“PARSANT”: A “NON DESTRUCTIVE” METHOD FOR ANTI-SEISMIC STRENGTHENING OF EXISTING BUILDINGS

John Marneris[1] and Vicki Kouskouna[2]

[1] *M.Sc. (dist.) Managing director, consulting firm “J. Marneris & Associates Ltd”, Athens, Greece*
[2] *Associate Professor, Department of Geophysics & Geothermics, Faculty of Geology, National and Kapodistrian University of Athens, Greece*
Email: info@marneris.gr, vkouskouna@geol.uoa.gr

ABSTRACT :

The method refers to the anti-seismic strengthening of existing buildings with a framing system made of concrete, using additional strong exterior bracing panels, pin connected to the existing framing system. The panels are truss type plane systems made of steel composite members and have their own foundations. The pin connection is achieved using steel connectors (tie rods), which go through existing and additional beam members, bolted at both sides. With this method the construction damages to the existing buildings are minimized, without interruption of their use, and with minimum cost and construction time. Due to great rigidity and strength of the additional panels, the overall behavior of the buildings can comply with the recent anti-seismic Codes. This paper describes briefly the method and presents the design of strengthening of an existing office building.

KEYWORDS: anti-seismic, non destructive, strengthening, existing buildings

1. INTRODUCTION

The need of anti-seismic strengthening of existing buildings has become a necessity during the last decade after the accumulated developments in this field, as shown in all major Codes of Practice. This necessity is more evident for structures of “great importance” such as hospitals, schools, administrative buildings, museums, universities etc, representing a major concern of the countries.
The most direct way to increase earthquake safety is to increase the strength of a structure. According to the latest structural views, the most efficient way for strengthening existing buildings is the addition of new shear walls, connected to the existing framing system. This is very clearly shown in the Greek Anti-Seismic Code (EAK). It is noted that such shearing walls do not exist, or are very insufficient, for all Greek buildings designed before 1984.
The method covers those buildings already damaged, usually by earthquakes, and those which intend to comply with the regulations of the new Codes of Practice. It is very useful in cases of floors addition, when the existent framing system proves to be inadequate for the extra loadings.
As already mentioned, PARSANT can ideally be applied to flexible buildings with sufficiently rigid horizontal diaphragms, like reinforced concrete buildings with columns, without or with poor shearing walls system. As a consequence, the method is not very appropriate for masonry buildings with wooden floors.
For the development of this system Mr. John Marneris, co-author of this paper, was awarded by the “Industrial Property Organization (OBI)” the patent No 1004531, in April 2004.
PARSANT was presented during the “5th International Conference of Steel Structures”, which took place in Xanthi, Greece, at the end of September 2005. It was officially submitted to the “Greek Ministry of Environmental Planning and Public Works” and the “Greek Earthquake Planning and Protection Organisation”, which ascertained that the method should be used by the Committee in charge of the under preparation “Greek Code for Repairing and Strengthening of Existing Buildings”.

First application of PARSANT is the design of strengthening of the “Preveza General Hospital”, which is at the moment under construction. Several other projects are designed using this method and have been approved by the Authorities, such as:
- University of Athens –School of Law
- Multi storey Shopping Center “Hondos Center” in Athens
- Bank office building in Athens
- IASIS private Hospital in Crete-Greece

2. BRIEF PRESENTATION OF THE METHOD

The proposed method of strengthening can briefly be described as follows:

- Addition of external walls in the form of steel frames with diagonal members attached at least at the 3 sides of the existing buildings. The beams of the external walls coincide in level with those of the existing building made of reinforced concrete and are attached to them by steel connectors made of high strength tie rods. The connectors act as regular steel members and are described as such for the structural modeling.
- The walls consist of hollow high strength steel sections and have usually a length of 1.5 – 2.5m and a depth of 0.25m including their final covering. Beams and columns are filled with small aggregate concrete for extra strength and rigidity (composite members).
- The foundation of the walls can be “conventional” using large external footings covering and connected to the existing ones. For more important buildings with more than one basement floors, the use of a “small diameter piles” system is recommended, in order to reduce disturbance.
- Balconies do not present any problem and only small holes have to be made to them so that the steel columns are able to go through.

  Figure 1 shows the addition of walls at the 3 sides of an existing building, whereas *Figure 2* shows the connection of the walls to the existing framing system, whose beams have to be strengthened by steel plates bonded to their sides (beton plaque), in order to become able to withstand the big forces applied during an earthquake. Steel connectors have to be placed as close to the existing slabs in order the seismic forces to be transferred directly to the slab diaphragm of each level.

  The holes for passing the steel connectors are vertically elongated, so that no vertical forces are transferred to the walls and no interference is caused to the existing framing system. For this reason this connection is referred as pin.

Figure 1: Addition of “double walls” at the 3 sides of a building

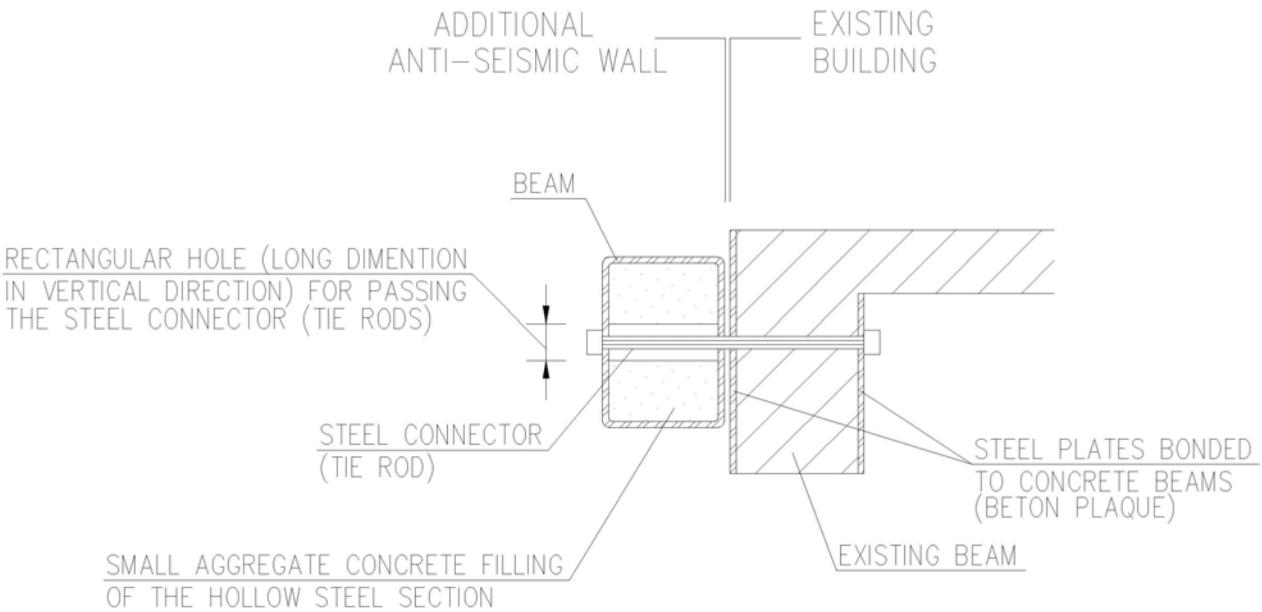

Figure 2: Connection detail to of external wall to the existing framing system

PARSANT is a very efficient anti-seismic method mainly due to the following reasons¨

- The walls' members consist of high strength and rigidity composite members.
- The location of the walls at the buildings perimeter is very favorable for anti-seismic purposes
- The walls are fully fixed on ground, especially in case of small diameter pile system foundation.

The walls can be covered with cement panels providing a nice smooth surface. In case of buildings with many openings in their facades (offices, schools) the walls can be covered with perforated decorative steel panels, which allow the light to go through, and provide a modern architectural view.

3. APPLICATION OF THE METHOD TO AN EXISTING BUILDING

3.1 Introduction

The building is used as offices of a bank in Athens and consists of one basement, ground floor, mezzanine floor and four typical floors with dimensions 25.9*9.4m, followed by two top floors with dimensions 13.5*9.4m. The construction of the building was completed in 1978.
The bank in order to proceed with some renovations assigned our office the checking of the structural system, which led to the conclusion that the strengthening of the buildings structural system is necessary. The PARSANT method was chosen for this purpose, mainly due to the fact that the operation of the building would not be interrupted.

3.2 Existing framing system

As it is shown in *Figure 3* the existing framing system consists of perimeter columns over about 4.0m connected with beams only along the longitudinal direction. Between these two frames extends a joist slab and the only transverse frames appear at the front and back side of this oblong building. At the back of the building appear also two shearing walls belonging to the elevator shaft.
At the time that the building was designed, it was not fully understood the seismic behavior of structures without adequate framing connections. As a consequence, excessive horizontal deflections emerge of 0.42m in

the transverse and 0.18m in the longitudinal direction, which have an effect in the overall elastic stability of the building. Also the existing column reinforcement is much less than the required.
Taking into account all the above one can conclude that the anti-seismic structural system of the building is very isufficient.

3.3 Description of strengthening

As shown in *Figure 3* three additional external walls are proposed at the three sides of the building as follows:

- Two similar walls T1ν, T2ν, 4.6m in length at the longitudinal sides of the building.
- One wall T3ν, 2.7m in length, at the transverse front face of the building.

The addition of another wall at the back transverse side was not possible, since this side is in contact with the next building. Nevertheless the walls in the three sides provide the necessary torsional rigidity, a fact that is helped by the presence of the two concrete walls of the elevator shaft.
Walls members consist of hollow sections, steel category Fe510, type RHS 300*200*10 for columns and beams and SHS 200*10 for the diagonal members.

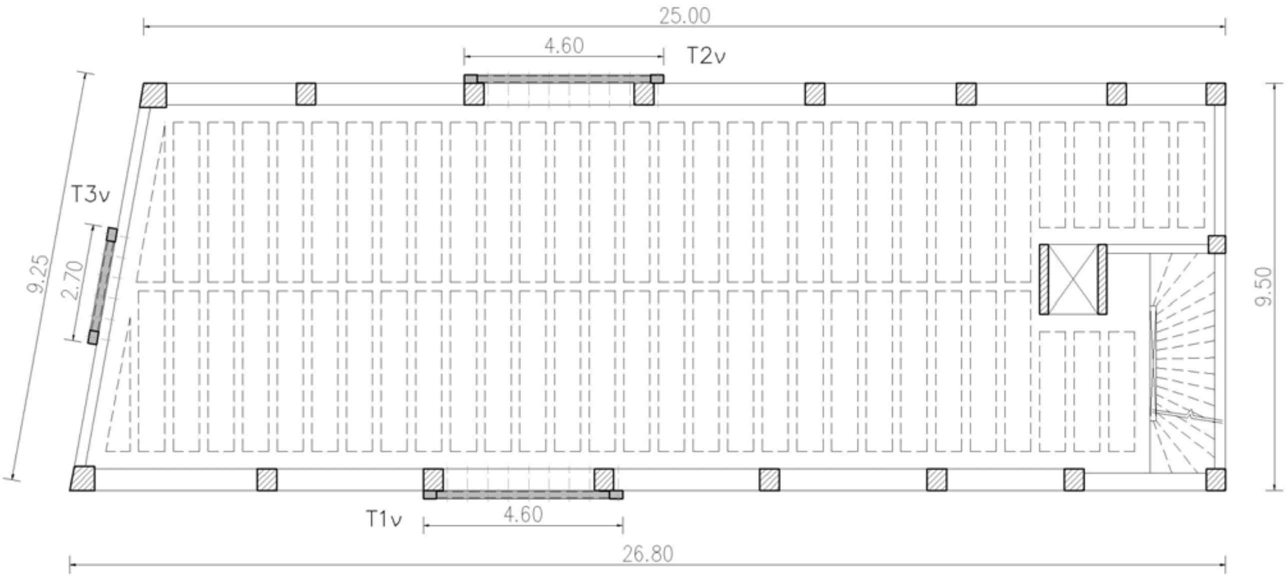

Figure 3: Typical floor framing plan after strengthening

The foundation of each wall consists of a group of small diameter piles of 0.25m diameter, with a connecting slab on their top. Underneath the slab, a layer of gravel is provided for a more efficient horizontal support of the piles.
The large seismic bending moments at the base of the walls are practically transformed to pairs of axial forces, tension-compression, which are carried out by the piles, mainly through perimeter friction forces. The values of these axial forces define the length of the piles as a result of geotechnical calculations. The upper parts of the piles are under considerable bending moments and they must be treated like columns, providing good concrete quality and adequate reinforcement. On top of the connecting slabs ground beams are formed, for support of the steel columns, so that they latter will not be in contact with the soil.

In the following wall T3ν of the main building's face is presented, and similar applies for the rest of the walls. *Figure 4* shows the wall's view consisting of one-floor frames, connected to each other by bolting. The diagonal members of each floor are connected to the frames also by bolting. The bolting connections are performed through plates that extend to the three sides of the sections, excluding the interior one in contact with the building.
The beams and columns of each floor are filled with small aggregate concrete prior to installing the frame of the next floor. The concreting procedure is facilitated by the use of plasticizers and surface vibrating devices. For

the circulation of concrete between members, holes are provided at the connecting plates. With concrete filling members become composite achieving greater strength, rigidity and buckling capacity.
Figure 5 shows a transverse section of the wall extending over the ground floor.

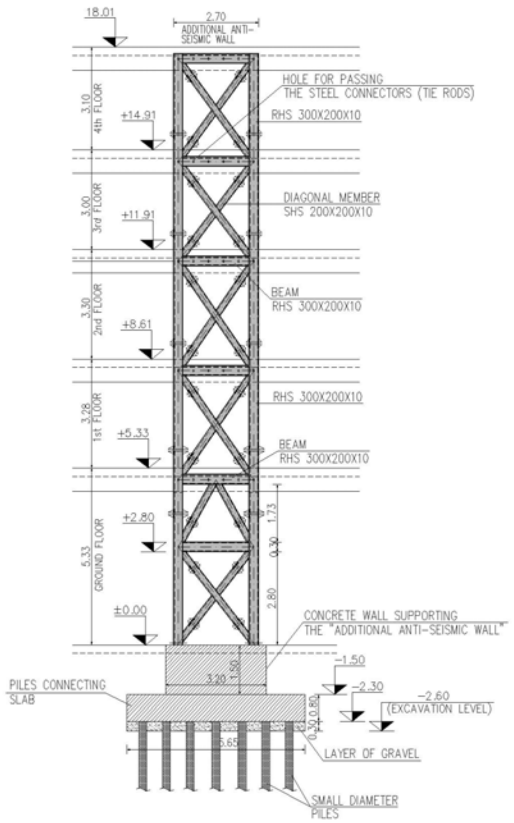

Figure 4: View of additional wall T3ν

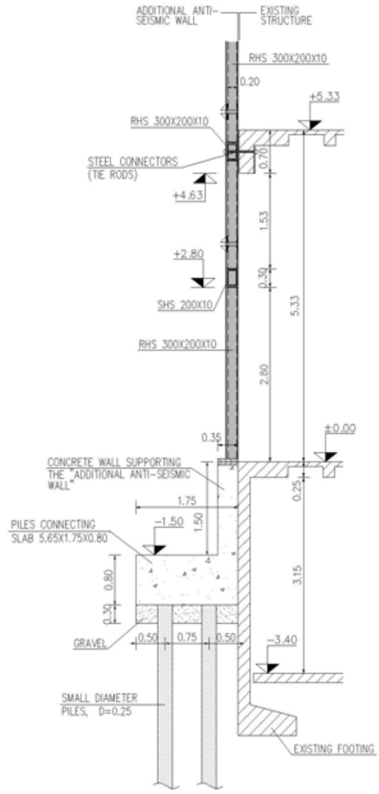

Figure 5: Transverse section of wall T3ν

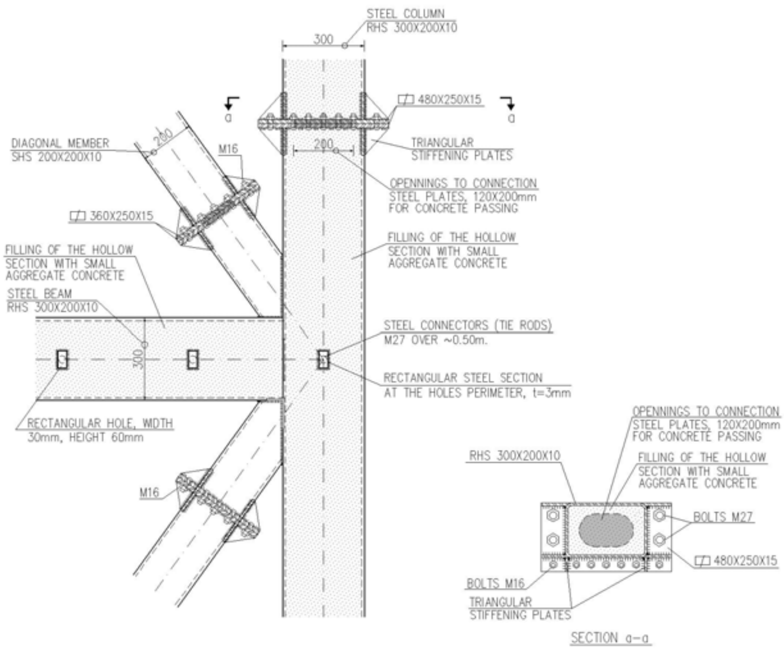

Figure 6: Joint detail of wall T3ν

Figure 6 shows a joint connection of the wall with the connecting plates extending at the 3 sides of the members and the hole on them for the concrete circulation between beams and columns. One can see the vertical rectangular holes for passing the steel connectors, which allow the free relative vertical movement between existing and new members. The drilling of holes to the concrete beams start from the center of the rectangular holes with modern lightweight drilling devices that are self supported to the beams surface.
Figure 7 shows the main connection detail between existing and new structural elements by the use of steel connectors, tie rods M27. The sides of the existing beams are strengthened with steel plates bonded to them (beton plaque). Anchor bolts help the bonding of the plates. One can see the steel connectors passing through both beams and bolted at their end.

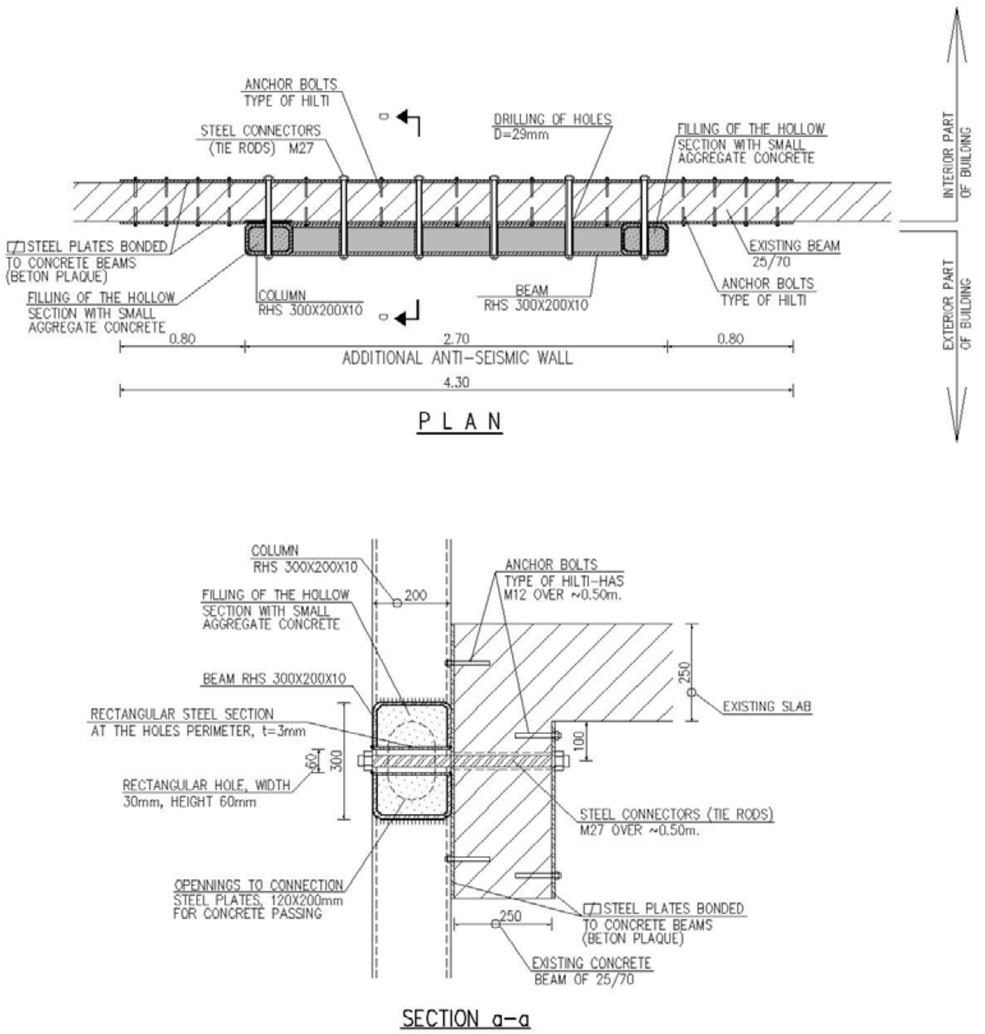

Figure 7: Connection detail of existing-additional members of wall T3ν

After strengthening with PARSANT method the anti-seismic behavior of the building is improved drastically. The walls undertake the 63% of the total seismic base shear in the longitudinal direction and 52% in the transverse (together with the concrete walls of the elevator shaft). The walls have also very much reduced the horizontal seismic deflections and the building behaves according to the new Codes. The maximum horizontal deflection in the longitudinal direction is reduced from 18cm to 8.4cm and from 42cm to 20.9cm in the transverse.
The cost of strengthening is 170.000€, which corresponds to about 110 €/m2 in relation to the total covered area of the building above ground level.

The additional walls are covered by perforated decorative steel panels, which allow the light to access the building.
Figure 8 represents the exterior of the building after the installation of the additional walls and *Figure 9* after their covering with perforated steel panels.

Figure 8: Building after strengthening

Figure 9: Building after covering of the strengthening

3.4 Design methods

The whole building is analyzed as a space frame together with its foundation using SOFISTIK program. Two separate structures are described, existing and new, and the steel members that connect them together. The distance between the structures is taken as 0.02m, which represents the gap that is likely to appear due to construction imperfections. This small member length does not create any “ill conditioning” during the analysis and it is checked that small variations of this distance have no substantial effect on the overall results.
The piles are described as members with elastic supports in the horizontal directions, with a vertical elastic support at their bottom. The horizontal rigidity of the upper supports corresponding to the gravel layers is higher than the rest. The connecting slab is described with finite plate elements.

The building was analyzed for the design spectrum of the Greek Seismic Code and also for the worst case of the spectrum of the Athens earthquake of the 9th September 1999. This event is considered as a representative earthquake to affect the building. The ground motions recorded at station Sepolia (garage) was used for the analysis. The acceleration time histories for the two horizontals and the vertical component are shown in figure 10 and the corresponding response spectra in figure 11. These particular station recordings selected were the ones that maximize the peak ground acceleration and velocity values for this earthquake.

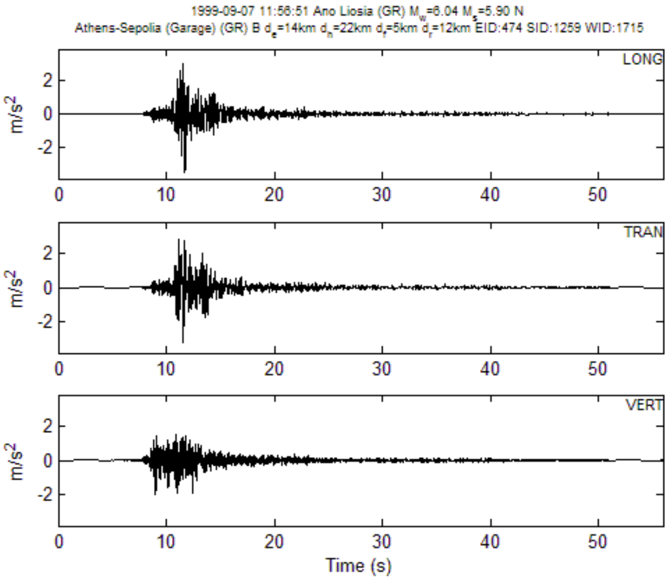

Figure 10. Acceleration time histories for the ground motions recorded at Sepolia (Garage) station during the Athens earthquake

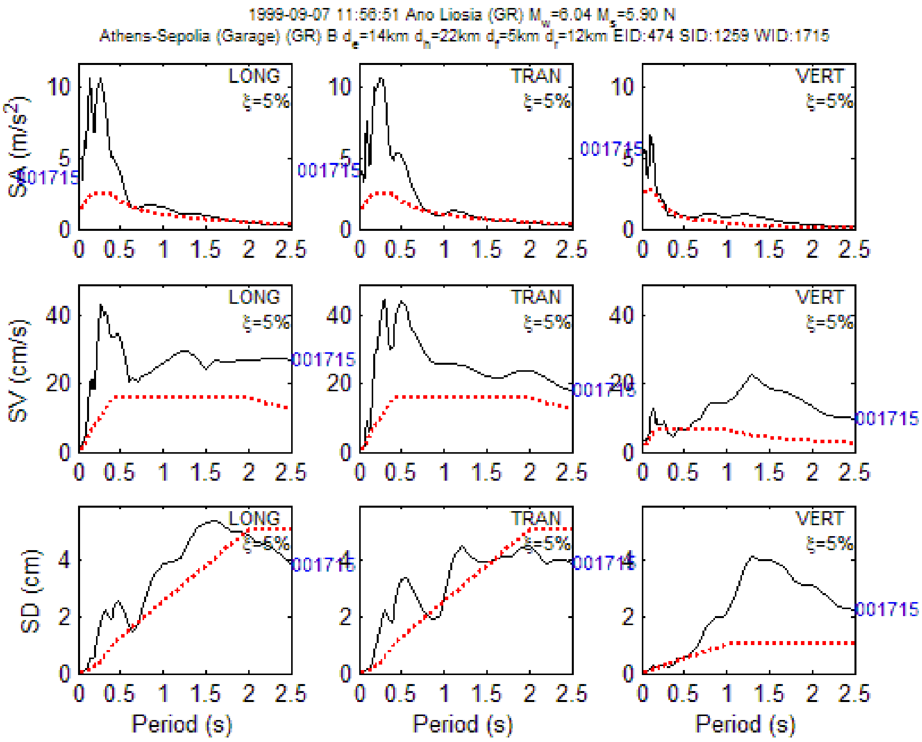

Figure 11. Linear elastic response spectra for the Sepolia (garage) station. Dotted lines represent the Eurocode 8 design spectra

4. REFERENCES

- Greek anti-seismic Code
- Ambraseys, N., Smit, P., Sigbjornsson, R., Suhadolc, P. and Margaris, B. (2002), Internet-Site for European Strong-Motion Data, European Commission, Research-Directorate General, Environment and Climate Programme.
- John Marneris "Additional pin-connected anti-seismic panels", paper for the "5th National Conference of metal structures" Greece 2004