

The Provision of Rescue / Safety Cores in Multi-storeys Buildings, Against Major Earthquakes

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Abstract— In countries with "traditional" catastrophic events due to hurricanes or typhoons shelters are provided, but they generally occur in either low-rise buildings, single family - in basement areas or even to smaller communities. There are some items and materials for a period of survival and of course there are so varied range of shelters, made by different companies, with different prices.

For single-family houses, villas type can easily be made conformable projects such shelters or safe rooms, including their use in case of an earthquake, but what can be done in the higher buildings case?

Based on a personal idea, a similar safety room variant, usable for multi-storey buildings (and so in each apartment, at every level), is presented in this paper for use in earthquake cases.

Keywords— shelter, safety, ductility, plastic hinges, cores

I. Introduction

Most times, when we are witnessing a major seismic event, under more or less panic, we want to find as soon as possible the safest place in the house, in general, not only for us but especially for entire our family. And even if we are civil engineers, knowing that anytime a high intensity earthquake (greater than so-called "design earthquake") may occur, we never feel completely safe and comfortable.

From Japanese experience we should realize the need of a "security package" (including small stocks of food, water, medicine, light sources and batteries, radios, clothing, mobile phone or radio transmitting station) ... but how many of us take into account the everyday reality? Also, important documents, values, are often located in areas "as safe" as the whole house and rarely safer.

Naturally the question arises: who would be the advantage of this kind of safe room, designed to remain intact in the event of a major earthquake, if otherwise the whole building will collapse?

Therefore, the next step was thought a superior alternative – would you have these safe rooms in each apartment, located on the same vertical within certain "safe cores" to be essentially "decoupled" from the rest of the structure complete resistance?

Such safety cores made of reinforced concrete structural walls were considered, with their own foundations, with own floor slabs (at each level) with a separate electricity production (a generator in the basement) with a space designed to meet the functional needs of minimal and simplistic safe space designed to provide a perfectly elastic range behavior in the event of earthquakes with higher intensity than the "design earthquake", so that even if the building (correct designed for an elastic-plastic behavior, for the a "design earthquake") is significantly damaged, with partial/local or general collapse – the safety cores will remain "standing" (so that the occupants life to be maintained for a period sufficiently long to be mobilized reaction forces after the Earthquake).

A minimal compliance space arranged at each level for a safety core is shown in Figure 1.

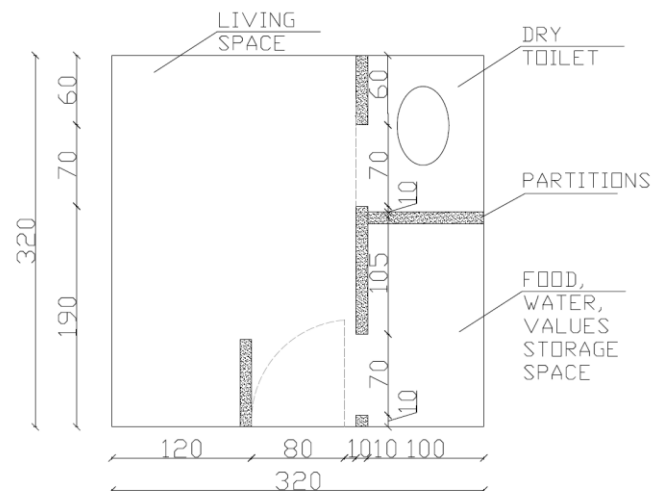


Figure 1. Example of a minimal safe room conformation.

II. Case Studies to Determine the Behavior of Buildings Equipped With Rescue or Safety Cores

A. Establishing the research plan

In this paper only the studies of RC frame structure buildings will be presented, for three different heights of the buildings (5, 10 and 15 levels). In accordance with EC8 [8] two peak ground accelerations were used – 0.30g for the main buildings (excepting the existence of safety cores) respectively

0.30g and 0.40g for the existing buildings together with safety cores.

The safety cores were designed for the 3 height levels so if we have the buildings originally located in an area with $PGA=0.30g$ it can remain in elastic stage including two levels of seismic intensity above. In our case $PGA=0.40g$.

B. Buildings structural data

We established the permanent load on the floor slabs (excluding the self-weight of their which is automatically considered by ETABS [4], uniformly distributed loads on beams, the walls closing facade and interior partitions; the structural elements were predesigned as follows (reinforced concrete frames for $PGA=0.30g$ and safety cores for $PGA=0.40g$). [1]; [2]; [3]; [7]

The following main stages of calculation were established:

1st Phase:

- After the predesign of structural elements were performed according to the method EC8 A method, in order to determine the vertical and horizontal structural reinforcement of RC frame type structures (without consideration of safety cores) for $PGA=0.30g$; for all level heights;
- Calculations were performed according to the method A of EC8 in order to determine the reinforcement in the RC safety cores for an elastic behavior including $PGA=0.40g$; for all level heights.

2nd Phase:

- Static biographical nonlinear calculations (pushover analyses) for buildings with RC frame structure were performed for all level heights without considering the contributions of RC safety cores;
- It may consider a sufficiently large gaps between the main structure and the RC safety cores treated so that no pounding occur between structural elements (structural frames) and the safety cores.

3rd Phase:

- Static biographical nonlinear calculations (pushover analyses) for buildings with RC frame structure were performed for all level heights with consideration of the contributions of RC safety cores - they are connected to the structure by means of special devices to mitigate poundings (ALGA - STU200-50), presented in the followings chapters and modeled as a link type GAP (working only in compression and not tension).

To avoid the poundings between the main buildings and safety cores were chosen devices made by ALGA Company in Italy, which has great experience for decades in dampers, including seismic base isolators, dampers, etc. [12]

Based on [6], [9], [10], [11] and [13] the following results were obtained:

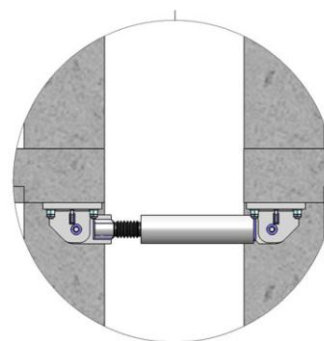


Figure 2 – Alga device for pounding avoidance

TABLE I – STRUCTURAL ELEMENT DIMENSIONS

5 storeys	10 storeys	15 storeys
Structural elements dimensions		
25x60 cm beams		
Floor slabs 15 cm thickness		
Corner columns [cm]		
60x60	75x75	90x90
Marginal columns [cm]		
60x60	75x75	90x90
Central columns [cm]		
60x60	85x85	100x100
Safety cores thickness [cm]		
40	45	50

C. Structural system responses from nonlinear biographical static analyses (pushover)

TABLE II - 1ST CASE STUDY – 5 STOREY MAIN BUILDING – WITHOUT SAFETY CORES:

Formwork plan	ETABS plan

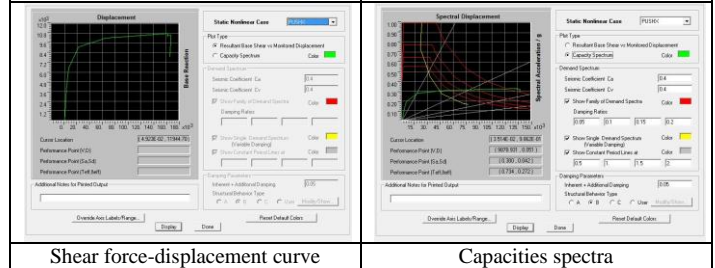
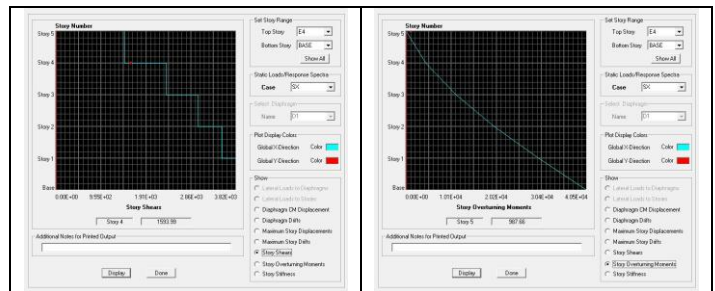
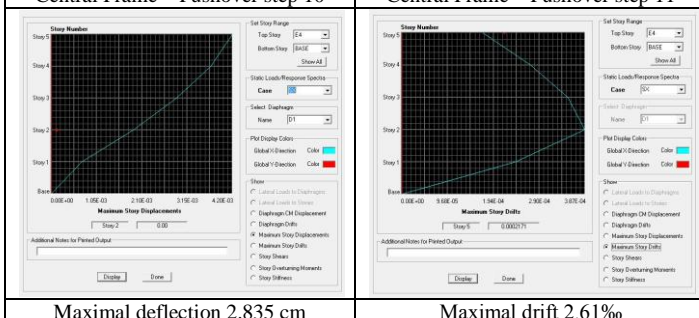
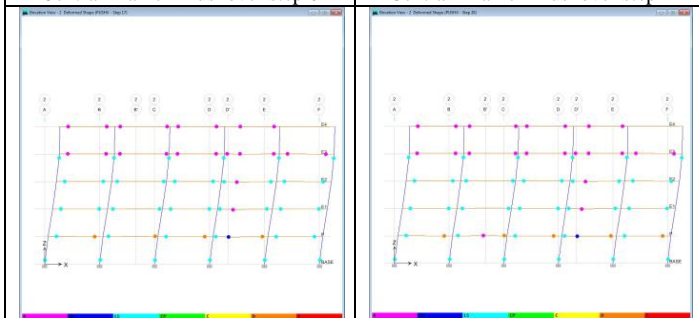
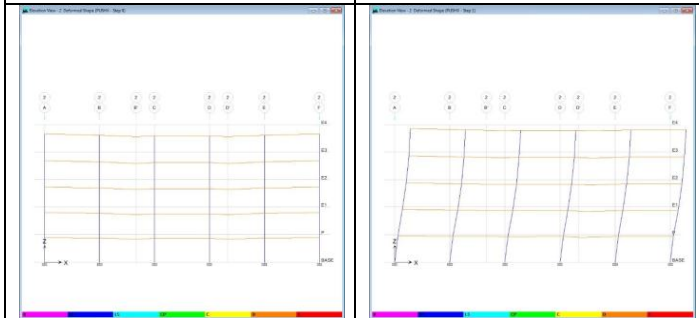
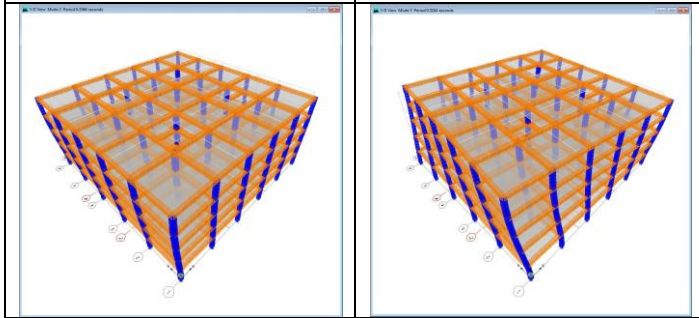
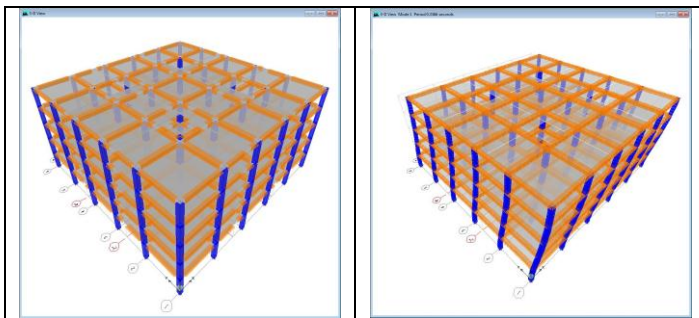
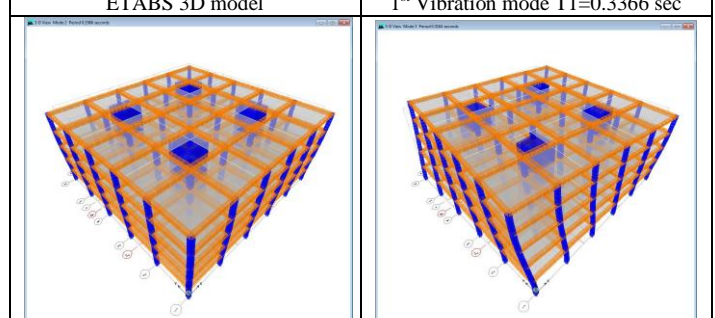
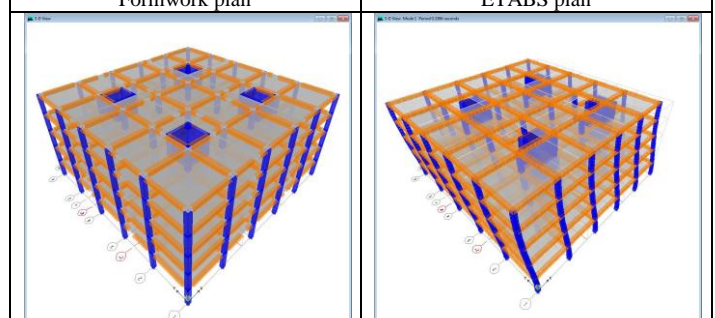
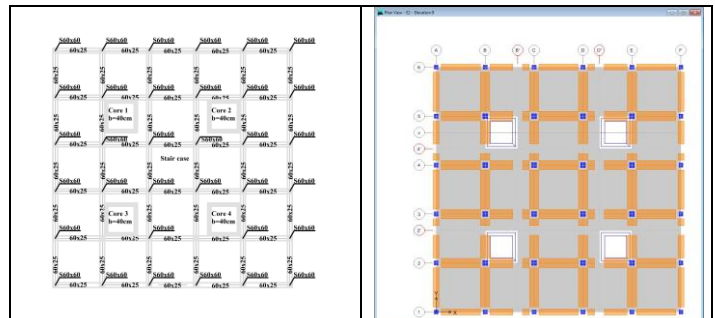
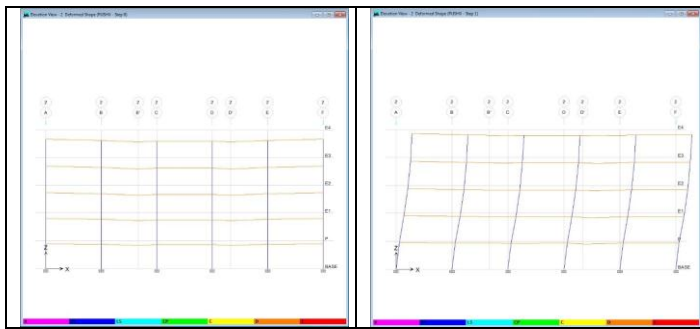


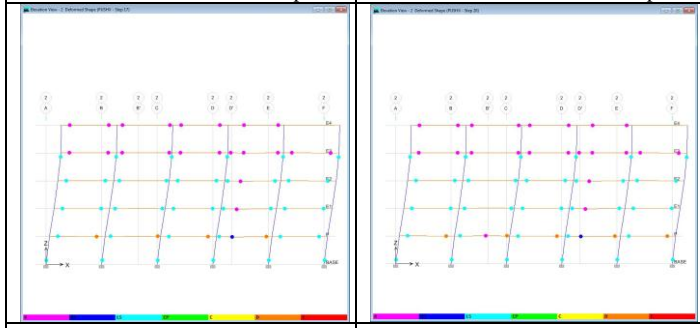
TABLE III – 2nd CASE STUDY – 5 STOREY MAIN BUILDING – WITH SAFETY CORES:





Central Frame – Pushover step 0

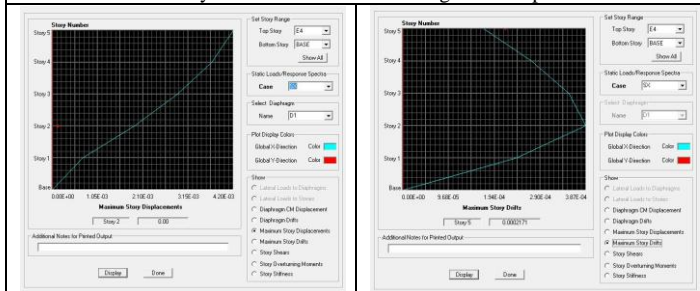
Central Frame – Pushover step 1



Central Frame – Pushover step 12

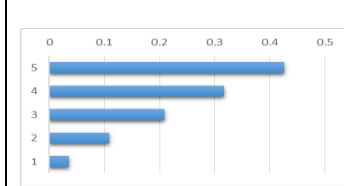
Central Frame – Pushover step 13

The safety cores remain in elastic range – so no picture

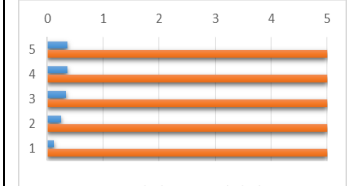


Maximal deflection 2.835 cm

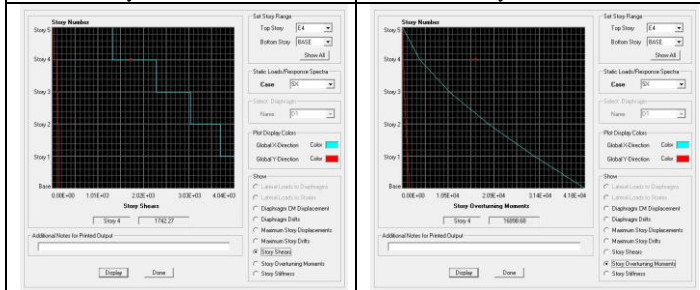
Maximal drift 2.61%



Safety cores deflection

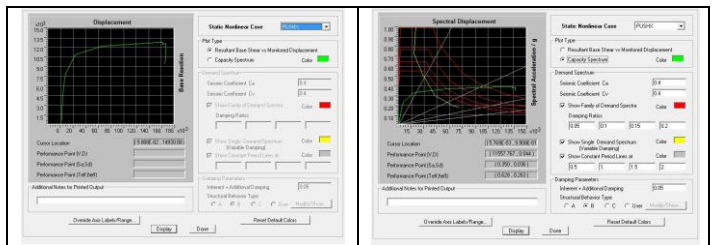


Safety cores drifts



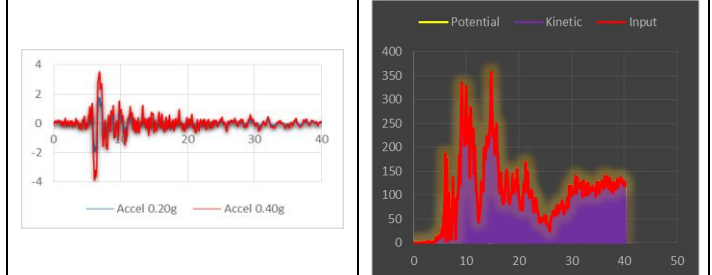
Shear forces – maximal 4040 kN

Overturning moments maximal 41800kNm



Shear force-displacement curve

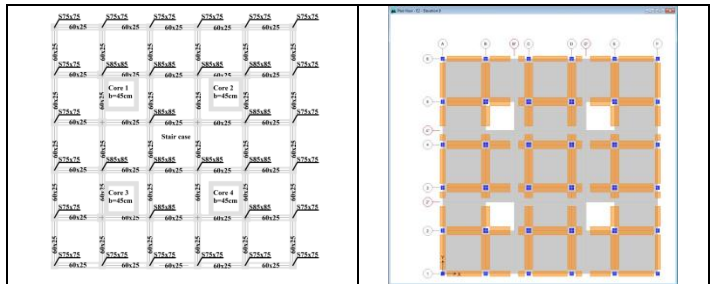
Capacities spectra



Vrancea NS 1977 accelerogram

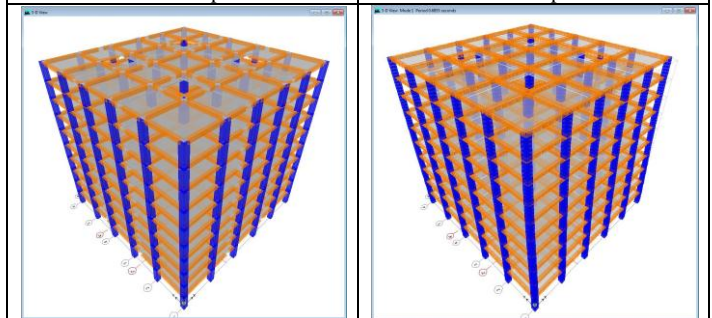
Energy Time History

TABLE IV – 3rd CASE STUDY – 10 STOREY MAIN BUILDING – WITHOUT SAFETY CORES:



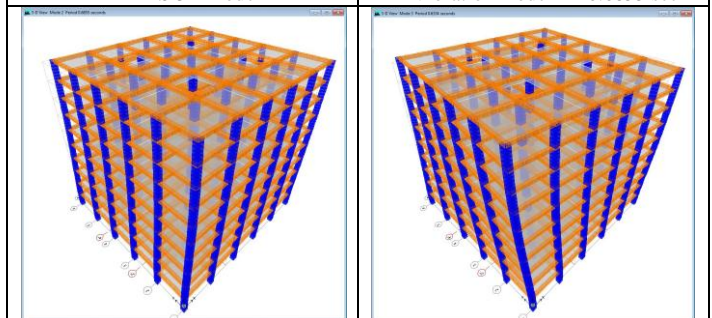
Formwork plan

ETABS plan



ETABS 3D model

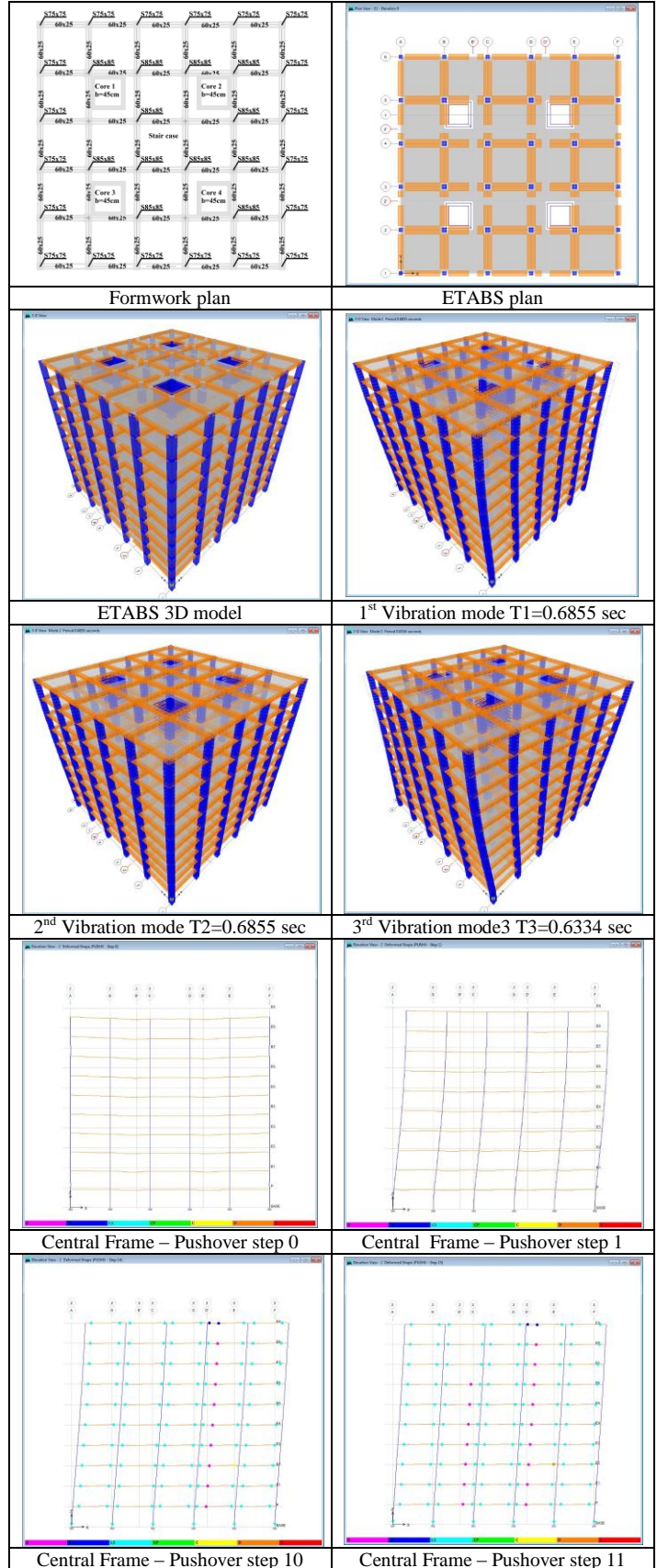
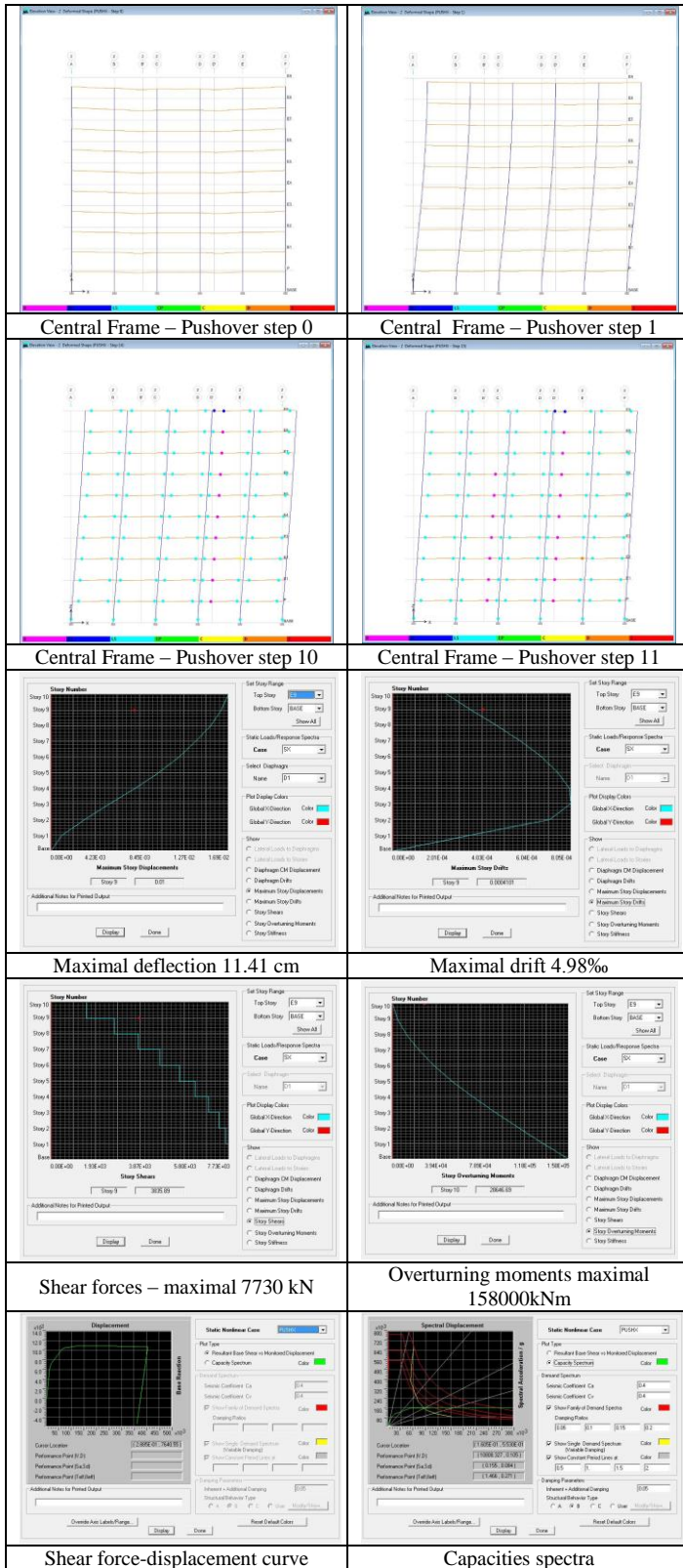
1st Vibration mode T1=0.6855 sec



2nd Vibration mode T2=0.6855 sec

3rd Vibration mode T3=0.6334 sec

TABLE V – 4th CASE STUDY – 10 STOREY MAIN BUILDING – WITH SAFETY CORES:



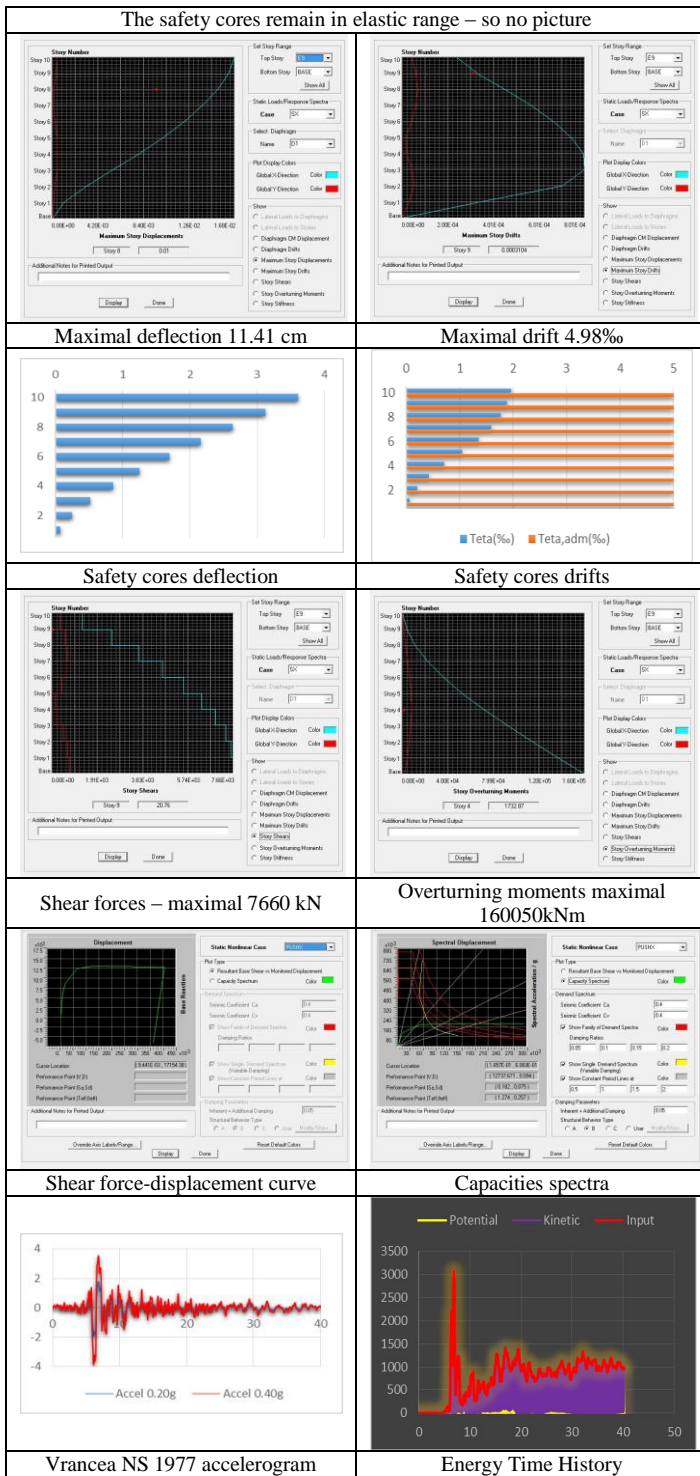
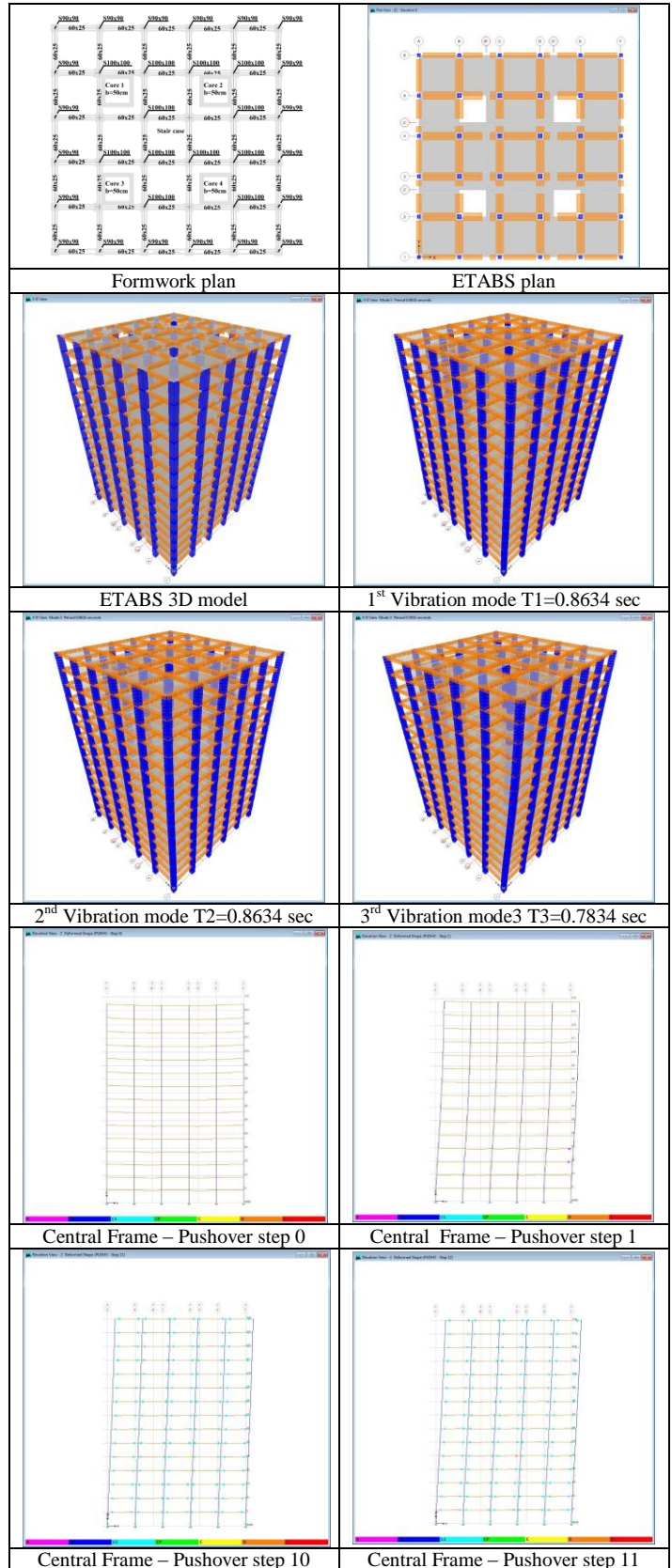
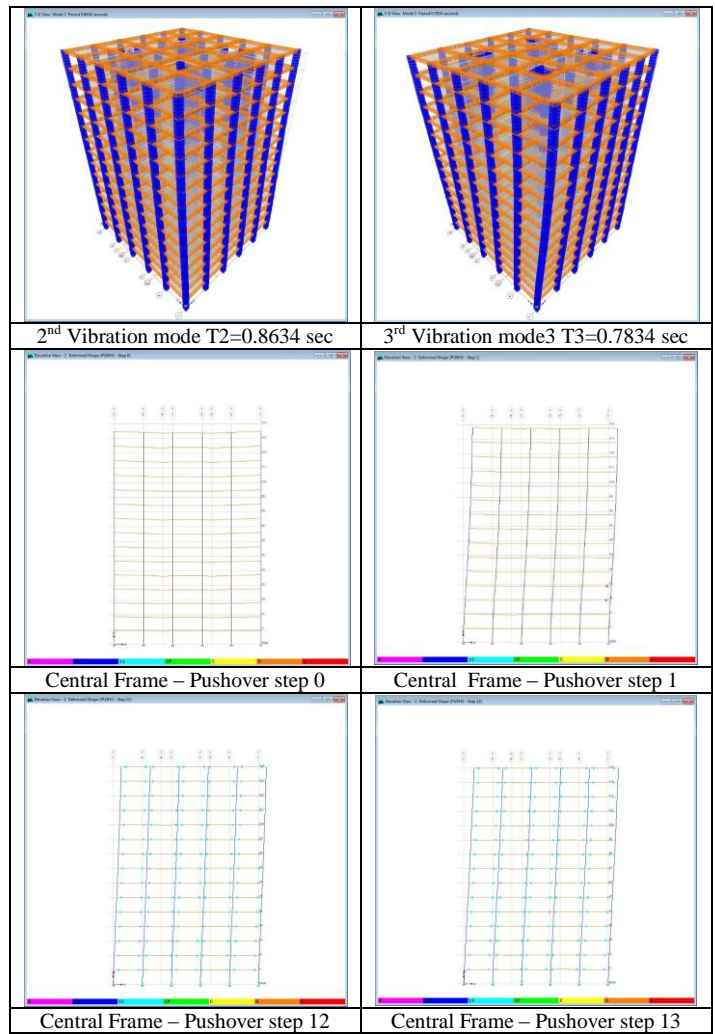
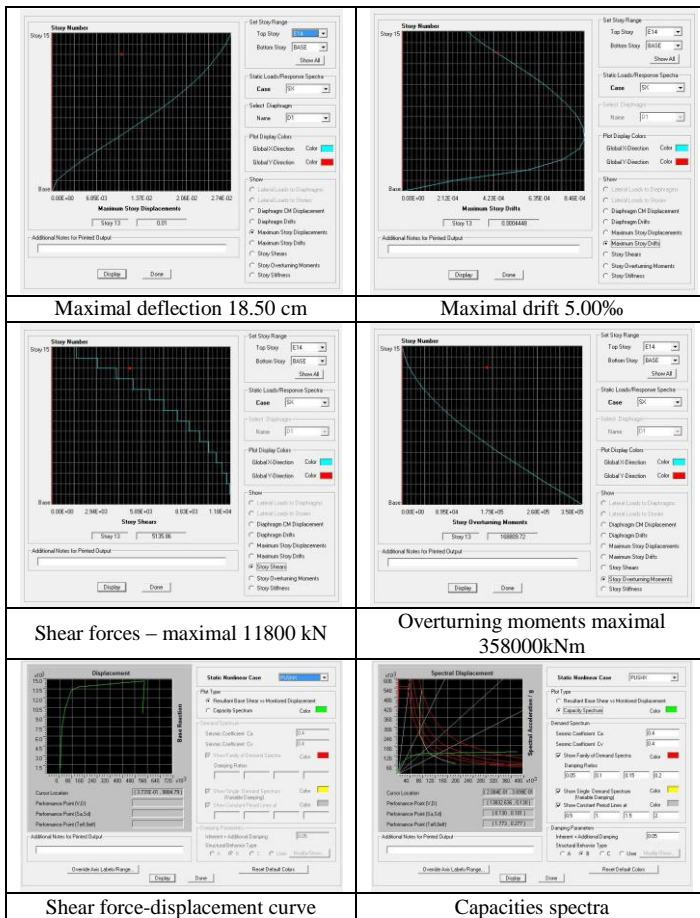


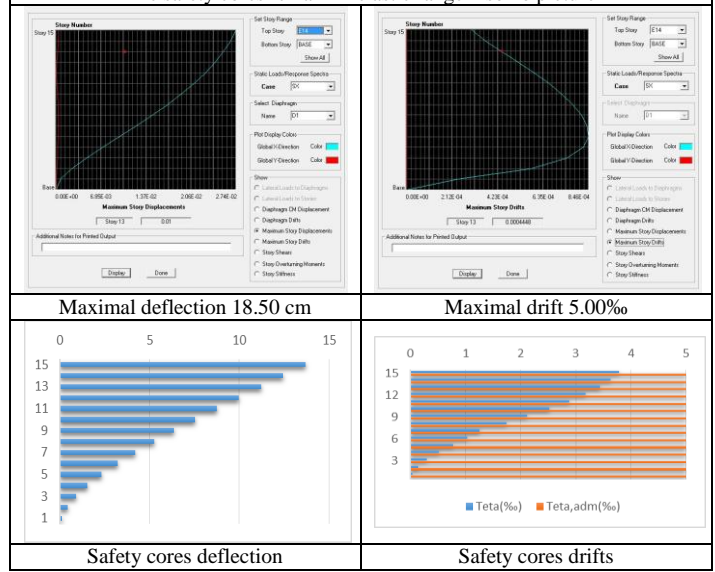
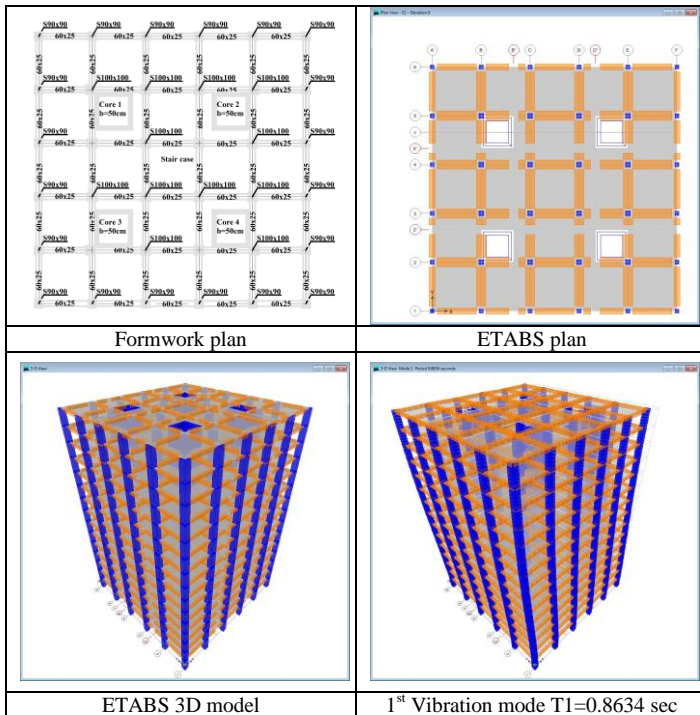
TABLE VI – 5th CASE STUDY – 15 STOREY MAIN BUILDING – WITHOUT SAFETY CORES:

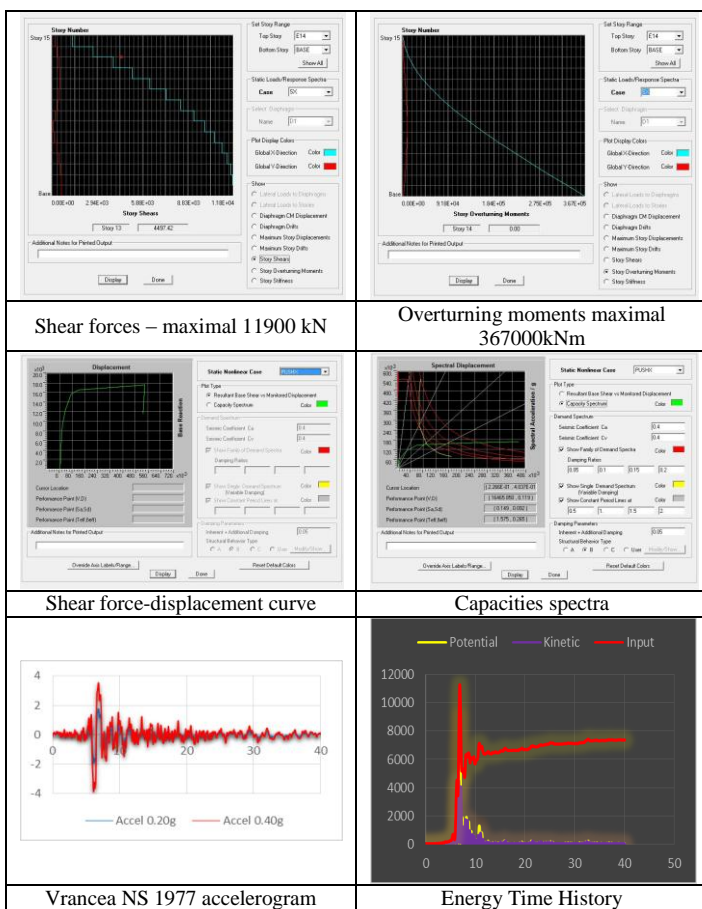




The safety cores remain in elastic range – so no picture

TABLE VII – 6th CASE STUDY – 15 STOREY MAIN BUILDING – WITH SAFETY CORES:





III. Conclusions

From all the studied cases the followings were obtained:

TABLE VIII – MDOF CAPACITY CURVES

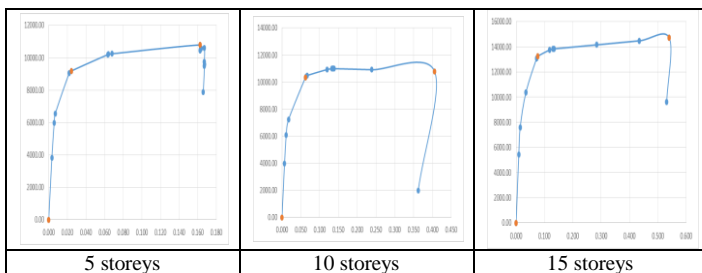


TABLE IX – CAPABLE DUCTILITIES FOR MAIN STRUCTURES

Structure	Ultimate displacement [m]	Yielding displacement [m]	μ_d
5 storeys	0.163	0.025	6.64
10 storeys	0.406	0.062	6.50
15 storeys	0.540	0.077	7.03

- The linear and nonlinear static analyzes found that the structures of the initial buildings were properly designed;
- It observed that an earthquake is considered superior (PGA=0.40g) than the design earthquake (PGA=0.30g)

some plastic hinges appear also in other areas of the main structure columns not only at the base (given that it is considered that all previous assumptions are correct design and after execution);

- It is easily to find that in these cases, the safety cores remain in the elastic range;
- The main conclusion is that this paper has achieved its intended purpose. We conducted a brief overview of this idea, based on the lack of bibliographic similar data about safety cores and right highlight a general idea from where to start an improvement of this unpatented yet idea.
- Although the assumptions made and the work has achieved its purpose that in the second stage there will be necessary and similar studies for other types of buildings, shapes, including other types of structures (even materials other than reinforced concrete used for the actual structure) height levels, seismic zones;
- The third stage must be the soil-structures interaction analyses;
- It also should be understood further a lot of supplementary series of technical and technological matters.

References

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About Author:



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