Aseismic Bearing with Partially or Totally Curved Sliding Surface and with Angular Corrector

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Abstract

This study examines a bearing that has the double function of being fixed in the absence of an earthquake and of becoming movable during an earthquake. Its special feature is its sliding surface, which may be have a partial or total curvature. Moreover, the presence of an angular corrector allows it to compensate for any eventual rotation of the building round its own vertical axis, locking it at the end of an earthquake. The seismic energy in the building is quite small when the bearing is with sliding friction and absolutely negligible when the bearing is with rolling friction. In addition, a system using this bearing, is economically competitive in comparison with all conventional and base isolating aseimic systems.

1 Introduction

The constitution and the operating principle of the proposed bearing are described in detail in the paragraphs below. In this short introduction I would like, on the basis of my current knowledge, to note that the friction seismic isolation systems known world-wide are not duly applied yet in my country, Italy, which has a high seismic risk. The persistent use of the conventional anti-seismic methods rather than isolation methods, allows me to presume that isolation systems are either unknown or very little understood in Italy, or, vice versa, that the bureaucratic procedure for passing the relative legislation (if it exists) is, as always, very incredibly lengthy.

2 The bearing

2.1 Constitution

It consists of:

a. a steel sliding surface 1, the central part of which is flat and horizontal, while the perimetric one is circular (see figure 1). Surface 1 may also have a totally circular section (see figure 2). It is connected to the intrados of the overhanging platform;
b. four steel bodies 2, placed in accordance with the two horizontal and perpendicular diameters of the sliding surface 1 and linked to it. The lower part of each body has a steel toothed surface;
c. real bearing 3, consisting of a movable steel ball (bearing with rolling friction) or of fixed steel ball coated with a thin layer of Teflon (bearing with sliding friction);
d. body 4 containing the ball 3, connected below to steel plate 8;
e. four devices placed in accordance with the vertical axes of the corresponding bodies 2, each of which consists of:
 - movable steel mass 5, surmounted by a steel toothed surface;
 - electromagnets with keeper 6;
 - pre-stressed spring 7.

 These movable devices rest on the steel plate 8 and may be subjected to a circular motion. On the upper part they penetrate, through of the steel teeth of the vertically movable masses 5, into the corresponding steel toothed surfaces of the fixed bodies 2;
f. steel plate 8, linked to the pier of foundation;
g. sensor 9;
h. electronic control station 10;
i. electricity generator 11;
j. angular corrector 12, firmly attached to each of the four devices referred to in point
k. sensors 13, able to start up the angular corrector 12 electronically.

2.2 Operating principle

In absence of an earthquake, and due to the elastic reactions of the pre-stressed springs 7, bodies 2 and 5 are perfectly connected to one another by means of the mutual penetration of the respective steel toothed surfaces and the bearing is therefore fixed. When an earthquake starts, the sensor 9 registers the seismic vibration and the electronic control station 10 closes the electric circuit of the electricity generator 11. The electromagnets 6, started up by the passing current, create a magnetic field, which attracts the masses 5 downward, winning the elastic reactions of the pre-stressed springs 7. In this situation the masses 5 and 2 are totally independent from one another and the bearing becomes movable and, therefore, free to translate horizontally with respect to the overhanging building, which remains almost motionless under the prevailing action of the weight force. Since the horizontal inertial force in the building does not depend on the seismic shock parameters (displacement, acceleration and frequency), it is constant and negligible if the bearing is with rolling friction, and is constant and minor if, on the other hand, the bearing is with sliding friction. The total inertial force in the building is:

$$F_{i,b} = c_f \, P_b \qquad 1)$$

where: c_f is the friction coefficient between the building and the bearings, P_b is the total weight of the building. At the end of the earthquake, the electronic control station 10 reopens the electric circuit of the electricity generator 11 and the absence of a magnetic field in the electromagnets 6 allows to the pre-stressed springs 7 to raise the toothed masses 5, which, penetrating into the corresponding toothed masses 2, lock the building. In this situation the bearing becomes fixed. It should be noted that the centring of the building does not always occur. This is not very important because it does not have any negative repercussions on the general equilibrium of the building, since any eventual residual displacement of the bearing is minor. The lock of the building is, on the other hand, always guaranteed, even if there is any slight eccentricity in the load, due to the greater size of the toothed surface of masses 5 with respect to masses 2. In addition, the curvature along the entire perimeter of the sliding surface allows the bearing to centre spontaneously and partially when a displacement of the foundation-soil complex exceeds the half-diameter of the central part of the sliding surface. In this situation the total inertial force in the building is:

$$F_{i,b} = \cos^2 \{\arcsin [(2\, S_h - d) / 2\, R]\} c_f\, P_b \qquad 2)$$

where: S_h is the horizontal displacement of the foundation-soil complex, d is the diameter of the central part of the sliding surface, R is the curvature radius of the perimeter part of the sliding surface, c_f is the friction coefficient between the building and the bearings. If the sliding surface has an entirely circular vertical section, on the other hand, the self-centring of the building at the end of an earthquake is total, while, during an earthquake and due to the horizontal displacement of the foundation-soil complex, the building is subjected to a vertical displacement according to the curvature of the entire sliding surface. The inertial force in the building is:

$$F_{i,b} = \cos^2 [\arcsin (S_h / R)]\, c_f\, P_b \qquad 3)$$

where the symbols are already known. It should be pointed out that, during an earthquake, the building could be subjected to a little rotation round to its own vertical axis when the bearing has a partially curved sliding surface. In this case, the building would not be able to lock at the end of an earthquake, due to the imperfect reciprocal connection between the toothed masses 2 and 5. This drawback could be overcome using an angular corrector 12, which is integral part of each bearing. It is electronically started up by the sensors 13 and allows the circular translation of the four devices made up by 5, 6 and 7, until the building rotation has been completely compensated. In this way the toothed devices 5 are perfectly connected to the toothed masses 2 and the building locks.

3 Conclusions

The aseismic system that use the proposed bearing has the following characteristics:

1. interruption of the solidarity between the building and the foundation-soil complex and the positioning of bearings with the double functions of being fixed bearings in absence of an earthquake and of being movable multidirectional bearings, with sliding or rolling friction, during an earthquake;
2. the sliding surface of each bearing is formed by two parts: the central part, circular, is flat and horizontal. During an earthquake, its function is to keep the building in a perfectly vertical position and almost motionless with respect to the horizontal translation of the foundation-soil complex. The perimetric part, on the other hand, has a circular vertical section and its function is to allow a spontaneous and partial centring of the building if the horizontal displacement of the bearing exceeds that

specified in the design. Conversely, if the bearing has a completely circular sliding surface, the building is subjected to a spontaneous and complete centring at the end of an earthquake, while, during an earthquake, it undergoes a vertical displacement that varies in function with the curvature of the sliding surface;

3. unlocking and locking of the building, respectively at the beginning and at the end of an earthquake, effected by electronically-controlled devices;
4. presence of an angular corrector able to compensate for any eventual rotation of the building on its own axis and to lock it at the end of an earthquake;
5. a moderate seismic energy in the building, equal to approximately 1% of the weight of the building, when using sliding friction bearings; this level is negligible if rolling friction bearings are used;
6. total or partial decrease of the psycho-physical discomfort in the inhabitants, according to whether the sliding surface is partially or totally curved;
7. economical competitiveness compared with both conventional systems and with similar base isolation systems. The higher cost due to the bearings is amply compensated by the lower cost of the structures out of ground;
8. system independent of the seismic frequency with the possibility of applying it to structures with a very low resonance threshold.

The proposed bearing needs careful experimental testing.

4 The planning aspect

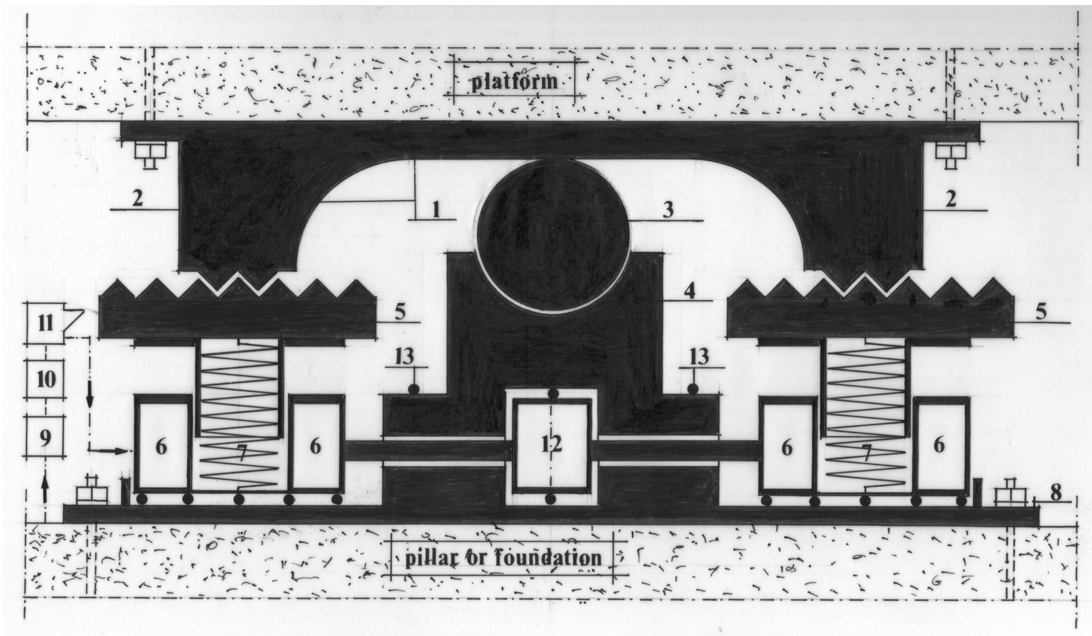

Figure 1. Vertical Section

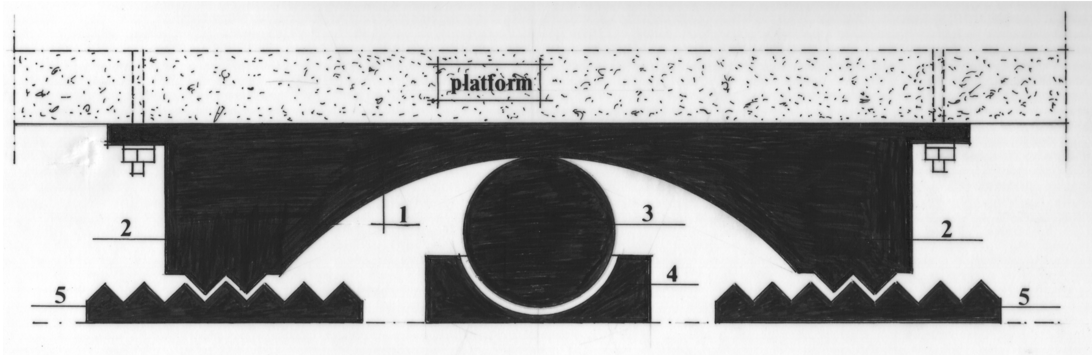

Figure 2. Detail of the sliding surface with entirely circular section

5 Acknowledgements

I have already participated in more than sixty international conferences on Earthquake Engineering and Soil Mechanics held in the most important countries and cities all over the world, except Italy. Now, without polemizing on this absurd situation, I believe that Italian "scientists" have no intention of accepting contributions from independent researchers like me, lacking any special academic title. Should this hypothesis be true, it would be very serious due to the significant negative repercussions relating to the full right to research freedom. In any case, I don't give a damn. By means of the eventual publication of this study, I wish to express my most intense gratitude to the vast foreign scientific world, which , over many years, has been lavish with attention and recognition on my behalf.

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7 Author's short biography

Federico Bartolozzi was born in Agrigento (Sicily) and lives in Varese (Italy). He was teaching of Buildings Technology and practised Civil Engineering, elaborating architectonic and structural projects. Holder of three patents, now he prevailingly devotes his time to the study of Base Seismic Isolation and Soil Mechanics Systems . As Independent Researcher, he has already participated in numerous International Conferences on Earthquake Engineering and Soil Mechanics.