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A Comparative Study of Displacement and Time Period in Mud Mortar Masonry Building with Changes in Modulus of Elasticity (Young Modulus) of Brick with Time

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Abstract: ***Masonry buildings are generally built by brick, mud mortar with timber as joist. The structural health of these masonry buildings deteriorates with time. The quality of materials used in the building in this case brick elements deteriorate with continuous use and application of load and action of heat and cold temperature. Thus, due to continuous exposure to hot and cold weather, vibration force either due to earthquake force or vibration due to vehicular movements the materials deteriorate years by years. But it would take years and years of practical and theoretical calculation to observe and predict the exact percentage of deterioration thus, in the present study, it is studied for the deterioration which causes decrease in young's modulus of elasticity by 10 to 40 percent. It is observed from the analysis that the maximum effect to the structure will be created due to the decrease in elasticity causing high displacement of structures and increment in stress. As modulus of elasticity is directly associated with the stiffness of the structures, stiffness decreases with decrease in modulus of elasticity which will further cause increment of fundamental time period.***

Keywords: Seismic Sensitivity, Displacement, Time Period, Young modulus

1. Introduction

Masonry buildings are built up by brick, mud mortar and timber. [2] The structural health of these buildings should be monitored to assess their ability to resist future threats. [16] The structural health of these buildings depends upon the effect of load, environmental erosion, material aging, accidental bumping on the structures and many other factors, which will ultimately lead to structural damage and destruction [17] one of the important parameter which effect the structural health of masonry buildings is modulus of elasticity.

1.1 Deterioration of Modulus of Elasticity

The modulus of elasticity (young's modulus) of brick and timber decreases with time because of the effect of constant load or stress, vibration due to earthquake or vehicular movements. The deterioration of material result in decrease in modulus of elasticity of the material. The exact pattern of decrease in modulus of elasticity takes years and years of practical and theoretical calculation, hence in this study the deterioration of modulus elasticity is taken by 10 to 40 percent with 10% gradual deterioration.

1.2 Modeling of structures

The numerical analysis used eight nodded isoparametric element is to discretize the layers of brick and mortars joints. For these two types of finite element model has been suggested and finite element analyses has been performed using computer software SAP 2000. [10]

The first model is idealized as a homogenized material. For this brick element and mortar joint element is replaced by the equivalent homogeneous material. Modulus of elasticity of masonry (E_m) in compression is calculated according to UBC 1991.

$$E_m = \frac{(1+\gamma_t)}{\left(1+\frac{\gamma_t}{\gamma_m}\right)} E_b$$

i. e

where;
γ_t =*Thickness ratio* = t_j/t_b
γ_m =*Modulus ratio* =E_j/E_b
t_j =*Thickness of mortar joint*
t_b =*Thickness of brick*
E_j =*Modulus of elasticity of mortar joints*
E_b = *Modulus of elasticity of brick*

The modeling technique of the buildings has been done by shell and solid modelling approach.

1.3 Selection of Buildings

The typical traditional Newari house of Bhaktapur is usually three or four stories high. It has a simple rectangular plan with depth about 6 m and length varying from 3 to 10 meters. The foundation is usually shallow, made out of stones. The superstructure is constructed with locally available sun-dried bricks and mud-mortar. Three walls, two outside walls and one spine wall at the center, support the whole structure. Timber joists over which wooden boards with a thick layer of mud topping is applied support the floors and roof. The roof is doubly pitched and has brick tile roofing.

Different parameters can be used for categorize the existing building. This makes easy to analyze the vulnerability of building and compare with each category. It also indicates the most powerful factor that cause building to more vulnerable to earthquake.

Here six parameters are taken as the primary indicators.
- Construction material
- Load transfer system
- No. of storey
- Age of building
- Openings
- Plinth area

Classification according to construction material:
- Adobe building (Building made with sun dried brick)
- Masonry building with mud mortar joint
- Masonry building with cement mortar joint
- Building with RCC structure.

Classification according to Load transfer:
- Load bearing
- Moment resisting frame structure

Classification according to No. of stories:
- Low rise – 1 to 2 storeys
- Medium rise – 3 to 4 storeys
- High rise – > 5 storeys

Classification according to Age of building
- Recent – 1 to 10 years
- Medium age-10 to 20 years
  -20 to 30 years
  -30 to 40 years
  -40 to 50 years
- Old – 50 to 75 years
- very old – > 75 years

2. Methodology

A masonry building of 4 storey building is selected for the study. The building is modeled by solid modeling approach i. e., the brick work is discretized as the eight nodded solid elements. The masonry building is analyzed with modulus of elasticity value as E=2000 N/mm^2, E=1800 N/mm^2, E=1600 N/mm^2, E=1400 N/mm^2, E=1200 N/mm$^{2.}$

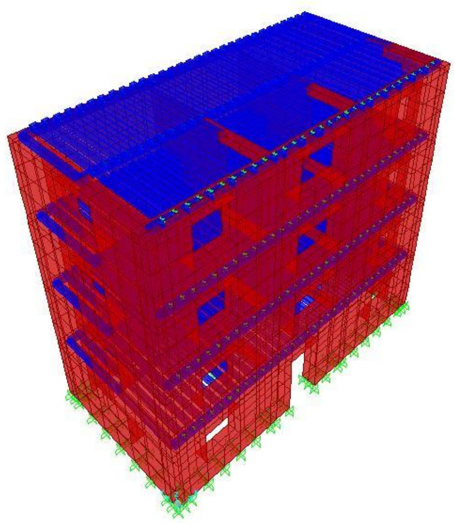

Figure 1: Solid model of masonry building of 4 storeys.

The initial material property of brick and timber is taken as follows:

Table 1: Material properties of Brick Masonry

Unit weight, γ	19.5kN/m^3
Young’s modulus of Elasticity, E	2000 N/mm^2
Poisson’s Ratio, υ	0.1
Compressive stress in axial compression, σ_c	0.606 N/mm^2
Permissible tensile stress due to vertical bending, σ_t	0.05 N/mm^2
Permissible shear stress, τ	0.20 N/mm^2

Table 2: Material properties of timber

Unit weight, γ	8 kN/m^2
Young’s Modulus of Elasticity, E	1250 N/mm^2
Poisson’s Ratio, υ	0.12
Permissible compressive stress parallel to grain	
Inside location	12 N/mm^2
Outside location	10.6 N/mm^2
Wet location	8.8 N/mm^2
Permissible compressive stress perpendicular to grain	
Inside location	6 N/mm^2
Outside location	4.6 N/mm^2
Wet location	3.8 N/mm^2
Permissible Tensile and bending stress along grain,	
Inside location	18.2 N/mm^2
Outside location	15.2 N/mm^2
Wet location	12 N/mm^2

Modulus of Elasticity of Brick decreased by 200 N/mm^2 each for subsequent models.
For the analysis of the masonry building Seismic coefficient method is proposed with the following load combination.
1) Dead load
2) Dead load + Lateral seismic load along positive X-direction
3) Dead load-Lateral seismic load along positive X-direction
4) Dead load + Lateral seismic load along positive Y-direction
5) Dead load-Lateral seismic load along positive Y-direction

Seismic Coefficient Method
In the seismic coefficient method, the lateral load acting on each floor is calculated. For this, the structure is idealized as a lumped mass multi-degree of freedom system interconnected by elastic elements. The mass lumped at each floor level and is equal to the weight of the building between the horizontal planes passing through the mid-height of successive floors. Based on the mass at each floor, first the base shear is calculated which is then distributed over each floor level based on their contribution factor,

Calculation of base shear
The horizontal seismic shear force acting at the base of the structure, in the
direction being considered, shall be:
V = Cd Wt

Where,
Cd= Design horizontal acceleration spectrum value =*CZIK*

Where,

C = basic seismic coefficient, C, shall be determined from Figure 8.1 of NBC 105: 1994 for the appropriate site subsoil category using the fundamental structural period determined in accordance with 7.2 of NBC 105: 1994 for the direction under consideration.
Z = The seismic zoning factor, Z, shall be obtained from Figure 8.2 of NBC 105: 1994 for the appropriate location.
I = The importance factor, *I*, for the structure shall be obtained from Table 8.1 Of NBC 105: 1994
K= The minimum permissible value of the structural performance factor, *K*, and Associated detailing requirements shall be as given in Table 8.2 of NBC 105: 1994.

Distribution of lateral force at each floor level
The lateral force on each floor level is distributed using the following relation

$$F_i = \frac{W_i * h_i^{\,2}}{\sum_{i=1}^{n} W_i * h_i^{\,2}} V_b$$

Where,
F_i = horizontal force acting at any floor i
W_i = seismic weight of i^{th} storey assumed to be lumped at i^{th} floor.
h_i = height of i^{th} floor above base of frame
n = number of storeys in the building
i = number of levels at which the masses are located.

3. Result and Discussion

The study is carried under following seismic parameters.1) Time Period 2) Displacement.

3.1 Time Period

As modulus of elasticity is directly associated with the stiffness of the structures, stiffness decreases with decrease in modulus of elasticity which will further cause increment of fundamental time period. With decreasing young's modulus at the rate of 10%, Time period of building increases at around 5%.

Table 2: Change in Time period (sec) in 4 storeys with floor solid model with change in young's modulus

Mode	E=2000	E=1800	E=1600	E=1400	E=1200	% Increase in time Period			
1	0.16624	0.174223	0.183561	0.194704	0.20835	4.80%	5.36%	6.07%	7.01%
2	0.116897	0.121681	0.127227	0.133821	0.141968	4.09%	4.56%	5.18%	6.09%
3	0.104643	0.109845	0.115903	0.12305	0.131589	4.97%	5.52%	6.17%	6.94%
4	0.08192	0.085351	0.089269	0.093801	0.099134	4.19%	4.59%	5.08%	5.69%
5	0.067562	0.070792	0.074566	0.079055	0.084513	4.78%	5.33%	6.02%	6.90%
6	0.058746	0.061154	0.063892	0.067109	0.071576	4.10%	4.48%	5.04%	6.66%

3.2 Displacement

It is observed from the analysis that the maximum effect to the structure will be created due to the decrease in elasticity causing high displacement of structures and increment in stress. With decreasing young's modulus at the rate of 10%, in plane displacement and out of plane displacement increases at around 15%.

Table 2: Changes of Out-of-Plane Displacement for Loading in Y-direction with decrease in young's modulus (E) as shown in the table

Height (m)	E=2000 Displacement mm	E=1800 Displacement mm	E=1600 Displacement mm	E=1400 Displacement mm	E=1200 Displacement mm	Increase in displacement			
0	0	0	0	0	0				
2.225	0.8643	0.9489	1.0527	1.1834	1.3534	9.79%	10.94%	12.42%	14.37%
4.45	2.288	2.5088	2.778	3.1161	3.5544	9.65%	10.73%	12.17%	14.07%
6.675	3.7919	4.1534	4.5951	5.1484	5.864	9.53%	10.63%	12.04%	13.90%
8.9	5.0849	5.567	6.1552	6.8904	7.8386	9.48%	10.57%	11.94%	13.76%

Table 3: Changes In-Plane Displacement of wall A for Loading in X-direction With decrease in Young's modulus (E) as shown in the table

Height m	E=2000 Displacement mm	E=1800 Displacement mm	E=1600 Displacement mm	E=1400 Displacement mm	E=1200 Displacement mm	Increase in displacement			
0	0	0	0	0	0				
2.225	0.4098	0.4544	0.51	0.5813	0.6758	10.88%	12.24%	13.98%	16.26%
4.45	0.9129	1.011	1.1329	1.2888	1.4911	10.75%	12.06%	13.76%	15.70%
6.675	1.3109	1.4513	1.6258	1.8488	2.1439	10.71%	12.02%	13.72%	15.96%
8.9	1.567	1.7345	1.9426	2.2083	2.5558	10.69%	12.00%	13.68%	15.74%

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