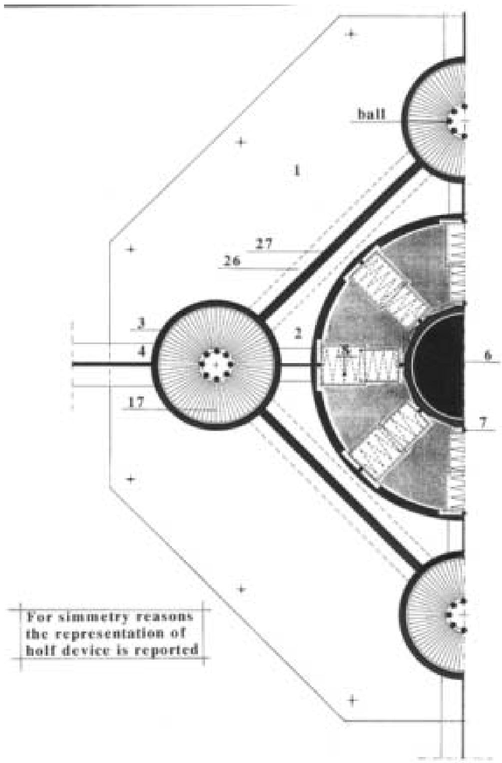
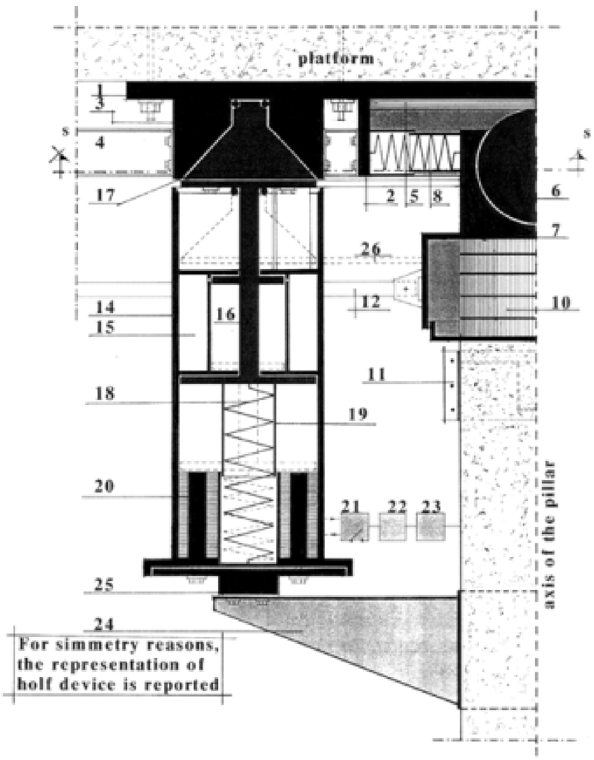
# Bearing with Fixed and Movable Functions

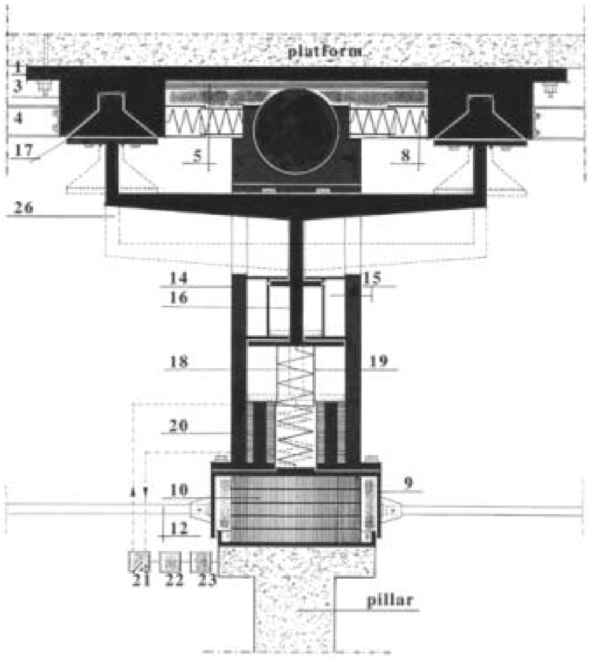
## Figures




**Compound version – Plan**




**Compound version - Section**




**Monoblock version- Section**

## <u>Constitution</u>

The compound bearing consists of three different devices, one of which is permanently fixed and the other two have the double function to make the fixed bearing, in absence of earthquake, and to make it movable, during the earthquake.

### *1 Fixed device*

It consists of:

- polygonal or circular steel plate (1), linked to the platform, on which the building is connected by means of anchoring bolts with a free screw lower ending;
- circular steel spandrel (2) welded to the plate and placed in the centre of the plate with the function of housing both of the stainless steel sliding surface (5) in contact with the ball (6) (alternatively, with the PTFE plate) and of the dolly-device pre-stressed springs (8). They, radially arranged and at the endings hinged, have the function of elastic linkages between the spandrel (2) and the steel body (7);
- No. 4 housings (3) of the steel movable truncated-conical masses (17). They are welded on the plate (1) and arranged in an external and symmetric position as to the spandrel (2);
- No. 4 stiff connections (27) of the housings (3);
- No. 4 stiff connections (4) of the housings (3) relative to a pier with the housings of the adjacent piers.

### *2 Devices with double function (fixed and movable)*

2.1 Vertical connection

It consists of the hollow pipe (14), divided into three sections:

- <u>lower</u>: containing an anchor electromagnet (20), a pre-stressed contrast spring (18) (auxiliary spring), arranged inside two coaxial pipes, one of which is fixed and the other is movable (19);

- middle: consists of two rooms. The central one houses a part of the movable piston (16) and the side one contains liquid and communicates with the central room by means of two or more valves;
- upper: containing the upper ending of the movable piston (16), surmounted by the truncated-conical mass, which is provided along the perimeter of the upper circular base with a friction device for the vertical sliding of the mass (17).

The vertical connection is stiffly anchored by means of the plate (25) and the steel bracket with variable section (24) to the pier. Besides the truncated-conical masses (17) are connected between themselves by means of the rods (26).

2.2 Proper bearing

It consists of the following devices:

- stainless steel ball (6) or, alternatively, PTFE (pure Teflon) or any other element with low friction coefficient, able to make the translation possible;
- for the bearing with rolling friction, steel housing of the ball (7)or, alternatively, for the bearing with sliding friction, steel full body with a transverse polygonal section. Radially this is connected to the fixed spandrel (2) by means of the pre-stressed contrast springs (8), hinged at the ending;
- housing of the elastomeric seismic insulator (9);
- elastomeric seismic insulator (10);
- stiff connecting rod (12) of the adjacent piers and of the peripheral piers with the retaining wall;
- hinge with horizontal axis of rotation (13);
- steel hoping (11).

The devices (9), (10) & (12) are absent in the case that it is used the solution of the movable bearing with no dissipating capacity of the sub-undulatory seismic energy.

***3 Other devices***

They are.

- current generator (21);
- electronic control station (22);
- seismograph or accelerometer (23).

## Operating principle

In the condition of rest of the soil, the anchor of the electromagnet (20) of the vertical connection, which is connected to the movable piston (16), owing to the elastic reaction of the pre-stressed spring (18), forces the truncated-conical mass (17) to occupy the relative housing of the fixed device (3), ensuring in this way the motionlessness of the building. In this situation the bearing is fixed.

During the earthquake, the accelerometer or the seismograph (23), in direct contact with the pier or with any other structural element stiffly connected to the foundation-soil complex, registers the acceleration or the intensity of the earthquake. The electronic station (22) closes the electric circuit of the current generator (21), connected to the electromagnet. The passage of the current through the electromagnet causes an attractive force of the anchor with the movable piston (16) towards the solenoid (20), which, winning the contrast elastic reaction of the pre-stressed spring (18), attracts the movable piston (16), forcing the truncated-conical mass (17) to leave its own housing, unclasping therefore the vertical connection from the fixed device.

At the same time the liquid of the container (15) is sucked in by the piston (16), occupying the expansion room. In this situation the bearing becomes movable and the pier-foundation-soil complex, as it is unclasped from the building, has the possibility to translate stiffly in horizontal direction as to the building itself. This remains almost still, in every moment of the earthquake, under the action of a balanced of forces, formed by the elastic reaction of the radial pre-stressed springs (8), the friction force between the building and the foundation-soil complex and the inertial force in the building, according to the following correlation, which expresses the dynamic equilibrium to the horizontal translation:

$$F_{i,c} = (S - S_c)\, k_t + c_a P_c \qquad 1)$$

where:

$F_{i,c}$ Inertial force in the building

$k_t = N k$ Total elastic constant, where N = 2 n is the number of pre-stressed springs in the direction of the motion, with n = 1,2,3,........number of the piers;

$S_c = - S / (r^2 - 1)$ Displacement of the building:
where S is the displacement of the foundation-soil complex Ψhe sign (-) indicates that $S_c$ and S are in phase oppositionβ This formula is valid in the hypothesis of harmonic vibration;

$r = f^* / f_o$ }} 1 Safety coefficient (for r = 1, it is $f^* = f_o$, that is the seismic frequency equals the natural frequency of the building and the resonance phenomenon occurs, as it is well-known);

$c_a$ Friction coefficient between the building and the foundation-soil complex;

$P_c$ Building weight.

Project formula is:

$$k_t = 4{,}024\, f^{*2} P_c / r^2 \qquad 2)$$

where f* is the minimum frequency of the earthquake.

At the end of the earthquake the electronic control station reopens the electric circuit and the current generator(21) does not produce current. Consequently, the magnetic field induced by the electromagnet (20) stops and the truncated-conical mass (17) penetrates into the opening of the fixed device (3), after an eventual displacement of the building has been gradually spoiled (removal of the damping liquid from the compression room) by means of the elastic reaction of the pre-stressed spring (18), connected to the anchor of the movable piston (16). In this situation, as the mass (17) and the fixed device are reciprocally locked, the bearing becomes fixed and the building-foundation-soil system becomes unmoved.

The penetration of the mass (17) into the corresponding opening of the fixed device (3) is favoured by the sliding of the mass itself along the wall of the opening, thanks to the friction device situated along the perimeter of the upper cylindrical ending of the mass. As for the elastomeric insulator (10), in the case that the bearings has it, it is subject, in state of rest, to a strain, caused by the vertical load transmitted from the overhanging building. In presence of earthquake, the sub-undulatory seismic energy, caused by the vertical component of the shock, is dissipated by the insulator (10).

Buckling in the vertical direction, it translates in the horizontal direction together with the pier-foundation-soil complex for the presence of the stiff connecting rods of the adjacent piers and of the peripheral piers with the retaining wall. At last, the elastic constant of the single spring (18) of the vertical link is:

- for the compound version (n* = 2,4,.....):

$$k^* = c_a P_p / c'_a n^* d \cos^2 \zeta \qquad 3)$$

- for the monoblock version (n* = 1):

$$k^* = c_a P_p / c'_a d \cos^2 \zeta \qquad 4)$$

where:

$c_a$ Friction coefficient between the building and the foundation-soil complex;

$P_p$ Load transmitted to the bearing from the overhanging building;

$c'_a$ Friction coefficient between the movable truncated-conical mass (17) and the inclined inward surface of the housing (3);

ζ# Inclination angle, respect to the horizontal plan, of the inclined inward surface of housing (3);

n* Number of the vertical springs (18) for each pier;

d Maximum stroke of the electromagnet keeper.

The attraction force of the single electromagnet is:

$$F^* = 2 k^* d \qquad 5)$$

**N.B. The bearing needs accurate experimental tests**