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STRENGTH AND STABILITY ASSESSMENT OF EXISTING BUILDINGS IN ISRAEL (COMPDYN 2015)

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Abstract. The Middle East is prone to frequent seismic tremors which affect buildings and civil engineering facilities. New demands of economical nature lead to achievement of larger structures with increased openings and augmented loads. This process affects both the existent and new structures with significant masses which contribute to the development of inertial loads endangering the structure loaded by dynamic effects (earthquake, wind, oscillations, blasts etc.).

The structural safety assessment must take into account the age of the existent building and the future demands previewed by development of the socio-economic conditions. Most of the existent buildings have been erected during the former century. The age of these buildings is close to the life limitation according to the codes. The strength and robustness of the buildings is affected by ageing, corrosion, fatigue etc., so that special attention must be accorded to these buildings to enable them to stand under the loads which might occur. The main goal of the assessment is to avoid occurrence of human or economic losses due to partial or full collapse.

The present work is devoted to the assessment of the strength and the stability of the reinforced concrete buildings according to different levels of assessment enabling the building with nonlinear abilities to stand the previewed seismic and wind excitations, as well as the influence of changes of the temperature.

1 INTRODUCTION

Civil engineering went under significant changes during the last decades. Many improvements have been done concerning the analysis, the structure, materials and the risk definition which endangers the structure. The elements for the modern facilities and commodities lead to new strategies of achievement or to the need to retrofit the existent buildings. The activity to upgrade the buildings and ensuring their stability affects their shape and the structural ability to stand increased loads.

This paper deals with the existent structures and the assessment of their ability to stand the increased loads of the actual demand. The existent structures are the ones built during the last decades and they are residential, cultural, commercial, administrative, communication, industrial, etc. facilities. Since these buildings were designed and erected the demands changed, the codes were improved, new materials are used and new technologies have been provided. But significant money have been invested into these establishments and they must be kept stable for the future. Most of the documentation of these buildings has been lost so that the possibilty to achieve the structural identification of these buildings is almost impossible. Meanwhile the building materials have been changed together with the environmental factors which produce the decay of the materials which did not corrode, calcified or deteriorate a long period during their structural life.

New strategies of ductility provision into new buildings lead to improved abilities of standing the loads which may occur. Reinforced concrete elements have been provided by increased ductility by confining them in specific zones to enable the dissipation of the energy induced by loads of dynamic nature.

The assessment of the structural ability to stand the environmental and physical loads is made according a series of criteria. Among the most common criterion is the age of the structure which involves the codes used at a certain period, the designer which provided the project and the builder which erected the building. Non-destructive tests enable to verify the strength and the stability of a certain structure. The data provided by a series of investigations lead to model the structure and check the structural behavior of the building.

Due to the demands of the structures prone to increased load due to the actual technologies and the dynamic effects due the earthquakes, which might occur, an intense trend of retrofitting the actual structures to increase their strength and stability capacity to the level provided by the actual codes.

2 THE STRUCTURAL ASSESSMENT

Engineers, designers and researchers devote large amount of time to study the causes leading to structural decay. The aim of this activity is to preserve the existing structures and to ensure their stability under the occurring loads. This activity is motivated by economical demands due to the necessity to provide residence and work opportunity for an increasing population with more demands and providing housing for modern technology.

Modern building industry [1] is based on updated codes which enable increased residential areas by achieving higher, more storied buildings with abilities to stand strong winds, temperature effects and other outstanding loads, among them earthquakes. All the mentioned effects may damage both the existent and the newly achieved buildings. The codes have been updated to provide improved materials, better methods of analysis and dissipative solution to diminish the energy penetrating into the structures.

Among the modern solutions which decrease the deformation effects of the structure [2] the piled-raft solution has been developed aiming the diminishing of the settlements of structures resting on clayey and sandy soils. These soils exhibit rheological behavior for clays and are prone to liquefaction under intense vibrations. The provided piled-raft solution ensures stability under the moisture sensitive soils and provides stability in case of liquefaction phenomena.

Reinforced concrete structures [3] must be enabled to stand against chain failure. The design must be accomplished in a manner to avoid the failure of a structural element sustaining more elements to cease to stand under the loads. Avoidance of the structural progressive failure is very important to ensure the stability of the structure which has to be robust and save the life of its occupants.

One of the ways to improve the structural stability is the use of FRP sheet to provide the confining of the sensitive zones in the structural elements increasing the ductility of the entire structure [4]. Increased ductility means the ability to dissipate more energy from the load acting upon the structure. The strengthened structure will absorb the energy of the load and save the retrofitted structure.

One of the most dangerous loads which might occur during the service of a building must be cnsidered the explosion of the gas used by the inhabitants to warm or to cook [5]. Since the danger of such an explosion to provoke a progressive failure is real it must be taken into account the way to ensure the desired robustness and to enable quick repair in case of the accident.

The ability of the structure to stand under the loads which might occur is judged by means of the assessment of the existent structure [5, 7, 8, 9, 10]. A large variety of scenarios have been provided to check both the existent and new buildings. Assessment can be done according several strategies ranging between the simplest to the most intricate way to obtain the robustness of the structure. The structural model built according the information obtained by various investigative procedures may be analyzed by simple methods or numeric software based on linear to nonlinear means [11]. More accurate results may obtained by monitoring of the structural response of the building under dynamic excitations which can be based on provoked loads or simply using the micro seismic movements occurring in the area. The changes of the registered structural frequencies indicate changes of the structural strengthening or decay with time.

The present work presents the expected decay of a wall due to horizontal loads, temperature changes, creep, corrosion, etc. In the same time there is presented a way to use structural monitoring to judge the structural changes.

3. NUMERICAL EXPERIMENTS

3.1 Causes of structural deterioration

The process of structural deterioration continues during the entire life of the structure. The environmental effects lead to loads which affect the properties of the materials the structure is made from.

The reinforced concrete structures are affected from their cast stage from the creep of the concrete and the relaxation or the reinforcement. These effects enable the formation of cracks and initial stresses which reduce the structural stiffness and contribute to further deterioration of the structure. The cracks enable the penetration of the moisture and Cl ions which affect the concrete and cause the corrosion of the reinforcement.

Temperature changes between seasons and day – night produce stress changes in the structure causing ageing effects leading to fractures in the structural system. Microseisms produce fatigue phenomena affecting the structure. More severe damages are produced by wind, earthquake, traffic and daily loading and unloading.

The phenomena which are exemplified further use the analysis by means the finite elements (ADINA), and the data acquisition by means of the CX1 Network Accelerometer & Inclinometer (SENSR).

3.2 The Dynamic Effects

To exemplify the effect of the horizontal loads on a reinforced concrete wall the ADINA routine was used. The nonlinear behavior was used to follow the deformation, stress - strain behavior and crack development. The structure represents a wall provided by a door opening. The wall was achieved from concrete B30 reinforced by steel F400. The horizontal load was increased gradually till the collapse was achieved. Fig. 1 visualizes the deformation of the wall in x direction (on the left side) and the stresses in z direction (on the right side)

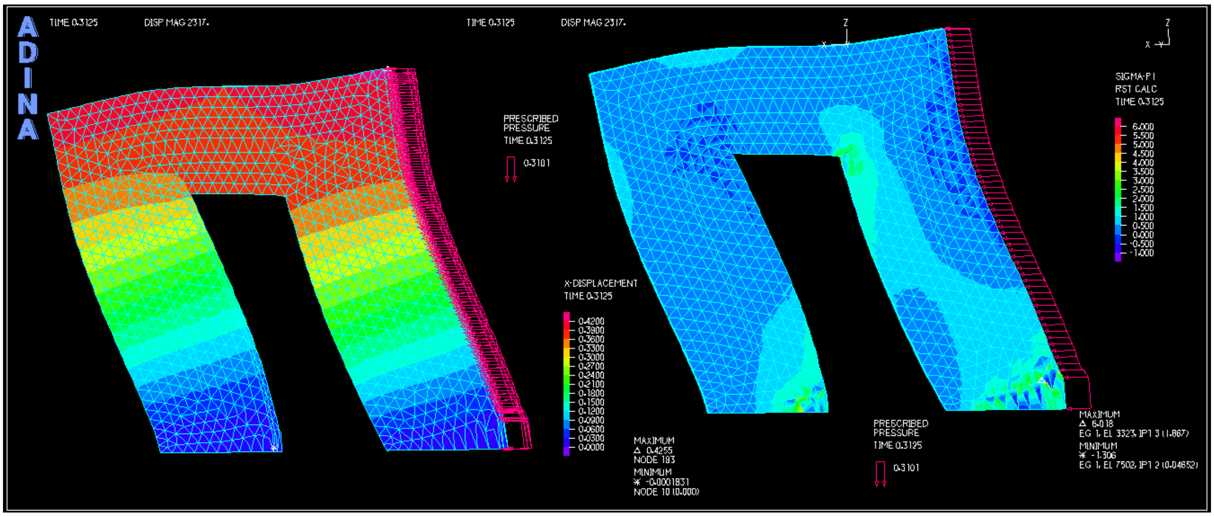

Figure 1 Deformations in direction x and stresses in direction z

Fig. 2 presents graphically the stresses in z direction along the bottom of the column of the concrete of the wall. Since the concrete of the wall exhibits its tension limit for 2 MPa it means that in the analyzed section cracks occur. The cracked area will permit the penetration of moisture and Cl ions enabling the calcification of the concrete and the corrosion of the reinforcement bars. As a demand to avoid development of the cracks on the face of the columns it is compulsory to provide bars with increased areas or to put the bars closer along the vertical direction. Another way to avoid these cracks is by providing steel profiles along the edges of the wall. Since this supplementary steel may corrode and endanger the wall, FPR sheets can be glued along the edges to avoid crack and to improve the ductility of the wall.

Fig. 3 visualizes the force and the stresses in the vertical and horizontal bars in the net which was provided as reinforcement of the wall. Due to modeling intricacy the horizontal bars continue through the opening. This shortcoming does not influence the results of the analysis. For better modeling the areas of the vertical bars at the edges of the wall have to be greater or placed closer.

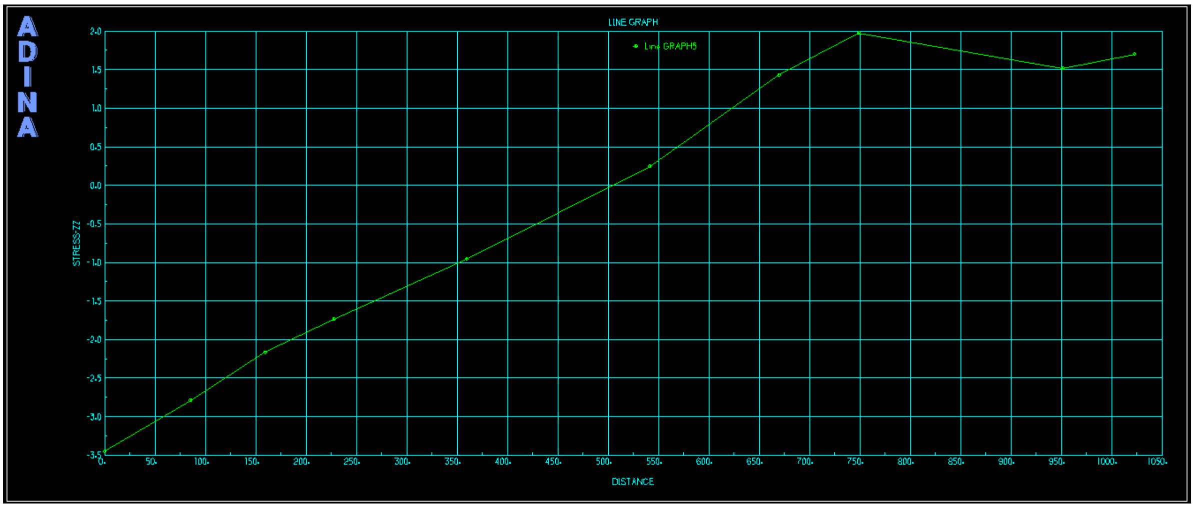

Figure 2 ZZ stress in the wall.

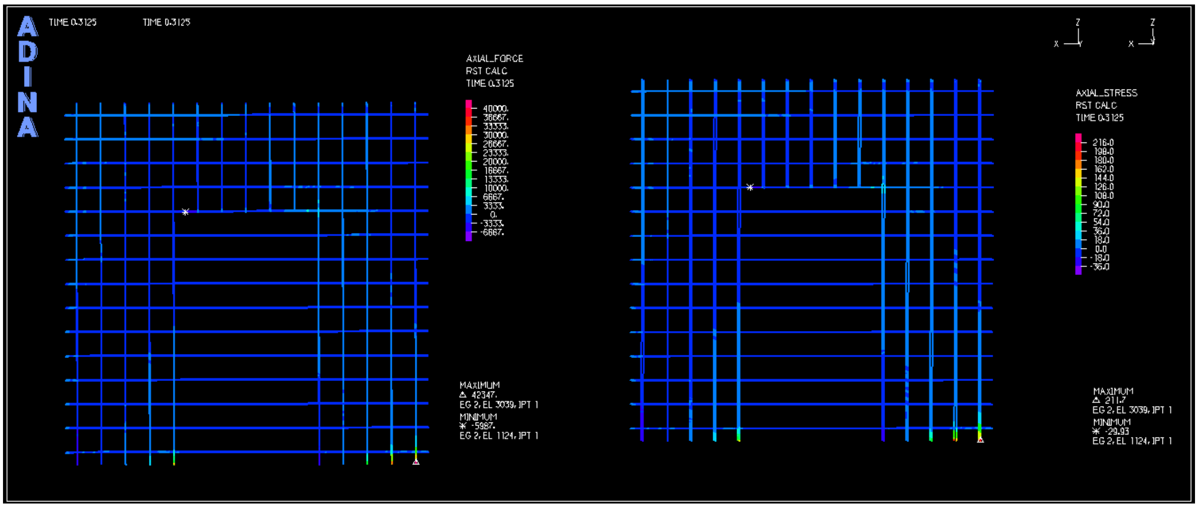

Figure 3 Axial forces and stresses in the reinforcement bars

Fig. 4 presents a graph of the displacement of the upper part of the wall loaded by the horizontal load. This graph visualizes the deformation of the base to the next story where more severe crack might occur in the lintels. This explains the crack which develop at the middle of the beams and their role in diminishing the stiffness of the entire structure. According to design provisions the development of cracks in the beams diminish the stiffness to 60% of the initial calculated stiffness. This kind of cracks may diminish the initial stiffness in a more severe manner and retrofitting is compulsory.

Fig. 5 indicates the zones in the wall where cracks develop. By means of the ADINA software the minimum and maximum amount of cracks are indicated. Taking into account that the dynamic loads act in a cyclic manner the analysis must be achieved in a hysterically. The analysis becomes more intricate and scaled models with similitude procedures can lead to the best assessment analysis.

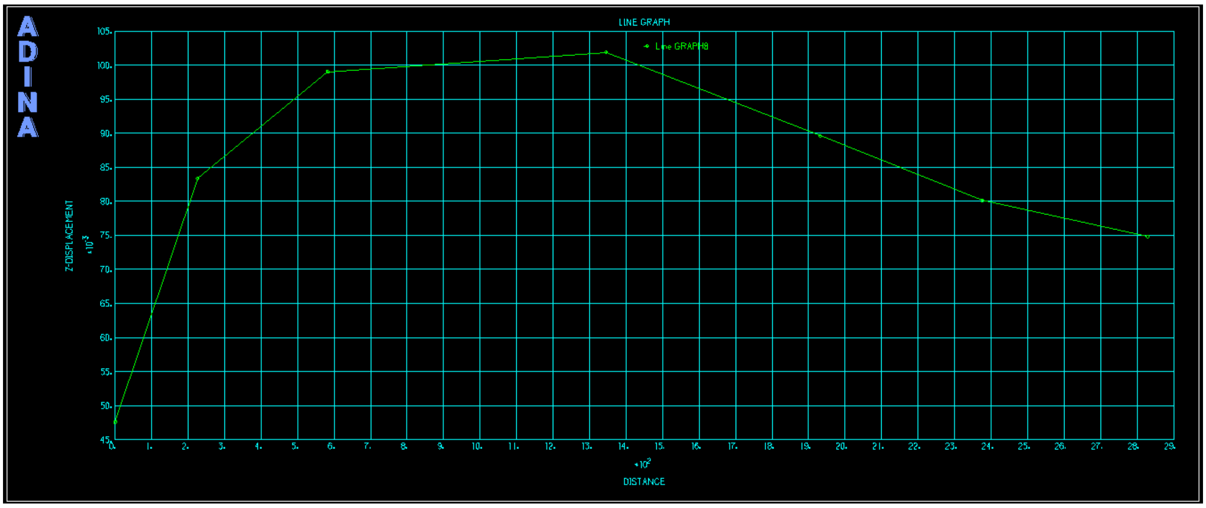

Figure 4. The vertical displacement at the top of the wall

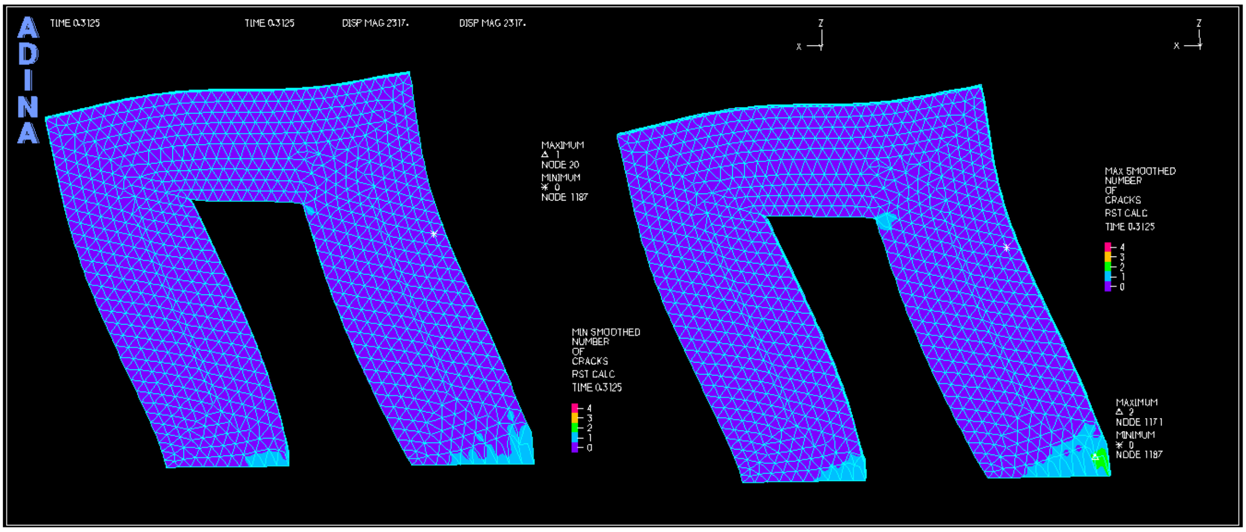

Figure 5 Minimal and maximal cracks in the wall

3.3 Temperature effects

The change of temperature during seasons or day and night affects the structure by inducing stresses into the elements. The design provisions underline the limitation of the dimensions of the buildings to avoid development of stresses due to lengthening or stretching under temperature changes. Taking into account the fact that the wall former presented is fixed at the base hence the dilatation or contraction is prevented at its base and stresses will develop in the structure. Fig. 6 presents the sections along them the stresses were visualized. From the left the first section is done perpendicular to the axe of the beam at its middle. The stresses in x direction are presented in Fig. 7. The section along the base of the columns enables the stresses along the x direction to be represented in the graph from Fig. 8. The last section was made at the middle of the columns while the stresses are presented in Fig.9.

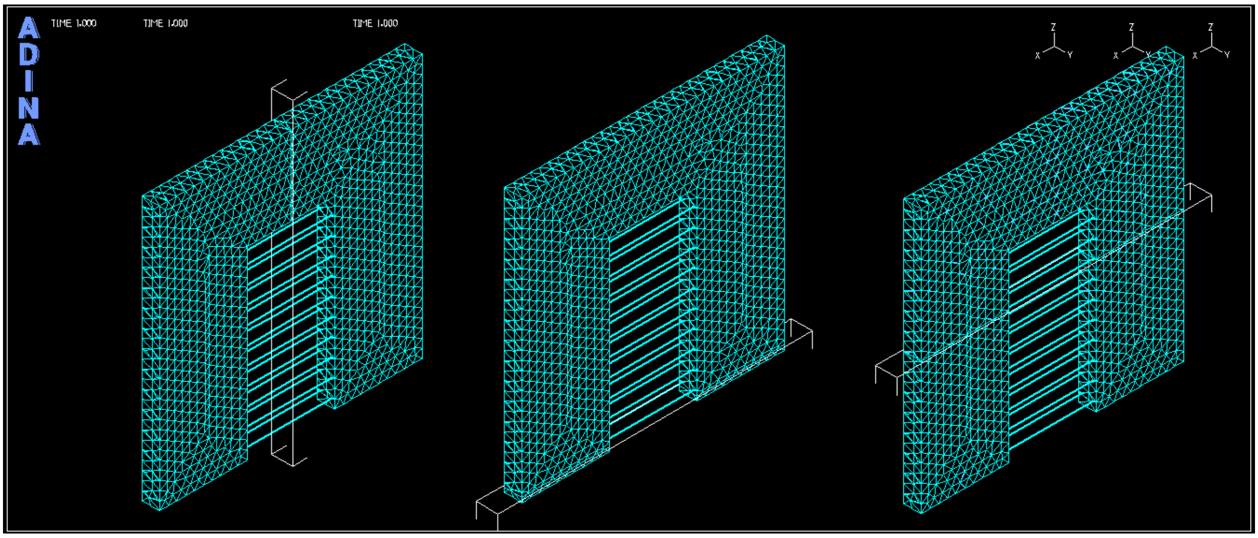

Figure 6 Sections through the wall

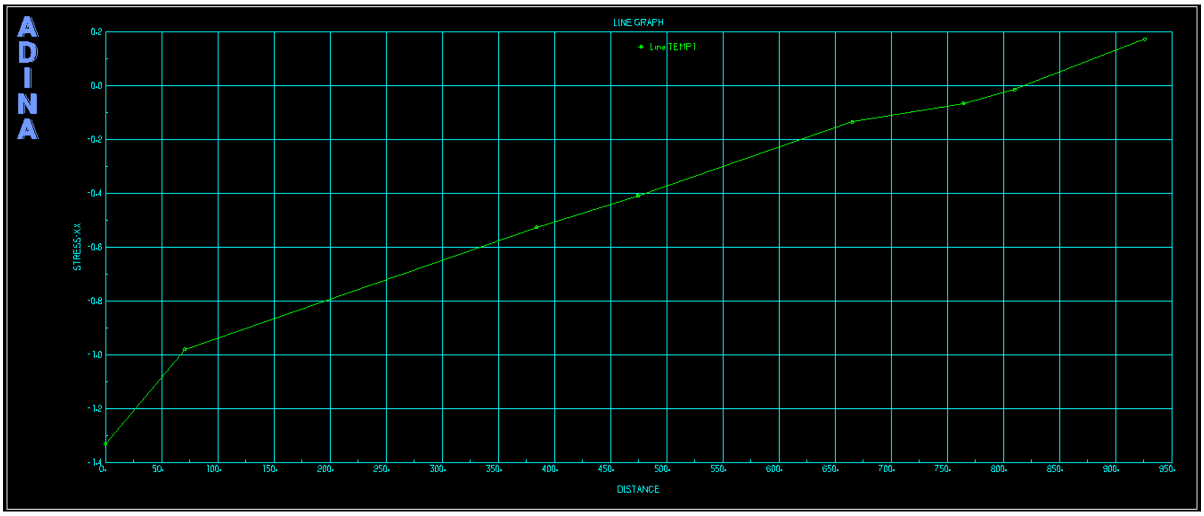

Figure 7 Stresses in the beam

The temperature was augmented by 10 °C a modest difference for most of the cases. The results show the stresses that develop as consequence the difference of temperature. Usually the stresses indicate compression for increasing the temperature. It means that in case of temperature decrease the effect is inverse the elements get tension which produces cracks in the elements.

According Fig. 7 the stress at the middle of the beam varies from -1.4 MPa to 0.2 MPa. This means that this temperature increment does not lead to cracking of the beam. Higher increment or decrement will produce the cracks with the consequence in stiffness diminution and corrosive factor penetration. The most dangerous section is placed at the bottom of the columns (Fig. 8) where for the former change of temperature the stresses vary between -2.35 to -3.45 MPa. It means that for similar contraction the entire section will be cracked. At the middle height of the columns the stresses will be less leaving the structure intact.

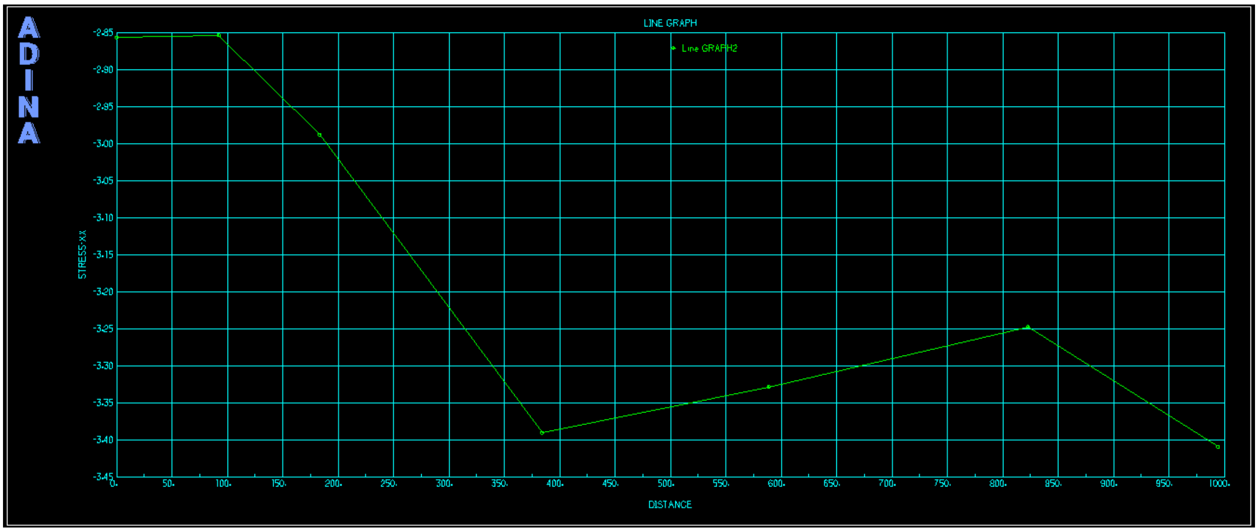

Figure 8 Stresses along the bottom of the columns

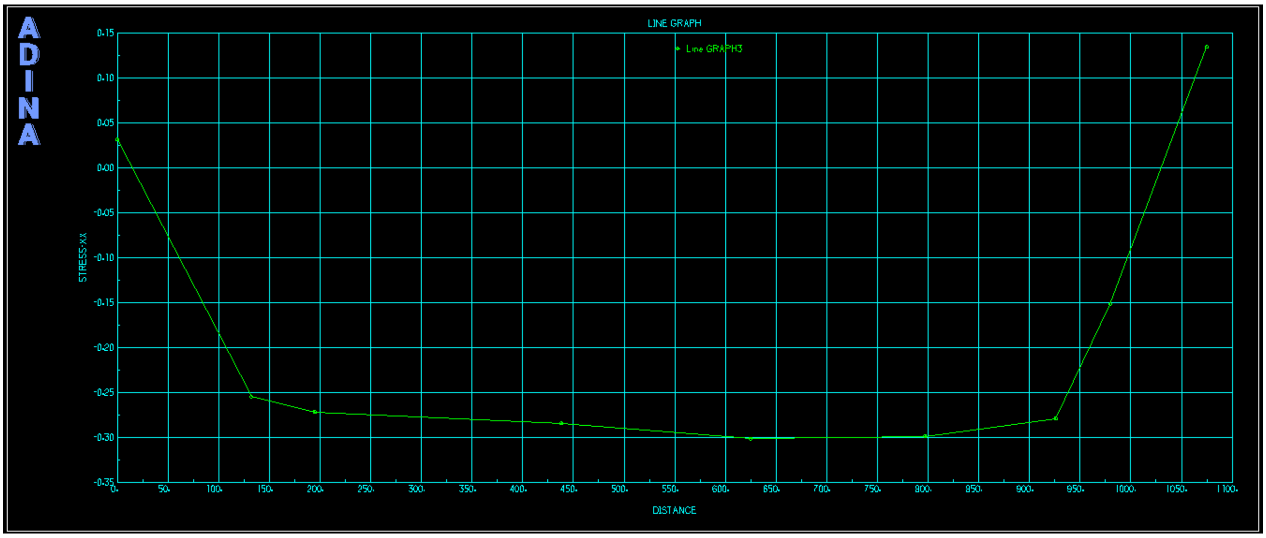

Figure 9 Stresses at the middle of the columns

3.4 Effect of seismic and micro-seismic movements

ADINA enables the dynamic identification of the wall previously analyzed. According the modal analysis in Fig. 10 three eigenvectors where represented for the structure. Following the modal analysis the seismic response can be determined. According the seismic map of the given area the seismic analysis can indicate the expected deformations and stresses in the structure. The expected behavior of the structure can be visualized indicating the damages to develop in the structure.

The dynamic identification of an actual structure can be found by means of a sensitive accelerometer (Fig. 11). The presented device is the CX1 Accelerometer and Inclinometer which can record (monitor) the oscillations of a structure prone to micro – seismic or induced dynamic movements (13). The device can record the vibrations in 3 directions and find the spectral response of the structure showing the eigenvalues of the actual structure. If as consequence of severe loads the eigenvalues change a new seismic analysis may be done and the repairs or structural control can be implemented.

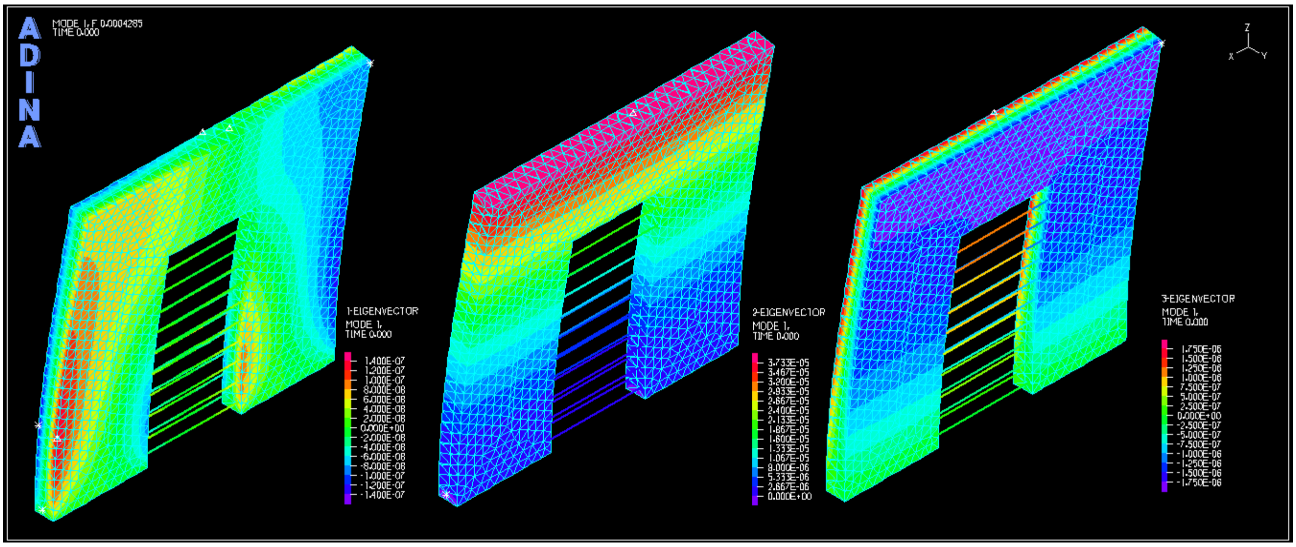

Figure 10 Eigen vectors of the wall

Figure 11 The device for data acquisition

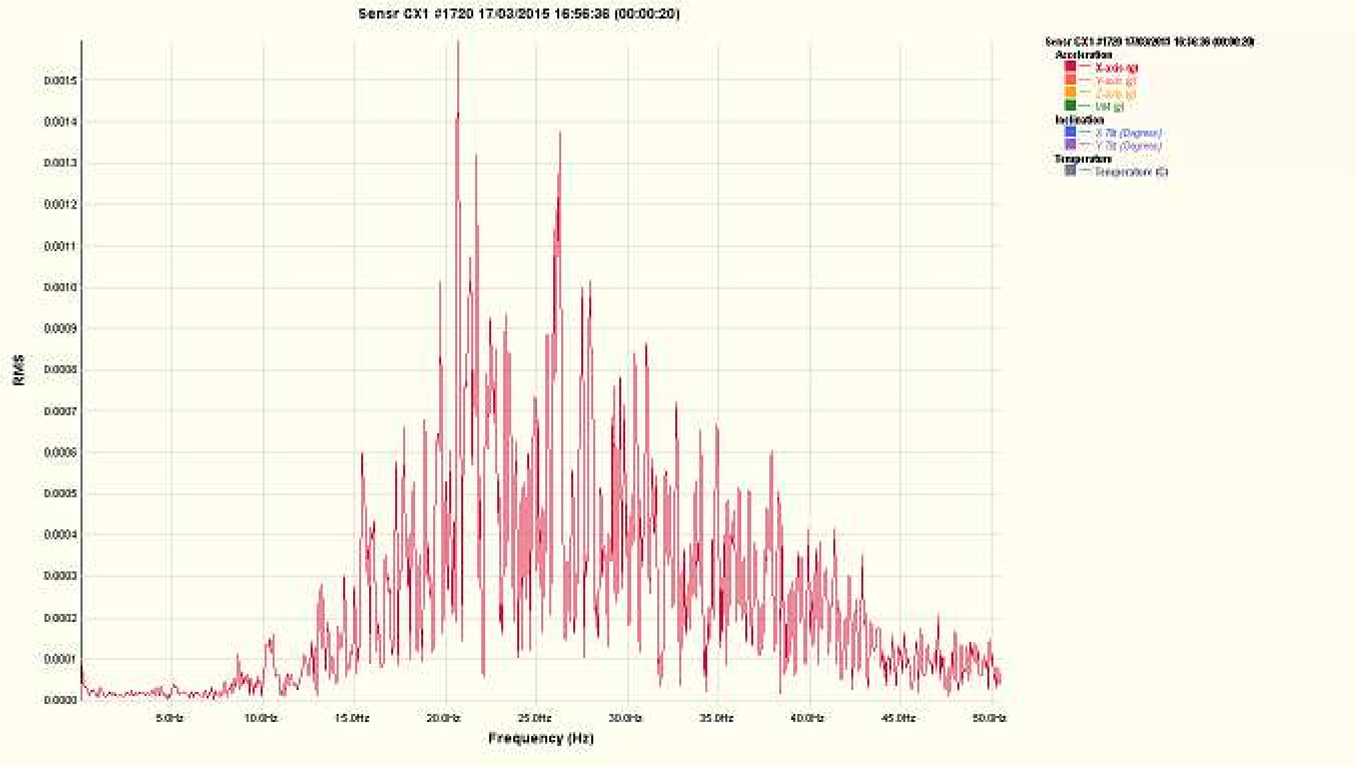

Figure 12 Power Spectrum

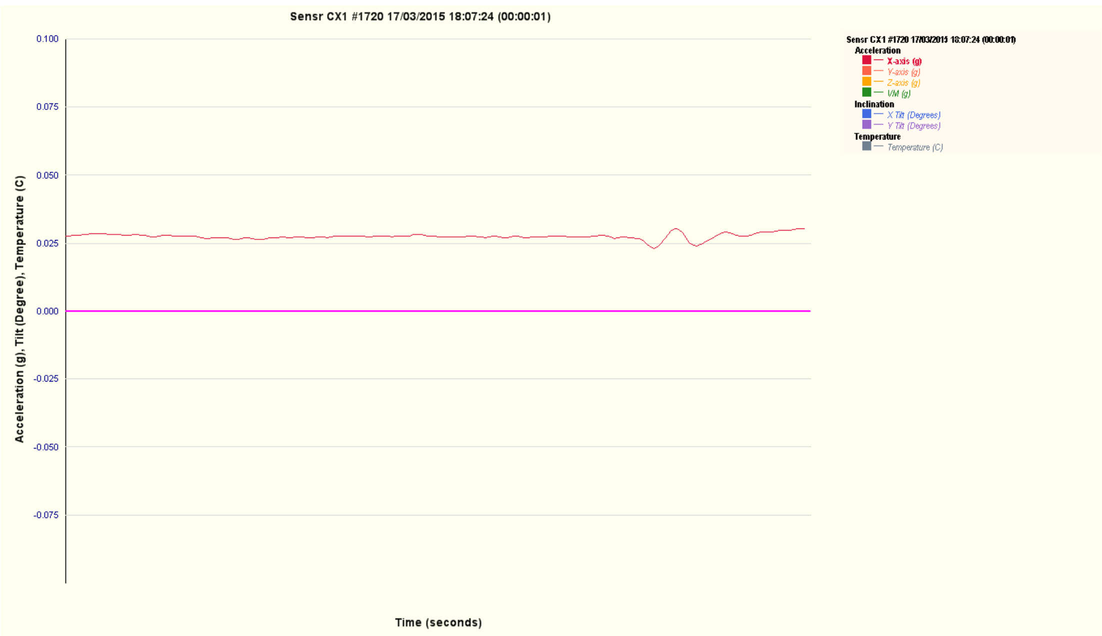

Figure 13 Data acquired for x direction

4 CONCLUSIONS

- In case of reinforced concrete walls the lateral reinforcement must be provided

- Walls may be strengthened by means of steel profiles.
- FRP sheets can be uses to strengthen the structural elements
- It must be taken into account the cyclic nature of most dynamic loads.
- Temperature changes can lead to crack development.
- The structure must be protected by materials which avoid the penetration of corrosive factors.

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