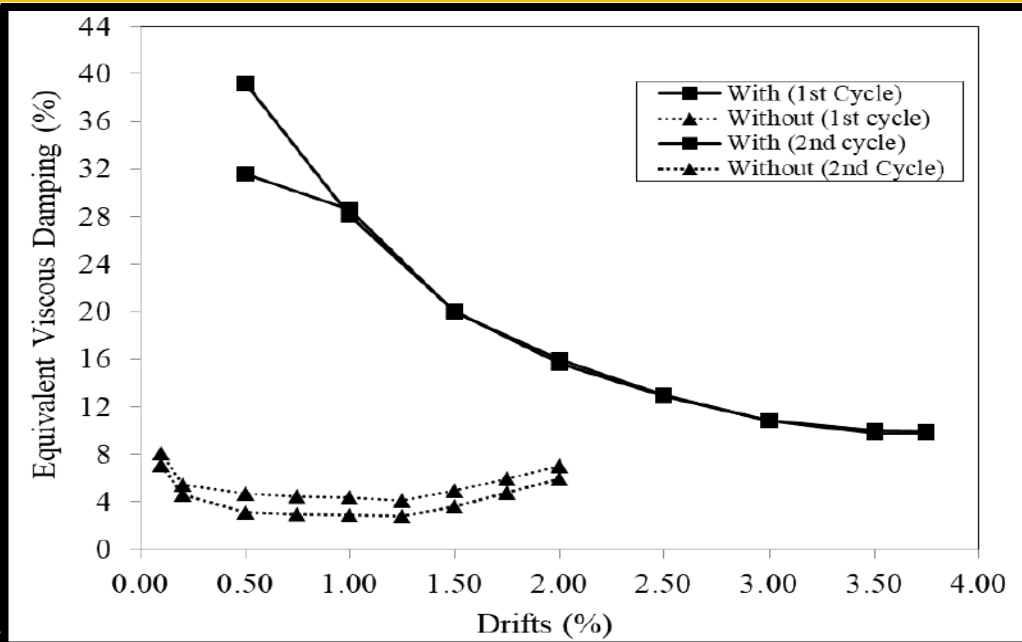
(a) Ductility of two-story RC frame with special base isolation for 1st and 2nd cycles.

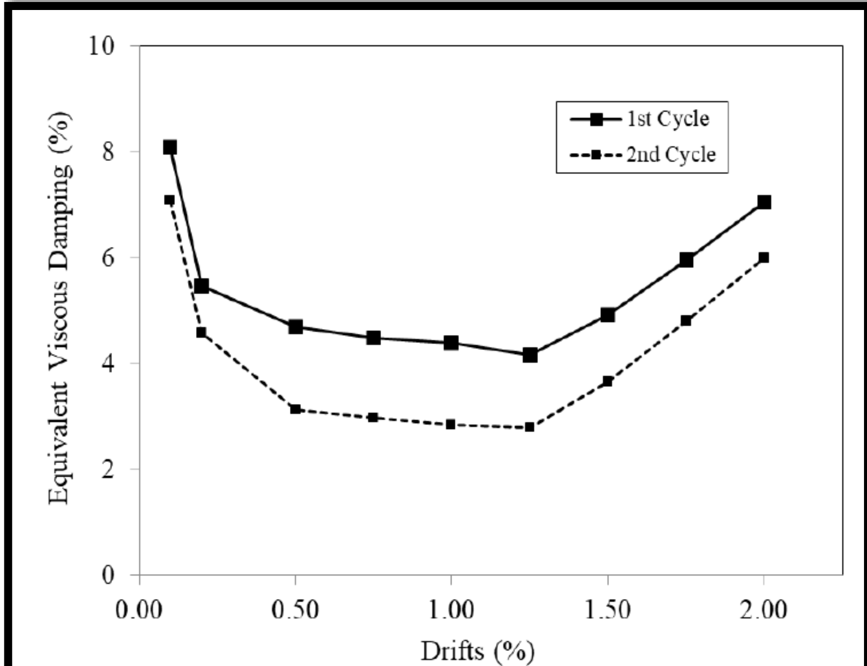
(b) Ductility of two-story RC frame without special base isolation for 1st and 2nd cycles.

(c) Comparison of ductility between RC frame with and without base isolation.

(5) EQUIVALENT VISCOUS DAMPING







(a) Equivalent viscous damping for two-story RC frame with special base isolation.

(b) Equivalent viscous damping for two-story RC frame without special base isolation.

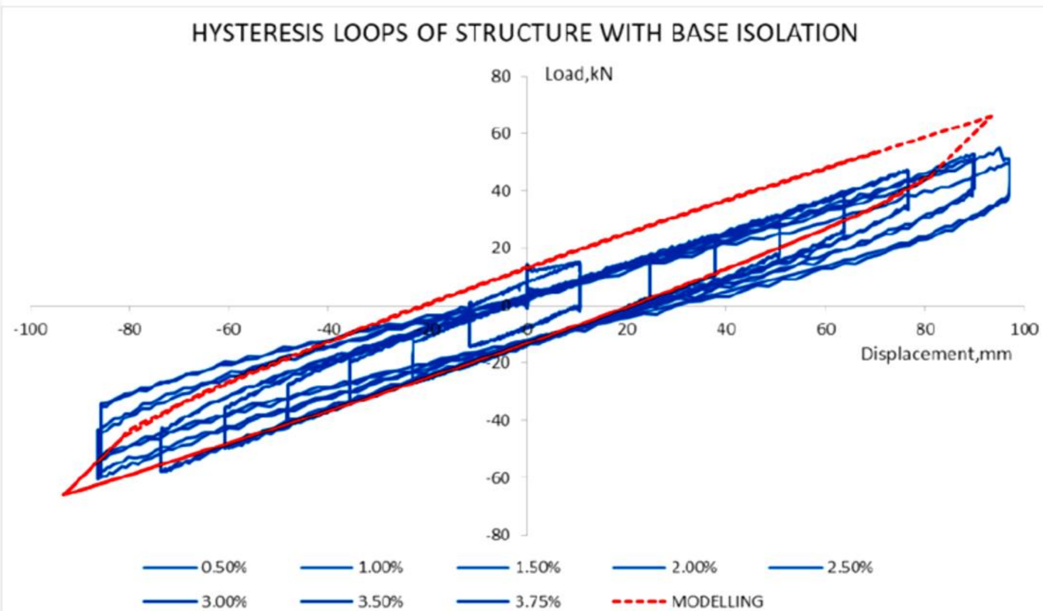
(c) Comparison of viscous damping between two-story RC frame with and without special base isolation.

ACHIEVEMENTS OF OBJECTIVE NO. 2

Parameters for BOUC Hysteresis Rule (IHYST=23)

PARAMETERS	RANGE	VALU
Stiffness		1.46
Bi-linear factor		0.35
Positive yield force		41.14
Negative yield force		-45.38
A1	(0.1 to 0.9)	0.9
A2	(-0.9 to o.9)	-0.55
A3	Usually 1.0	0.27
A4	Usually 1.0	1
A5	Usually 1.0	1
N	(1 to 3) Usually 1	1
D3	(0.0 to 0.1) (0.0 no degradation)	0
D4	(0.0 to 0.2) (0.0 no degradation)	0
D5	(0.0 to 0.2) (0.0 no degradation)	0
Mode (=0 Constintino Version =1 Baber and Wen Version		0
Init (=0 Normal =1 Bi-linear until first unloading after yielding)		0

Comparison between experimental hysteresis loops and modeling hysteresis loops using HYSTERES Program for two-story RC frame with special base isolation



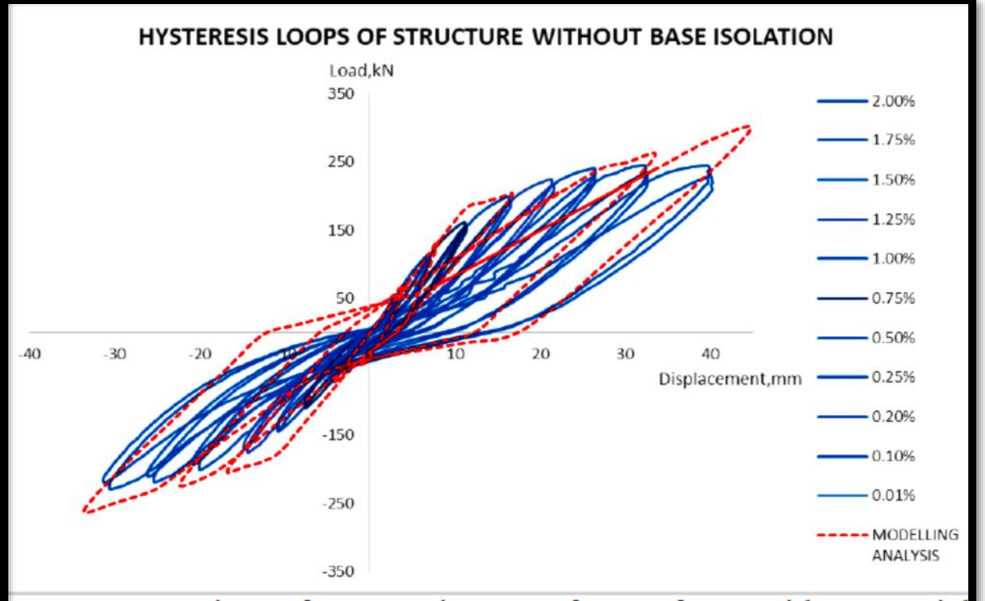
ACHIEVEMENTS OF OBJECTIVE NO. 2

Parameters for Pampanin RC Beam-column Hysteresis (IHYST=44)

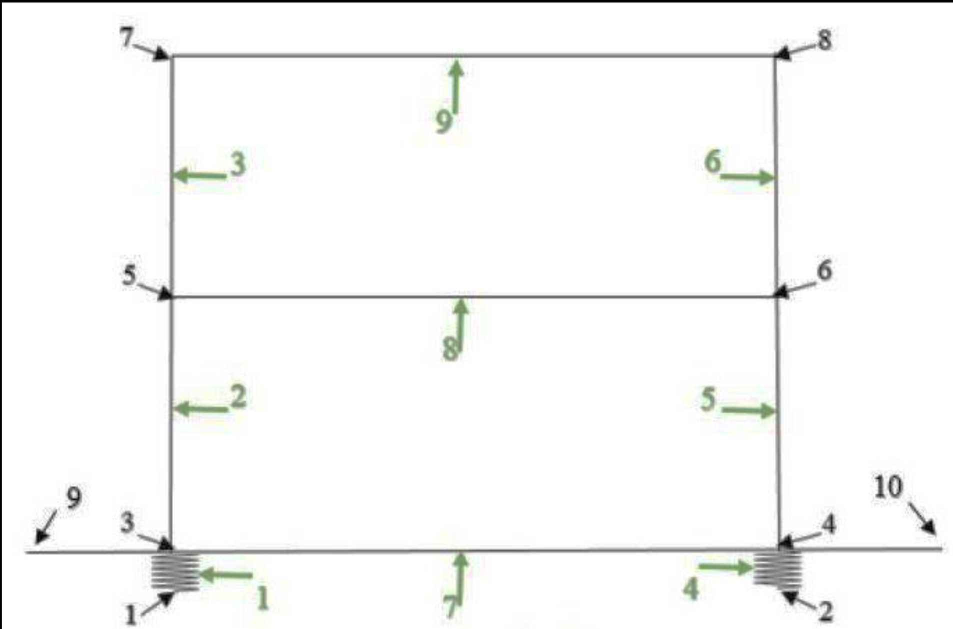
Stiffness, K_o	16.43
Bi-linear factor, r	0.21
Positive yield factor, P+	184
Negative yield factor, P-	-172

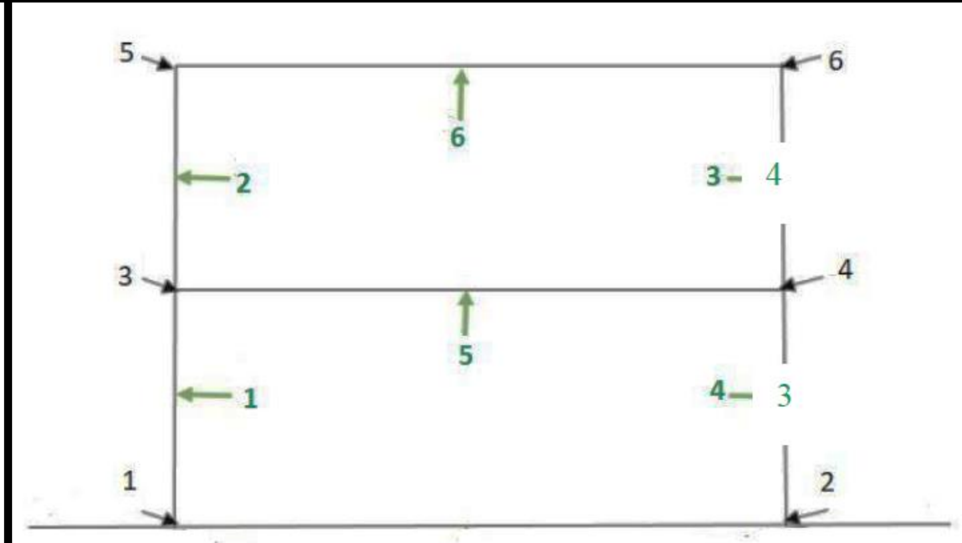
Reloading Factor Option, IOP	2
ii. Slip Stiffness Power Factor, As1	1.5
iii. Reloading Slip Factor, Xi	1.5
iv. Initial Unloading Power Factor, Au1	0
v. Final Unloading Power Factor, Au2	0.3
vi. Unloading Force Factor, DeltaF	20
vii. Reloading Factor, Beta	-0.3

Comparison between experimental and modeling hysteresis loops using Ruaumoko 2D for two-story RC frame without special base isolation



ACHIEVEMENTS OF OBJECTIVE NO. 3





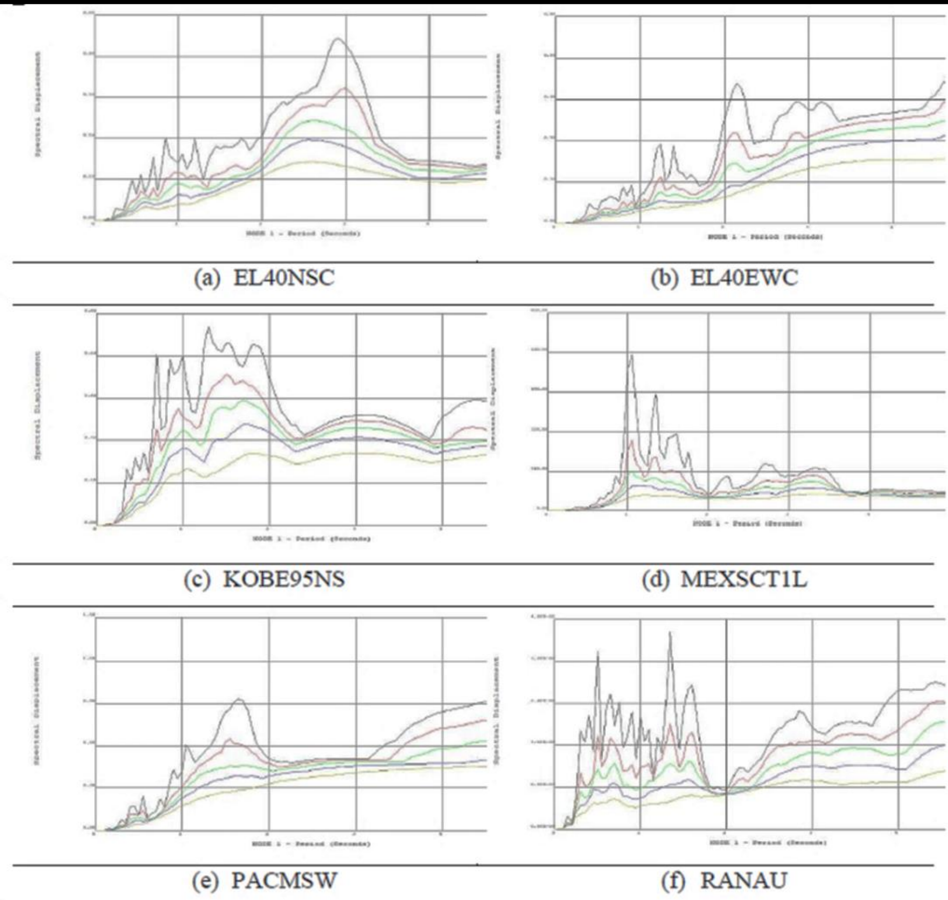
(a) Modeling two-story RC frame with special base isolation using Ruaumoko 2D.

(b) Modeling two-story RC frame without special base isolation using Ruaumoko 2D.

(c) Characteristics of six selected past earthquake records.

Earthquake Record and Format	Location	Year	Magnitude (M_w)	PGA (g)	Category
EL40NSC.EQB	El Centro North South	1940	7.1	0.348	Moderate
EL40EWC.EQB	El Centro East West	1940	5.5	0.214	Moderate
PACMSW.EQB	Pacoima Dam	1971	6.6	1.19	Great
RANAU.EQF	Ranau, Sabah	2015	6.0	0.12	Moderate
MEXSCT1L.EQC	Mexico City	1985	8.1	0.89	Strong
KOBE95NS.EQN	Kobe	1995	7.2	0.62	Strong

ACHIEVEMENTS OF OBJECTIVE NO.3



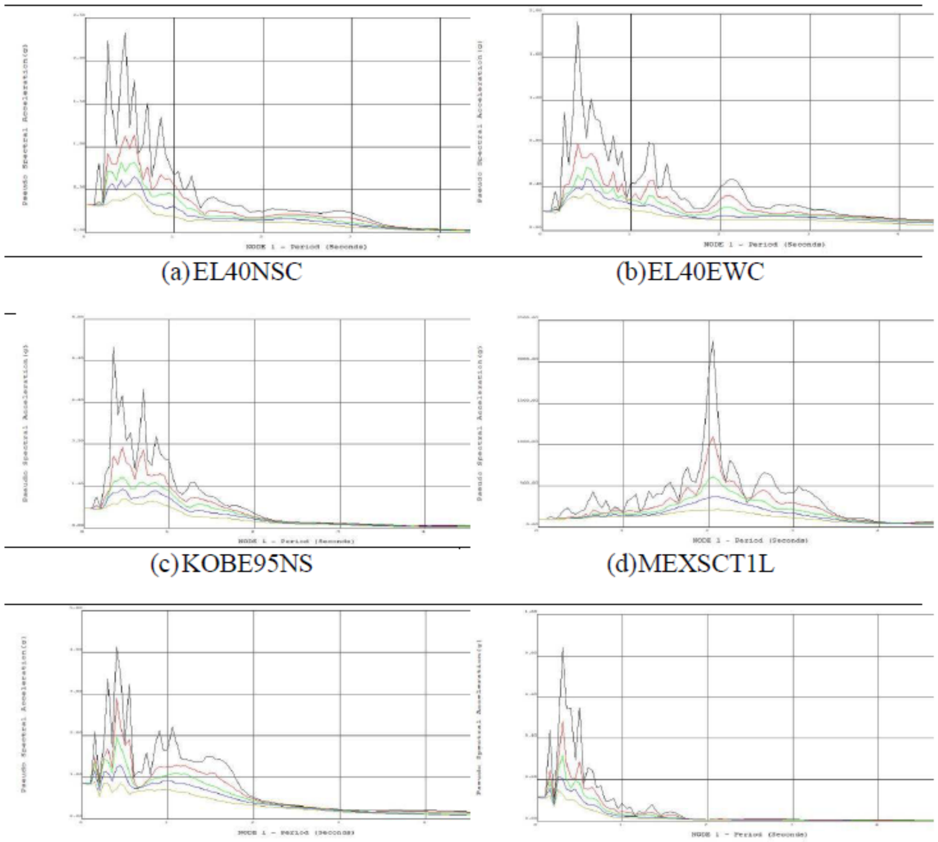
	5% damping	Time (s)	10% damping	Time (s)	20% damping	Time (s)
EL40NSC	288	2.75	235	2.70	165	2.85
EL40EWC	499	5.00	366	5.00	276	5.00
KOBE95NS	473	1.70	382	1.75	273	1.80
MEXSCT1L	641	2.05	419	2.20	264	2.40
PACMSW	705	5.00	559	5.00	466	5.00
RANAU2015	57	4.75	45	5.00	31	5.00

(a) Graphs of spectral displacement versus time for six past earthquake records.

(b) Maximum lateral displacements after running the above model with 5%, 10% and 20% damping under six past earthquake records.

It can be observed that as the damping increase, the lateral displacement reduce

ACHIEVEMENTS OF OBJECTIVE NO.3


(a)EL40NSC (b)EL40EWC
(c)KOBE95NS (d)MEXSCT1L
(e)PACMSW (f) RANAU

	5% damping	Time (s)	10% damping	Time (s)	20% damping	Time (s)
EL40NSC	0.824	0.40	0.657	0.55	0.464	0.55
EL40EWC	0.509	0.40	0.474	0.50	0.34	0.50
KOBE95NS	1.939	0.45	1.51	0.45	1.121	0.45
MEXSCT1L	0.614	2.05	0.371	2.20	0.214	2.40
PACMSW	1.961	0.40	1.287	0.45	0.904	0.15
RANAU2015	0.32	0.30	0.217	0.25	0.128	0.30

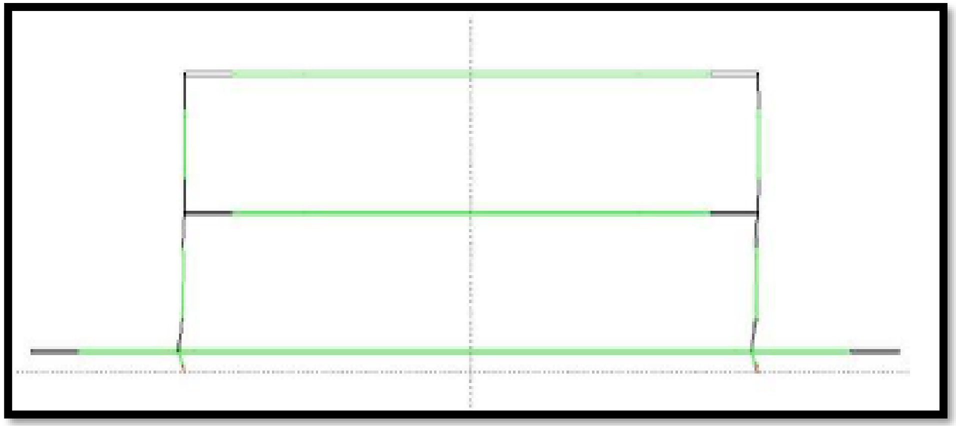
(a) Graphs pseudo-spectral acceleration versus time for six selected earthquakes.

(b) The maximum accelerations for the model after running under six past earthquake records under 5%, 10% and 20% damping.

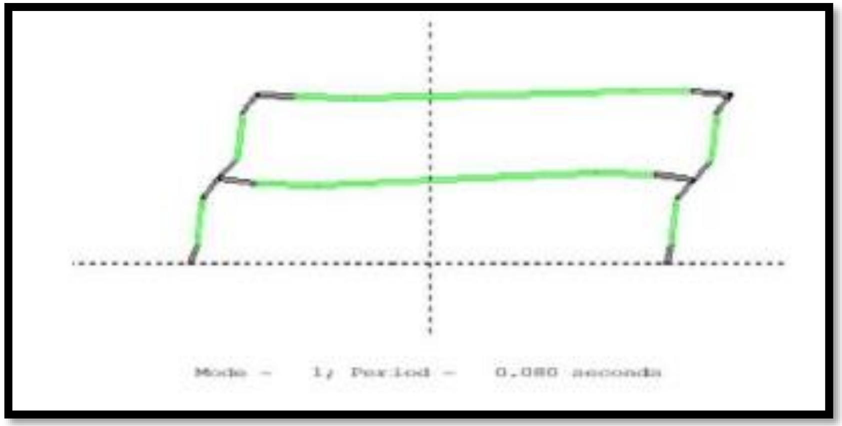
It can be observed that as the damping increases, the acceleration is decrease.

ACHIEVEMENTS OF OBJECTIVE NO. 3

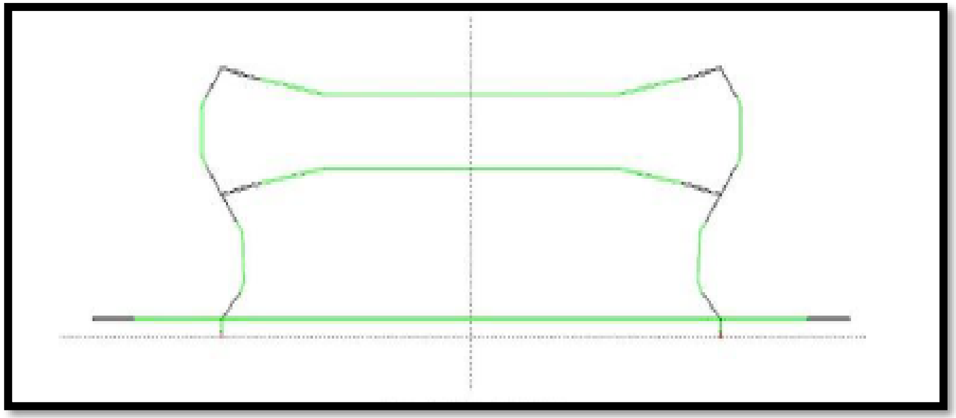
(a) Modes Shape with base isolation **(b) Modes without base isolation**



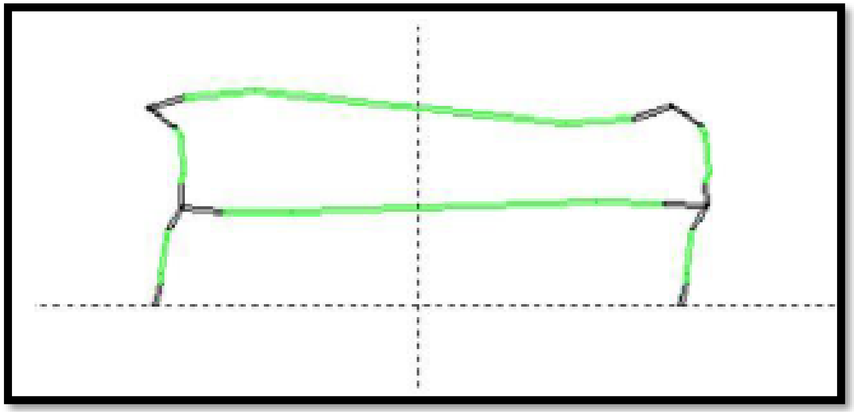
First Mode Shape with T_n=0.109s



First Mode Shape with T_n=0.08s



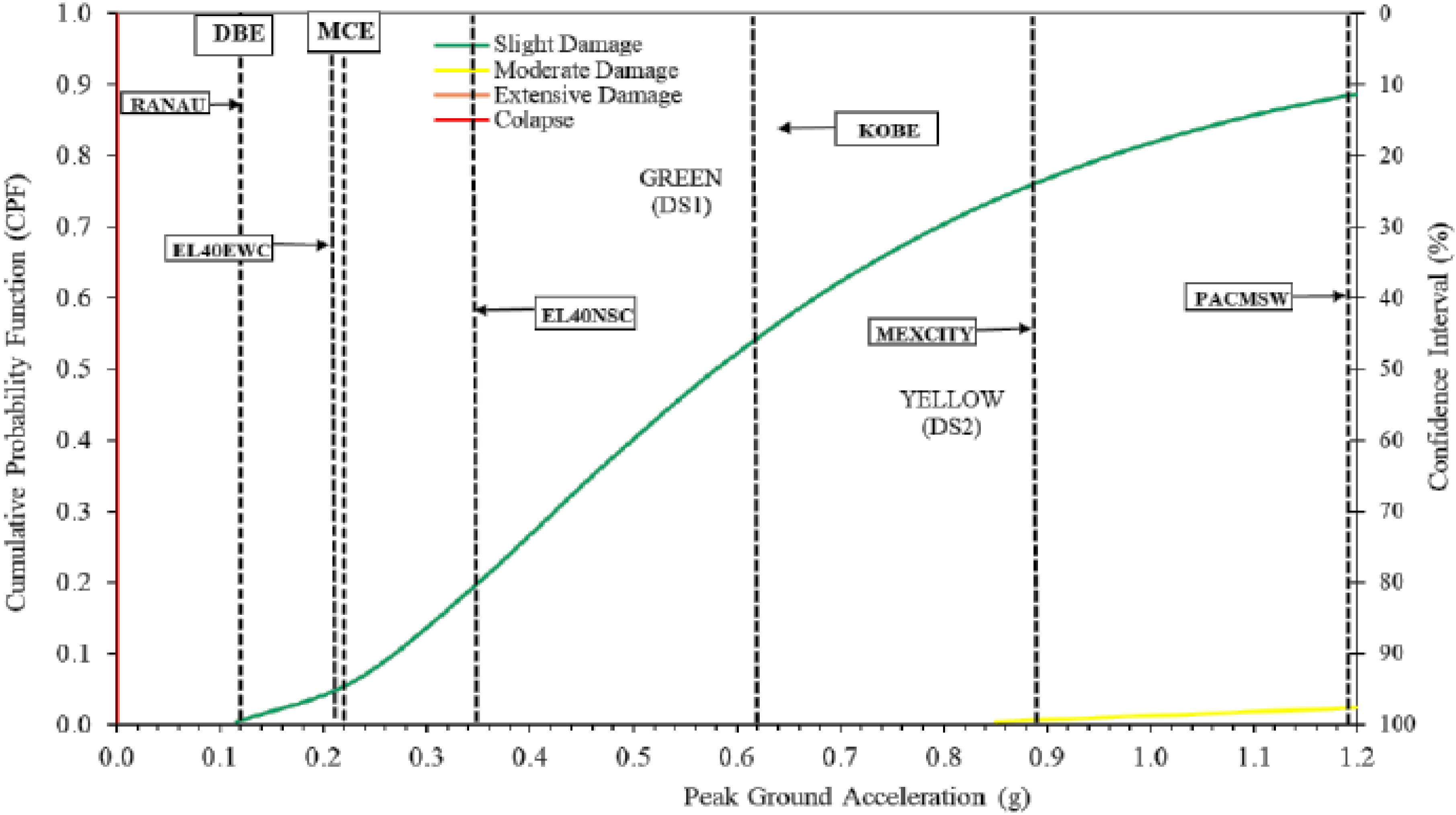
Second Mode Shape with T_n=0.047s



Second Mode Shape with T_n=0.032s

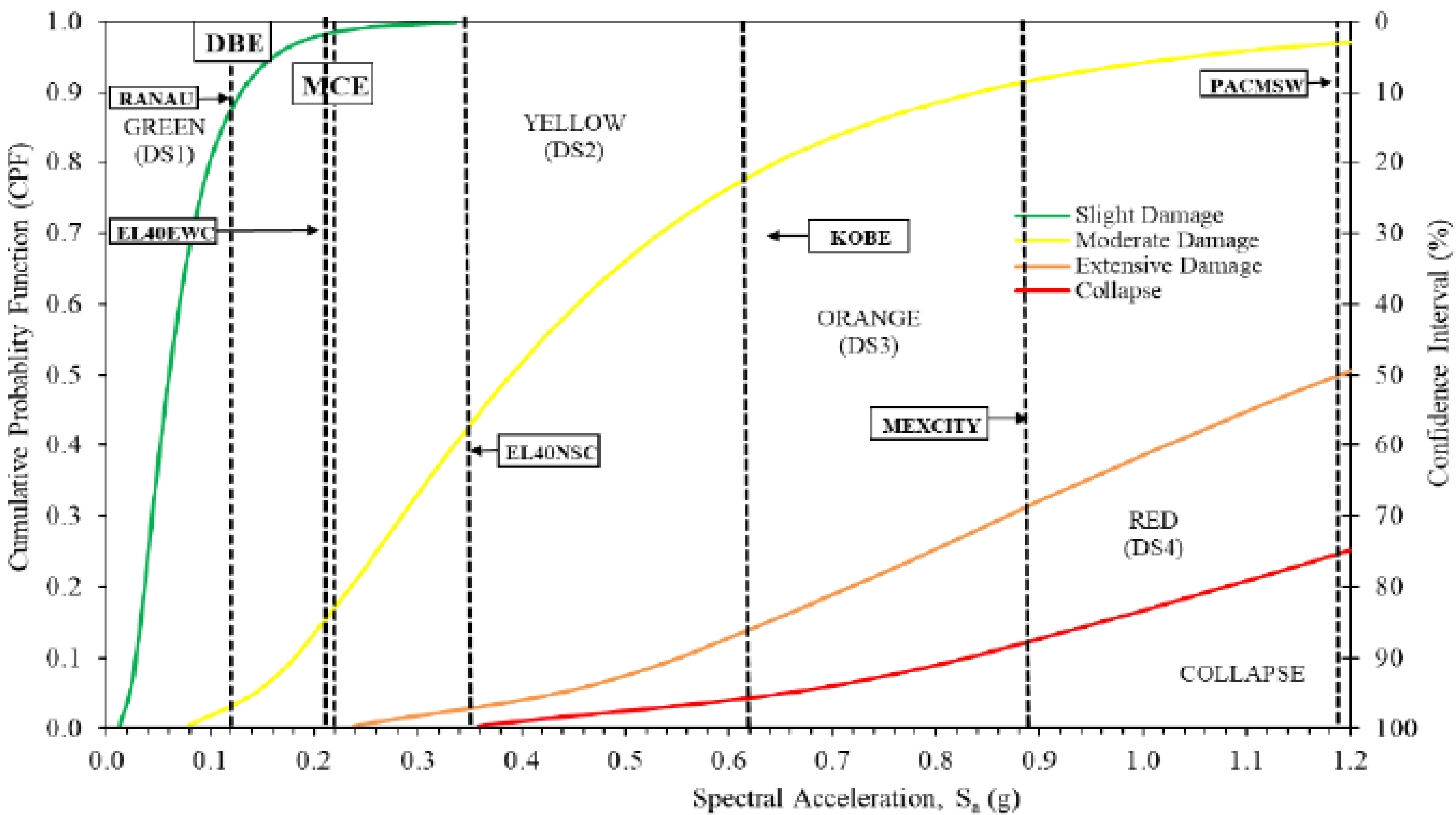
ACHIEVEMENTS OF OBJECTIVE NO. 4

Fragility curve for two-story frame with special base isolation based on visual observation at lab

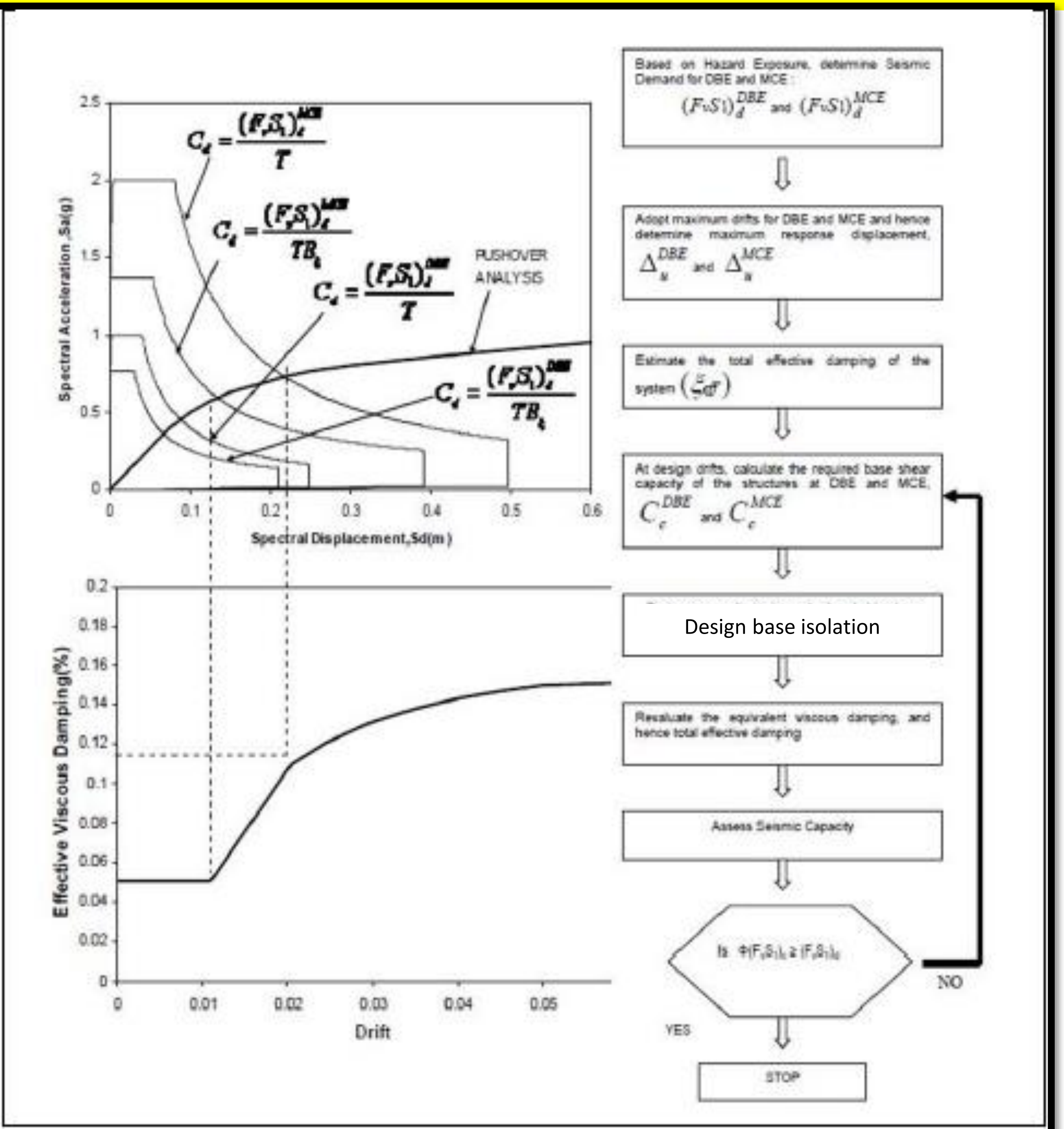


ACHIVEMENTS OF OBJECTIVE NO. 4

Fragility curve for two-story frame without special base isolation based on visual observation at lab

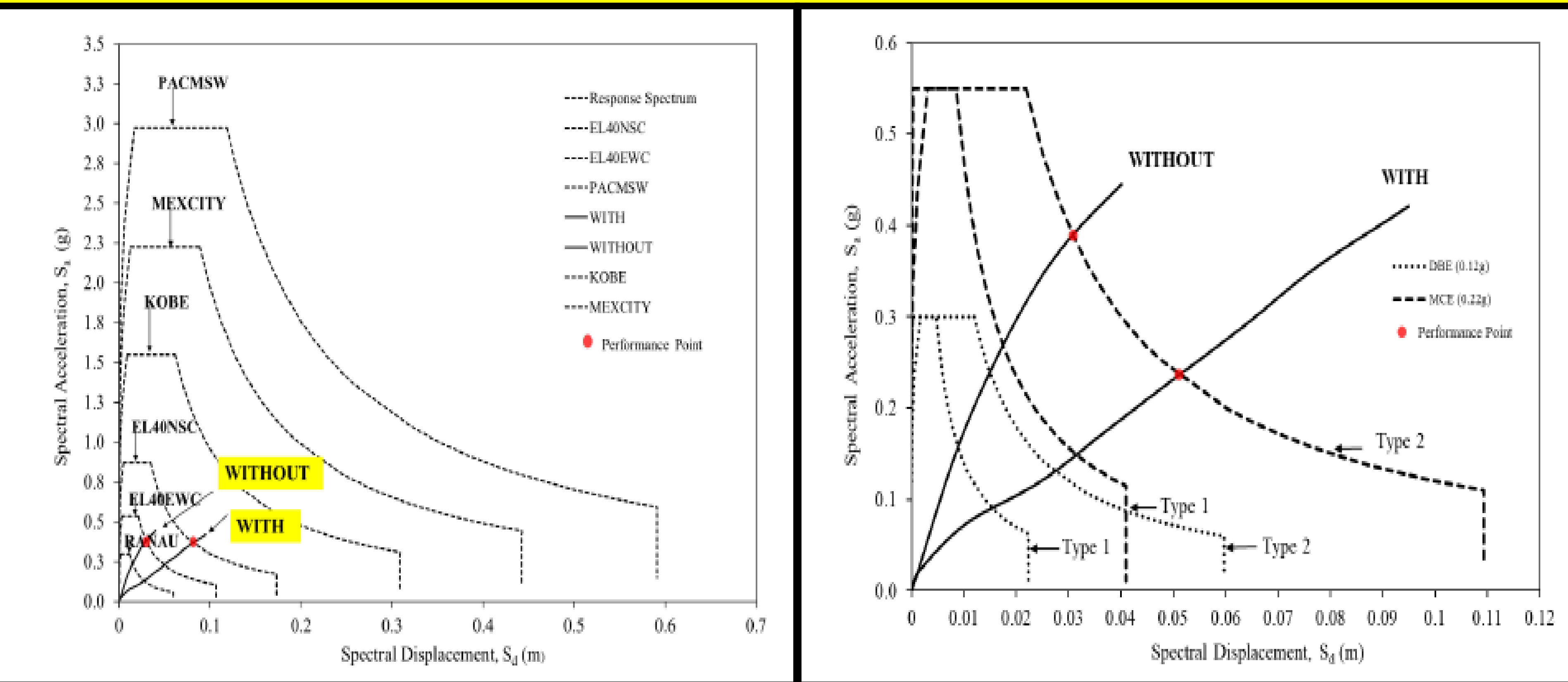


ACHIEVEMENTS OF OBJECTIVE NO. 5



1) Flowchart of the proposed design procedure for RC building with special base isolation using Direct Displacement Based Design (DDBD)
2) Develop the Capacity-Demand Curve by mapping them with Pushover Analysis
3) Determine the effective damping.
4) Design the special base isolation to cater for DBE and MCE

ACHIEVEMENTS OF OBJECTIVE NO. 5

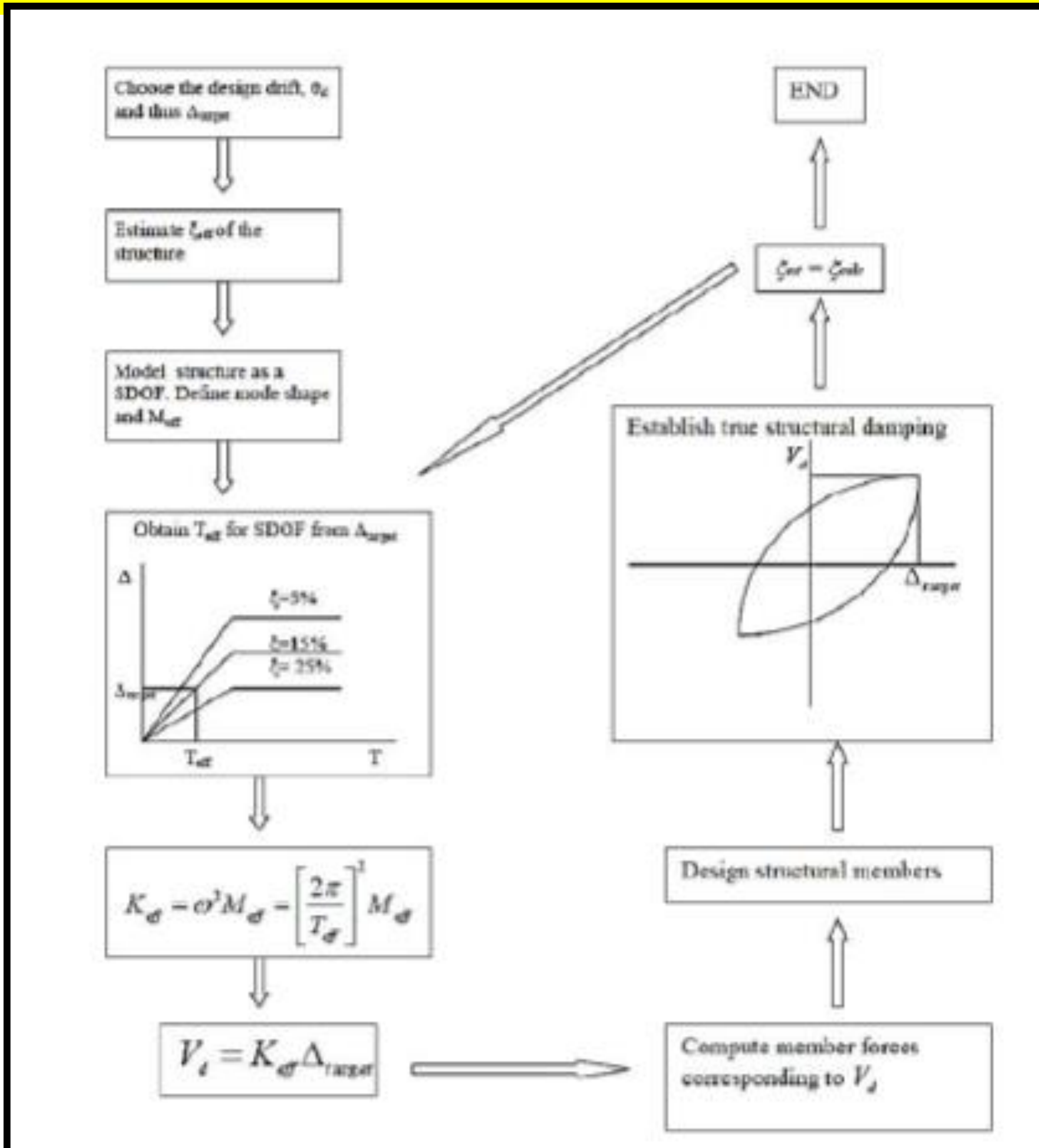


(a) Capacity – Demand Response Spectrum for the selected six past earthquake records

(b) Capacity – Demand Response Spectrum for the DBE and MCE

-Based on Clause 3.2.2.2 of Eurocode 8 and the Pushover Analysis were taken from experimental work in the lab

ACHIVEMENTS OF OBJECTIVE NO. 5



1) Flow chart for design structure members
2) Estimate the damping of the structure by including the damping of the special base isolation.
3) Obtain the Teff
4) Calculate Keff
5) Calculate base shear
6) Compute member forces
7) Design structural members

CONCLUSIONS AND RECOMMENDATIONS

(1)The seismic behavior of two-story RC frame with special base isolation performs better as compared RC frame without special base isolation in term visual observation, lateral strength capacity, elastic stiffness, ductility and equivalent viscous damping.

(2)Both of hysteresis loops for two-story RC frame with special base isolation and without base isolation were successfully modeling using HYSTRESES program in Ruaumoko 2D folder and comparison had been made between them.

(3)The seismic response of two-story RC frame with and without special base isolation had been successfully performed under six selected past earthquake excitation .

(4)The seismic vulnerability assessment using two fragility curves for two-story RC frame with and without special base isolation had been successfully developed and established .

(5)The guideline for design the structural members and special base isolation had been proposed using Direct Displacement Base Design (DDBD)

CONCLUSIONS AND RECOMMENDATIONS

1. Based on the modeling results, the lateral displacement provided by this special base isolator is not sufficient for Kobe Earthquake, Mexico Earthquake and Pacoima Dam Earthquake where their PGA were high. It is recommended to increase the size and dimension of these isolators to cater for higher lateral displacement.
2. In order to get the realistic and accurate of structural seismic response, it is recommended to test the two-story RC frame with and without special base isolation under the six past selected past earthquake records using shake table.
3. It is recommended to repair and retrofit the damages existing of RC buildings at Ranau, Sabah after experience moderate damage during the 2015 Ranau Earthquake with these special based isolations.

THANK YOU VERY MUCH FOR YOUR ATTENTION AND CO-OPERATION