June 3, 1930. F. D. CUMMINGS 1,761,659

BUILDING CONSTRUCTION (QUAKEPROOF BUILDING)

Filed Jan. 18, 1928

Fig. 1.

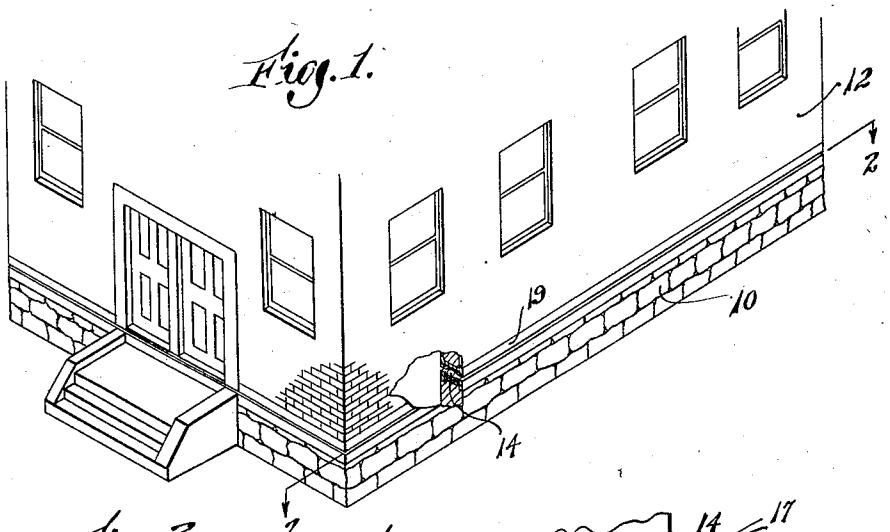


Fig. 3.

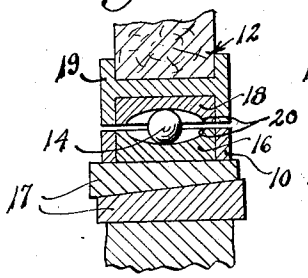


Fig. 4.

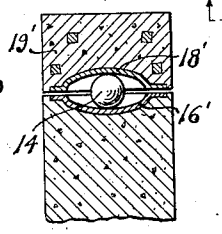
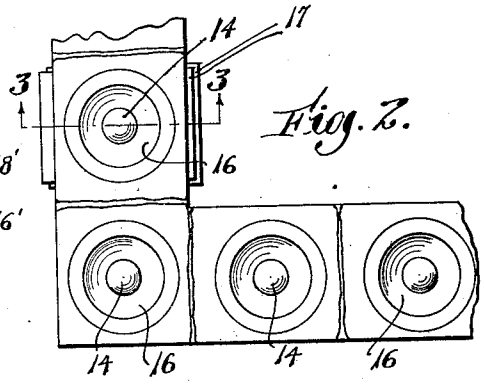


Fig. 2.



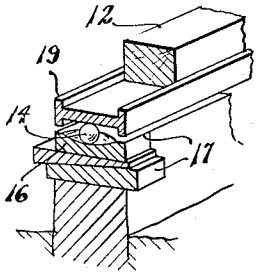


Fig. 5.

Fig. 6.

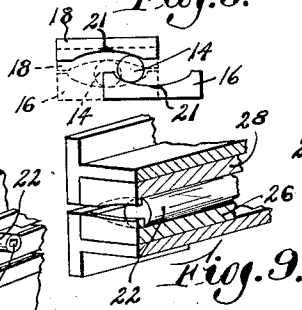


Fig. 9.

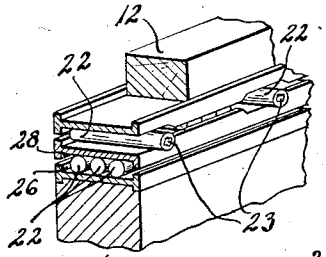


Fig. 8.

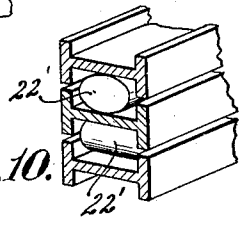
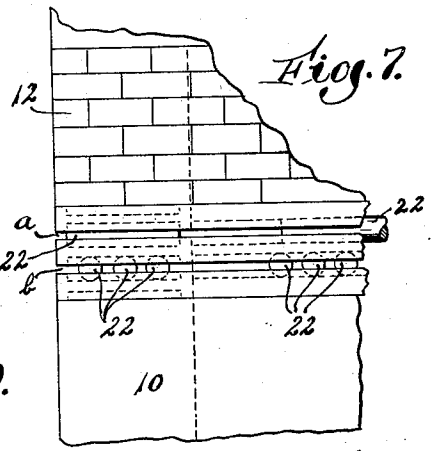


Fig. 10.

Fig. 7.



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UNITED STATES PATENT OFFICE

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BUILDING CONSTRUCTION (QUAKEPROOF BUILDING)

Application filed January 18, 1928. Serial No. 247,607.

This invention relates to improvements in building construction, (quake-proof building).

More especially it provides for the embodiment of quake-absorbing elements, which have particular utility and importance in regions where buildings are liable to receive sudden and severe shocks, such as result from earth-tremors, and violent horizontal earth movements.

The enormous property damage and incidental destruction of life caused by earthquakes, particularly in cities, may be attributed in large measure to the prevailing rigid type of building construction which lacks flexibility so that the swaying of the earth produces all stages of injury, ranging from mere dislocation of furniture to complete collapse of buildings. Even in the modern steel frame buildings where tensile strength of frame has proved sufficient to avoid collapse, the contents and walls have suffered from the severity of the shaking. And in regions where earthquakes are prevalent, they constiute an ever present threat of danger to life which makes the population extremely uncomfortable. Yet in answer to this challenge, civilization has not heretofore, so far as I am aware, developed any means for making the structure and contents of sizable buildings safe against earthquakes.

The present invention provides relief by resort to the principle of inertia and of flexible or slip connection to the ground, a combination which holds the building and contents approximately stationary while the earth shakes back and forth beneath it. To this end it proposes to erect the building with provision for limited movement of building horizontally, relative to its foundation. That is, the foundation may move with the quake while the building proper remains substantially at rest, due both to its inertia and to gravity, which tend to resist its displacement from normal position. A feature of importance is that this movement, relatively of foundation and building, although confined to a single horizontal plane, may be in any direction in that plane. And it is a further feature that provision is made for easy and automatic subsequent adjustment by which gravity can restore the building to its normal position with respect to its foundation after the disturbing force has been spent.

These objects and results may be attained by providing one or more horizontal-slip cleavages in the foundation, specifically illustrated herein as a series of bearing cups arranged in suitably spaced relation along each side of the foundation; and a like series of inverted cups on the building proper, registering with the first cups; and one or more rolling bearing elements in the pocket thus constituted between each pair of opposed cups. Specifically the bearing elements are represented, in one form, as balls, of diameter sufficient to space apart the halves of each pocket so that the entire weight of the building will rest on the balls. The cups should be large enough in horizontal diameter, and shallow enough in curvature, to permit of a desired relative horizontal movement of foundation and building, with but little vertical movement; but preferably the curvature should increase toward edges of the cup, which limits the relative movement in any direction, so that there will be a constantly increasing opposing effect, due to the gentle raising of the building proper which is occasioned by such movement. And when the quake is past the slight curvature of the cups will permit gravity to draw the building back to normal position on its foundation. During a lateral movement of the earth, the foundation moves with it, but by the effect of inertia the building tends to remain stationary. The slight rise in the bottom of the cup lifts it a little, a motion which is harmless to the building, especially when applied equally to all parts of the building as a unit; and this tends to restrain the building from rolling out of its cups, both during the quake and at all times, due provision having been made in the under pinning to prevent an uneven settling of the foundation into the earth with lapse of time.

Although ball-bearings appear, at the present time, to be the preferred means of

providing for the mentioned relative movement of building and foundation, roller bearings may be employed with somewhat similar results. In such case, however, the rollers would be arranged in two horizontal planes around the building walls, those in one plane extending all in like direction and providing for movement to and fro in opposite directions, east and west for example, while the rollers in the other plane would extend all in a direction differing by ninety degrees to provide for movement in other opposite directions, as north and south. Then an earth oscillation in any horizontal direction could occur by movement on one or both sets of rollers, without being transmitted in any dangerous degree to the building itself. Both forms involve the principle of constructing a building so that one portion thereof can be moved with respect to another or other portions; and so that the several portions readjust themselves after the moving force has departed.

The illustrated embodiments of the invention are intended merely to disclose working embodiments of the inventive idea, without limiting the scope of the invention to these embodiments. It is intended that the patent shall cover by suitable expression in the appended claims whatever features of patentable novelty exists in the invention disclosed.

In the accompanying drawings, which are more or less diagrammatic:

Figure 1 is a perspective of a portion of a building embodying features of the invention;

Figure 2 is a plan of a fragment of the foundation of Figure 1, the upper structure being removed to the cleavage plane indicated at 2—2;

Figure 3 is a fragmentary elevation in section on 3—3 of Figure 2, but including a bit of the superstructure;

Figure 4 is a view like Figure 3 showing a variation in the cup and surrounding construction;

Figure 5 is a perspective of another embodiment;

Figure 6 is a diagrammatic view showing positions which may be assumed by cups and ball when a shock occurs;

Figure 7 is an elevation of a fragment of a building illustrating another embodiment of the invention, using rollers in place of balls;

Figure 8 is a perspective in section through a wall of Figure 7;

Figure 9 is a perspective, in section, of another modified form of the invention; and

Figure 10 is a perspective, in section, of still another modification.

Referring to the drawings and especially to the form of the invention illustrated in Figure 1, a building foundation is represented at 10 and the building proper 12, is mounted on this foundation, but is held apart from it, at a plane of cleavage at the level 2—2 by a multiplicity of balls 14 which intervene and carry the total weight of the building above this level. The balls 14 may be arranged in any suitably spaced relation along the foundation, on all four sides, they being of sufficient number and of sufficient individual and aggregate strength to withstand the stresses due to weight, which can be calculated or estimated with reasonable accuracy. And they are of sufficient diameter to hold the superstructure at a desired small distance above the foundation, and to roll easily. Preferably they would be of steel or alloy, non-corrodible metal. As many can be used as are necessary for subdividing the weight to the reasonable carrying capacity of each ball. As illustrated in Figures 1–3 each ball stands singly in a shallow cup 16, and is covered by a shallow cup 18, the two together making a pocket which incloses the ball securely. The lower cup 16 is embedded in the foundation 10 and opens upward; the upper cup 18 is embedded in the building 12, preferably in a sill 19 thereof, opens downward, and registers with the cup 16 under normal conditions. Preferably the cups are considerably greater in horizontal diameter than are the balls, according to the expected amplitude of oscillation of the earth by quake, for which it is desired to provide, and each cup bottom has a shallowing curvature from centre outward in all directions to near the edge lip 20 where the curvature becomes more abrupt. Thus the building 12 under normal conditions rests squarely above the foundation 10, and is so maintained by the curvature of the respective cups, against being moved horizontally, with respect to its foundation, under the influence of any light or inconsequential force. But a force which is capable of moving the earth's surface of the region is free to do so without equally moving the building. The foundation can oscillate to and fro under the building, as indicated in Figure 6, while inertia holds the building itself substantially unmoved, with the balls 14 acting as ball-bearings between foundation and building. With twelve inch cups and three inch balls there can be a relative movement approximating a little less than twelve inches in any direction in the horizontal plane of the balls. However, there will be an opposing effect produced by the curves of the cups, slight at first but continually increasing, because in order for a ball to roll toward the lips of its associated cups there must be a slight raising of the building from its foundation. As a result, very little of earth oscillation will be communicated to the building and

that little will not be applied directly and suddenly. What force is transmitted to the building is applied in a manner to cause its slight, gradual and easy rise above the foundation, with little tendency to upset or dislocate the building's contents.

The abruptness of the curve near the lip of each cup 16, 18, constitutes a limitation of relative motion of building and foundation, eliminating the possibility of such a large movement as would carry the building off its foundation, or the foundation from under the building. If the earth vibration should be so extensive in horizontal amplitude as to reach this limit, any excess would have to be transmitted to the building. While it might be hoped that the building would in this event suffer only mildly, or not at all, nevertheless this shows the desirability of taking into account the known or expected amplitude of oscillation of earth in designing the size of the cups. But the gentle rise of the main surfaces of the cups 16, 18 of each pocket acts on the balls with camlike effect; and when the oscillating force has ceased gravity of the building will return the balls to the centres of their respective pockets, thus returning the building, in gentle and easy fashion, to its normal position with respect to the foundation 10.

The structural arrangements for introducing the rolling bearing between building and foundation may vary, but in general each cup should be set securely in its own part of the structure and the bearing surfaces of cups and balls or other rolling element should be hard, so that the weight will not produce indentation. To provide a low intensity of indenting force, and of crushing force on the rolling element the number of balls may be increased or rollers may be used. The employment of rollers provides line contacts instead of point contacts, and thus reduces the intensity of crushing force due to weight of building, but introduces the problem of caring for earth oscillations which are not strictly in the direction of rolling. The invention provides for this by making two planes of cleavage as indicated at *a* and *b* in Figure 7, close together, in which all rolls 22 in the same cleavage are parallel, and are at right angles to those in the other cleavage. By this device a horizontal oscillation of foundation in any direction whatsoever can find relief in one or the other or in both of these two cleavages, without the oscillation being communicated to the building itself, so long as the structural limits of permissible rolling are not exceeded by the earth oscillation. To provide for the return to normal position, if building be not left squarely over foundation, one or both of the troughs 26, 28, for the rollers, corresponding to the cups 16, 18, for the balls, may be made with bearing surfaces concave, having a cam profile in cross section resembling that of the cups and balls in Figure 2; or the bearing blocks for the rolls may have plane faces, Fig. 8, and means be provided to restore normal position by power manipulation applied to certain of the rolls, which may have sockets 23 in their ends, to turn them as by an arm or wrench and so to roll the building back to place. The use of plane surfaces for the bearing has some advantages, among which are simplicity of manufacture of the blocks, accuracy of handling and setting, the opportunity to set a plurality of rollers in a group thus further diminishing crushing force, and the fact that horizontal oscillations of earth could occur without raising the building even the trifling amount which is incidental to the form of Figure 3. But such a slight raising should not be serious, because a building is naturally constructed to withstand vertical stresses. The use of plane platens for bearing blocks can be combined with the advantages of rollers and of automatic return to normal position by making the rollers 22′ of cam shape, as in Figure 10, and any desired amplitude of oscillation may be cared for by making the peripheral surface of the cam large enough for the desired lateral travel to ocur while the cam roll is rocking from its normal quiet position, illustrated, nearly ninety degrees to its maximum elevation.

Each ball, or each roller, as the case may be, should carry its proportionate amount of the total weight of the building above, and thus it may be desirable to provide for their individual vertical adjustment, removal and replacement. In Figures 3 and 5 wedges 17 are suggested for this purpose, the lower bearing block 16 being mounted loosely for movement vertically, influenced in one direction by the wedges and in the other direction by gravity. Thus, each ball 14 may be made to carry its share of the load; and, when desired, the wedges may be taken out to permit block 16 and associated ball 14 to be removed, and replaced, or new ones to be substituted.

The drawings indicate several of the various ways in which the invention may be embodied so as to constitute the desired cleavage between foundation and superstructure of a building. Thus Figures 1 and 3 indicate the use of a rigid steel sill for the superstructure which may conveniently be in the form of an I-beam 19. In Figure 4 the use of a reinforced concrete sill 19′ is suggested and the shallow bearing cups are made of stamped steel sheets, 16′ and 18′.

In Figure 5 the upper cup 18 is omitted and the plane under surface of the web of the I-beam 19 runs on the ball.

In Figure 8 the absence of lifting effect

when a lateral movement occurs makes it desirable to provide special means for restoring position to normal if necessary. For which purpose it is suggested that certain of the rollers be made accessible and provided with means for the attachment of gearing for turning them, the crushing stresses here being reduced by arranging the rollers in groups; but in Figure 9 where arranged singly cam surfaces can be provided so that when there has been displacement gravity will cause a return. The cam surface may be either on the roller or on its bearing; and in Figure 10 is illustrated the former of these styles.

When balls are used the balls may be expected to become slightly flattened in their normal positions, by compression, and with lapse of time, or their cup bearings may intentionally be made each with a slight depression 21, in Figure 6, at the centre to guide the ball when free to a setting in its desired central normal position. Such flattening or depression tends to make the device unresponsive to diminutive and harmless earth tremors, but the severe suddenness with which any shock of importance occurs will effect a rolling. The very considerable inertia of the heavy building will insure that even though there be a tendency of the bearing to stick, the cleavage will always occur at this place provided by the invention, rather than by a breaking part of the regular structural materials 12 of the building, in all parts of which the bonding and the friction are much greater. The building will tend to remain stationary and intact while the ground moves freely under it. And, preferably, the piping and wiring connections within the building, at the plane or planes of cleavage, will be flexible enough to permit the said rolling without breaking or damaging the connections.

It will be understood that the term "building" is herein used in a general sense to include various sorts of structures, and that the invention may be applied to engineering constructions built for purposes other than buildings, as for example, bridges, roads, abutments, pipe lines; and that in other respects the invention is not limited to the precise structures herein shown.

The invention claimed is:

A structure divided with horizontal foundation cleavage and provided at the cleavage with antifriction bearing devices; adjustable means associated with one member of a bearing for adjustment of said member vertically with respect to the building and the other member, thereby to set the position of that bearing for carrying load equally with other bearings.

Signed at Boston, Massachusetts, this thirteenth day of January, 1928.

FRANK D. CUMMINGS.