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STRENGTHENING OF BUILDINGS BY SEISMIC BASE ISOLATION. PROS AND CONS FOR APPLYING THE STRENGTHENING METHOD TO BUILDINGS LOCATED IN BUCHAREST

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Abstract

At present, earthquake engineering can take advantage, among others, of the modern consolidated technique, namely "seismic base isolation". Base isolation is a technique that is easily enforceable in the case of buildings or other structures of new building, but it can also be used for the "strengthening" of already existing buildings. This technique has been often used with success, first in New Zeeland and USA, and now also in Italy, Japan, and other countries. The main objective of paper is to analyze the dynamic response of base isolation system under specific local seismic conditions. Local seismic conditions were established on the base of Vrancea earthquake records obtained during strong Vrancea earthquakes in 1977, 1986 and 1990. As results of this analysis at the end of paper are presented pros and cons for applying the strengthening methods to buildings located in Bucharest. The most important aspect is that high amplifications are present in response spectra of relative displacements at long periods. For this seismic local condition are very difficult to design an effective base isolation system.

Keywords: *seismic action, response spectra, strengthening works, seismic base isolation*

1. INTRODUCTION

The increasing demand for safe and comfortable buildings, together with the worldwide huge public and private housing programs currently in progress in high seismic areas, call for use of new industrialized construction systems.
Earthquake engineering can take advantage, among others, of two modern but consolidated techniques as seismic isolation and energy dissipation. The seismically isolated structures make use of devices, called seismic isolators, which are placed between the part to be protected and that from which protection is necessary.
When using rubber isolators, dissipation is achieved by mixing additives to the rubber compound – High Damping Rubber Bearings – HDRBs – or by inserting lead plugs or silicone fluids in the isolators, when it is desired to obtain damping values larger than 15%. It is also possible to install some dampers in parallel to the isolators, usually low damping.

In Eurocode 8 is emphasized that the structure shall be designed to withstand the seismic action with 10% in 50 years arrival probability without collapsing.
For example of seismic isolated structure in Figure 1 is presented University of Basilicata, Potenza which was first Italian isolated "school" in 1995. For that scope were used 221 High Damping Rubber Bearings.

Figure1.University of Basilicata, Potenza (Martelli, 2008)

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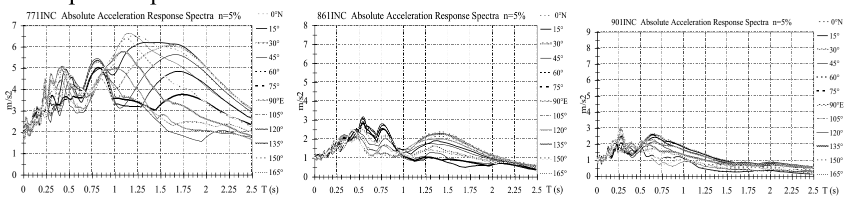
2.SEISMIC HAZARD OF BUCHAREST CITY

About 10% of the population of Romania is living in In City of Bucharest where more than 90% of the life losses occurred during the destructive earthquake of 1977.03.04. Unfortunately, during that earthquake, a single strong motion record was obtained in Bucharest at ground level.(the development of the strong motion network after 1978, due essentially to the generous aid provided by US/AID) made it possible to obtain, during following strong earthquakes, more valuable instrumental information. Among the absolute acceleration response spectra determined for various records, concerning various sites and events, the results obtained for the 1977.03.04 record of Bucharest – INCERC (upper plots of left column of Fig. 2) are obviously the most severe, due to:

a) High peak spectral values, exceeding 0.6 g;

b) Long dominant oscillation periods, exceeding 1.0 s, which involved high peak values of relative displacement response spectra.

The examination of the various processing data as response spectra makes it possible to remark following facts:



a. 1977.03.04 b.1990.05.30 c.1990.05.31

Figure 2. Response spectrum of accelerograms recorded in Bucharest – INCERC (INC)

- The transfer function derived for the case of considering a single layer (plot up left) corresponds obviously to the analytical solution;
- increasing gradually the number of layers considered leads to a gradual increase of the fundamental period characterizing the transfer function;
- the shape of the transfer function changes considerably when the number of layers considered changes; a certain tendency to stability of the transfer function shape appears in case one considers more than four layers (when the interface with stronger contrast at a depth of 600 m, after the fourth layer, is exceeded);
- in case one considers a deep geological package, one remarks that the transfer function has several main peaks of comparable importance, which means that, the spectral characteristics of ground motion will be determined primarily by the features of the input disturbance;
- the peaks of the transfer function (numbered leftwards) in case of considering all eight layers, up to a depth of 2800 m, present an interesting correspondence with instrumental data at hand: the first peak (period: ~ 5.7 s) corresponds fairly to the dominant periods of some 6 s, observed for records of remote earthquakes and to the frequencies of 0.15 … 0.2 Hz; the fourth peak (period: ~ 1.5 s) corresponds fairly to the main spectral peak for the 1977 event; the last important peak to the left (period: ~ 0.7 s) corresponds fairly to the main spectral peaks for the 1986 and 1990 events respectively.
- the stability of the oscillation periods corresponding to the transfer function peaks is obvious; this represents an explanation of the tendency to stability put to evidence by the sequence of response spectra at hand;

3. BASE ISOLATION SYSTEMS

In practice, the principle of Seismic Isolation is that of shifting the fundamental period (= reciprocal value of the frequency) of a building (Fig. 3) using the installation of devices with a low horizontal stiffness between foundation and building (Fig. 4).

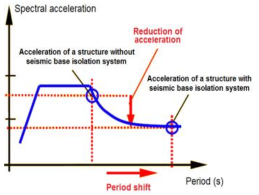


Figure 3. Response spectrum

Figure 4 below shows the effects of seismic movements on both a non-isolated and an isolated structure. Many non-isolated buildings have fundamental periods of 0,2-0,5 sec, especially old buildings with lowest height regime, i.e. the same fall within the typical range of high spectral acceleration (i.e. where the maximum energy content of the response spectrum is concentrated). Thus, the non-isolated buildings undergo resonance that results in dramatic amplification of ground accelerations within the structure as well as large inter-storey displacements. In the case of an isolated building, the fundamental period is shifted into an area with lower spectral accelerations.

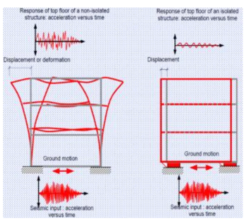


Figure 4. Displacements and deformations of a non-isolated and of an isolated structure

Resonance effects can be avoided and the building moves smoothly without showing appreciable structural deformations (Dragomir, 2008).

The four fundamental functions of aseismic isolation system are: 1.Transmission of vertical loads; 2.Allowance of displacements on the horizontal plane; 3.Dissipation of substantial quantities of energy and 4. Assurance of self-centring. These functions can be realized by so called *isolators* and *dampers*. The first function means that the isolation system acts as a conventional bearing system i.e. transfers vertical loads in the intended location from the superstructure to the substructure. The second function produces uncoupling between foundation and superstructure and thus reduces transmitted forces or the amount of mechanical energy, which is essentially the same. The uncoupling allows horizontal flexibility of the structure. The dissipation of energy limits relative displacement of the isolated structural mass and provides better structural control with bigger safety for the structure. The purpose of the self-centring capability requirement – return of the structure to former neutral mid position - is not so much to limit residual displacements at the end of a seismic attack, but rather, prevent cumulative displacements during the seismic event. Self-centring assumes particular importance in structures located in close proximity to a fault, where earthquakes characterized by highly asymmetric accelerograms are expected. It should be noted that energy dissipation and self-centring capability (sometimes referred to as restoring force) are two antithetic functions and their relative importance depends primarily on the case under examination.

In Figure 5 it can see the general installation of isolation system with High Damping Rubber Bearings.

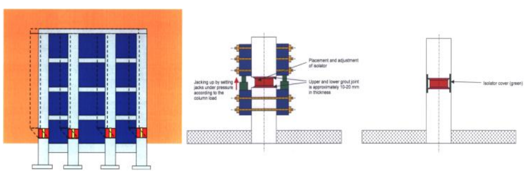


Figure 5. General installation of isolation system

The concept of the energy approach (1) reduces effectively the energy induced into the structure (Ei) by ground motion through its foundations. The amount of the structurally stored energy (Es) has to be as low as possible to avoid damages. Therefore the value of the dissipated energy (Ed) must be great.

$$E_i \leq E_s + E_D = (E_e + E_k) + (E_h + E_v) = = \oint -m\ddot{x}\,dx \qquad (1)$$

where, Ee = elastic strain energy; Ek = kinetic energy; Eh = energy dissipated by hysteretic or plastic deformation; Ev = energy dissipated by viscous damping; m = mass of isolated structure x_G = absolute ground displacement.
The amount of the structurally stored energy (Es) has to be as low as possible to avoid damages. Therefore the value of the dissipated energy (Ed) must be great. The energy part Eh out of Ed due to plastic deformation of the structure has to be kept low, as this way of energy dissipation causes structural yielding and cracks.
The drastic increase of the value of the energy of viscous phenomena (Ev) is the final opportunity to control the energy balance of the structure. It should be pointed out that (Ev) is associated with the response forces (F) that depend only on the velocity (v) through a constitutive law.

4. RESULTS AND DISCUSSION

The use of *base isolation systems(BIS's)*may be highly beneficial, yet it requires a considerable investment, not only in financial terms, but also in terms of specific technology and, ultimately, in terms of specific know-how.
A factor of highest specific importance is represented by an appropriate consideration of the seismic conditions at the sites where *BIS's* are intended to be used. The information at hand shows that accepting without a kind of specific, qualified, control the provisions of codes specifying design seismic action for usual buildings may lead in case of use of *BIS's* to considerable errors and, consequently, to over conservative protection or to coarse under design. The concern for the seismic conditions represented the bulk of this paper.
A geographic zone requiring highest attention in relation to earthquake protection, due to the severity of seismic conditions, combined with the importance and vulnerability of elements at risk, is represented by the City of Bucharest, extended to some of its surroundings (which are, by the way, planned to develop quite soon like an extended urban area).
The differences between the seismic conditions at different sites inside this area are of secondary importance. It turns thus out that the results of analysis of seismic conditions for a certain site are significant for a wider area. This enrightens the organization of in depth analysis of site conditions for some reference site, investing considerable scientific, technical and financial resources, since the results will be to a high extent valuable for a wider area, i. e. for a lot of other sites. A pilot study deserves therefore to be organized for a reference site (Sandi and Borcia, 2008).

5. CONCLUSION

The most important aspect is that high amplifications are present in response spectra of relative displacements at long periods. For this seismic local condition are very difficult to design an effective base isolation system.
The results of analyses performed by *Sandi and Borcia in 2008* put to evidence the modification of dominant periods of ground motion from one event to the other, as well as the potential of occurrence, for very strong earthquakes, of ground motions having dominant periods longer than those observed for the event of 1977.03.04, raises special problems of seismological nature.
The need to anticipate dominant periods for earthquakes of very high magnitudes, in the range of $M_{GR} \in (7,5 \ldots 7,7)$, for which the rupture length would considerably exceed the value of about 60 km of 1977.03.04, is thus raised.

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