TIME HISTORY AND DAMAGE INDEX ANALYSISOF RC STRUCTURES

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Abstract – *In the present study RC structure undergoes nonlinear time history analysis of previous earthquake records in India. This seismic records are available on PESMOS (Programme for Excellence in Strong Motion Studies) data centre maintained by IIT Roorkee. It isused to determine the seismic response of a structure under dynamic loading of representive earthquake. The inelastic dynamic analysis is done on INSPECT software. After running this program the damage index output occur in terms of damage of elements and overall structural damage. By observing the damage result of all elements, the member which undergo more damage is again analyse with different parameter and property to reduce its damage. Similarly the time history analysis and inelastic dynamic analysis is carried out on second model. After getting the result of damage, that compare with previous models damage result to see its percentile reduction. The non-linear dynamic analysis i.e. time history analysis is done on ETABS where the inelastic dynamic analysis is done on INSPECT software. It is created in C# environment it utilizes .NET libraries and SQLite database.*

***Key Words*: Nonlinear time history analysis, PESMOS, Damage index, Inelastic dynamic, INSPECT.**

1. INTRODUCTION

Damage Indexes have received special attention during past two decades, mainly based in possibility of correlating Damage Indexes to Limit States of performance- based design. Global seismic damage indexes provide a measure to the structural deterioration. They are calculated from the numerical simulation of structures with lateral static or dynamic forces representing seismic forces. Depending on the load type, various damage indexes have been formulated. These damage indexes includes the main characteristics of non-linear response (static or dynamic) of structures. Some indexes measure overall seismic damage of a structure from its local damage.

1.1 Nonlinear Time History Analysis

Time history analysis is an important technique for the structural seismic analysis specially when evaluated structural response is nonlinear. It is step by step analysis of the dynamic response of a structure to a specified loading that may vary with time. It is used to determine the seismic response of a structure under the dynamic loading of representative earthquake.

Most of the modern seismic codes specify two fundamental performance criteria for reinforcedconcrete(RC) structures:

1. No collapse and no excessive damage (under the design earthquake)
2. Limitation of damage (under an earthquake with higher probability of occurrence than the design one).

1.2 Damage Analysis

Damage indices based on the results of a nonlinear dynamic analysis, on the measured response of a structure during an earthquake etc. In most of the cases damage indices are dimensionless parameters intended to range between 0 for the undamaged (elastic) state and 1 for the collapsed state of a structure, with intermediate values giving some measure of degree of damage.

- **Building A** Almost all of the tied columns in the base story collapsed. The upper stories suffered slight damage or no damage.
- **Buildings B and G** These three story buildings collapsed during the ground action.
- **Building C** Extensive flexural crackings were observed in the beams of the middle frame.
- **Building D** Shear crackings and crushing of concrete, was concentrated in the columns.
- **Buildings E and I** Only slight damage was observed in the third story, whereas Building I with less damage.

- **Building F** All of the columns in the first story collapsed through shear failure. A slight sag was also observed in the second floor.

- **Building H** Crackings was observed in the short columns.

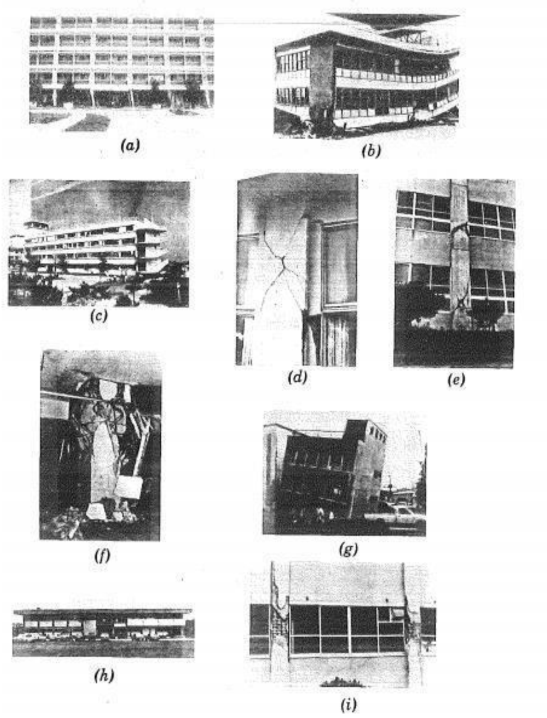


Fig.1 Photographs of Damaged Buildings

1.3 OBJECTIVES

1. To analyse a RC framed building for available earthquake time histories considering different earthquake.

2. To compare seismic behaviour of RC framed building for different earthquake intensities in terms of various responses such as, displacements and drift.

3. To investigate the damage indices of RC frame in terms of element damage (column -beam), overall damage of structure.

4. To compare percentile difference in previous model and redesigned model to reduce its damage index and provide the more stability to the structure.

2. LITERATURE REVIEW

From studying the findings of earlier investigations on the Nonlinear time history analysis and damage index analysis further conclusion is occur. A nonlinear dynamic analysis is the only method to describe the actual behaviour of a structure during an earthquake.

The response of RC structure are strongly dependent on the frequency content of the ground motion. Park andAng index mostly use to determine damage, based on non-linear dynamic response. Element damage, storeylevel damage and overall building damage is need to analyse for predicting the structure life.

3. ANALYSIS

3.1 Nonlinear Time History Analysis

It is also known as Fast Nonlinear Analysis (FNA). It is a step-by- step analysis of the dynamical response of a structure to a specified loading that may vary with time. The analysis may be linear or nonlinear. Time history analysis is used to determine the dynamic response of a structure to arbitrary loading. If the load includes ground acceleration, the displacements, velocities, and accelerations are relative to this ground motion. Any number of time history Load Cases can be defined. Each time history case can differ in the load applied and in the type of analysis to be per formed.

3.2 Damage Analysis

The terms 'damage variable' and 'damage index' are usually interchangeable in the literature, with the possible exception of the last few years. Strictly speaking, and in order to avoid difficulties of interpretation, a damage index(D) is a quantity with zero value when no damage occurs and a value of 1(or 100%) when failure or collapse occurs. Furthermore, a damage index may involve more than one damage variable.

Table-1. Damage Levels

Damage Index	Description
DI < 0.1	No damage or localized minor cracking
1≤ DI < 0.25	Minor damage: light cracking throughout
0.25 ≤ DI <0.40	Moderate damage: severe cracking
0.4 ≤ DI <1(0.8)	Severe damage: concrete crushing,reinforcement exposed
DI ≥ 1(0.8)	Collapse

4. MODELING

Frame Geometry –

A building with 3 Storey was considered for studying the response of structure for various earthquake records.

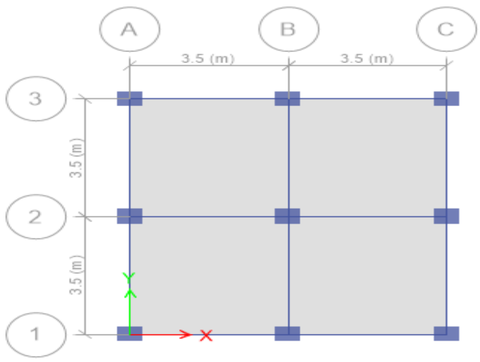


Fig. 2 Plan of frame

Table-2. Design Parameters

Height of structure	9m
Storey height	3m
Size of beam	450mm x 300 mm
Size of column	550 mm x 450 mm
Thickness of slab	125mm
Dead load	1kN/m2
Live load	3kN/m2
Wall load	11.73kN/m2
Grade of concrete	M30
Grade of reinforcement	Fe500
Plan dimension	7m x 7m
RCC design code	IS 456:2000
Steel design code	IS 800:2007
For structure-2, Column size	400mm x 400mm (Str.1 causes more damage in column)

Table-3. Seismic Records

Ground motion	Date	Time (sec.)	Magn. (kN)	PGA (m/s2)
Dharmsala	26.04.1986	20.0	5. 5	2.430
Shillong	10.09.1986	21.50	5. 2 0	1.1100
Uttarkashi	20.10.1991	40.0	4. 8	1.930
Chamba	24.03.1995	18.22	6. 5	1.4284
Chamoli	29.03.1999	25.0	6. 4	0.2617

5. SOFTWARE ANALYSIS

The structures are modelled and analyzed in the commercial engineering software ETABS. Show the various loading conditions and structural dimensions considered for modelling the structure. The frame considered has 3 bays in x-direction of length 3.5m for each bay, 3 bays in y-direction of length 3.5m for each bay. Beams and column have rectangular sections. Frame 1 and frame 2 are same structure with different element dimensions having plan dimension 7m x 7m.

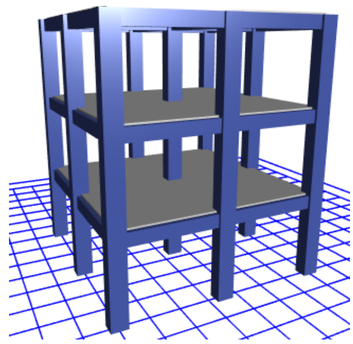


Fig 3. Structure 1 modelled on ETABS

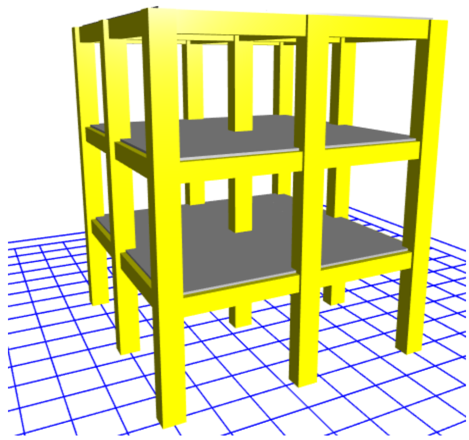


Fig 4. Structure 2 modelled on ETABS

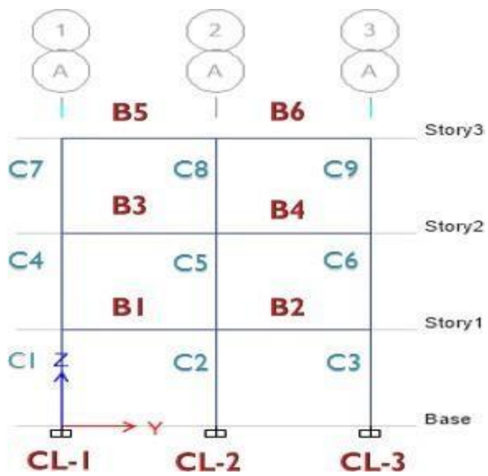


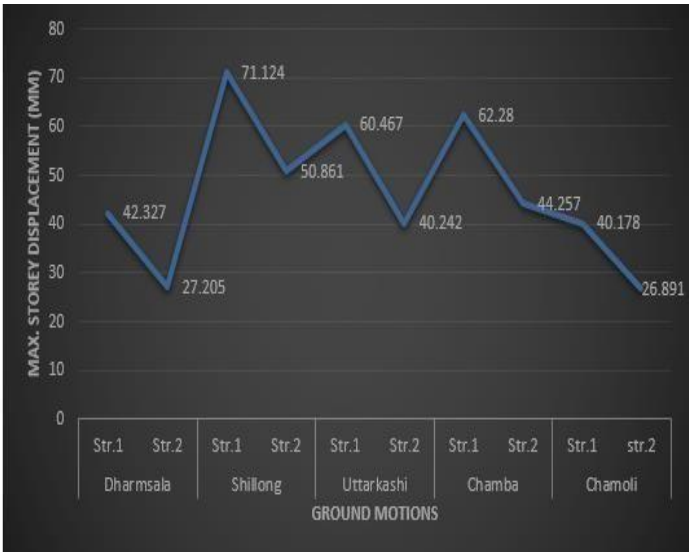
Fig 5. Elements and connections schematic representation of structure on INSPECT software

6. RESULTS

6.1 STOREY DISPLACEMENT OFSTRUCTURES

Table-4. Storey Displacement

Ground Motion		Max. storey displacement (mm)
Dharmsala	Str. 1	42.327
	Str. 2	27.205
Shillong	Str. 1	71.124
	Str. 2	50.861
Uttarkashi	Str.1	60.467
	Str.2	40.242
Chamba	Str.1	62.280
	Str.2	44.257
Chamoli	Str.1	40.178
	Str.2	26.891

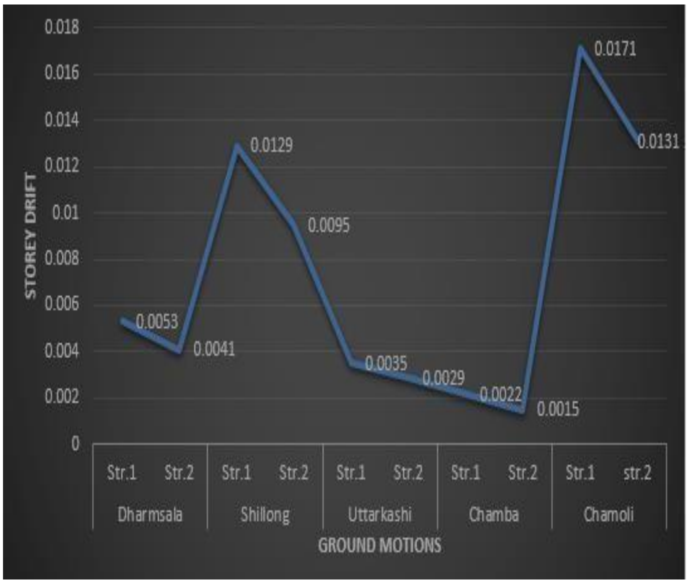


Graph 1. Maximum storey displacement(mm) vs Ground motion

6.2 STOREY DRIFT OF STRUCTURES

Table-5. Storey Drift

Ground Motion		Storey drift
Dharmsala	Str. 1	0.0053
	Str. 2	0.0041
Shillong	Str. 1	0.0129
	Str. 2	0.0095
Uttarkashi	Str.1	0.0035
	Str.2	0.0029
Chamba	Str.1	0.0022
	Str.2	0.0015
Chamoli	Str.1	0.0171
	Str.2	0.0131



Graph 2: Maximum storey drift vsGround motions

6.3 DAMAGE FOR COLUMN - WALL ELEMENT

Table-6. Damage of column-wall

Ground Motion		Storey Level	Column-wall damage	Max damage
Dharmsala	Str1	3	0.017	0.047
		2	0.024	
		1	0.047	
	Str2	3	0.015	0.141
		2	0.141	
		1	0.010	
Shillong	Str1	3	0.227	0.227
		2	0.006	
		1	0.15	
	Str2	3	0.019	0.106
		2	0.106	
		1	0.048	
Uttarkashi	Str1	3	0.010	0.031
		2	0.031	
		1	0.018	
	Str2	3	0.237	0.107
		2	0.067	
		1	0.107	
Chamba	Str1	3	0.007	0.215
		2	0.215	
		1	0.033	
	Str2	3	0.111	0.186
		2	0.186	
		1	0.097	
Chamoli	Str1	3	1.285	1.285
		2	0.098	
		1	0.026	
	Str2	3	0.019	0.056
		2	0.071	
		1	0.056	

6.4 DAMAGE FOR BEAM - SLAB ELEMENT

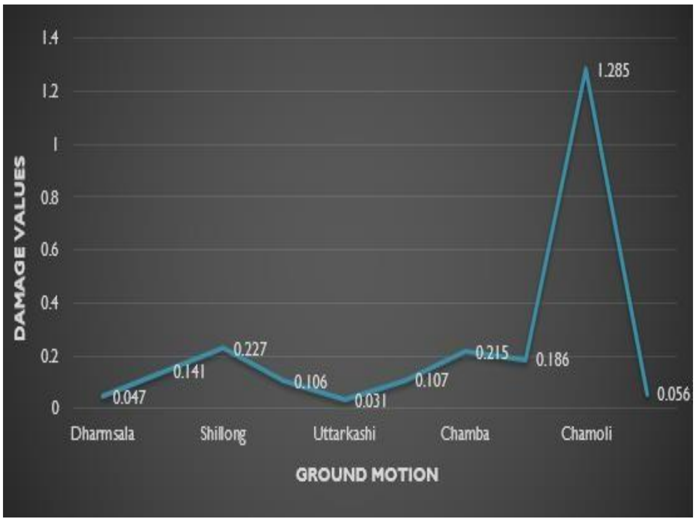
Table-7. Damage of beam – slab

Ground Motion		Storey Level	Beam-slab damage	Max damage
Dharmsala	Str 1	3	0.071	0.256
		2	0.256	
		1	0.045	
	Str 2	3	0.017	0.027
		2	0.027	
		1	0.024	
Shillong	Str 1	3	0.500	0.500
		2	0.33	
		1	0.15	
	Str 2	3	0.046	0.141
		2	0.141	
		1	0.054	
Uttarkashi	Str 1	3	0.060	0.152
		2	0.152	
		1	0.018	
	Str 2	3	0.475	0.475
		2	0.033	
		1	0.127	
Chamba	Str 1	3	0.088	2.690
		2	2.690	
		1	0.21	
	Str 2	3	0.038	0.275
		2	0.275	
		1	0.021	
Chamoli	Str 1	3	0.615	0.615
		2	0.082	
		1	0.017	
	Str 2	3	0.316	0.316
		2	0.012	
		1	0.026	

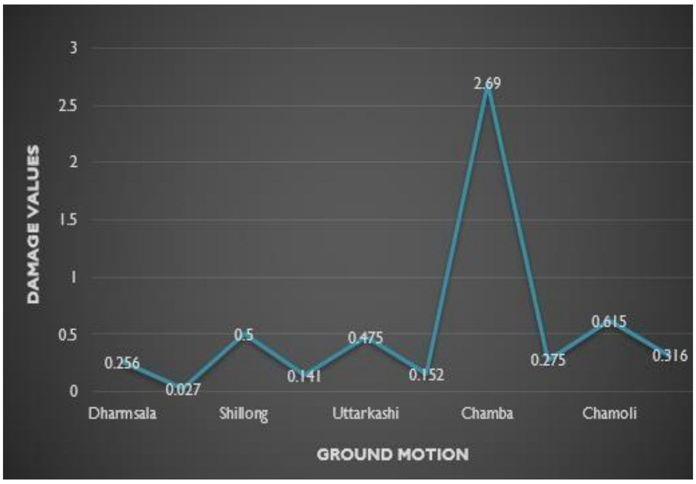
6.5 DAMAGE OF OVERALL STRUCTURE

Table-8. Overall structural damage

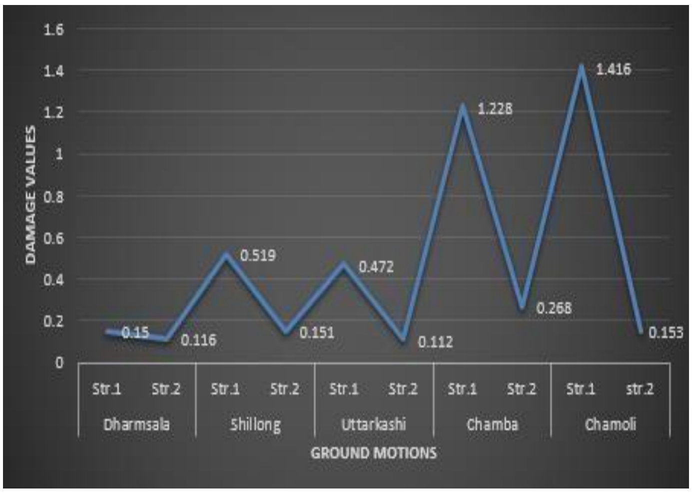
Ground Motion		Overall structural damage	Damage Level
Dharmsala	Str. 1	0.150	Minor damage
	Str. 2	0.116	Minor damage
Shillong	Str. 1	0.519	Severe damage
	Str. 2	0.151	Minor damage
Uttarkashi	Str.1	0.112	Minor damage
	Str.2	0.472	Severe damage
Chamba	Str.1	1.228	Collapse
	Str.2	0.268	Moderate damage
Chamoli	Str.1	1.416	Collapse
	Str.2	0.153	Minor damage



Graph 3: Damage for column-wall element vsground motion



Graph 4: Damage for beam - slab element vsground motion



Graph 5: Overall structural damage vs ground motion

7. CONCLUSIONS

The results of nonlinear time history analysis of structure-1 and structure-2 in five different time history records shows that structure-2 provides more stability than structure-1 in all cases i.e. against maximum storey displacement and against storey drift because the structure 2 having the column size differ than structure1. The nonlinear time history analysis helps to provide the result of damage index with different time intervals. An accurate determination of damage is essential for meaningful nonlinear dynamic analysis of concrete structures, because the damage index is closely tied to the residual strength reserve of a member, after it has undergone large inelastic load cycles. Park and Ang solves the problem of singularity at the collapse threshold by implementing a calculation iterative process which considers obtaining a certain damage index as a convergence standard.

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