A SIMPLE AND SUSTAINABLE APPROACH FOR STRUCTURAL HEALTH MONITORING OF STRUCTURES

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INTRODUCTION

›Structural health monitoring (SHM) is an advanced and multi-disciplinary technology that is used to monitor structures with the help of different techniques, sensors, management of data acquisition, and algorithms.

›For developing countries, its need is undermined due to its costly deployment. However, contrary to the costly belief, its use is direly needed in densely populated developing countries.

OBJECTIVES

›To analyze the gaps in the application of SHM in developing countries and then to recommend a simple and sustainable approach to achieve its amenities.

›Suggest and achieve a simple approach.

›Develop and set up the basic concept and instrumentation of the said approach.

›Correlate reliably between the damage stages and the SHM parameters.

SCOPE OF WORK

›The scope of our work is to devise a simple and sustainable SHM approach by experimenting for reliable results on a prototype structure and ultimately if time and effort are given on an old-built structure.

›Our study is limited to a steel structures only, and the SHM is performed on a locally made shake table that is limited to 1-D motion only with fixed loading amplitude.

METHODOLOGY

SHM MODULES

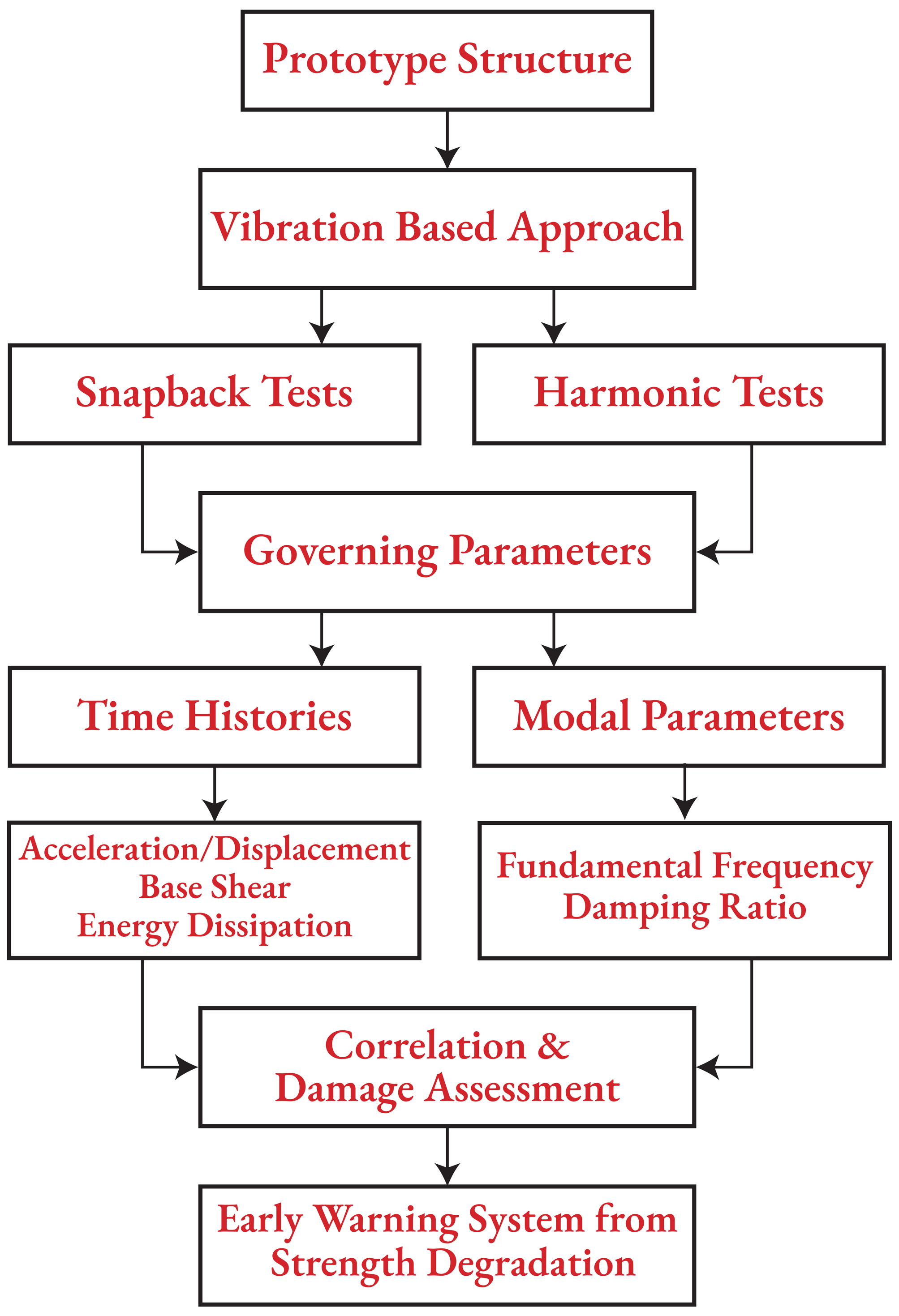
Sensory System (Accelerometers)

Acquisition System (Arduino Microcontroller)

Control System (MATLAB & Siesmosignal)

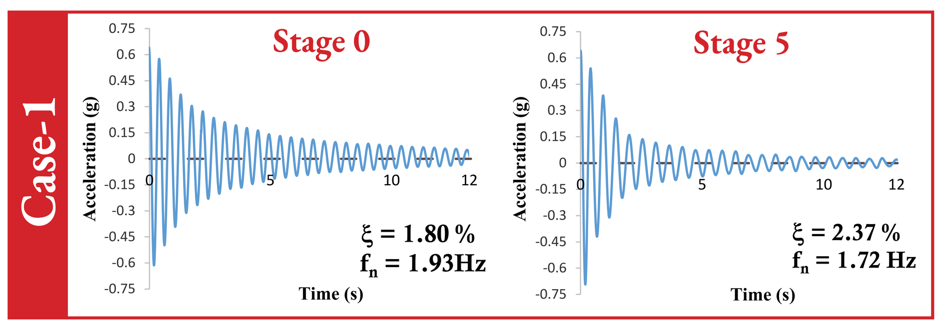
Validation System (Base Shear & Energy Dissipation)

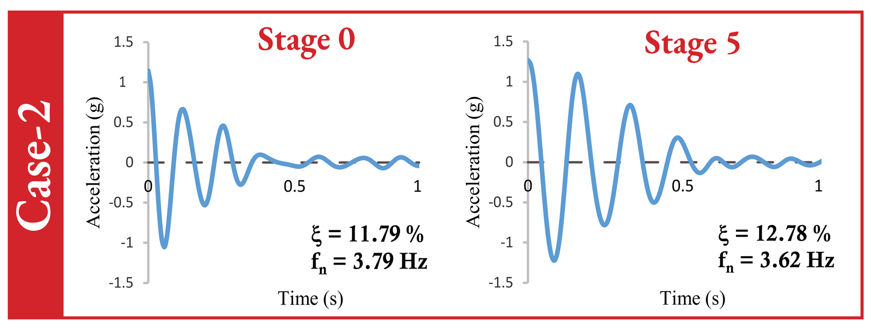
PROCEDURE CHART



MAIN FINDINGS

NATURAL FREQUENCY AND DAMPING RATIO



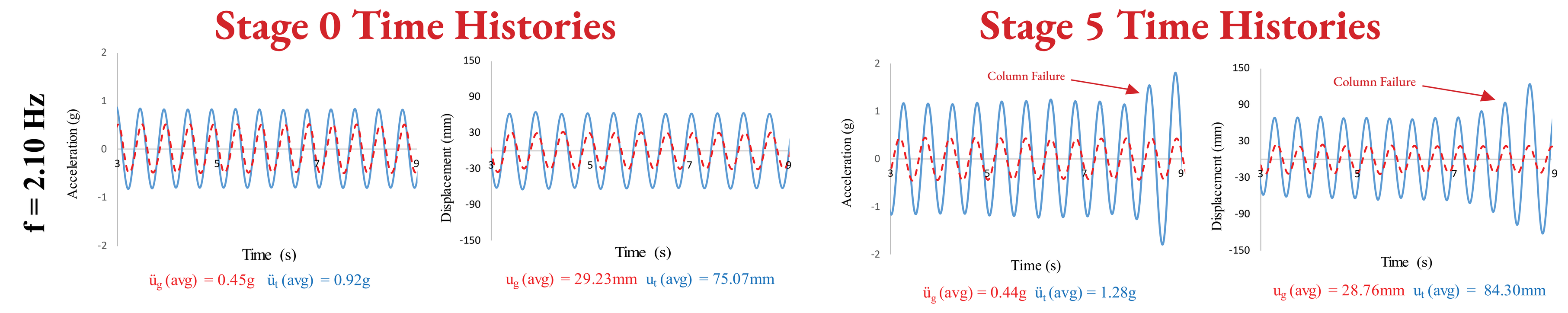


ENERGY DISSIPATION IN DAMAGE STAGES

Harmonic Frequency	Stage 0			Stage 1			Stage 2			Stage 3			Stage 4			Stage 5		
	e_0 (J)	n_0	E_0 (J)	e_1 (J)	n_1	E_1 (J)	e_2 (J)	n_2	E_2 (J)	e_3 (J)	n_3	E_3 (J)	e_4 (J)	n_4	E_4 (J)	e_5 (J)	n_5	E_5 (J)
1.5	0.084 {-}* [-]**	122	10.248	0.104 {-} [24%]	118	12.272	0.14 {-} [66%]	102	14.28	0.15 {-} [79%]	105	15.75	0.22 {-} [162%]	96	21.12	0.23 {-} [173%]	120	27.6
1.7	0.17 {102%} [-]	88	14.96	0.2 {92%} [18%]	109	21.8	0.23 {64%} [35%]	89	20.47	0.2 {33%} [18%]	96	19.2	0.24 {9%} [41%]	102	24.48	0.41 {78%} [141%]	113	46.33
1.8	0.19 {126%} [-]	127	24.13	0.23 {121%} [24%]	134	30.82	0.26 {86%} [37%]	108	28.08	0.31 {107%} [63%]	126	39.06	0.251 {14%} [32%]	104	26.104	0.49 {113%} [158%]	108	52.92
1.9	0.21 {150%} [-]	165	34.65	0.32 {208%} [21%]	141	45.12	0.31 {121%} [48%]	129	39.99	0.36 {140%} [71%]	94	33.84	0.35 {59%} [67%]	93	32.55	0.54 {135%} [157%]	152	82.08
2.1	0.3 {257%} [-]	93	27.9	0.35 {236%} [17%]	162	56.7	0.42 {200%} [40%]	142	59.64	0.45 {200%} [50%]	110	49.5	0.46 {109%} [53%]	84	38.64	0.78 {240%} [160%]	96	74.88
2.1 (ii)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.91 {296%} [203%]	160	145.6
2.1 (iii)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.98 {326%} [227%]	91	89.18
2.1 (iv)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.03 {347%} [243%]	122	125.66
2.1 (v)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.9 {726%} [533%]	186	353.4

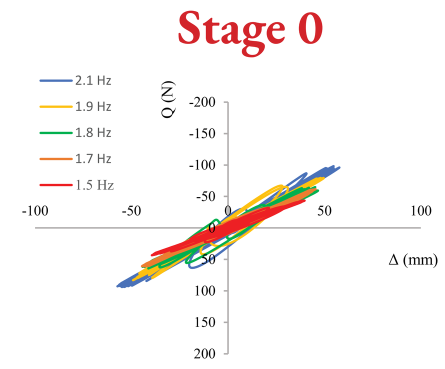
*Shows the percentage increase w.r.t to the base frequency of the same damage stages
**Shows the percentage increase w.r.t to the base damage stage frequency for any corresponding damage stage

ACCELERATION & DISPLACEMENT GRAPHS

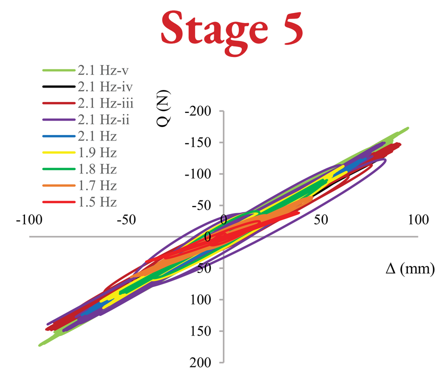


BASE SHEAR

Stage 0



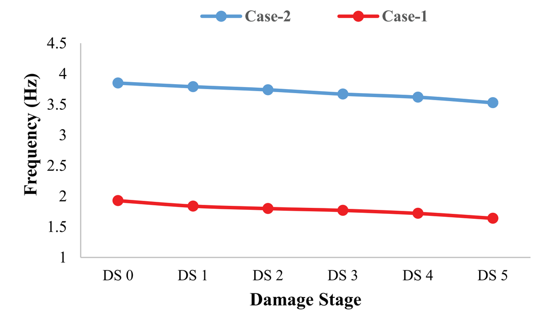
Stage 5



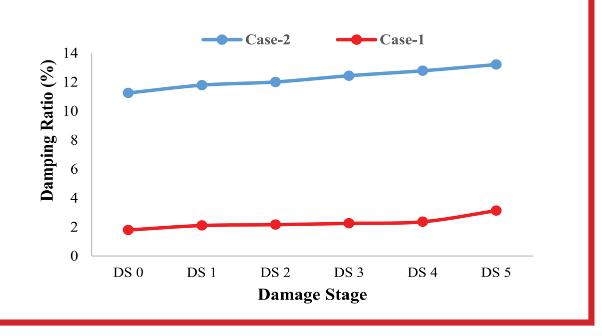
COLUMN FAILURE

MODAL CHANGES

Frequency of Damage Stages

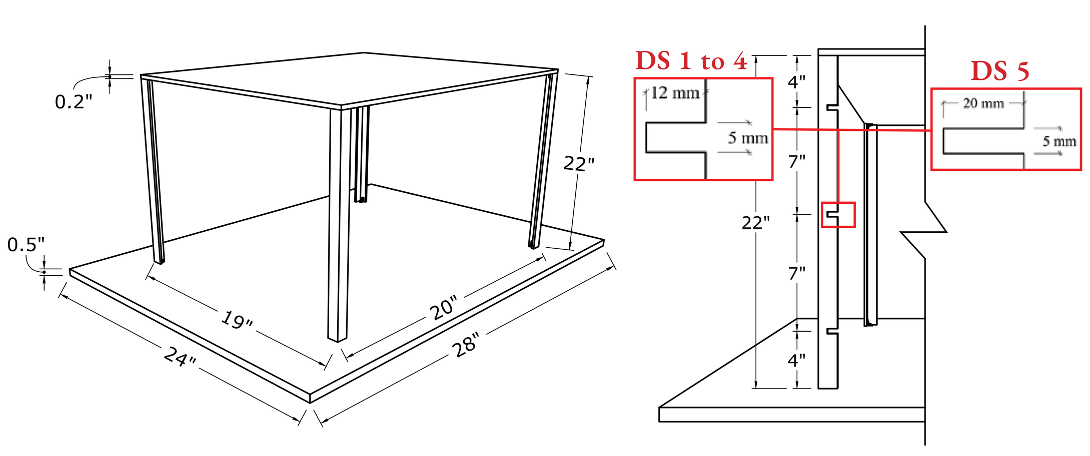


Damping Ratio of Damage Stages



EXPERIMENTATION

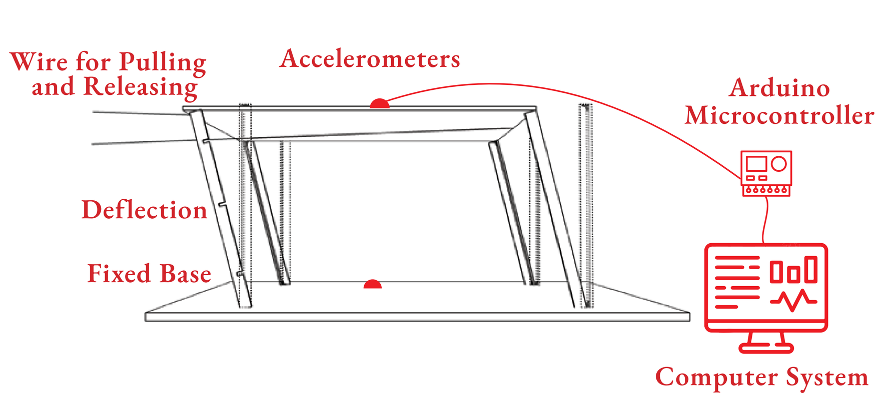
PROTOTYPE STRUCTURE



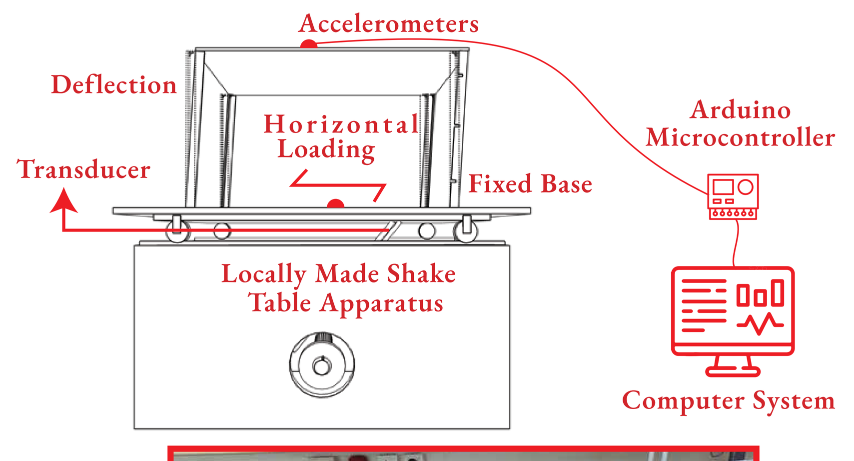
Damage Stages Criteria Table

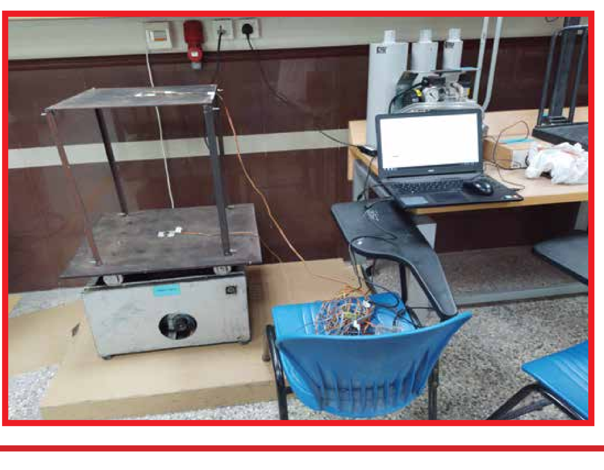
Damage Stages	Damaged Angle Sides	Fully Damaged Columns
DS_0	-	-
DS_1	2	1
DS_2	2	2
DS_3	2	3
DS_4	2	4

Snapback Test



Harmonic Test





CONCLUSION

›Due to recent advancements in technologies, modal techniques have resurged due to better equipment availability and data segregation ML algorithms; making them cost-effective.

›The acceleration and displacement curves obtained from local and cheap instruments seem to be reliable. Thus, the use of such equipment is recommended for real-life applications in a developing nation like Pakistan.

›Overall the energy dissipation in the joint failure and according to the damage stages was well displayed by the acceleration-time and displacement-time curves.

›An automated system that would generate a warning upon the changes in structural responses would result in an early warning system that could prevent countless lives.

PROJECT OUTPUT

›Intended Journal Article: Khan, A., Ilyas, H., Khan, J., and Ali, M. (2022). A simple and sustainable approach for structural health monitoring of structures. Engineering Structures (Impact factor = 4.471)

›Referred Conference Articles:

(1) Ilyas, H. & Ali, M. (2022). Low price instrumentations for structural health monitoring – A review. 1st International Conference on Advances in Civil & Environmental Engineering, University of Engineering & Technology Taxila, Pakistan. Taxila: University of Taxila. (Published)

(2) Khan, J. & Ali, M. (2022). A review on the correlation between damage stages in structure lifespan and structural health monitoring. 12th International International Civil Engineering Conference, NED University, Pakistan. (Published)

(3) Ilyas, H. & Ali, operties of structure using snapback test. 1st International Conference on Engineering and Applied Natural Sciences, Konya, Turkey. European Journal of Science and Technology. (Published)

(4) Khan, A. and Ali, M. (2022). Consideration of simple approaches for structural health monitoring of structures in developing countries - An overview. 3rd European Conference on Earthquake and Seismology, Romanian Association for Earthquake Engineering Bucharest, Romania. (Accepted)

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