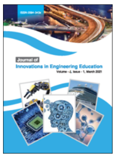

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Seismic performance of timber band in dry stone masonry building

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Abstract

A research has been done to determine the performance of the dry stone structure using FEA in the form of a solid element named Solid65 in the ANSIS modeling. The solution method used in the study model was implicit. A model of plasticity damaged concrete was chosen for this study which could explain the behavior of thickness and non-linearity in the plastic range. In the first model (M1), the non-reinforced stone structure is considered whereas in the second model (R1), the non-reinforced concrete stones are considered. The capacity of both buildings was assessed on the basis of shearing compared to the area to remove the roof. The performance of the structure was also determined by setting the capacity and the demand curve to the plot obtained using FEMA 356. A two-step analysis of the dry stone structure was performed; modal analysis and pushover analysis. The analysis focused heavily on pushover analysis, while modal analysis was used to understand the behavior of the structure under free vibration. Model R1's first mode time was found to be 31.65% lower than that of the M1 model. Also, the model volume R1 was found to increase by 45% and 49.74% in the case of x and y-direction respectively. It was found that the performance of a dry stone structure reinforced with wood was better for strengthening the site of an earthquake building.

1. Introduction

The dry stone construction method is one of the oldest built in the Alpine Himalayan lands In the past earthquake, most of the unstable dry stone structures collapsed causing many casualties during the earthquake. Cohesion in the dry stone wall significantly reduces the maximum vertical acceleration during side loading by earthquake action and significantly affects the degree of collision of the joint joints rather than the horizontal acceleration. This friction-slip action produced by gravity or seismic waves may cause structural instability, collapse, or collapse. Another possible way to improve the wall would be to use wooden elements called Hatil (Spence and Coburn 1992) in Turkey and Bhatar (Schacher 2007) in Pakistan. Wooden elements have traditionally been used in stone buildings and are still used in new buildings built in earthquake zones in developing countries, with excellent seismic performance features [1, 2, 3, 4]. The purpose of this study was to investigate the effectiveness of the wood band on stone structures.

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2. Methodology

A study was conducted aimed at capturing the vernacular behavior of dis-continuum masonry [5] when modeling was performed to study the cause and effect of wood-based interventions as a reinforcement in a dry stone structure. The unstructured dry stone model (M1) and the solid stone structure (Figure 1) reinforced with wooden object (lace) (R1) are modeled and analyzed by Finite Element (FEA) analysis by modeling using 65 solids on the ANSYS2000 [6]. In landslides that are widely used in landslides, stone walls contain a large number of unequal stones, and modeling of each stone and its combination in its shape as built would not be possible [7, 8]. The simplified model was developed based on [9, 1]. Based on past experiences, a simplified method of modeling is done as explained in the following section.

3. Model Buildings and Parameters

A building with a size of 8.65 m and 3.95 m is considered to have two rooms with a size of 3.65m X 3.65 m each (Figure 1). The height of the building was 3.8 m including 0.9 m of attic. Door and window sizes are 0.9 m X 2.035m and 0.9m X 1.2m respectively.

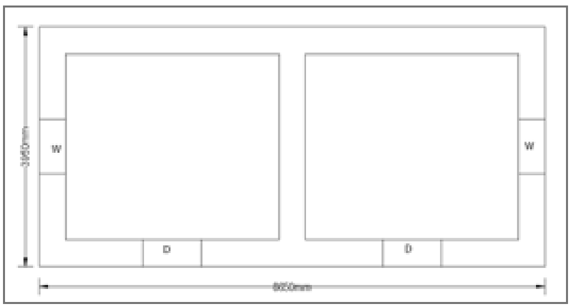

Figure 1: Plan of one storey dry-stone masonry building

The flexible floor is considered throughout the modeling and study. The main load-bearing element of the building is a 0.45m thick stone wall. The floor size was considered 0.08m X 0.13m and a wooden band of 0.075m X 0.1m was considered.

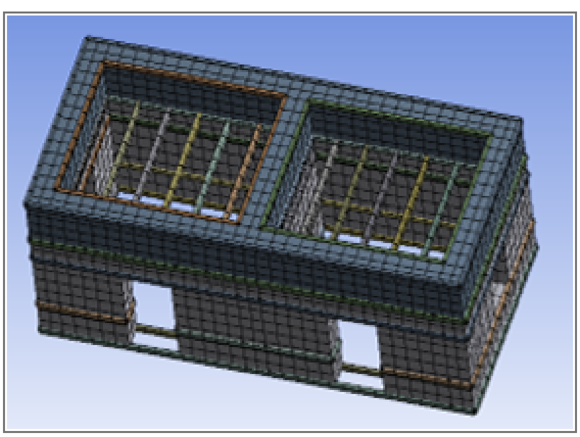

Figure 2: FEM model of building reinforced with timber laces

3.1. Mechanical Properties

Considering almost similar nature of work done in South America, the mechanical properties of dry-stone masonry are taken from the previous experiment result done by [10] corresponding to coefficient of friction value 0.4 (Table 1).

The material properties based on [12] concrete model for dry stone masonry are mention in Table 3. Although the above parameters are sufficient for the non linear concrete model of ANSYS 2000, it is better to keep the stress strain curve for concrete backbone for gaining accuracy in the results. So try to put stress strain curve.

Table 1: Elastic properties

S.N	Description	value
1.	Unit weight	1700 kg/m3
2.	Elastic modulus	500 MPa
3.	Shear modulus	208 MPa
4.	Poisson's ratio	0.2

Table 2: Elastic properties of Timber [11]

S.N	Description	value
1.	Unit weight	805 kg/m3
2.	Elastic modulus	12500 MPa
3.	Shear modulus	4699 MPa
4.	Poisson's ratio	0.33

Table 3: Material Properties for FEA simulation

S.N	Description	value
1.	Compressive strength of masonry	3.05 Mpa
2.	Tensile strength of masonry	0.15 Mpa
3.	Open shear crack transfer coefficient	0.30
4.	Closed shear crack transfer coefficient	0.60

Table 4: Stress-strain properties

S.N	Stress(MPa)	Strain(mm/mm)
1	0.000	0.00000
2	0.915	0.00458
3	1.954	0.01106
4	2.636	0.01754
5	2.965	0.02402
6	3.050	0.03050

The dead load, live load and gravity load are considered to the structure. The value of the load is based on IS 875 part II as shown in table below.

Table 5: Dead and live load on building

S.N	Load	Value
1.	Floor finish	1.0kN/m2
2.	Roof live load	2.5 kN/m2
3.	Live load	3.0kN/m2

The monotonic lateral loading is applied in the form of inertial load. The loads are applied through a horizontal acceleration. The static structural analysis consists in the application of self-weight in a first step and after deformation and stresses are produced by this section a lateral load is applied in second step.

4. Analysis

4.1. Linear Static Analysis

4.1 Linear Static Analysis Linear static method is done using equivalent static method as described in the code IS 1893(part I):2002. The horizontal, vertical force equal to the vibration of the base of the design is used mathematically. Equivalent lateral forces at each floor level are applied to the ground level. In this analysis, different parameters are taken for calculation of design seismic coefficient according to IS 1893(part I):2002 [13] are as given below (Table 6).

Table 6: Design parameters

S.N	Parameters	Value	Remarks
1.	Building types		Residential
2.	Lateral Load resisting system		Unreinforced /reinforced masonry wall system
3.	Seismic Zone factor	0.36	Zone v
4.	Importance factor (I)	1	
5.	Response reduction factor(R)	1.5	Unreinforced masonry building
6.	Soil Type	II	Medium

4.2. Non-linear Static Analysis

Static line analysis of selected structures is performed in two-way longitudinal (X-direction) and transversal (Y-direction). The gravitational force is applied in the first loading step and then the seismic force is applied in proportion to the weight of the structure and increased until the analysis stops to wrap the loads. Response spectrum is taken from IS 1893(part I):2002 [13] for 5% damping and converted to demand spectra as per as our assumption of seismic parameters. Finally, the performance point of buildings is determined as per FEMA 356 as shown in the table below. For further [4] is referred.

Table 7: Performance limit as per FEMA 356

Performance point	Roof Drift (%)		
	Collapse prevention (CP)	Lift Safety (LS)	Immediate Occupancy (IO)
Unreinforced Masonry	1	0.6	0.3
Reinforced Masonry	1.5	0.6	0.2

5. Result

5.1. Modal and time period of analysis

Total 12 modes were considered in modal analysis. The first, second and third mode of the building show translation in x-direction, y- direction and rotation respectively in all model. It can be seen that time period of building model reinforced (RF) with timber laces is decreased than that of unreinforced (URM) case for the building (Figure 3).

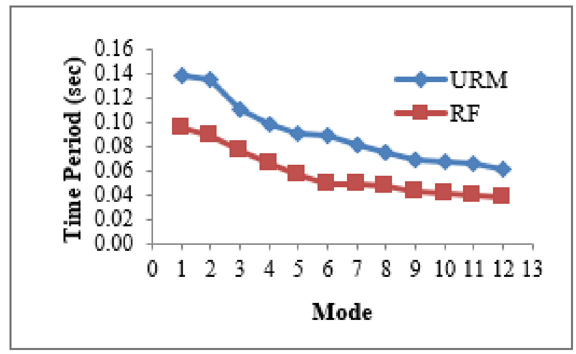

Figure 3: Natural period in different mode for model M1 and R1

Capacity of one storey model M1 and R1

a. Longitudinal x-Direction

In line with the positive longitudinal direction (+ x), the first horizontal branch of the capacity curve is detected in the base shear of 92.3 KN on the M1 and 149.5 KN at R1. The ultimate state is achieved at a base shear of 163.3 KN and a 57 mm roof displacement on the M1 model. Similarly, the ultimate state is reached for at base shear of 300.85 KN and a roof displacement of 73.69 mm for model R1. Hence it can be seen that after the building is reinforced with timber elements, the capacity of building is increase by 45 % and roof displacement is increase by 22.99% as shown in Figure 4.

b. Transverse y-direction

Along the positive transverse direction (+ y), the first horizontal branch of the capacity curve is detected in the base shear of 86.78 KN on the M1 and 166.31 KN at R1. The ultimate state is achieved at a base shear of 104.64 KN and a roof displacement of 55.912 mm on the M1 model. Similarly, the ultimate state is achieved at a base shear of 287.48 KN and a roof displacement of 70 mm with the R1 model. Hence it can be seen that after the building is reinforced with timber laces, the capacity of building is increase by 49.74 % and roof displacement is increase by 21% as shown in Figure 5.

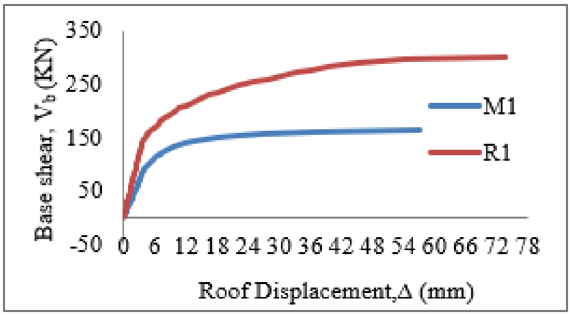

Figure 4: Capacity curve for M1 and R1 along x-direction

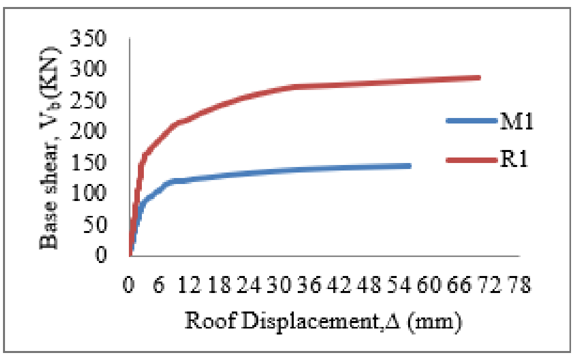

Figure 5: Capacity curve for M1 and R1 along y-direction

Performance of one storey model M1 and R1

a. Longitudinal x-Direction

The performance point in terms of storey drift from analysis is found to be 0.99% for unreinforced masonry M1 and 0.52% for reinforced masonry with timber laces R1.

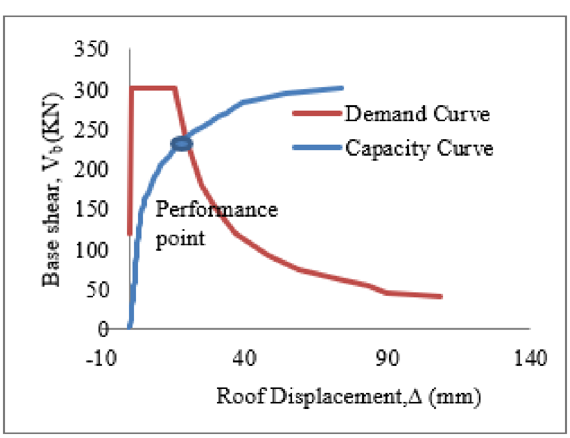

Figure 6: Performance level for model M1 along x-direction

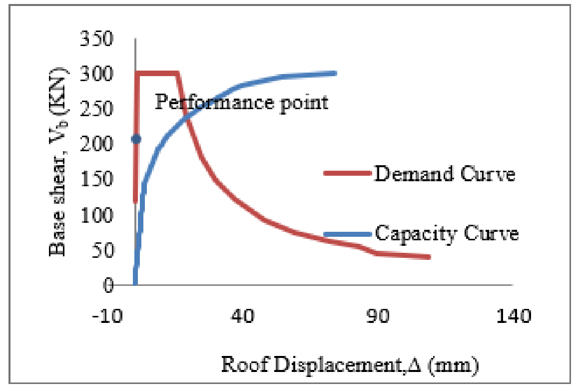

Figure 7: Performance level for model R1 along x-direction

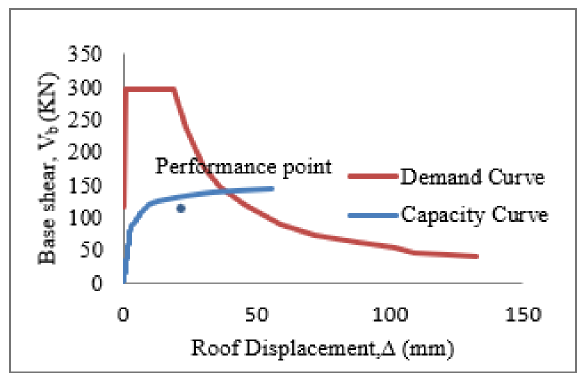

Figure 8: Performance level for M1 along y-direction

This value clearly shows that the performance of un-reinforced masonry lies near of collapse prevention as shown in Figure 6. But after the building is reinforced with timber laces, performance of building is increased and immediate occupancy to life safety limit is achieved as shown in Figure 7. This due to the reason that timber laces give structural integrity to the building and during the earthquake building shows box behavior and prevent from collapse.

b. Transverse y-Direction

The performance point in terms of storey drift from analysis is found to be found 1.02 % for unreinforced masonry M1 and 0.6% for reinforced masonry with timer laces.

This Value clearly shows that the performance of unre-inforced masonry lies in Collapse prevention as shown in Figure 8. But after the building is reinforced with timber laces, Performance of building is increase and Life safety is achieved as shown in Figure 9. This due to the reason that timber laces give structural integrity to the building and during the earthquake, building shows

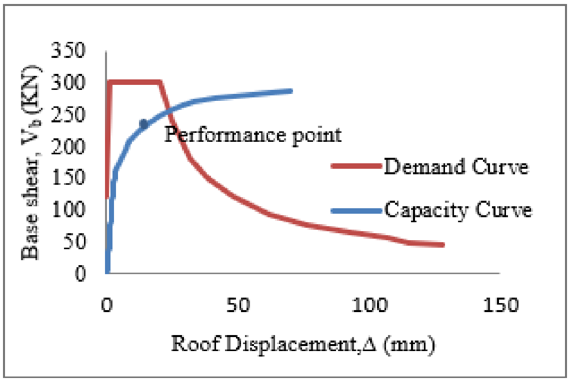

Figure 9: Performance level for model R1 along y-direction

box behavior and prevent from collapse and causalities.

6. Conclusion

Based on the above investigation following conclusion are made.

1. The modal analysis results showed a decrease in first mode time period after reinforcement with timber laces, indicating an increase in the structural stiffness due to the reinforcement. The first mode time period of Model R1 decreased by 31.65% than that of model M1. Similar results were found for the other different modes also. After application of reinforcing element, there is no change in entire masses of the structures but due to changes in stiffness which makes changes in natural frequencies. Timber band can give additional strength to improve seismic capacity of dry-stone masonry building. The capacity of model R1 increased by 45% and 49.74% in case of x-direction and y-direction respectively.

2. This is due to the timber bands as reinforcing materials inserted into the walls that could effectively take tensile load at the time of diagonal cracking due to seismic loading. The vertical columns connected to the horizontal bands significantly increase the structural integrity and improve deformation capabilities.

3. Since timber is locally available and as compared to other materials, it can be most preferred solution for rural areas to save lives and properties in the future earthquakes.

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