A PROPOSED METHODOLOGY FOR SEISMIC EVALUATION AND STRENGTHENING OF EXISTING SCHOOL BUILDINGS IN THE SUDAN

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SUMMARY:
The evaluation of seismic performance of existing school buildings has received a great attention in the last decade. A common engineering practice in The Sudan not to consider earthquake effects in the design of all buildings. Therefore, all school buildings in The Sudan are not earthquake-resistant. The objective of this paper is to assess the seismic performance of existing school buildings in The Sudan. Two typical case studies have been chosen for this purpose. The evaluation has proved that the two-story school is not seismically safe. A comparative study has been done to choose a suitable strengthening method. An effective method has been proposed by adding steel shear walls.

Keywords: Evaluation, Strengthening, School buildings, Seismic, The Sudan

1. INTRODUCTION

Schools play a vital role in the community. They are not only the places where students learn and teachers teach; they are also used for social gatherings, theatre and sports. In addition, school buildings play an important role in responding to and recovering from natural disasters. In the event of an earthquake, hurricane or flood, schools can serve as emergency shelters and, as such, can be used to house, feed and care for the local population.

The Sudan is not free from earthquakes. It has experienced many earthquakes during the recent history, and the previous studies in this field demonstrated this argument. This paper is an attempt to study the effect of seismic loading on school buildings in The Sudan.

2. DESCRIPTION OF STUDY CASES

Two study cases are considered. The first case is a typical one-story model for elementary schools in The Sudan while the second represents a typical two-story model for secondary schools. Both buildings are comprised of a reinforced concrete structural frame with infill masonry walls. The structure members are made of in-situ reinforced concrete .The overall plan dimension is 28.5x36.5m. Height of the building is 3.5 m .The floor is a beam supported solid slab system. Figure 1.gives detailed information on the structural and architectural layout of both schools.

3. CURRENT DESIGN

It is a common practice in The Sudan to design buildings without any consideration of seismic loads. Therefore, the two typical school buildings have been studied first under the effect of gravity loads and without consideration of seismic loads in order to check the current design. Dead and live loads are following the rules given in the (BS 8110, 1997).

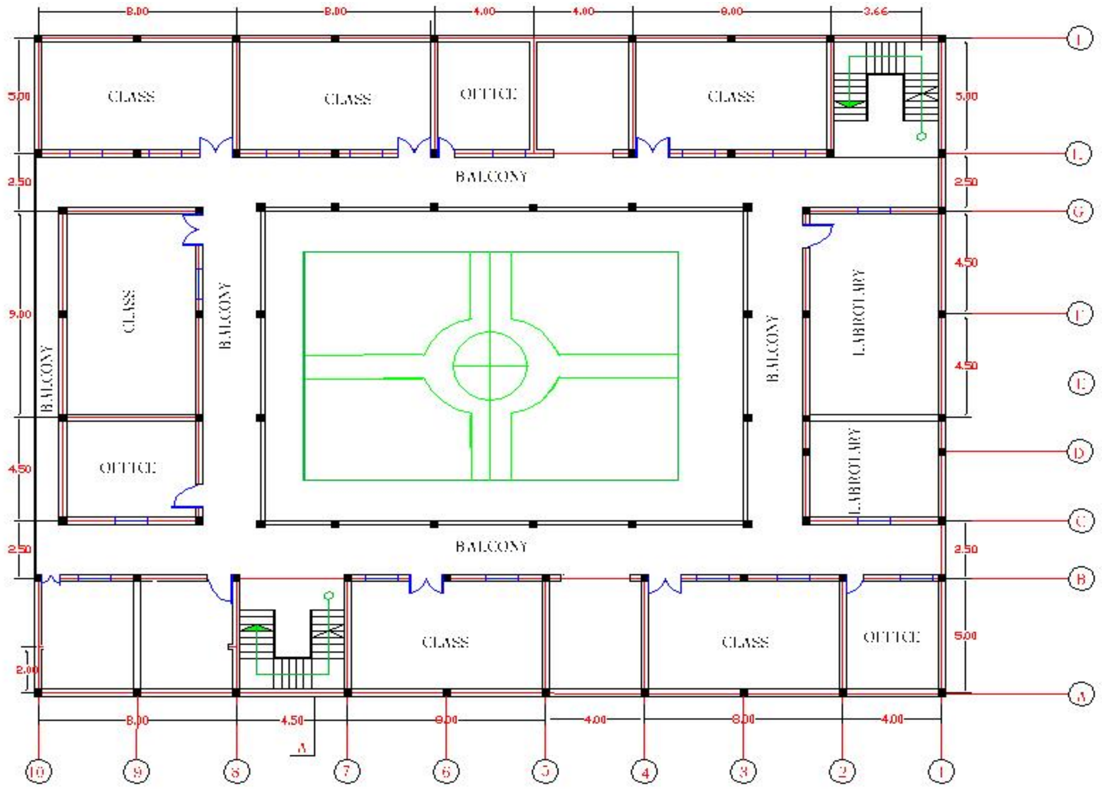

Figure 1. Plan of school buildings considered

3.1 Numerical model

Numerical models for the two studied cases have been prepared using SAP2000 version 10 (Computers and Structures , 2001). Beams and columns are modeled as beam elements while walls are modeled with shell elements.

Figures 2 and 3 show the models for the one-story and two-story buildings, respectively. The layout of columns is the same for both models and shown in Figure 4.

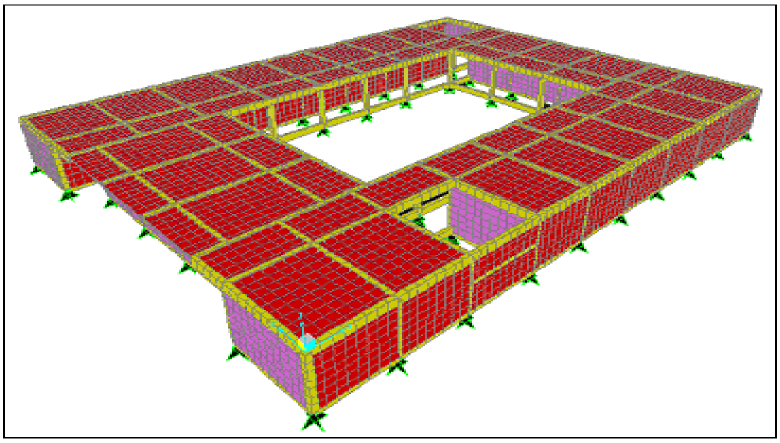

Figure 2. Model of 1-story school building

3.2 Check of design for gravity loads

The internal forces obtained from the computer analysis program SAP2000 are used to design the reinforced concrete sections of the structural elements of the two school buildings using the (BS 8110

, 1997) using the limit state design method (Mosley and Bungey, 1997). It has been found that the existing design of beams under the effect of gravity loads is adequate for the study cases. As for the design of columns the computer program called ISACOL (Shehata, 1999) has been used. A typical result of this computer program is shown in Figure 5 for column number 40 (C40).

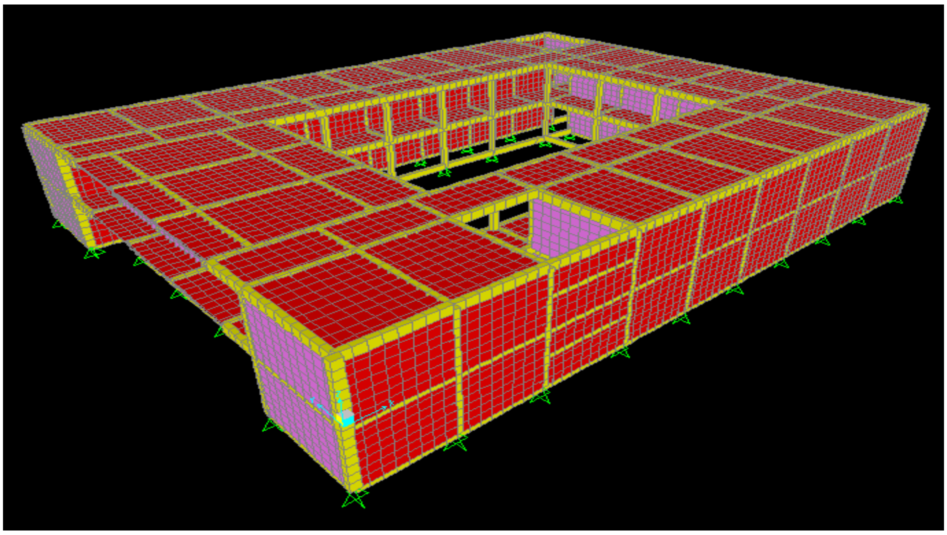

Figure 3. Model of 2-story school building

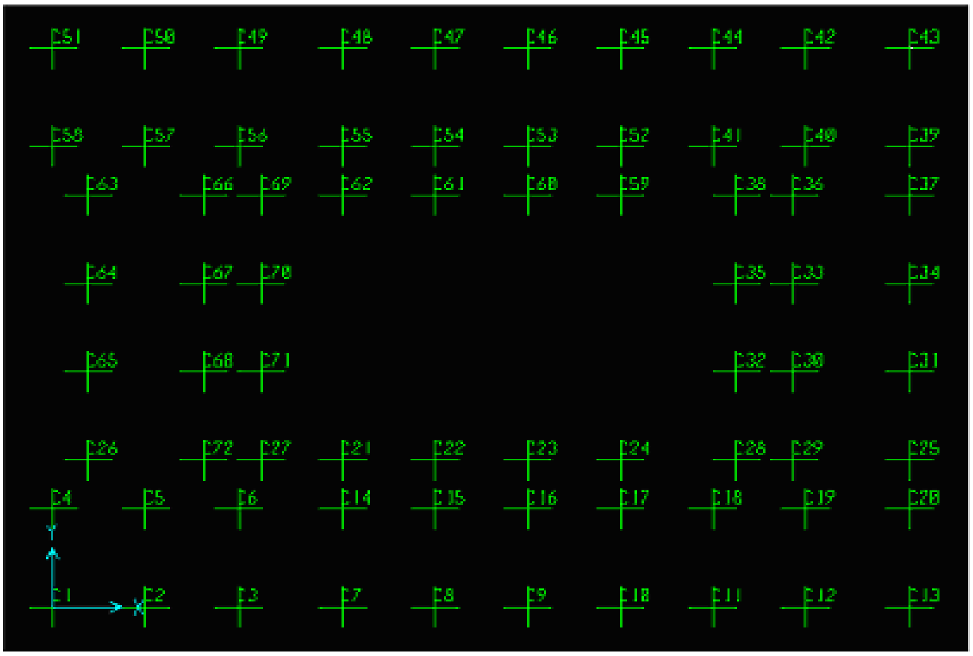

Figure 4. Layout of columns

Table 1 shows the present design compared with the original design of critical columns for the two studied cases. It is clear that the original design of these columns exceeds the present design which means that it is satisfactory for gravity loads.

It is worthy to mention that internal forces in beams of the two study cases have been calculated under gravity loads. Then the (BS 8110, 1997) has been used to check the existing design. It has been found that the existing design is adequate for the two study cases.

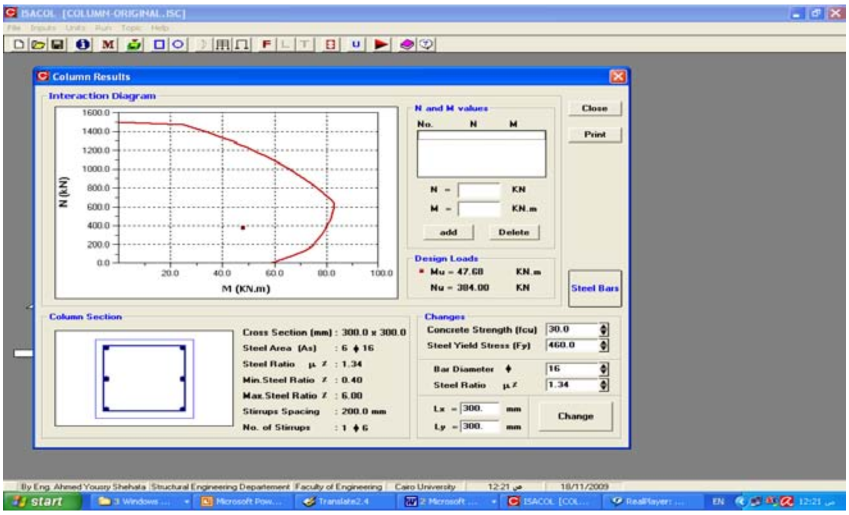

Figure 5. ISACOL program results for column C40

Table 1. Comparison Between Original and Present Design For Gravity Loads

Column No.	First Case Study				Second Case Study			
	Original Design		Present Design		Original Design		Present Design	
	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.
C40	300x450	8 Φ 16	300x300	6 Φ 16	300x450	8 Φ 16	300x400	6 Φ 16
C68	300x450	8 Φ 16	300x300	6 Φ 16	300x450	8 Φ 16	300x400	6 Φ 16
C72	300x450	8 Φ 16	300x300	6 Φ 16	300x450	8 Φ 16	300x400	6 Φ 16

* Section dimensions are in mm.

3.3 Check of design considering earthquake loads

3.3.1 Earthquake loads

It is well known that The Sudan has no regulations for the seismic design of buildings. Therefore, in the present paper earthquake loads are calculated following the rules which are given in the Regulations for earthquake resistant design of building in Egypt, (ESEE, 1988). These regulations have been prepared by the Egyptian Society for Earthquake Engineering (ESEE).

In order to apply the ESEE regulations a seismic map for The Sudan is required to determine the site seismicity factor. In 2009, Hassaballa et. al. developed a new seismic maps for The Sudan (Hassaballa et al, 2009) , as shown in Fig.6.

3.3.2 Check of design for study cases

Numerical analysis for the study cases have been performed using SAP2000 (Computers and Structures, 2001) and the reinforced concrete sections are designed according to the (BS 8110 , 1997) using the limit state design method (Mosley and Bungey, 1997).

Tables 2 and 3 show comparison between original and present design including seismic loads for first and second study cases, respectively. It has been found that all columns in the first study case are safe when considering earthquake loads, whereas some columns in the second study case are unsafe.
Therefore, a strengthening scheme is needed for the two-story school building in order to resist earthquake forces.

4. PROPOSED STRENGTHENING METHOD

There are different methods for seismic strengthening of existing buildings. However, social and economic conditions should be considered to choose the appropriate method. Adding structural walls is one of the most common structure-level retrofitting methods to strengthen existing structures. This approach is effective for controlling global lateral drifts and for reducing damage in frame members. Structural walls may be either reinforced concrete or steel plate. The addition of steel plate shear wall (SPSW) has gained recent interest (Abolhassan, 2001).

Table 2. Comparison Between Original and Present Design Including Seismic Loads For First Study Case

Column No.	Seismic Loads in direction (x)				Seismic Loads in direction (y)			
	Original Design		Present Design		Original Design		Present Design	
	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.
C40	300x450	8 Φ 16	300x350	8 Φ 16	300x450	8 Φ 16	300x350	8 Φ 16
C68	300x450	8 Φ 16	300x300	6 Φ 16	300x450	8 Φ 16	300x350	8 Φ 16
C72	300x450	8 Φ 16	300x350	8 Φ 16	300x450	8 Φ 16	300x350	8 Φ 16

* Section dimensions are in mm.

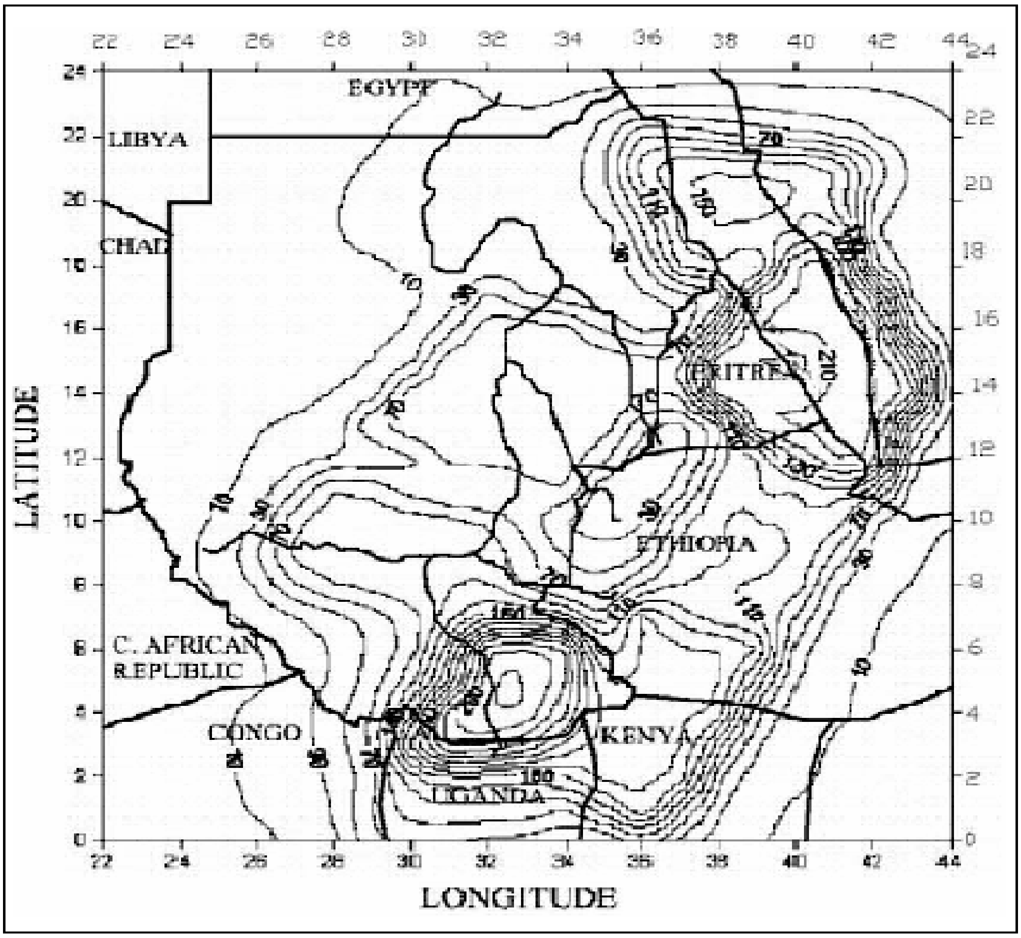

Figure 6. Zoning Map of The Sudan (Hassaballa et al, 2009).

Table 3. Comparison Between Original and Present Design Including Seismic Loads For Second Study Case

Column No.	Seismic Loads in direction (x)				Seismic Loads in direction (y)			
	Original Design		Present Design		Original Design		Present Design	
	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.
C40	300x450	8 Φ 16	300x550	12 Φ 16	300x450	8 Φ 16	300x550	12 Φ 16
C68	300x450	8 Φ 16	300x500	10 Φ 16	300x450	8 Φ 16	300x550	12 Φ 16
C72	300x450	8 Φ 16	300x500	10 Φ 16	300x450	8 Φ 16	300x450	10 Φ 16

* Section dimensions are in mm.

4.1 Modeling of Steel Shear Walls

The steel plate shear walls can be modeled using full shell elements and isotropic material. It is suggested that the wall panel be modeled using at least 16 shell elements (4x4 mesh) per panel (Abolhassan , 2001). The lateral force resisting system consists of moment resisting frames with steel plate shear walls. The school building of the second study case is analyzed for gravity and seismic loads as previously explained, i.e., using SAP2000 structural analysis software package (Computers and Structures, 2001), British standard code (BS 8110 , 1997) , and ESEE -Regulations ((ESEE , 1988).

4.2 Comparative Study

Five cases of different positions for the shear walls have been examined. Reinforced concrete walls with thicknesses of 20 cm and 25 cm, and metal shear walls with thicknesses of 15 mm, 20mm 25mm have been chosen for this case study. Five different positions for shear walls have been suggested as shown in Figures 7-11.

The following results have been obtained:

1- For the first four cases and using the shear walls of concrete and steel, with different thicknesses indicated that some columns in both directions x and y are still not safe.
2- The results of the fifth case when using steel shear walls 25 mm thick showed that all the columns in both directions x and y are safe, as shown in Table 4.

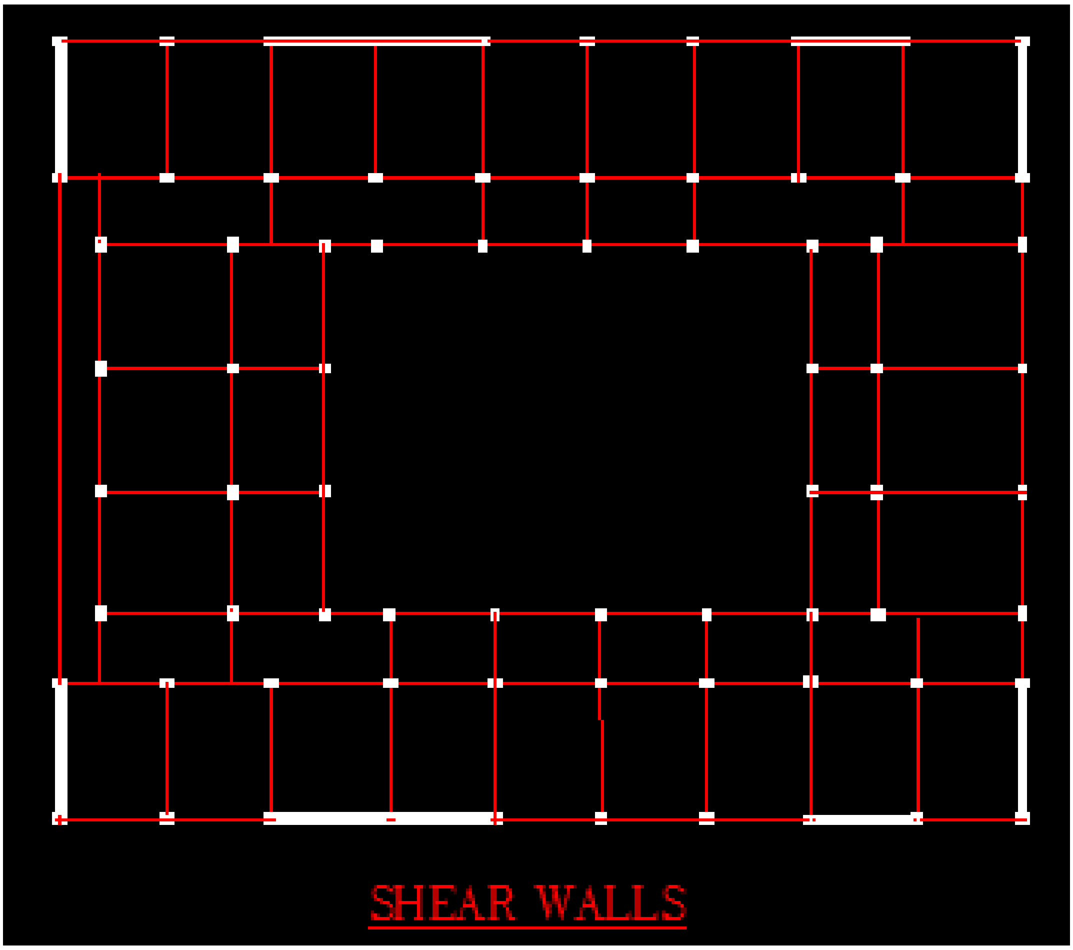

Figure 7. Case one

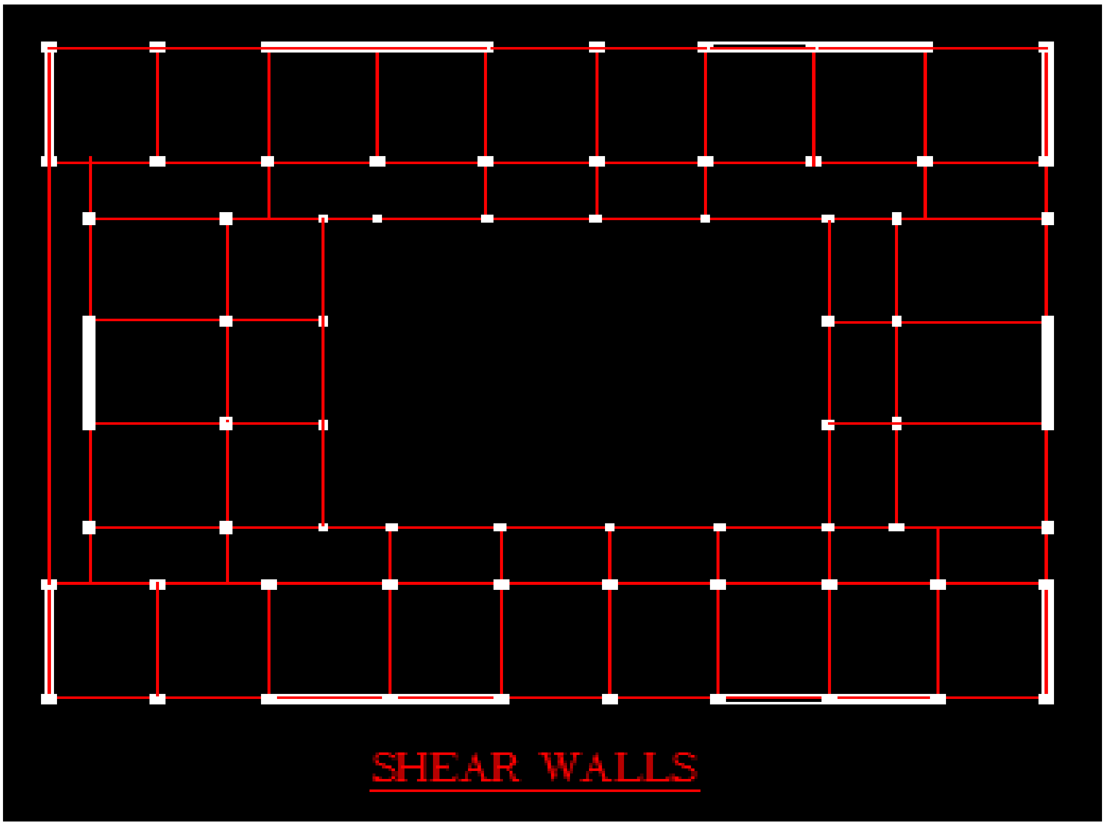

Figure 8. Case two

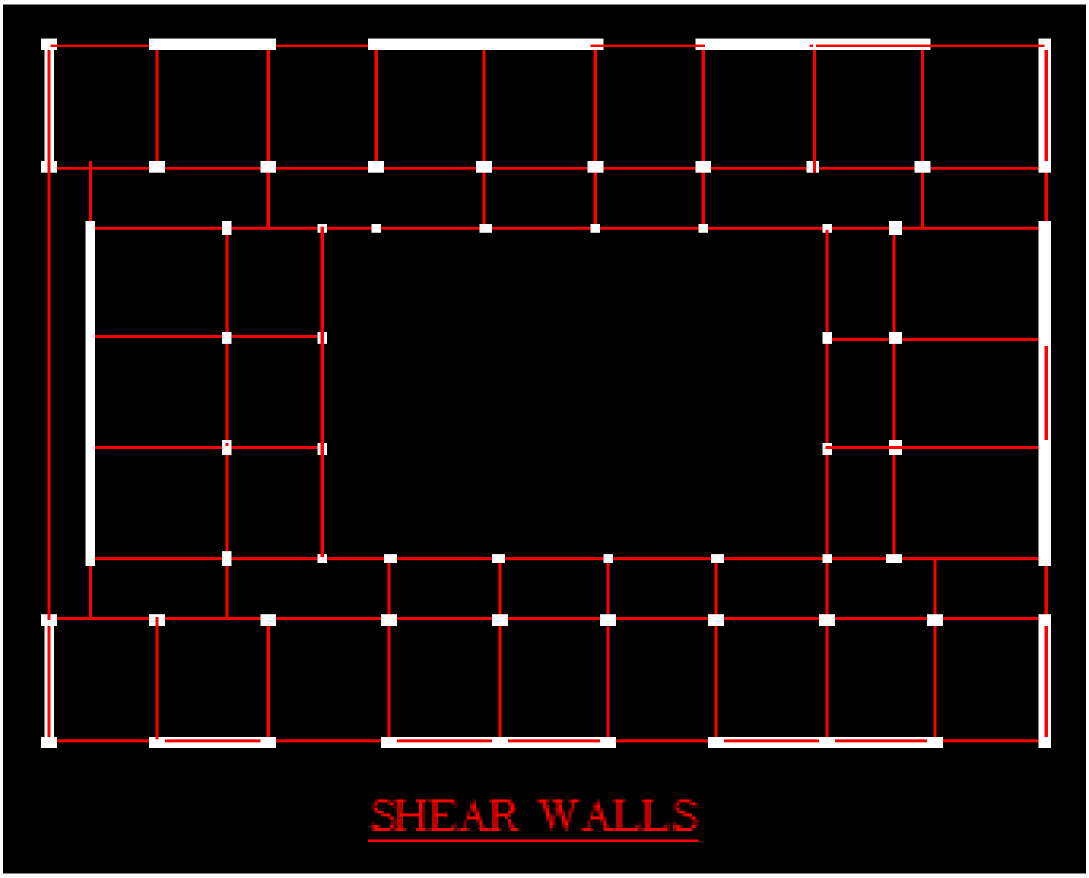

Figure 9. Case three

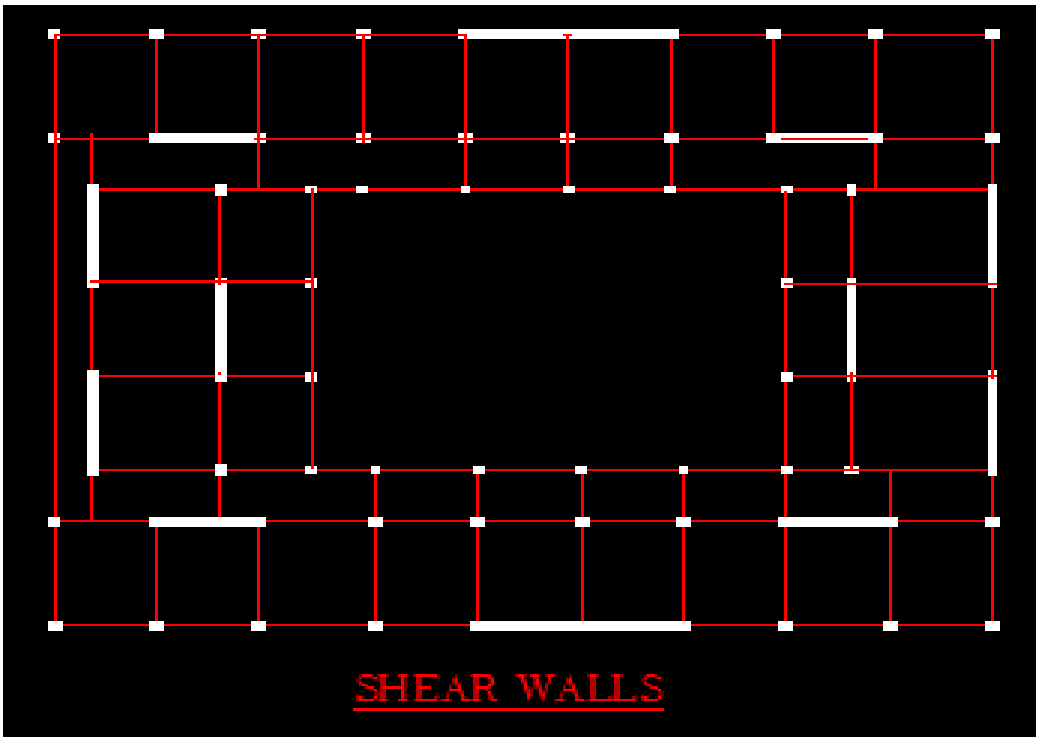

Figure 10. Case four

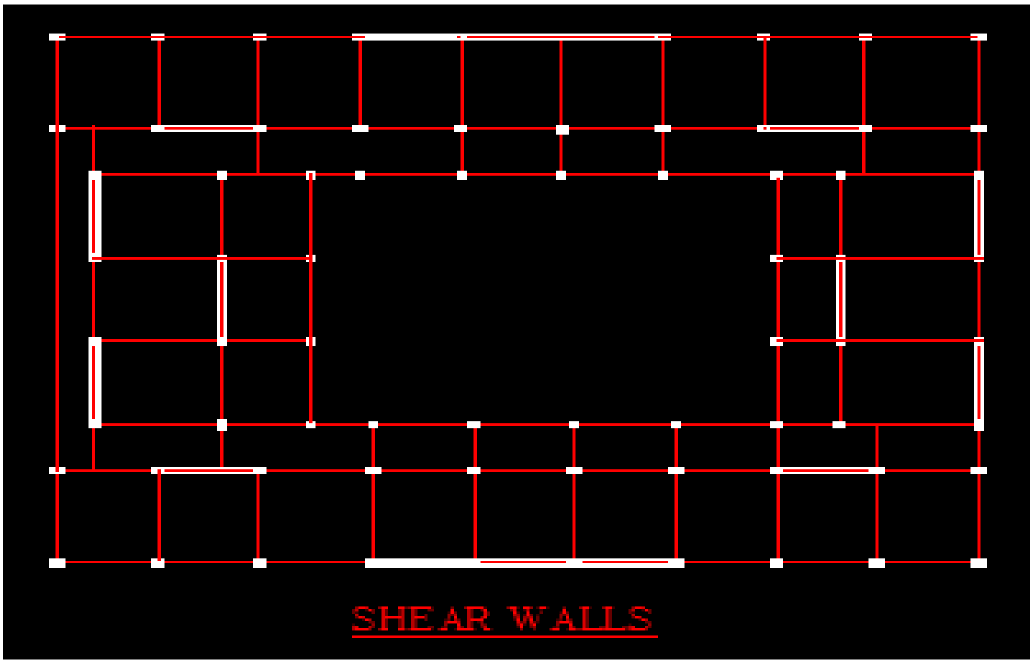

Figure 11. Case five

Table 4. Comparison Between Original and Strengthened Design for Second Study Case

Column No.	Seismic Loads in direction (x)				Seismic Loads in direction (y)			
	Original Design		After Strengthening		Original Design		After Strengthening	
	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.	Section*	Reinf.
C40	300x450	8 Φ 16	300x300	6 Φ 16	300x450	8 Φ 16	300x400	6 Φ 16
C68	300x450	8 Φ 16	300x300	6 Φ 16	300x450	8 Φ 16	300x300	6 Φ 16
C72	300x450	8 Φ 16	300x400	8 Φ 16	300x450	8 Φ 16	300x300	8 Φ 16

* Section dimensions are in mm.

5. CONCLUSIONS

The present study represents the first attempt to investigate the seismic resistance of school buildings in The Sudan. Due to the lack of knowledge about the seismic activity in this country all school buildings are designed and constructed without any seismic load consideration. Seismicity of The Sudan may be considered as moderate. Hence, all school buildings should be checked against earthquake resistance. The present paper proposes a simple procedure to check the seismic resistance of such buildings.

The obtained results emphasize the following conclusions:

1- Current design of school buildings in the Sudan does not consider earthquake loads.
2- It has been found that the current design of school buildings in The Sudan is not safe for the current seismicity of The Sudan.
3- A proposed methodology has been presented for evaluation of seismic resistance of existing school buildings in The Sudan.
4- A strengthening technique for existing school buildings has been presented. It has been proved that shear metal panels actually represent a very suitable strategy to reduce the seismic vulnerability of exiting (RC) school buildings in The Sudan.

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