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BEHAVIOR OF SINGLE STORY BEARING WALL MASONRY STRUCTURES IN VARIOUS CONDITIONS

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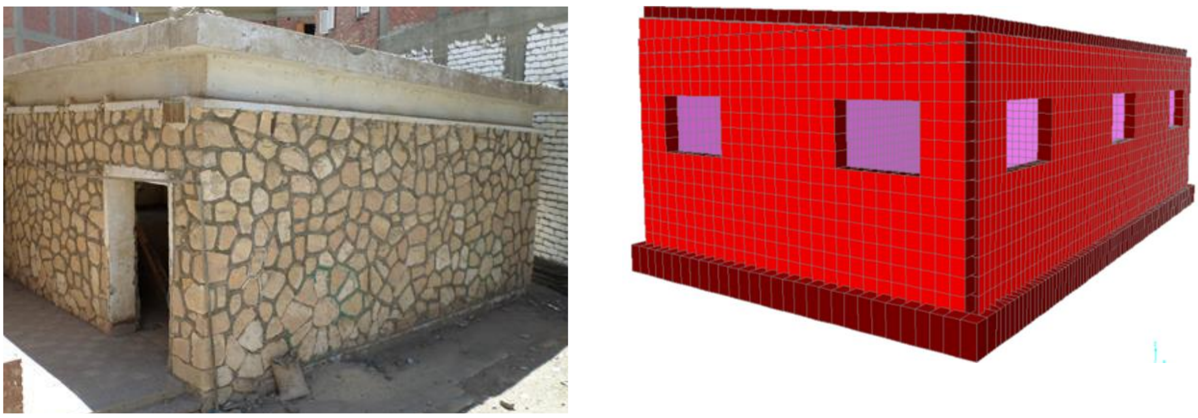
Abstract. As a part of a governmental action for studying the structural condition of public schools across Egypt, there was an awesome opportunity to perform such a research, using a valuable amount of available data for typical school models built in different environments and subjected to various loading and environmental conditions. A field study has been performed on fourteen, geometrically typical, single story schools to study effects of permanent gravitational loads, differential settlement and lateral pressure on the structural response of concrete and masonry. Structures under investigation were built by bricks or boulders and covered with an inclined reinforced concrete deck or steel or timber cladding. Finite element analyses have been performed to allocate regions and directions of principles stresses, expect failure pattern and compare with real structures. Modelling was capable to take into account various material and geometric parameters. Outcomes related to significance of various design parameters, loading and environmental conditions have been extracted. In addition response of various construction materials to the loading environment.

1 INTRODUCTION

Even bearing walls system is an ancient system for building lightly loaded structures, it is still the most used system worldwide, especially for single and double floor buildings. This extensive use of that system imposes a supporting research work studying structural properties, behavior, and response towards various loading conditions. This research was based on the opportunity arising from a governmental project of studying structural safety of school buildings all over EGYPT. The study has been performed on a typical single story bearing wall system used for educational purposes. Field investigation and measurements have been performed, in addition parametric and structural analyses have been established. All buildings studied in that paper have been built about twenty years ago and did not show seismic failure patterns since they did not face any significant seismic motion, in addition low rise restrained bearing walls behave well in moderate seismic actions[1&2]. Two main types of bearing walls materials were adopted in this research. The first is boulders and the second is bricks. The first type is known for its cracking resistance due to having irregular mortar interfaces[3]. Foundations of all the investigated models were of the same configuration and sub-base, resulting in the same stiffness[5].

2 FIELD INVESTIGATION

A typical building model, as shown in figure 1, has been considered for both investigation and analysis. The building is composed of a single compartment with a 15^{o} inclined ceiling.



a) investigation model b) analysis model

Figure 1: Building typical model

Openings for the door and windows are shown in figure 2. Bearing walls are 25 cm thick with a typical strip footing as shown in figure 3. Building geometry and life time were not studied parameters (constants), while construction material for walls and ceiling, soil pattern, natural ground level inclination, presence of neighboring structures, and interference with ground water table were considered as studied parameters.

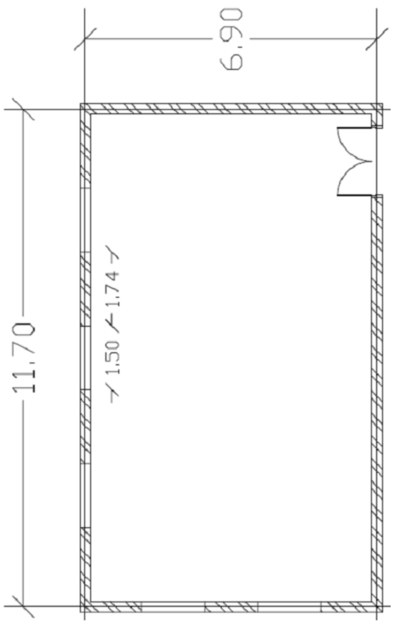


Figure 2: Building typical plan (Dim. in meters)

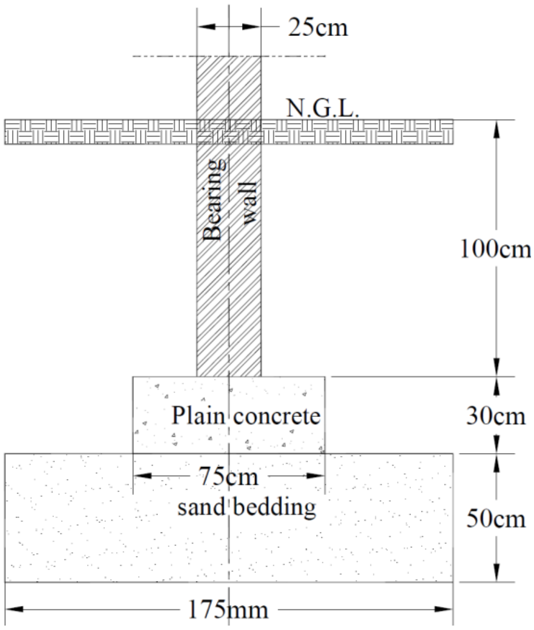
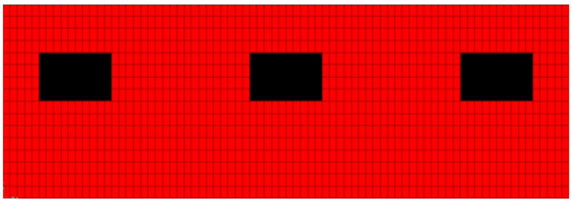


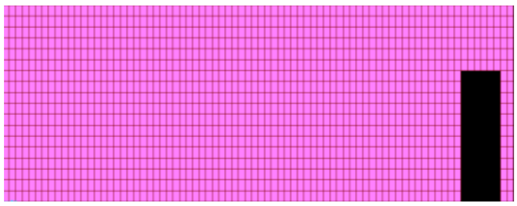
Figure 3: Typical wall x-section

3 FINITE ELEMENT MODEL

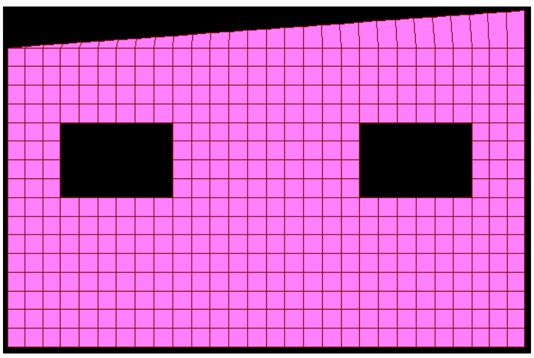
A finite element model has been developed to study stress distribution within the bearing walls body considering various loading conditions arising from field investigation. Shell elements were chosen to model walls and ceiling, as shown in figure 4. Specific releases were assigned at ceiling-walls interface to account for the difference in material and absence of rotational constraints. Springs have been used to model foundation elasticity, since foundation and subgrade properties were identical. Concrete slabs and bearing walls material non-linearities have been considered.



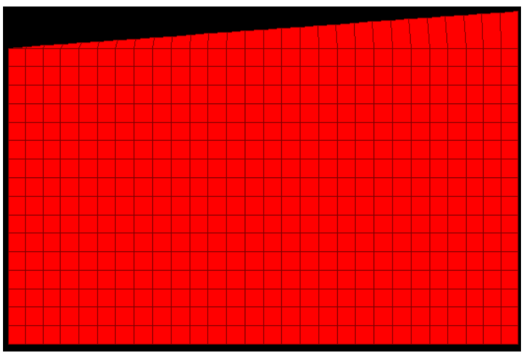
a) First side



b) Second side



c) Third side



d) Fourth side

Figure 4: Finite element model

4 RESULTS AND DISCUSSION

Outputs of the study have been divided into two categories. The first is field investigation and measurements. Investigations considered loading conditions clarifying the structure's status, concentrating on the proposed most significant parameters as building material, ceiling type, soil type, natural ground level profile, presence of close neighboring structures, and interference with ground water level; in addition to crack pattern. While measurements concentrated on major crack width. Special conditions, as the presence of side embankment were found in a single building; so it was not considered as a studying parameter, but a load case. Table 1. Summarizes conditions of each building concerning studied parameters and noticed patterns of failure (major crack pattern and width).

Table 1: Brief Description of buildings condition

	walls		Ceiling			Soil			N.G.L.		Neigh.		G.W.T.		Crack Pattern				Crack width		
Building Id	Brick	Boulders	Concrete	Steel	Timber	Sandy	Clayey	Silty	Horizontal	Inclined	Close	Far	High	Low	Vertical	Inclined	Horizontal	None	x<5	5≤x≤10	x>10
1		■		■			■		■		■		■					■			
2		■		■			■		■		■		■					■			
3		■		■			■		■		■		■					■			
4		■	■				■	■	■		■		■					■			
5		■	■					■	■			■		■				`			
6	■		■				■			■	■		■			■				■	
7	■		■				■		■			■	■			■	■			■	
8	■				■			■	■		■		■					■			
9	■				■			■	■			■	■					■			
10	■		■					■	■			■	■		■				■		
11	■		■				■			■	■			■		■	■			■	
12	■		■			■			■			■		■	■	■					■
13	■		■					■		■		■	■			■	■				■
14	■		■				■	■	■		■		■			■			■		

The second output pattern is the finite element modeling. Two main finite element models have been established. The first reflects normal gravitational loads, while the second reflects the case of side embankment resulting in lateral loads. Figures 5, 6, and 7 represent horizontal normal stress (S11), vertical normal stress (S22), and maximum tensile stresses (Smax) in (kN/m^2).

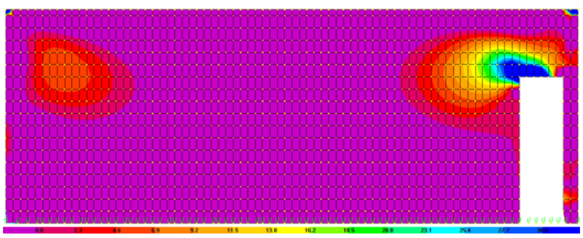


Figure 5a: S11 (gravitational loads)

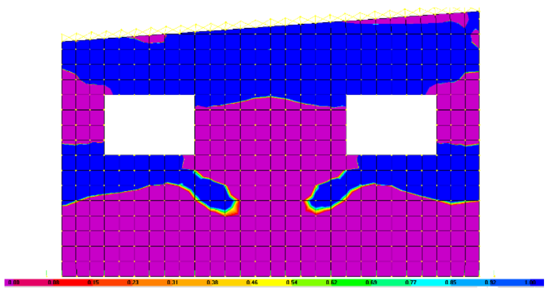


Figure 5b: S11 (gravitational loads)

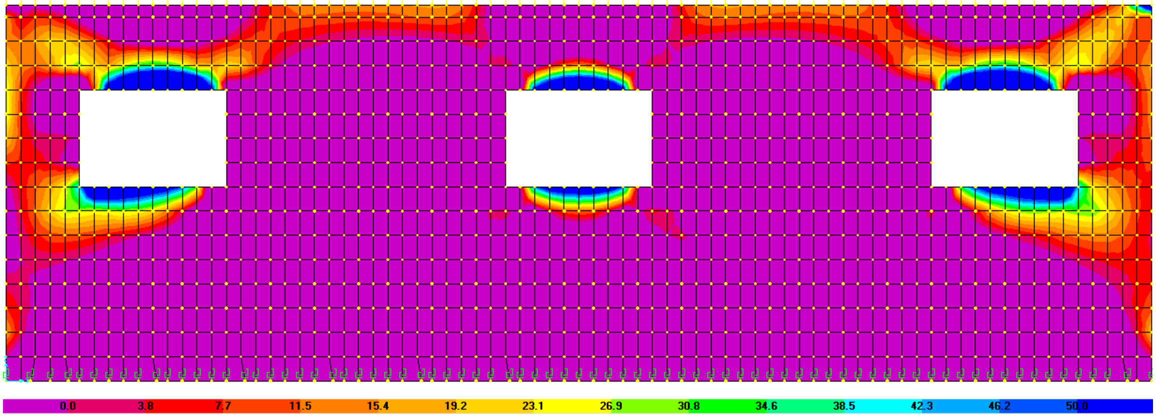


Figure 5c: S11 (gravitational loads)

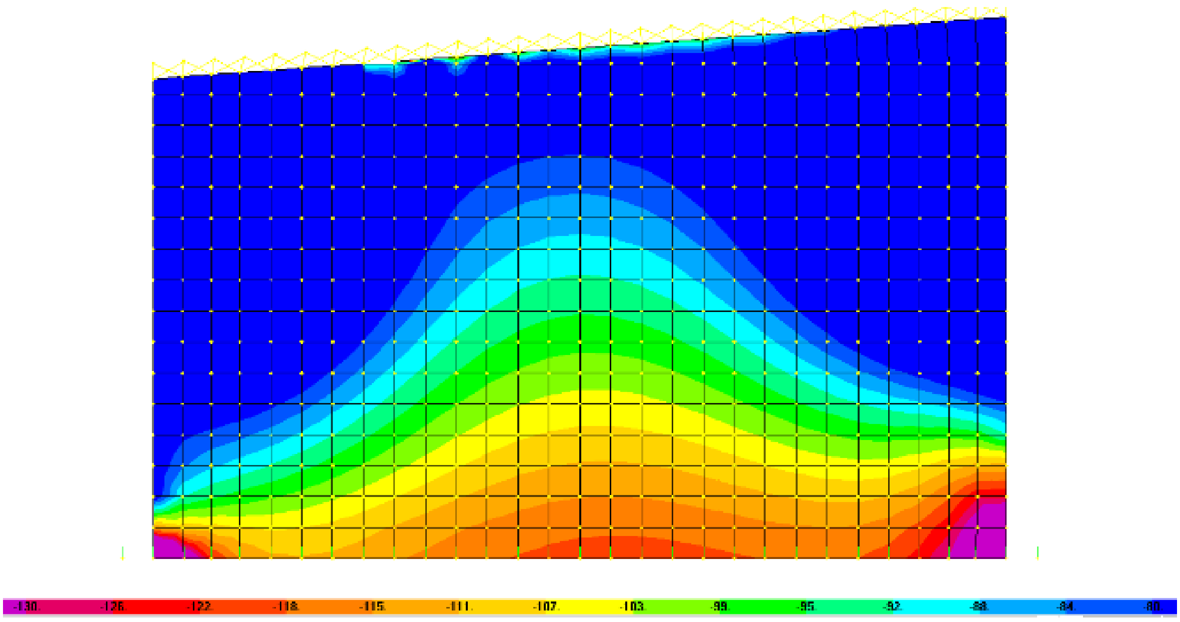


Figure 6a: S22 (gravitational loads)

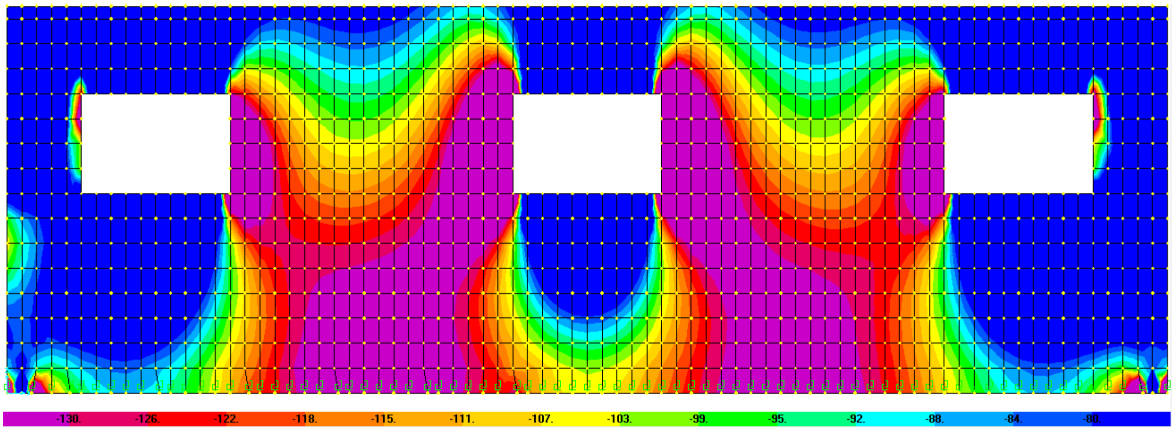


Figure 6b: S22 (gravitational loads)

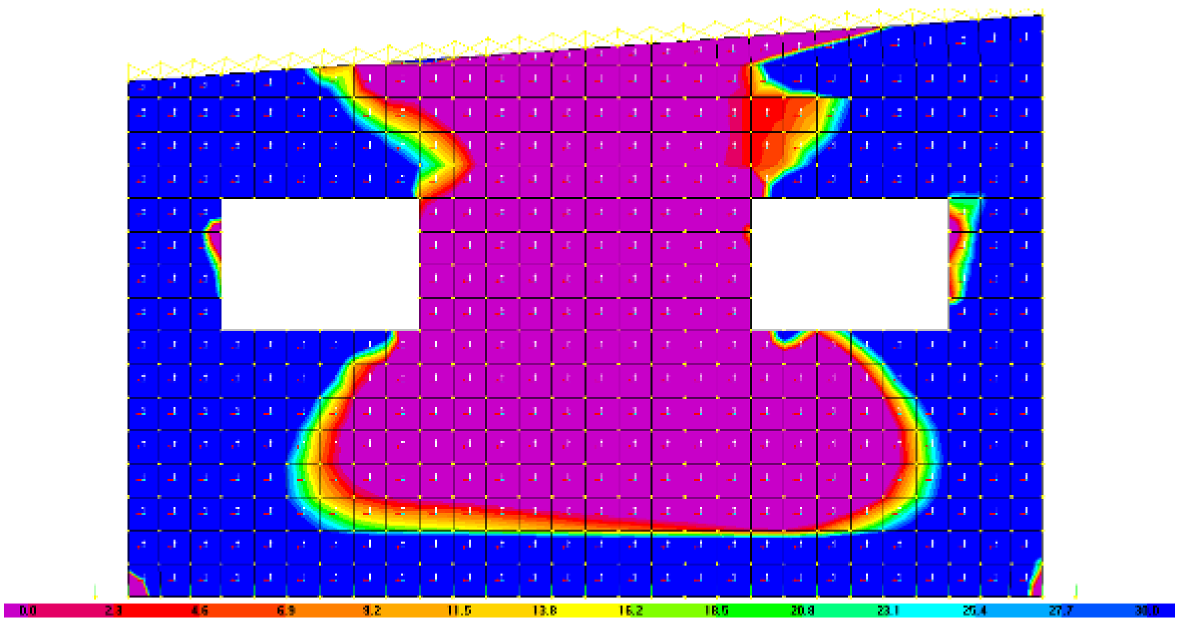


Figure 7a: Smax (lateral loads)

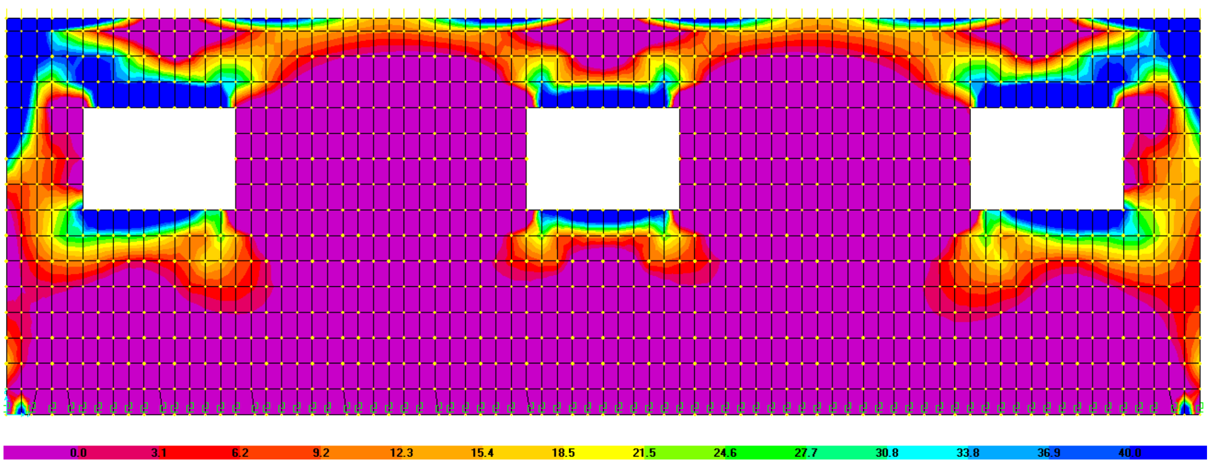


Figure 7b: Smax (lateral loads)

Reviewing field study outputs and analysis outputs showed an accepted level of compatibility between both of them. Consequently both of them have been considered to perform a parametric analysis to study parameters significance. Outputs of the parametric study could be summarized as follows. The most significant parameter concerning cracking is the use of boulders, where 35% of the investigated buildings were constructed by boulders and they all showed a high level of resistance towards cracking, this could be attributed to two factors, the first is the higher strength of boulders relative to bricks, while the second could be due to the irregularity if boulders interfaces that make crack propagation difficult. The second significant parameter is the natural ground level profile, where 21% of the investigated buildings were built on a sloping ground or at the edge of a slope. All these buildings suffered inclined cracking exceeding 5 mm width. The third significant parameter is soil formation, where 57% of structural failure took place in clayey soils, putting into consideration that clayey soils represent 57% of the investigated buildings sub-base. The forth significant parameter is applied loads, where lightly loaded buildings (steel or timber ceilings) did not show any failure patterns. Other parameters as interference with ground water table and the presence of adjacent structures seems to be insignificant.

A comparison has been conducted between field study and structural analyses. This comparison concentrated on location of relatively high tensile stresses, resulting from structural analysis and cracking, noticed in field investigation. Figure 8 shows door cracking at location of maximum tensile force due to gravitational loads, which is compatible with figure 5a. Figure 9. Shows windows cracking at the location of maximum tensile stresses, which is compatible with figure 5b. Figure 10 shows lateral earth pressure resulting from natural embankment reaching windows. This earth pressure resulted in tensile stresses shown in figures 7a and 7b and appeared in the form of cracking shown in figure 11

Figure 8: Door cracking (gravitational loads)

Figure 9: Window cracking (gravitational loads)

Figure 10: Windows Earth pressure loads

Figure 11: Window cracking due to earth pressure loads

5 CONCLUSIONS

Field and analytical studies resulted, concurrently, in the following conclusions:

- Bearing walls, built by boulders showed much more durability than those by bricks.
- Natural ground inclination has a highly passive influence on bearing walls failure.
- Lightly loaded ceilings (timber or corrugated sheets), results in no structural cracking, in case of proper foundations.
- Foundation submergence in ground water table does not influence bearing wall failure significantly.
- Most long-term cracking takes place in non-granular soils

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