July 23, 1940. F. N. ROPP 2,208,872

ROCKER SUPPORT FOR BUILDING STRUCTURES AND THE LIKE

Filed Feb. 11, 1938 2 Sheets-Sheet 1

Fig. 3.

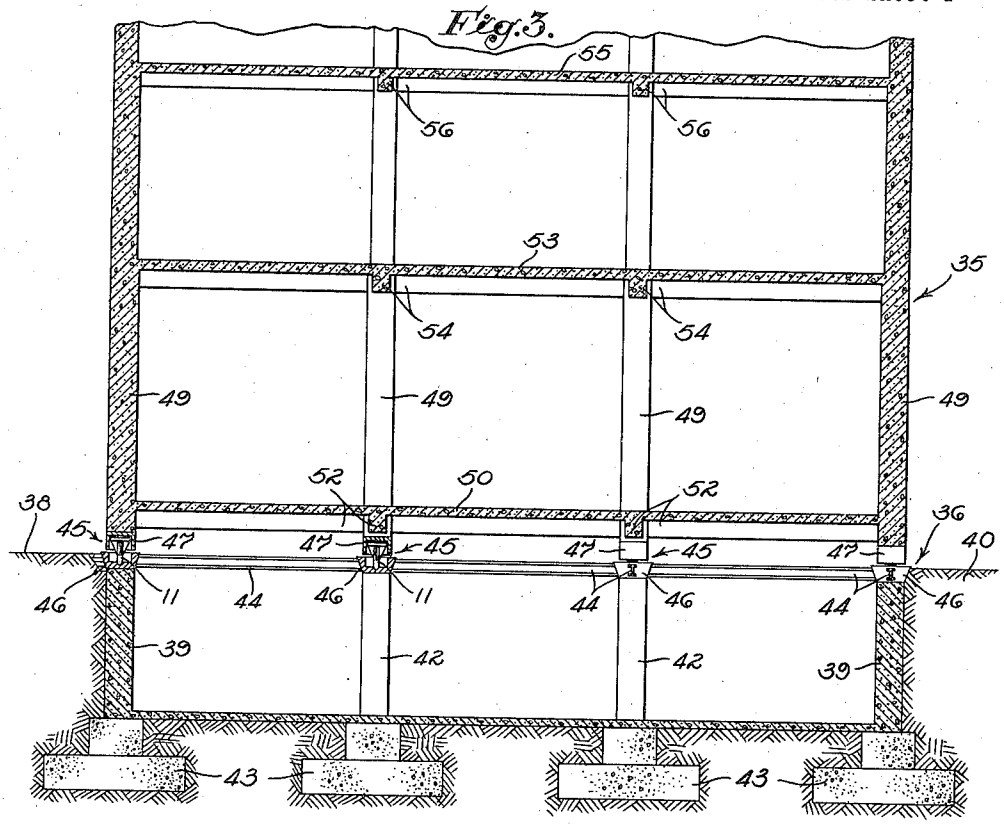


Fig. 1.

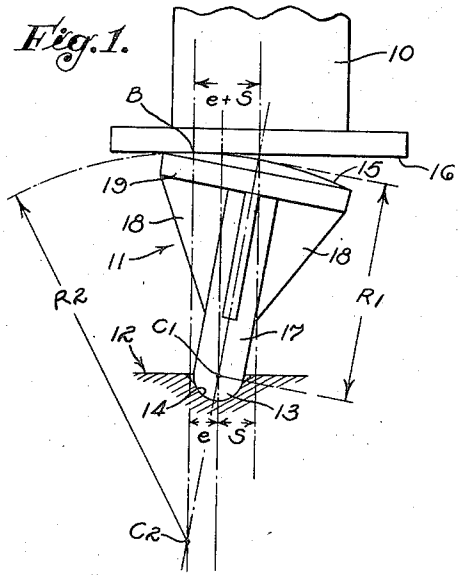
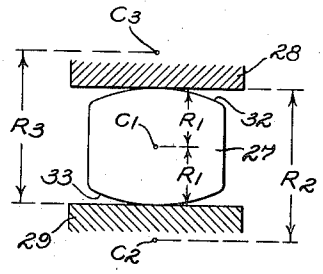


Fig. 2.



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Fig. 4.

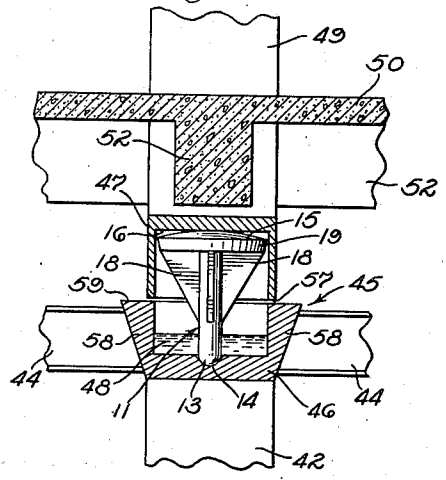


Fig. 7.

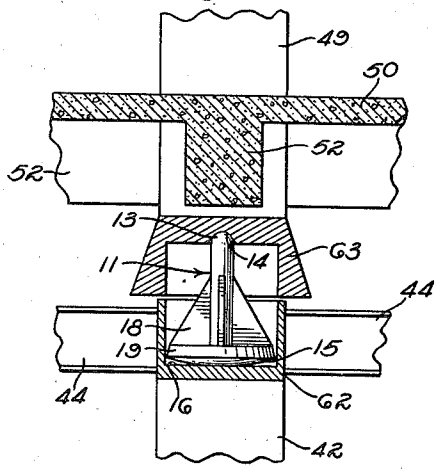


Fig. 5.

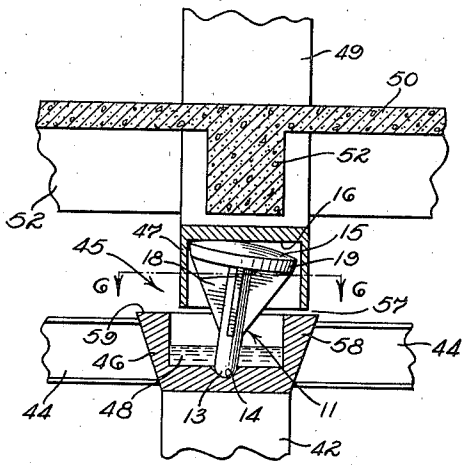


Fig. 8.

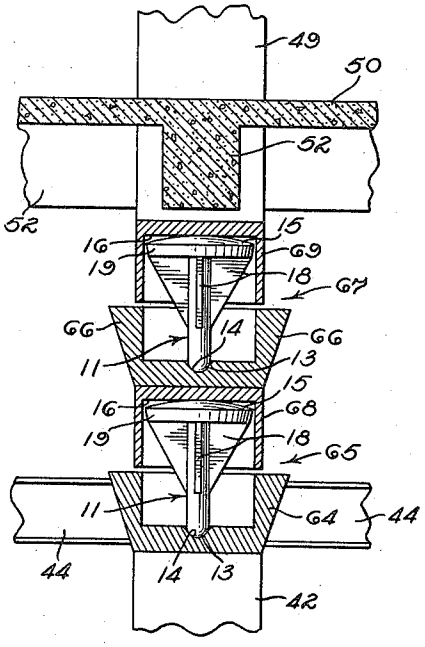
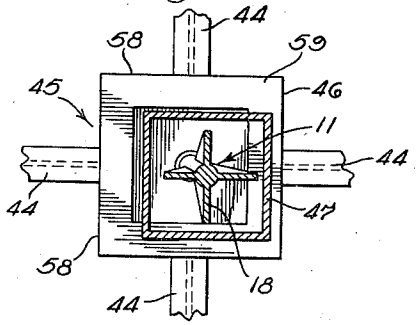


Fig. 6.



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UNITED STATES PATENT OFFICE

2,208,872

ROCKER SUPPORT FOR BUILDING STRUCTURES AND THE LIKE

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Application February 11, 1938, Serial No. 189,989

8 Claims. (Cl. 72—77)

My invention relates to supporting means for buildings and other structures, with special reference to the type of support that permits relative lateral movement between a structure and the earth.

Damage to a building structure by earthquake may be broadly attributed to the fact that the relatively high inertia of a building structure prevents the structure as a whole from freely following the relatively sharp and irresistible lateral movements of the earth. It is well known that the damage may be largely averted by providing freedom for lateral relative movement between the building structure and the earth, and various means for the floating support of structures have been proposed for such purpose.

Some of the prior art devices in this field have the disadvantage of being excessively complicated in structure; some are relatively costly to manufacture; and other prior art devices require excessive space allowance vertically or horizontally. For example, some of the prior art arrangements require relatively large pits or extensive basements to house elaborate cradles or similar understructures. The general object of my invention is to provide, in contrast with these prior art devices, a floating support means that is simple, relatively inexpensive, and that requires a minimum of space.

Some prior inventors have sought the required mobility by inserting supporting balls between a structure and its base, and providing some expedient to maintain a normal central disposition of the building on the supporting balls. Ball arrangements may, in general, be less complicated, less expensive, and less subject to structural failure than cradle suspensions, but the designer of a ball-bearing building support is confronted with a certain dilemma. If he decides to employ relatively small balls, a large number will be required for even an average building. The resistance involved in relative movement between a building and the earth represents the unabsorbed force of an earthquake movement that is transmitted to the building; for this reason it is not desirable to raise friction to excessive values by the employment of numerous small balls. If, on the other hand, fewer relatively large balls are decided upon by a designer to reduce friction, the cost per ball mounts rapidly and the problem of providing space for ball movement may become formidable.

An object of my invention is to avoid this dilemma in a construction without sacrificing the rolling contact characteristic of a ball-bearing arrangement. More specifically, it is my purpose to provide in a building support, rolling contact surfaces having relatively large radii of curvature without employing balls of corresponding radii, and without the necessity of providing the space either vertically or horizontally required by such balls.

In each of the various ball arrangements old in the art, some equalizing means is required to keep the mobile building normally in a centralized position. For example, opposing springs have been used in some arrangements, and in others concave surfaces have been provided to cooperate with the balls. In my invention, by contrast, I propose to provide the equivalent of such equalizing means in the configuration of the various support members themselves.

Broadly described, the support member by which I achieve the above objects and in which I embody the equalizing function, constitutes a rocker having a convex supporting surface shaped to permit rolling movement in any lateral direction and to provide a certain eccentricity that causes the superimposed structure to seek its normal disposition at all times.

The above and further objects of my invention will be apparent in my detailed description to follow, considered with the accompanying drawings.

In the drawings:

Fig. 1 is a diagrammatic representation of the preferred form of my rocker showing the relationship involved.

Fig. 2 is a similar diagrammatic representation of a second form of my rocker.

Fig. 3 is a vertical section through a typical building showing a base structure fixedly related to the earth and a superstructure floatingly mounted thereon in the manner taught by my invention.

Fig. 4 is a vertical section through a portion of a typical building construction incorporating one form of my support unit.

Fig. 5 is similar to Fig. 4 showing the disposition of the support unit resulting from relative movement between the earth and the building.

Fig. 6 is a horizontal section taken as indicated by the line 6—6 of Fig. 5.

Fig. 7 is a view similar to Fig. 4 to show that the rocker member of the support unit may be employed in reverse disposition.

Fig. 8 is a view similar to Fig. 4 showing one of my support units mounted on top of a second support unit to indicate how a building may in-

corporate a plurality of such units arranged in tiers.

For the purpose of disclosing the relationships involved in the functioning of my invention, I show in Fig. 1 a structural member 10 resting upon a rocker member 11, the rocker member in turn resting on a base member 12. The lower end 13 of the rocker is spherical in configuration and rests in a socket 14 concentric therewith. Since the rocker member oscillates about a fixed point C_1 at the center of curvature of the socket 14, the rocker may be regarded as pivotally related to the base member 12, and the lower end of the rocker may be termed the pivot end. The upper end of the rocker is convex, preferably spherical, to provide an arcuate surface 15 for rolling contact with the bearing face 16 of the structural member 10. For economy of material, the body of the rocker may be formed with a lower cylindrical portion 17 from which wings 18 extend radially to brace an arcuate end wall 19 providing the rolling surface 15.

Any relative lateral movement between the structural member 10 and the base member 12 will result in oscillation of the rocker about the point C_1. The radius of such oscillation is defined as the shortest distance between C_1 and the convex rolling surface 15. This radius R_1 in the form of my invention shown in Fig. 1 may also be regarded as the effective length of the rocker, but in other forms of my invention, as will appear hereinafter, the radius R_1 may not so aptly be termed the length of the rocker.

Fig. 1 shows a second radius R_2 measured from the rolling face 15 to the center of curvature C_2 of that face. At the heart of my invention is the conception that a certain useful eccentricity may be provided by simply designing the rocker with R_2 greater than R_1.

The character and effect of the eccentricity involved may be understood by reference to Fig. 1 in which the rocker is tilted to show the effect of a sudden shift of the earth, displacing the bottom of the rocker laterally a distance S. It will be noted that the upper bearing point B follows the center of curvature C_2, being always directly above that center. But the center of curvature C_2 because of the tilt of the rocker, is displaced laterally a distance e in addition to the displacement S of the center of oscillation C_1, the result being that the bearing point B is shifted laterally a greater distance than the bearing member 12. The additional shift of the bearing point B produces a moment tending to restore vertical alignment between the bearing point B and the point C_1 through which the vertical resistance supporting the load of the structural member 10 is exerted. In addition to this moment, there is also a gravitational tendency of the rocker to return to its normal vertical disposition, since any oscillation of the rocker from that normal disposition elevates the structural member 10.

If friction is neglected, the resistance to displacement of the rocker from its normal vertical position is equal to the tendency of the rocker to return to that position, and both depend upon the relative lengths of R_1 and R_2, both increasing with increase in the relative difference. Any friction involved in the oscillation of the rocker, however, increases the resistance of the rocker to movement away from its normal vertical disposition, but decreases the tendency of the rocker to return to its normal disposition from a displaced position.

Part of the friction is in the rolling resistance of the spherical surface 15 in contact with the bearing face 16 and the remainder of the friction is caused by sliding contact of the lower spherical end 13 in the socket 14. The rolling resistance can be reduced only by decreasing the permissible bearing value on contact surfaces, which reduction is accomplished by increasing the radius of curvature of the arcuate surface 15. The socket resistance to oscillation of the rocker may be reduced by decreasing the radius of curvature of the socket or by increasing the length of the rocker, and, regardless of dimension, may be minimized by proper lubrication.

Knowing that the degree of responsiveness of the rocker to lateral forces depends upon the eccentricity involved or the relative lengths of the two radii R_1 and R_2, together with the mentioned factors of friction, those skilled in the art may readily design rockers for specific requirements. A too sensitive arrangement will permit a building to respond undesirably to ordinary wind pressures, but, on the other hand, since the total resistance attributable to eccentricity and friction determines the proportion of shock transmitted to the building structure during an earthquake, it is desirable that such total resistance be not greater than necesary to allow for wind pressures.

The required radius of the convex rolling surface 15 of the rocker is a function of a constant times

$$\sqrt{E \times \text{load}}$$

divided by the permitted bearing value on the contact surface. Thus, if a load N of 150,000 lbs. is assumed, the permissible steel stress δm being 20,000 lbs. per sq. in. and E the coefficient of elasticity being 30,000,000, then the radius of curvature for the convex surface =

$$\frac{.395}{\delta m}\sqrt{NE} = 42 \text{ in.}$$

The area of contact at the bottom of the rocker for carrying such a load=

$$\frac{150{,}000}{20{,}000} = 7.5 \text{ sq. in.}$$

The diameter d of the shaft to provide such contact may be ascertained from the formula

$$(.7071d)^2 \times \frac{\pi}{4} = 7.5$$

from which it is found that $d = 4\frac{3}{8}$ in., say $4\frac{1}{2}$ in.

The frictional resistance at the socket is the load times the frictional coefficient times the radius of the rocker shaft, divided by the length of the rocker. Taking the frictional coefficient as .2 and assuming the shaft to be 33 in. long, the horizontal force to overcome the socket friction=

$$.2 \times \frac{150{,}000}{33} \times 2.25 = 2050 \text{ lbs.}$$

The rolling resistance of the convex face of the rocker =

$$\frac{N}{3} \times \sin \sigma = \frac{2N}{3}\sqrt{\frac{\delta m}{E}\left(1 - \frac{\delta m}{E}\right)} = 2580 \text{ lbs.}$$

The total force required to overcome friction then is 2050+2580=4630 lbs., and the coefficient against lateral movement=

$$\frac{4630}{150{,}000} = .0309$$

If a ground movement of 6 inches away from center each way is assumed, the eccentricity de-

veloped by the movement of a rocker constructed in accordance with the above calculations will be

$$\left(\frac{42-33}{42}\right)\times 6=1.285 \text{ in.}$$

The rise of the load caused by the oscillation of the structure will be

$$9-\sqrt{9^2-1.285^2}=.09 \text{ inch}$$

The forces tending to return the load to normal disposition of the rocker creates a moment, the value of which is

$$\left(1.285+\frac{.09}{4.715}\right)\times 150{,}000=195{,}500 \text{ inch-pounds}$$

The starting moment required to overcome the frictional resistance $=33\times 4630=153{,}000$ inch-pounds. The returning moment then is in excess of the starting moment by 42,500 inch-pounds, representing a force of

$$\frac{42{,}500}{33}=1290 \text{ lbs.}$$

The rocker need not be designed for ball-and-socket engagement with the base members. Thus, in the second form of my invention, the construction of which is indicated by Fig. 2, the rocker **27** has rolling contact with both the supported structural member **28** and the base member **29** on which the rocker rests. Both the upper spherical face **32** and the lower spherical face **33** of the rocker have relatively long radii of curvature, the center of curvature of the face **32** being shown at C_2 and the center of curvature of the face **33** being shown at C_3. The rocker may be regarded as oscillating about a center C_1 that shifts both laterally and vertically, and R_1, the radius of oscillation of the rocker, may be taken as the shortest measurement from C_1 to either of the two faces **32** and **33**. The eccentricity developed by this form of my rocker depends upon the length of R_1 relative to both R_2 the radius of curvature of the face **32**, and R_3 the radius of curvature of the face **33**, eccentricity being developed by both of the spherical faces of the rocker.

The manner in which my rocker may be incorporated in a building is indicated by the remaining figures of the drawings. All of these figures incorporate the first form of my rocker shown in Fig. 1, but it will be apparent that other forms of the rocker, such as shown in Fig. 2 for example, may be employed in the same manner with equal facility.

In Fig. 3, I show a multi-story superstructure, designated by the numeral **35**, floatingly supported on a base structure generally designated by the numeral **36**. Since allowance must be made for relative lateral movement between the superstructure and the base structure, I prefer to arrange the plurality of supporting rockers **11** on a level at or above the ground level **38**. In such an arrangement the exterior columns **39** of the base structure may lie against the earth **40** with no intervening clearance for relative movement. As shown in the drawings, both the exterior columns **39** and the interior columns **42** of the base structure are supported by buried foundation structure **43**, and the various base columns are interconnected by stay struts **44** shown in the form of I-beams. It is apparent that the whole base structure is rigidly related to the earth.

As best shown in Figs. 4, 5, and 6, a rocker unit, generally designated by the numeral **45**, comprises a base member **46** and a structural member **47** floatingly supported by the rocker **11** seated in the base member. The base member **46** is incorporated in the construction of a basement column **42** to comprise an integral part of the base structure **36** shown in Fig. 3. Preferably the base members **46** will be distributed on the level by the I-beam stay struts **44**. In the preferred form of my invention, the base member **46** has the general configuration of a pan, and, therefore, may be employed to retain a suitable quantity of lubricant **48** to minimize friction in the socket **14**. The floating structural member **47** is incorporated in a column **49** of the superstructure that corresponds to the basement column associated with the base member **46**.

Just above the rocker unit **45** may be the first floor **50** of the building supported by floor beams **52** interconnecting the various columns **49** of the superstructure. Above the first floor **50** of the superstructure are additional floors, the second floor **53** supported by beams **54** and the third floor **55** supported by beams **56** being shown in the drawings. Since the points of support, or the aforementioned bearing points B of Fig. 1, shift laterally under each column **49**, when there is any relative displacement of the building, it is advisable to make the portions of the columns **49** between the first floor **50** and the second floor **53** somewhat heavier than the portions above the second floor of the superstructure, as indicated in Fig. 3.

It will be noted that the floating structural member **47** in the preferred form of my invention has the form of an inverted pan so that the base member **46** and the floating member **47** together form a housing normally encasing the rocker member **11**, the rocker being completely enclosed except for a slight clearance **57** between the base member **46** and the floating member **47**.

Relative movement between the superstructure and the base structure causes the rocker member to oscillate to a tilted position, as indicated in Fig. 5, the base member **46** being displaced laterally with respect to the floating member **47**. Preferably the rocker unit will be so designed that opposed surfaces of the floating member and the base member **46** will come into supporting engagement if the relative movement between the superstructure and the base structure is so excessive as to tilt the rocker beyond an operative angle. Thus, the upwardly extending walls **58** of the base member **46** may incline outward to present a relatively extensive horizontal surface **59** upon which the lower edge of the floating member **47** may come to rest whenever the rocker is tilted beyond an angle that will permit the rocker to return to normal. Such an arrangement prevents the building from being dropped any material distance if an earthquake should throw the rockers out of operation.

Fig. 7 is similar to Figs. 4, 5, and 6, the essential difference being that the rocker member **11** is shown in inverted position to indicate that the rocker may be reversed without interfering with the functions heretofore described. In this figure, the rocker unit of Figs. 4, 5, and 6 is simply reversed, the base member **62** of Fig. 7 having the configuration of the floating structural member **47** of Fig. 4 and the floating structural member **63** of Fig. 7 having the configuration of the base member **46** of Fig. 4.

The purpose of Fig. 8 is to indicate that more than one level or tier of rocker units may be incorporated in a building structure with certain advantages. The resistance to lateral movement

of the lower rocker unit is transmitted to the upper rocker unit, instead of directly to the super-structure, with the result that shocks are absorbed to an increased degree.

In Fig. 8 the base member 64 of the lower rocker unit 65 is incorporated in the base structure of the building in the same manner as the base member 46 of Figs. 4 to 6. The base member 66 of the upper rocker unit 67 rests upon the floating member 68 of the lower rocker unit 65. The floating member 69 of the upper rocker unit 67 is incorporated in the column 49 of the superstructure in the same manner as the floating structural member 47 of Figs. 4 to 6. While Fig. 8 shows the two levels of rocker units as close together as possible, the two levels may be considerably spaced if desired.

For the purpose of disclosure and to illustrate the principles involved in my invention, I have described specific forms of my rocker and rocker unit in explicit detail. It will be apparent to those skilled in the art, however, that the forms shown and described may be variously changed and modified without departing from the spirit of my conception. I specifically reserve the right to all such changes and modifications that properly come within the scope of my appended claims.

I wish to point out also that my invention is not restricted to building structures nor is its function limited to the cushioning of earthquake shocks. It will be readily recognized by those skilled in widely divergent arts that the principles of my conception are applicable to any arrangement where it is desirable to support an element in a laterally yieldable manner with an inherent tendency to maintain a centralized normal position. For example, it is conceivable that a loading platform subject to occasional lateral impact might be so mounted as to yield to such impact with minimum damage. It is to be noted that such a platform would serve as a bumper to decelerate without damage a vehicle making the impact. This observation suggests the employment of my invention primarily for such deceleration purpose.

A spherical rolling surface is employed in the particular form of my invention set forth in this disclosure. A spherical rolling surface is required, however, only in installations where the displacement may occur in diverse lateral directions. In installations where relative movement is to be expected in only one direction, a cylindrical rolling surface may be substituted.

I claim as my invention:

1. In a building structure, the combination of: a base member adapted to retain a quantity of lubricant; a building member; and a rocker supporting the building member above the base member, said rocker having one end seated in said base member and its other end in rolling contact with the building member, said rolling end having a radius of curvature greater than the vertical length of the rocker.

2. A structure of the class described, having: a fixed base member; a structure member spaced above said base member, one of said members having a substantially plane supporting face; and a rocker member floatingly supporting said structure member on said base member, said rocker member having a convex surface in rolling contact with said plane supporting face, the radius of curvature of said convex surface being greater than the radius of rotation of the rocker.

3. A rocker for floatingly supporting building structures and the like comprising, an elongated body portion providing a point at one end thereof and having a transversely extending wall with a convex outer surface at the opposite end thereof, the radius of curvature of said convex surface being of greater length than said elongated body portion.

4. A rocker for floatingly supporting building structures and the like comprising, an elongated body portion providing a pivot at one end thereof and having a transversely extending wall with a convex outer surface at the opposite end thereof, and webs extending from said elongated body portion reinforcing said wall, the radius of curvature of said convex surface being of greater length than said elongated body portion.

5. A rocker for floatingly supporting building structures and the like comprising, an elongated body portion providing a pivot at one end thereof and having a transversely extending wall with an arcuate outer surface at the opposite end thereof, the radius of curvature of said arcuate surface being of greater length than said elongated body portion.

6. A rocker for floatingly supporting building structures and the like comprising, an elongated body portion rounded at one end thereof and having a transversely extending wall with an outer arcuate surface at the opposite end thereof, and webs extending from said elongated body portion reinforcing said wall, the radius of curvature of said arcuate surface being of greater length than said elongated body portion.

7. In a building structure, the combination of: a base member fixedly related to the earth; a building member; and a rocker supporting the building member above the base member, said rocker compriisng a body having one end thereof rotatably engaging one of said members, and the other end of said body having an arcuate outer surface in rolling contact with the other of said members, the radius of curvature of said arcuate surface being of greater length than said body, whereby when said rocker is oscillated from its normal vertical position said building member will be slightly raised by said arcuate surface thus creating a poential force for returning said rocker to its original vertical position.

8. A rocker for the floating support of building structures and the like, said rocker having a substantially spherical end for rolling contact with a support surface, said spherical end having a radius of curvature greater than the vertical dimension of the rocker.

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