March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 1

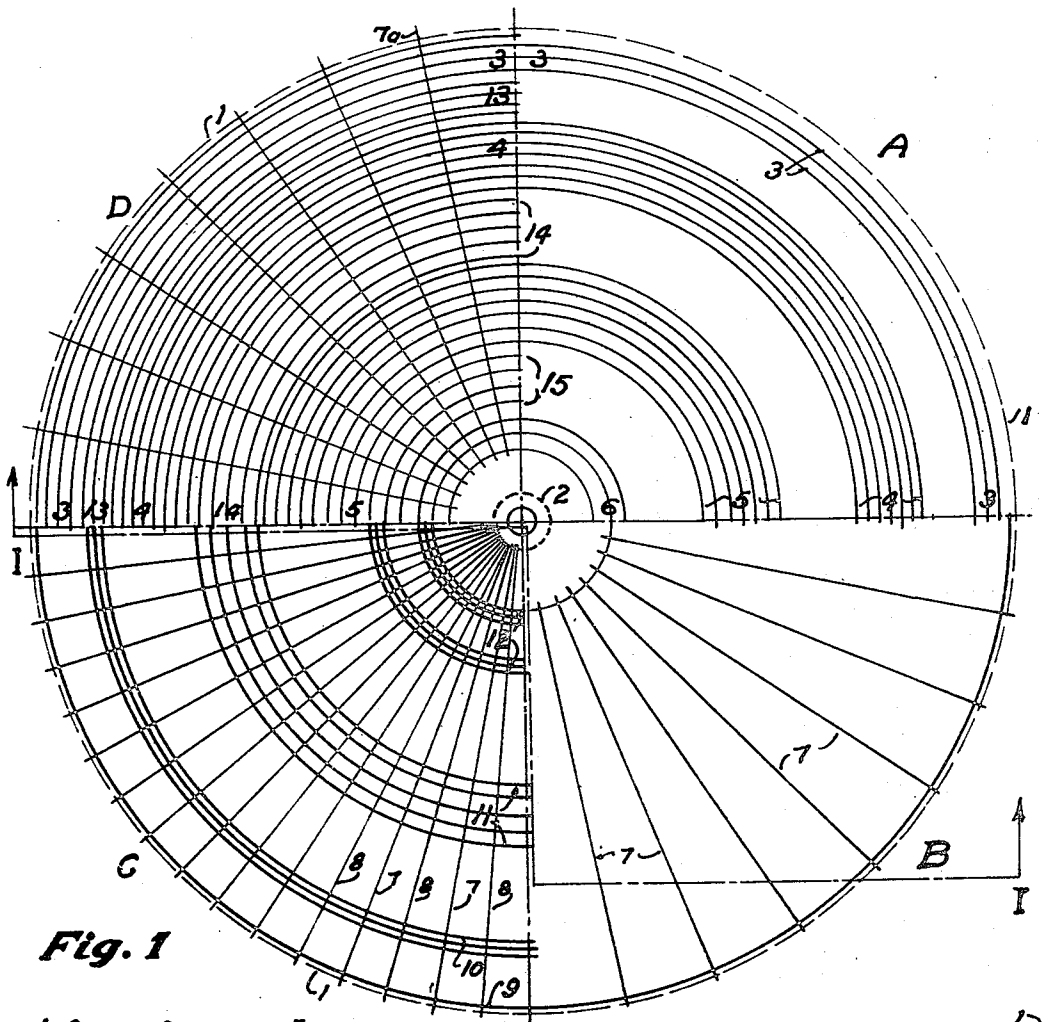


Fig. 1

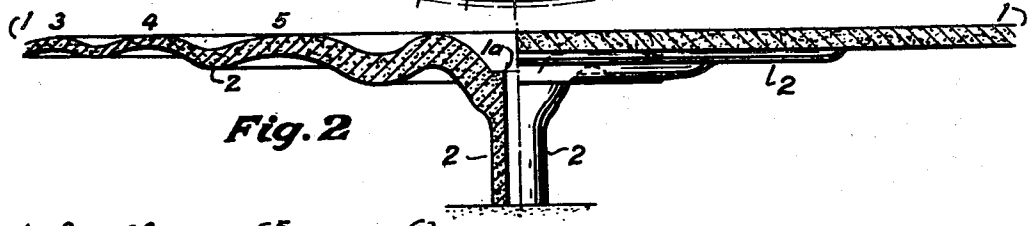


Fig. 2

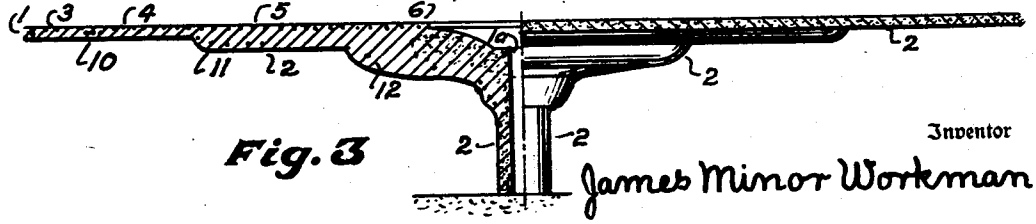


Fig. 3

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 2

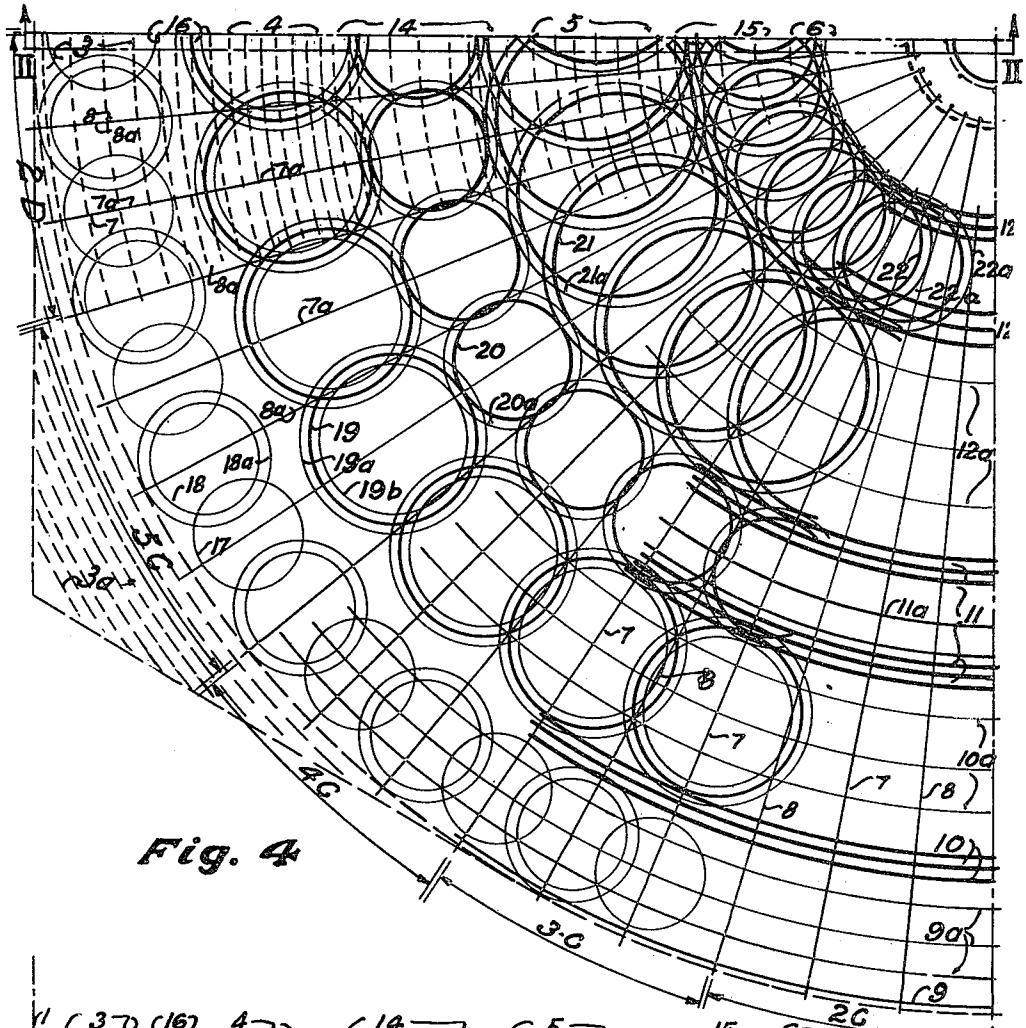


Fig. 4

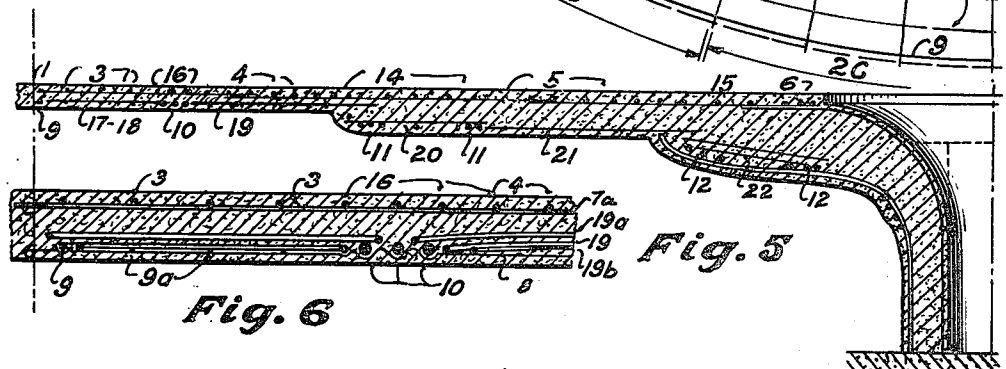


Fig. 5

Fig. 6



Fig. 6-A

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 3

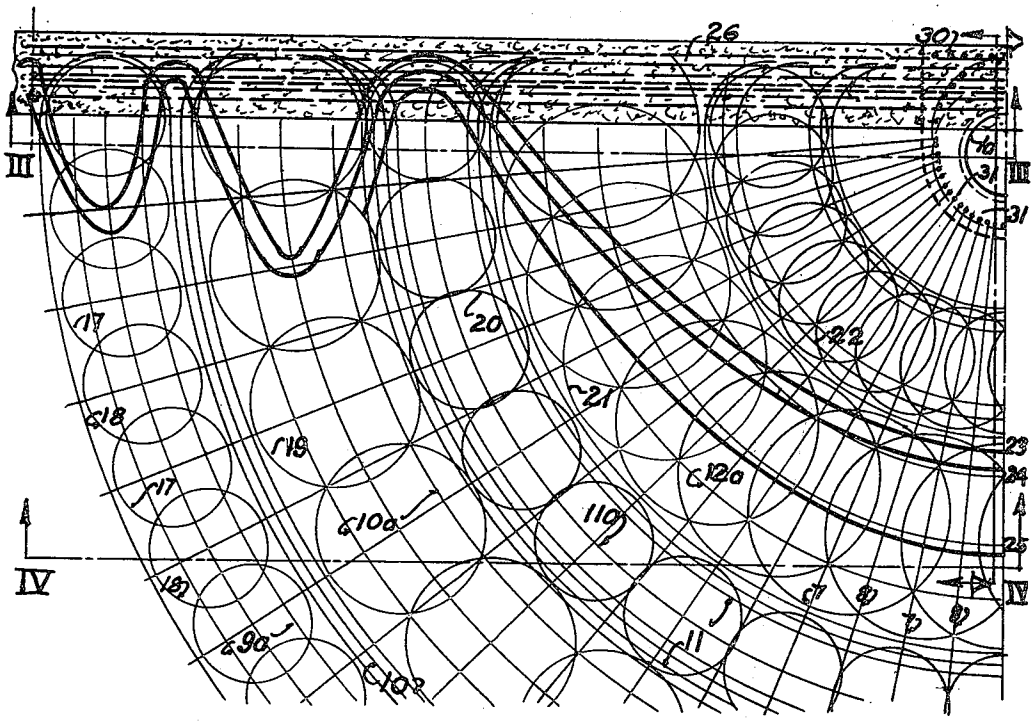


Fig. 7

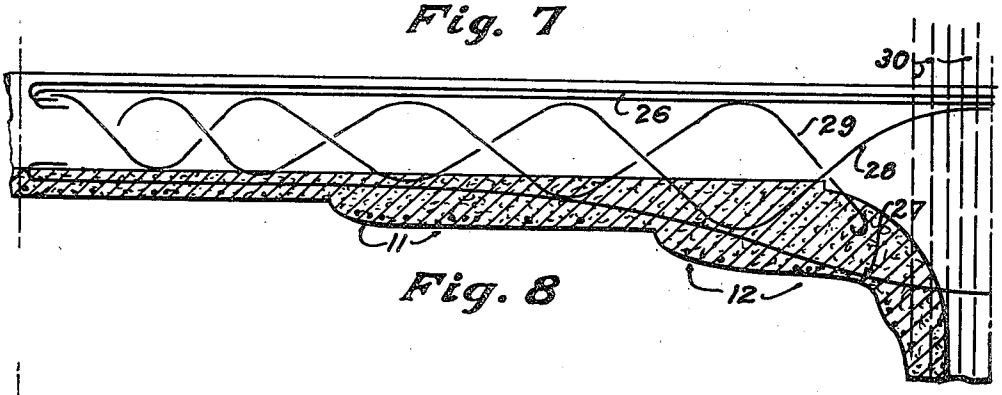


Fig. 8

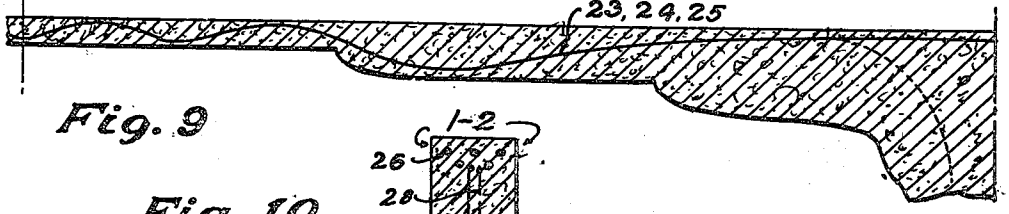


Fig. 9

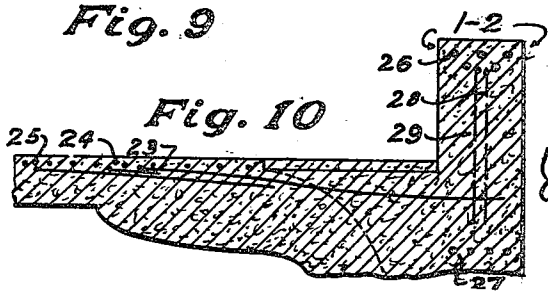


Fig. 10

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 4

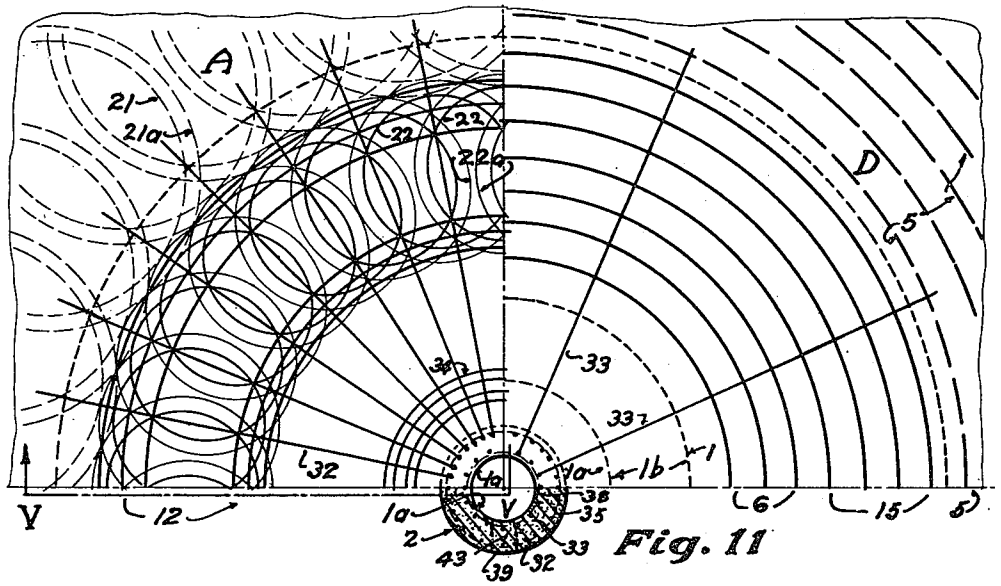


Fig. 11

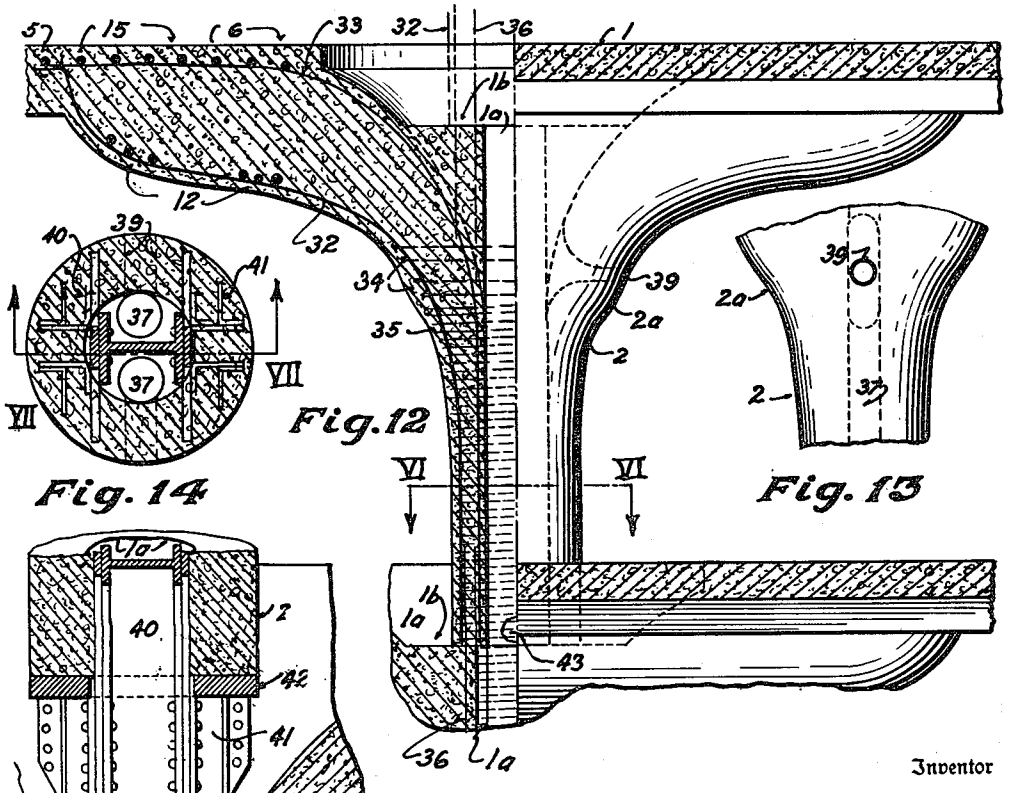


Fig. 12

Fig. 14

Fig. 13

Fig. 15

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 5

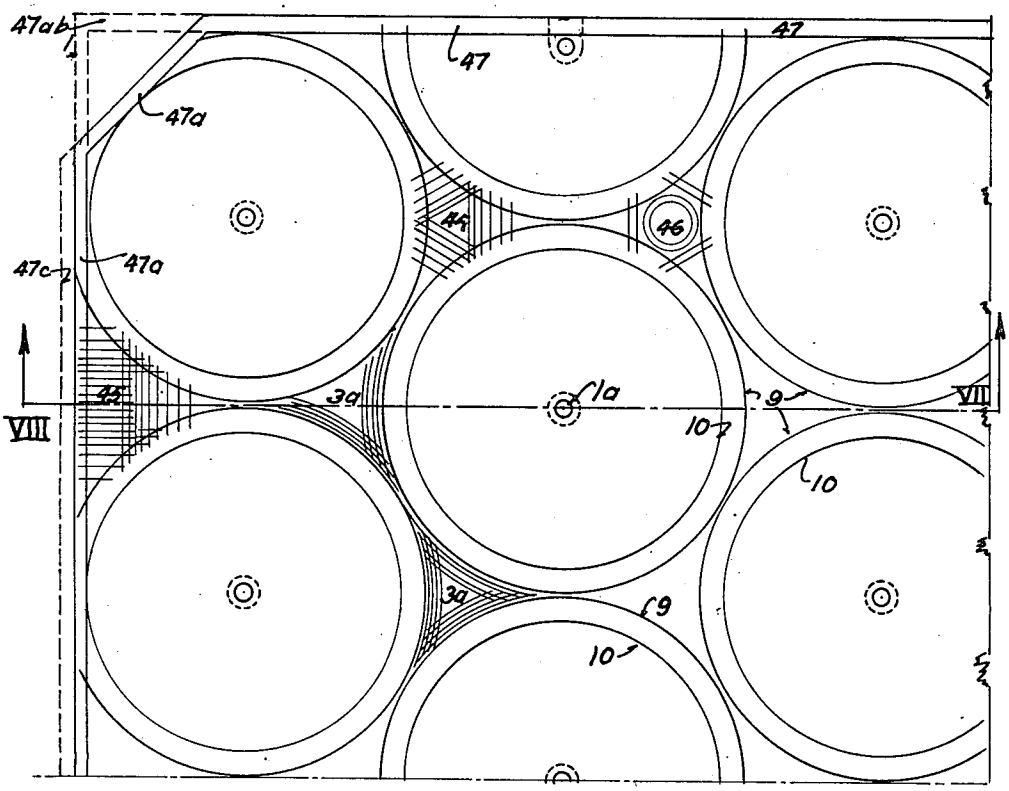


Fig. 16

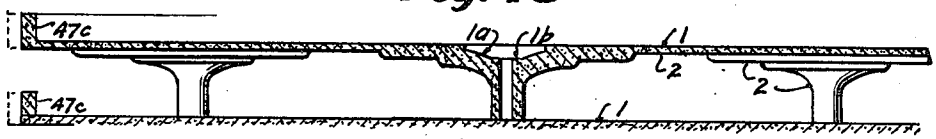


Fig. 17

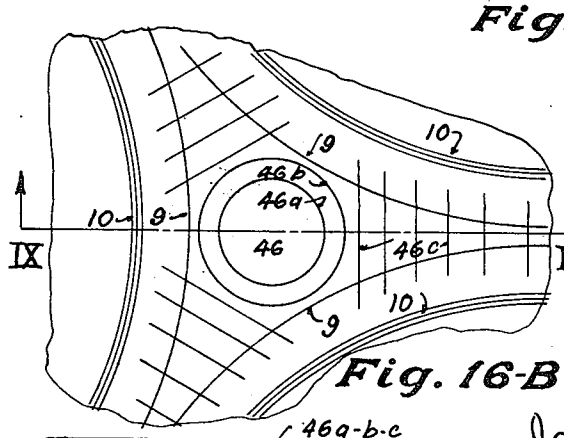


Fig. 16-B

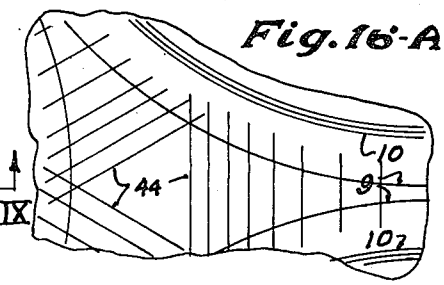


Fig. 16-A

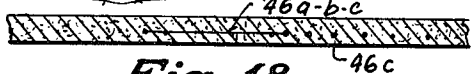


Fig. 18

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 6

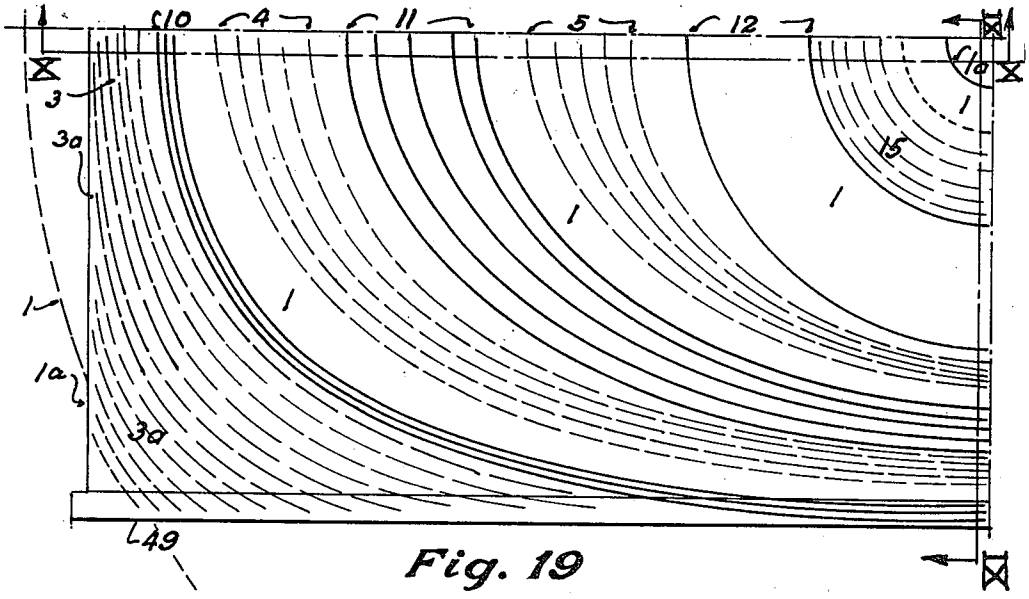


Fig. 19

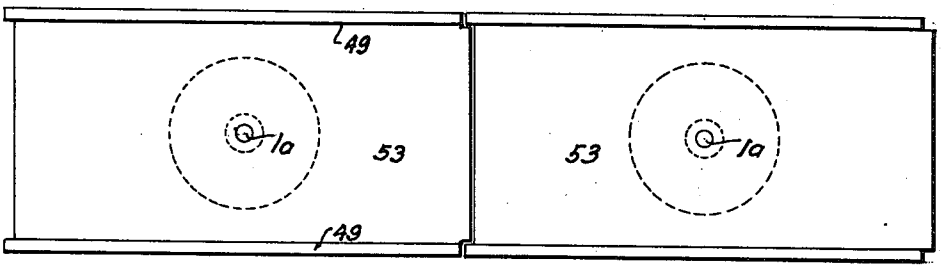


Fig. 20

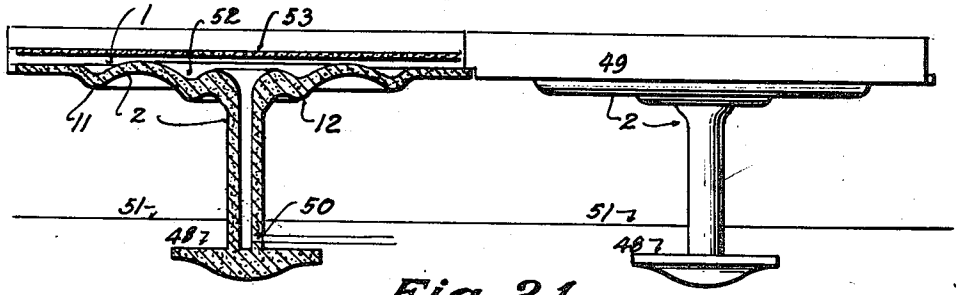


Fig. 21

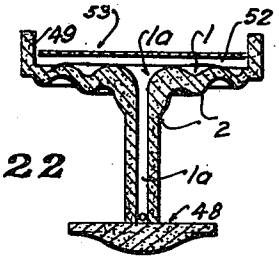


Fig. 22

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 7

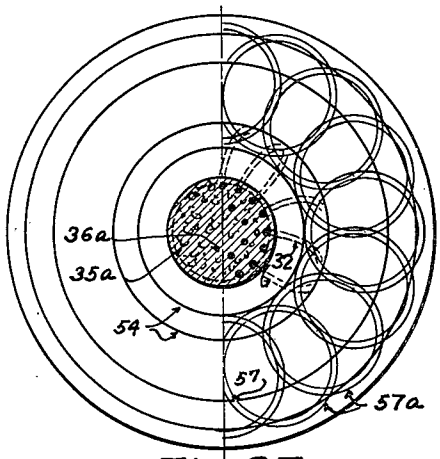


Fig. 23

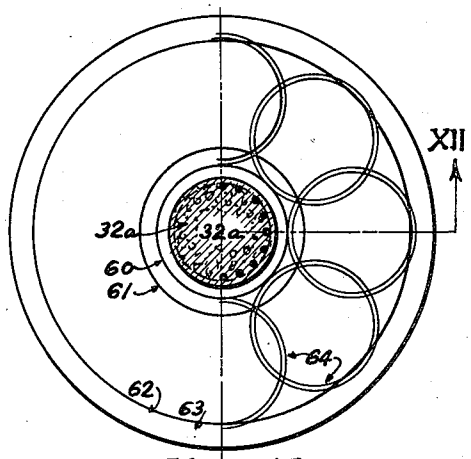


Fig. 27

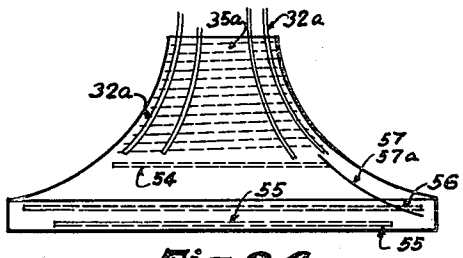


Fig. 24

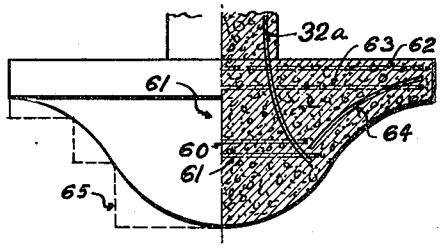


Fig. 28

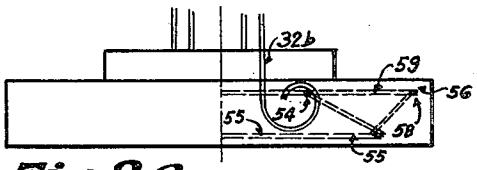


Fig. 26

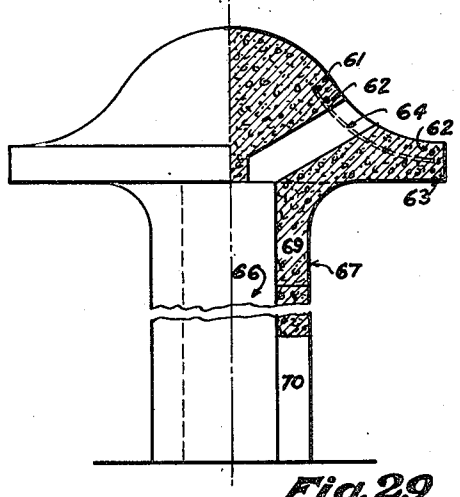


Fig. 29

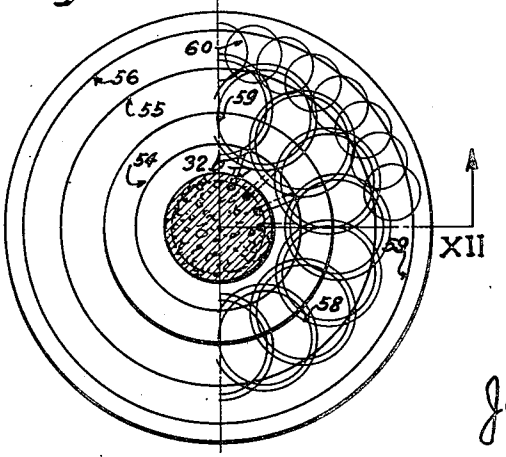


Fig. 25

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 8

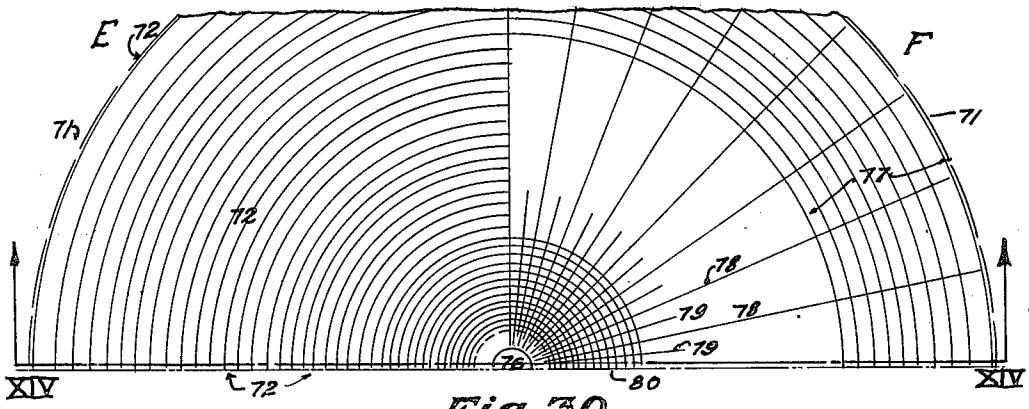


Fig. 30

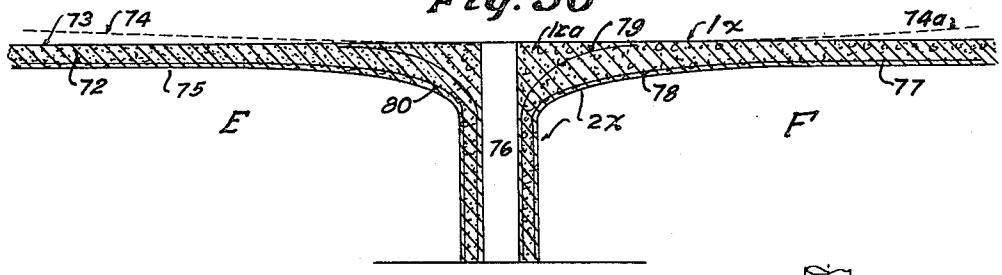


Fig. 31

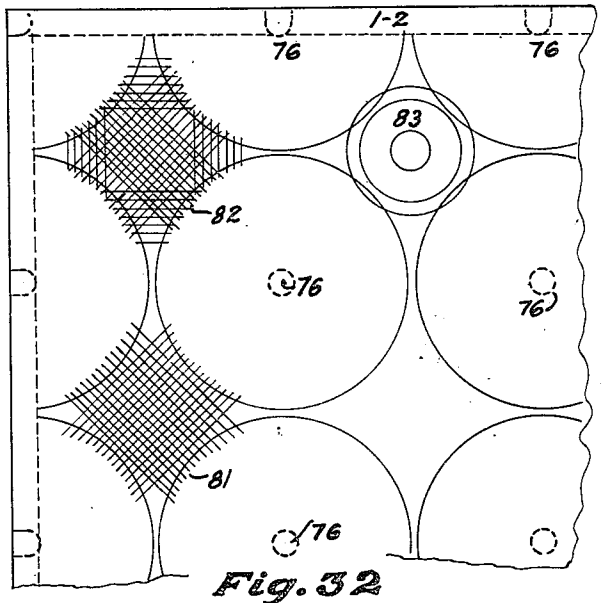


Fig. 32

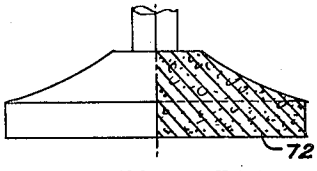


Fig. 33

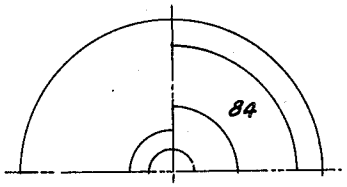


Fig. 34

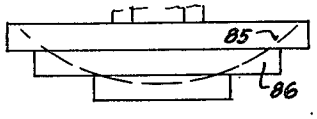


Fig. 35

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 9

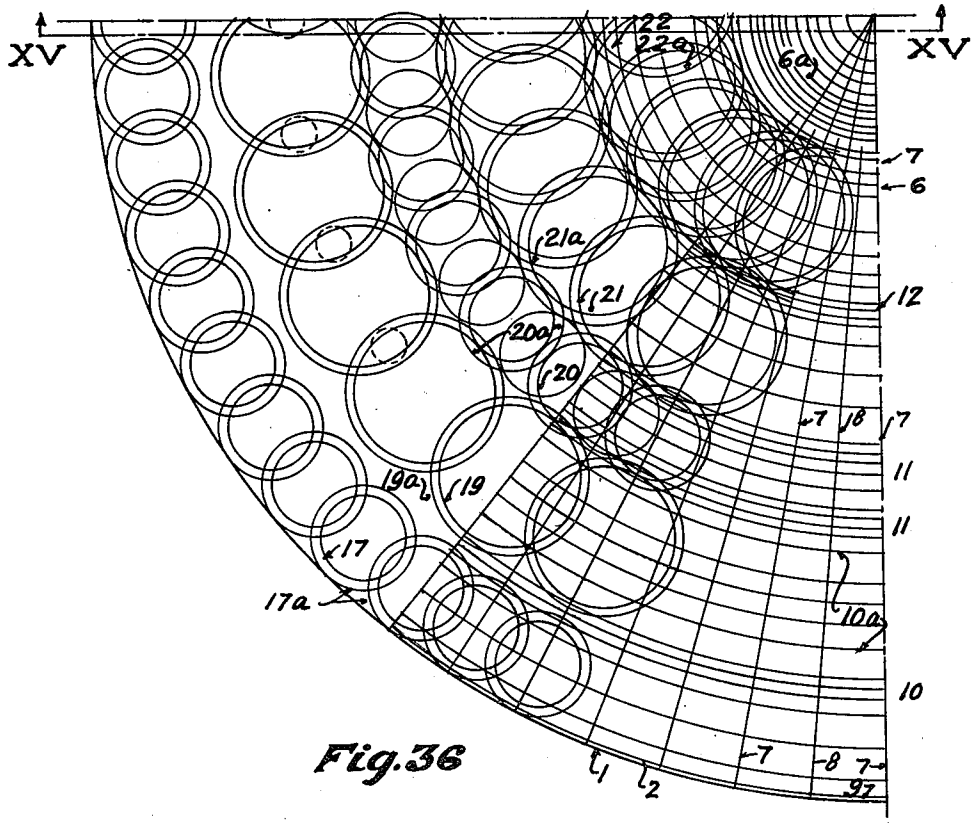


Fig. 36

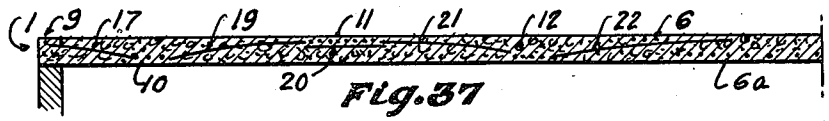


Fig. 37

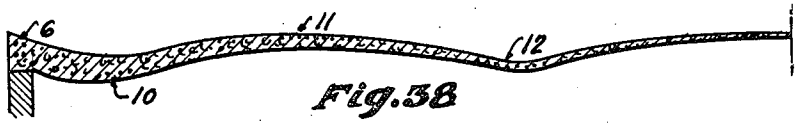


Fig. 38

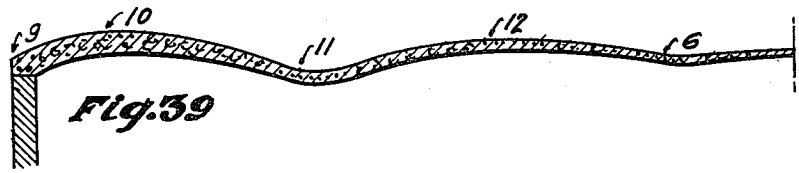


Fig. 39

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 10

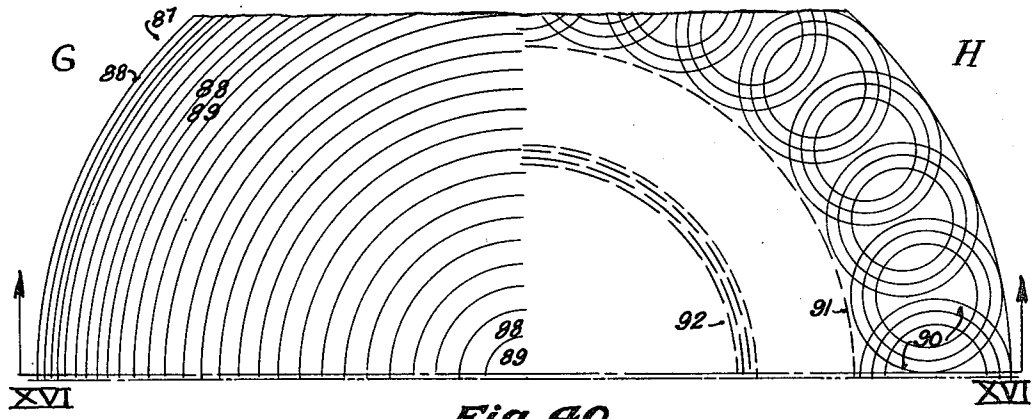


Fig. 40

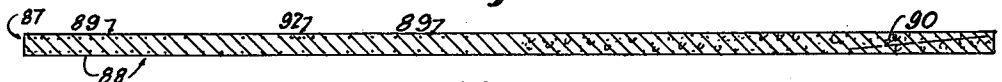


Fig. 41



Fig. 42

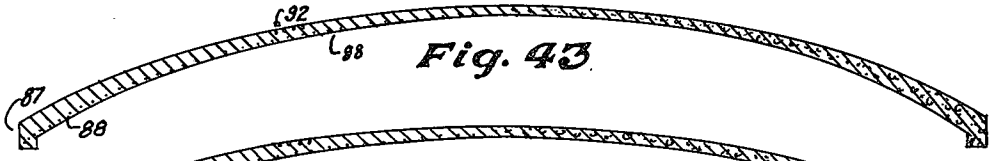


Fig. 43



Fig. 44

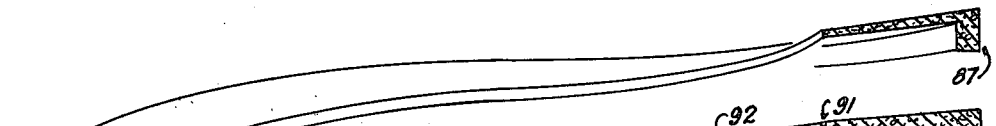


Fig. 45

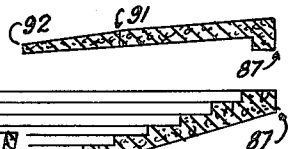


Fig. 46

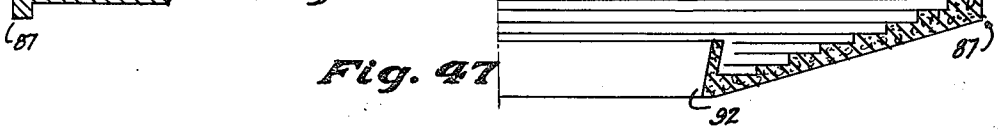


Fig. 47

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 11

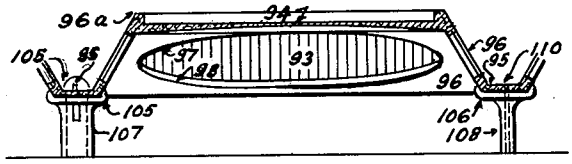


Fig. 48

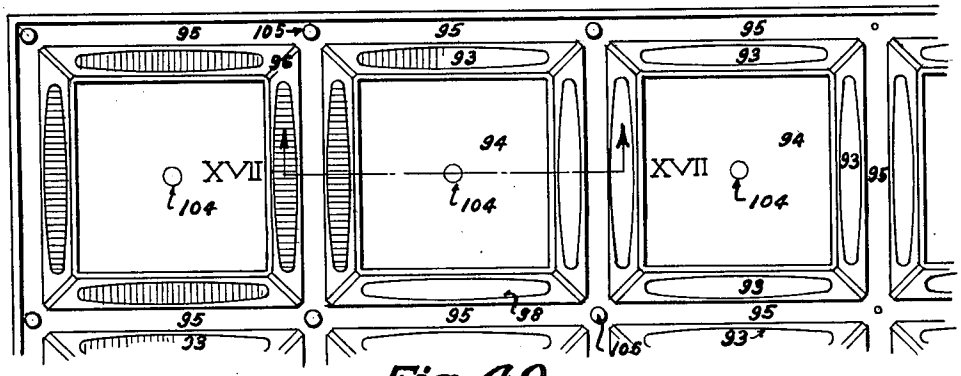


Fig. 49

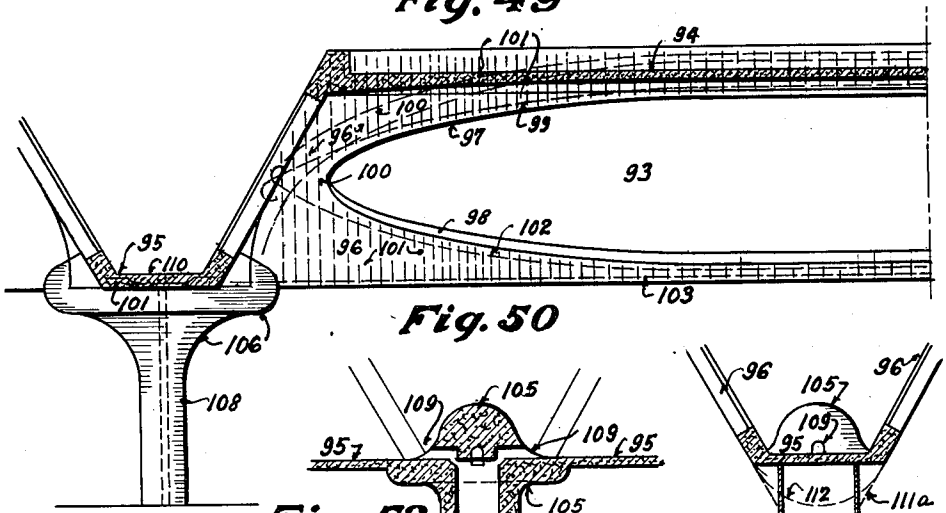


Fig. 50

Fig. 52

Fig. 54

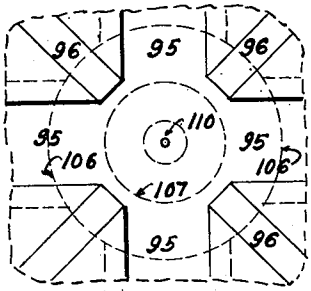


Fig. 51

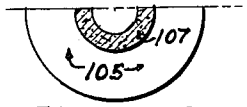


Fig. 53

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 12

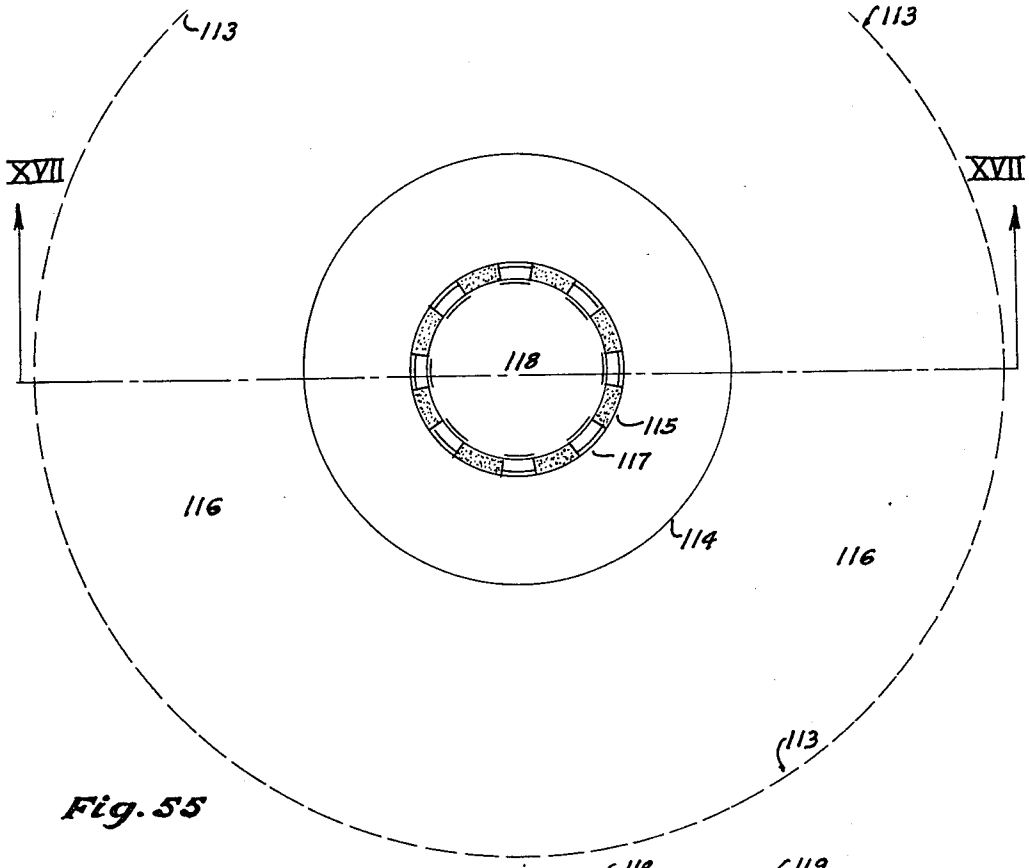


Fig. 55

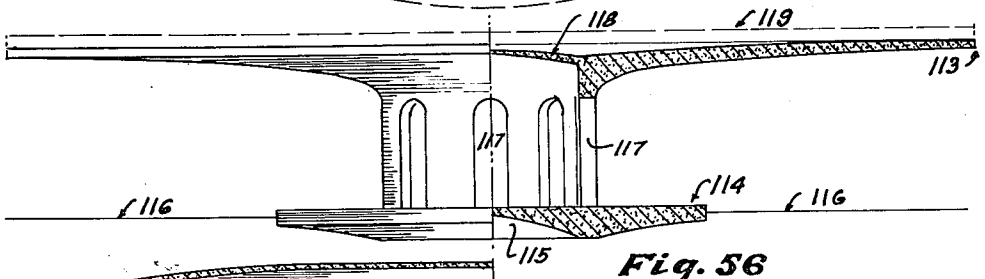


Fig. 56

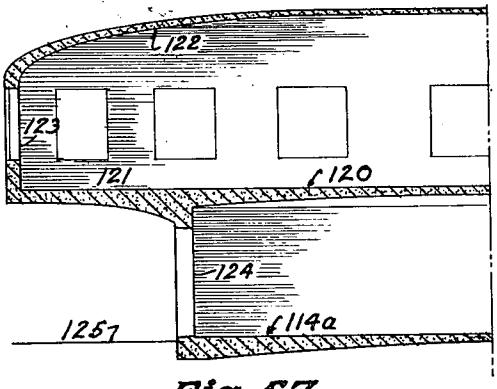


Fig. 57

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 13

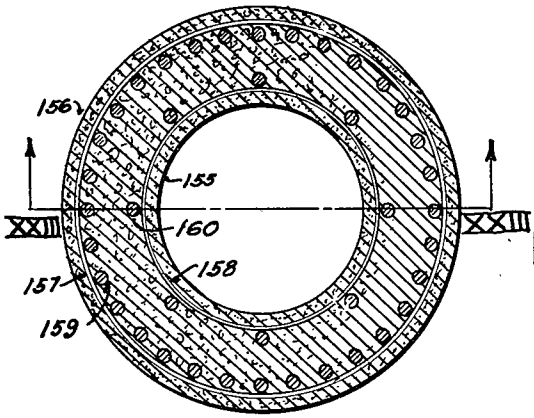


Fig. 58

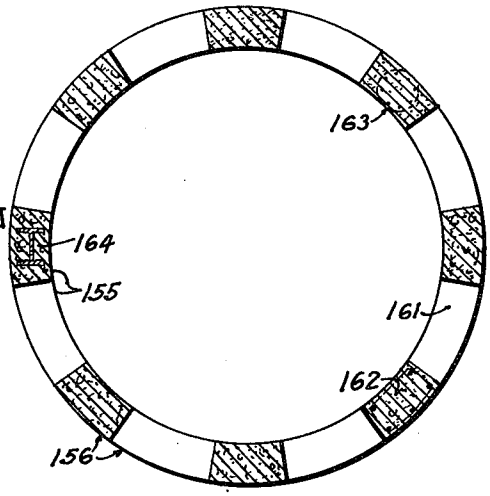


Fig. 60

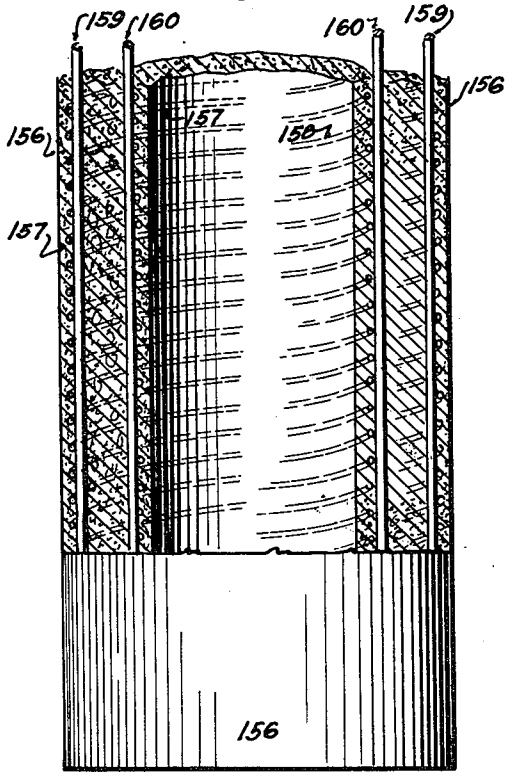


Fig. 59

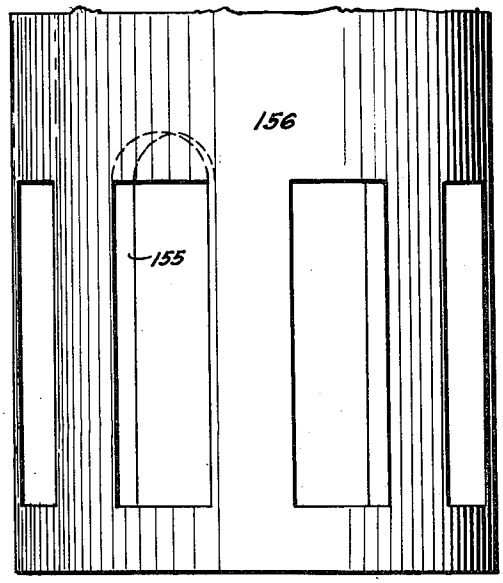


Fig. 61

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 14

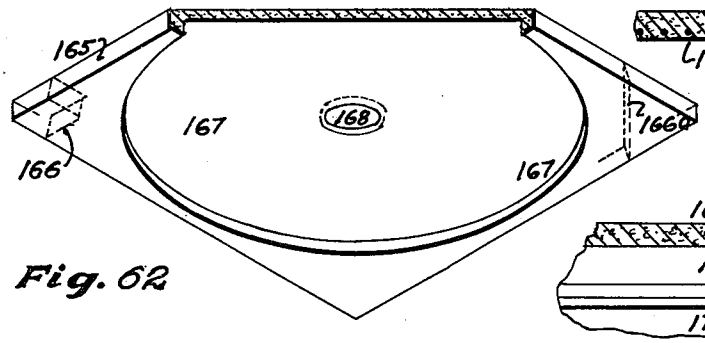


Fig. 62

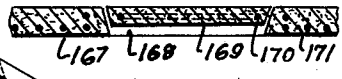


Fig. 64

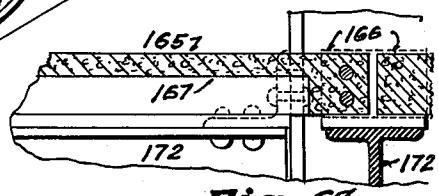


Fig. 67

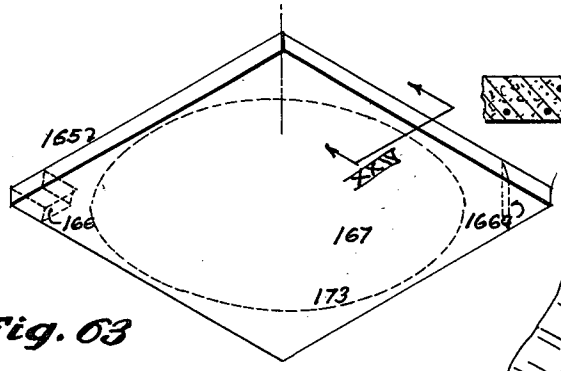


Fig. 63

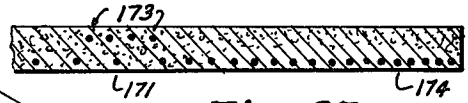


Fig. 65

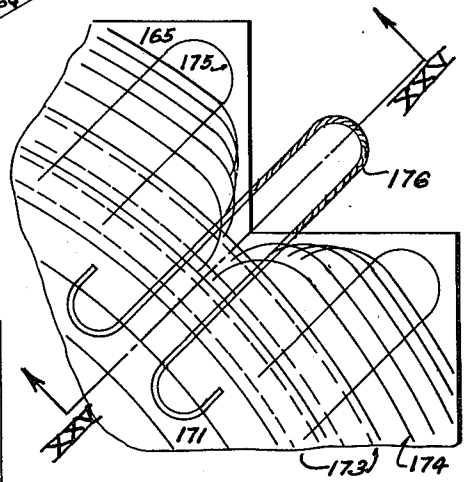


Fig. 66

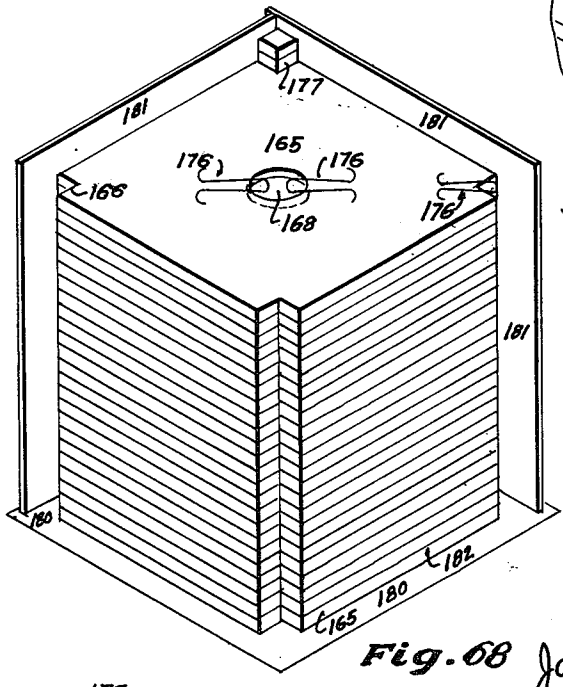


Fig. 68

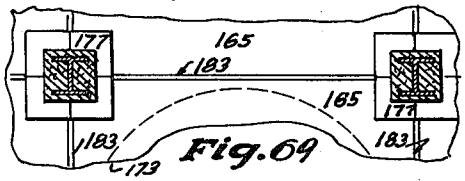


Fig. 69

Inventor

James Minor Workman

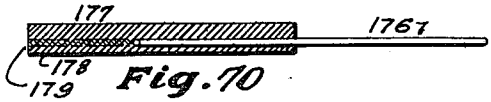


Fig. 70

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 15

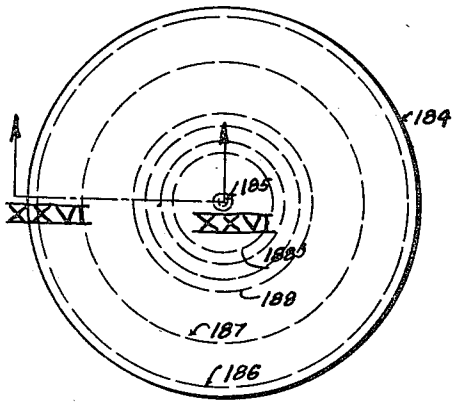


Fig. 71

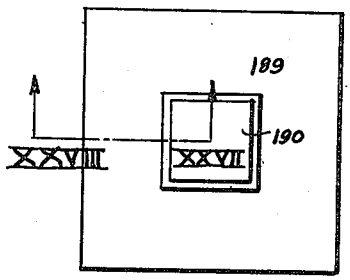


Fig. 77

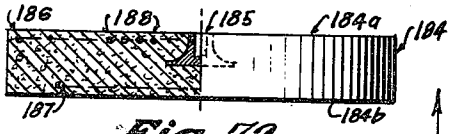


Fig. 72

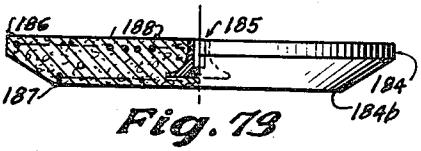


Fig. 73

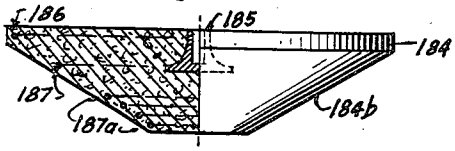


Fig. 74

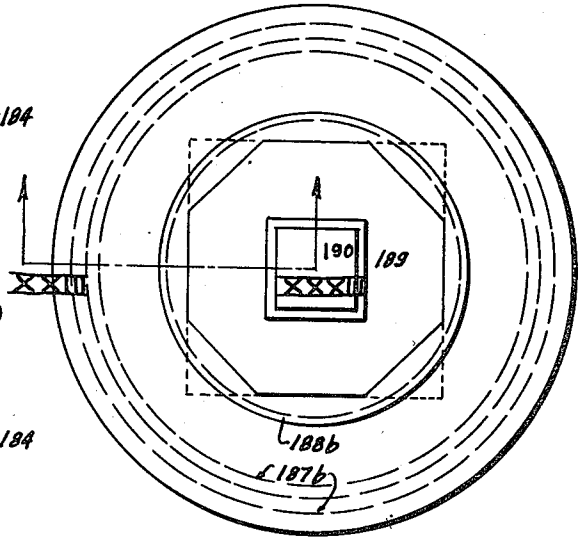


Fig. 78

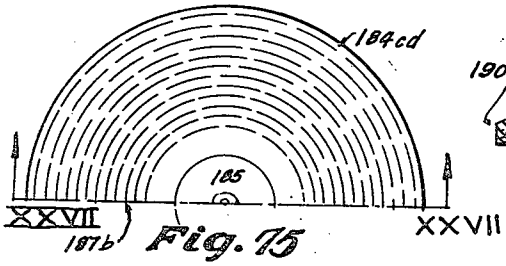


Fig. 75

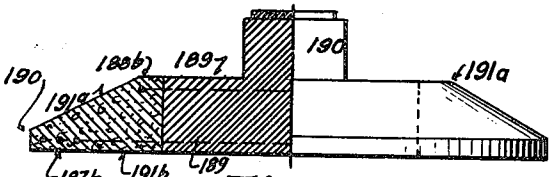


Fig. 79

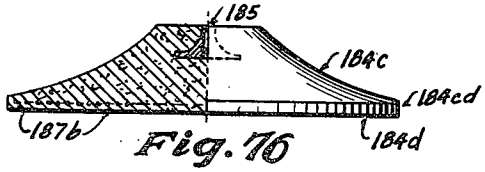


Fig. 76

Inventor

James Minor Workman

March 24, 1936. J. M. WORKMAN 2,035,007

CONCRETE CONSTRUCTION

Filed Aug. 21, 1933 16 Sheets-Sheet 16

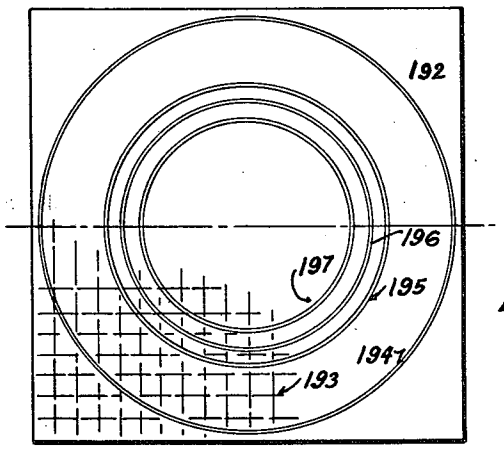


Fig. 80

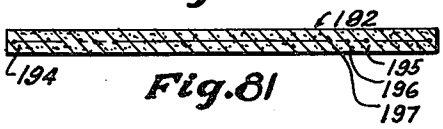


Fig. 81

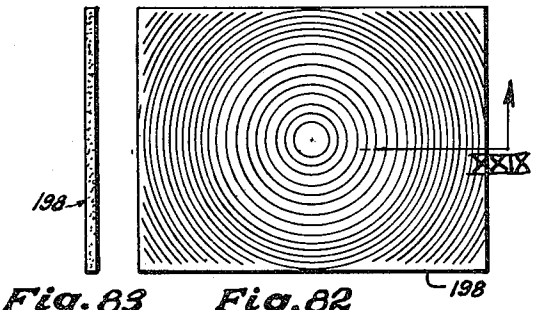


Fig. 83 Fig. 82

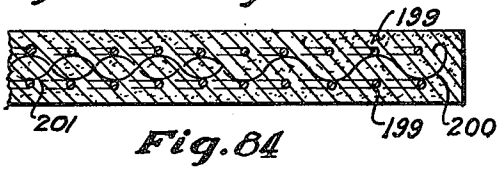


Fig. 84

Fig. 85

Fig. 86

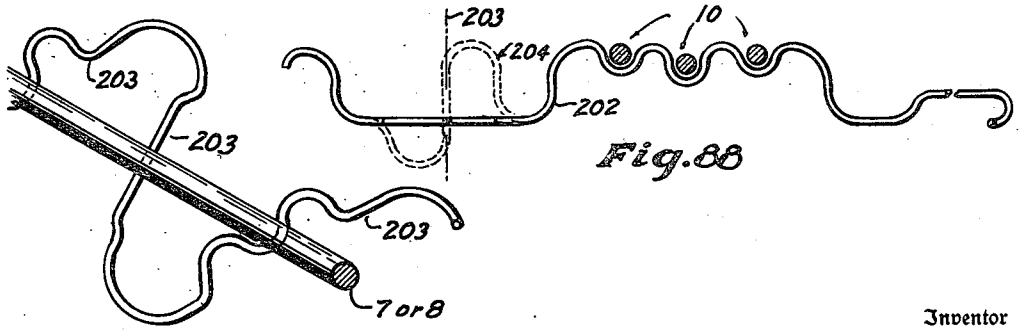


Fig. 87

Fig. 88

Inventor

James Minor Workman

Patented Mar. 24, 1936

2,035,007

UNITED STATES PATENT OFFICE

2,035,007

CONCRETE CONSTRUCTION

James Minor Workman, Winnsboro, S. C.

Application August 21, 1933, Serial No. 686,183

21 Claims. (Cl. 72—15)

My invention, or discovery relates to structures and more particularly to a novel theory of design for concrete structures and the application of such designs to the construction of buildings, dams, bridges and any other structures employing reinforced concrete.

The primary object of this invention is to provide a stabilized concrete structure in which the stresses developed therein shall be of a suitable direction and intensity, and combined in such a manner so as to produce a minimum resultant stress with all compensating movements of the materials employed.

Another object of my invention is to provide a structure of the character designated in which there is produced circumferential rotation about an internal concentric circle.

Another object of my invention is to provide a structure of the character designated in which the rotation of the stresses is primarily of a general master rotation within which there is auxiliary rotation of subdivided circular areas producing circumferential stress bands or areas alternating between compressive stresses in said alternate bands.

Another object of my invention is to provide a structure of the character designated in which the compressive and tensile stresses are connected and reacting upon each other by means of stress whirls (or over-lapping wave stresses) within which the predominant stress at the center of said wave is radially compressive and, circumferential tensile, and in which the compressive stress is partially progressively deflected through a rotation of substantially 90°.

Another object of the invention is to provide a novel form of concrete structure in which the natural rotative tendency of the structure is utilized to prevent general rotation as a whole and produce internal stress band rotation of relatively narrow stress bands in which the predominant stress is radially compressive and circumferentially tensile, with the formation adapted to delay the lateral deflection of said radially compressive stresses into circumferential stress until said stress has reached a predetermined circumferential band position whereat said radial compressive stress becomes predominantly circumferential in direction.

A further object of my invention is to provide a novel form of concrete structure of the character designated wherein provision is made for utilization of the rotational stress principles in a centrally supported structure or an externally supported structure, the general principles being identical but with the intensity of stress in its relation to circumferential or peripheral location being reversed.

These and other objects of the invention will be more manifest from the following specification and drawings and more particularly set forth in the claims.

Figure 1 is a plan view; Figure 2 a half-section, half-elevation; all of a reinforced concrete structural unit as for a floor or roof of a building. Figure 3 is a modified form of Figure 2.

Figure 4 is a fragmentary plan view and Figures 5, 6, and 6A are fragmentary sectional views of an elaborated form of the structure disclosed by Figures 1 and 3.

Figures 7, 8, 9, and 10 are corresponding views of a special adaptation of the structure disclosed by the preceding figures.

Fig. 11 is a plan view partially in section of a column embodying the principles of my invention;

Fig. 12 is a view in elevation partly in section on line V—V of the column shown in Fig. 11;

Fig. 13 is a fragmentary view showing a discharge opening;

Fig. 14 is a sectional view on line VI—VI, Fig. 12;

Fig. 15 is a sectional view on line VII—VII, Fig. 14;

Figure 16 is a plan view, Figure 17 is a sectional view, Figures 16—A and 16—B are enlarged detail fragmentary plan views and Figure 18 is a corresponding section, all illustrative of the preferred arrangements of assembly of the structural elements shown by the preceding figures.

Figures 19, 20, 21, and 22 are respectively detail, plan, sectional-elevation and section of a variation of the preceding structural units adapted to and assembled as a viaduct, bridge, or lineal structure.

Fig. 23 is a plan view partially in section of a foundation structure embodying my invention;

Fig. 24 is a view in elevation of a base structure;

Fig. 25 is a modification of the structure shown in Fig. 23;

Fig. 26 is a modification of the base shown in Fig. 24;

Fig. 27 is a modification of the column shown in Figs. 23 and 25;

Fig. 28 is an elevational view partially in section of a modified base structure;

Figure 29 is an elevational view of a column and shows a modification and inversion of the struc-

ture shown by Figures 27 and 28 for adaptation as roof or other supporting element.

A modification of the preceding applications is shown by Figure 30, a half-plan; Figure 31, a section; Figure 32, an assembly plan. A suitable foundation is shown Figure 33, a half elevation-half section; Figure 34 a half-plan, half inverted view; Figure 35, an elevation of alternate form; all adapted to the scheme of reinforcement as shown by Figures 30 and 31.

Figure 36 shows a detail plan view of a quadrant of a circular slab designed for substantially continuous circumferential support, variations in sectional form being shown by Figures 37, 38 and 39.

Figure 40 shows a detail half plan of a circular slab adapted to continuous or intermittent circumferential or perifeteral support, various modifications being disclosed by sectional views, Figures 41, 42, 43, 44, 45, 46, and 47.

Combination of development of the foregoing slab and column structures are shown as combined with an arch support having its thrust absorbed by a suspension tie, all of reinforced concrete, and designed to provide groups of roof monitors assembled as a single roof is shown by Figure 48, being a sectional elevation, Figure 49 being an assembled roof plan, Figure 50 being a fragmental sectional elevation of construction. Figure 51 being a detail plan view over a column structure, Figure 52 being a sectional elevation of the same, Figure 53 being a section through said column looking up, and Figure 54 being a section through the suspension tie element.

Application of the several structural systems as referred to so as to provide a self contained vending station is shown by the plan as Figure 55, the half sectional and half elevation as Figure 56; while a variation of the same general adaptation is shown by Figure 57 being a fragmentary sectional elevation of a double story structure conforming in general to plan as disclosed by Figure 55.

New type hollow column as used for column shaft in structural systems described hereinbefore is shown in horizontal section by Figure 58, and vertical sectional elevation by Figure 59.

Shell column form as used in structures previously described is shown by Figure 60, a horizontal section, and by Figure 61, which is a fragmental elevation.

Plate construction for any use but particularly adapted to floor and roof elements or slabs, together with illustrative facilities for manufacture and utilization are:

Fig. 62 is a perspective view of a slab embodying my invention;

Fig. 63 is a perspective view showing a modification of the slab shown in Fig. 62;

Fig. 64 is a fragmentary sectional view showing a center section of the slabs shown in Fig. 62;

Fig. 65 is a fragmentary sectional view showing circumferential reinforcement of the slab;

Fig. 66 is a fragmentary plan view of an anchor member for the slab;

Fig. 67 is a fragmentary sectional view showing connection of the slab to an adjacent structure;

Fig. 68 is a perspective view of the manner of stacking the slabs;

Fig. 69 is a plan view partially in section showing slab connection to an adjacent support; and

Fig. 70 is a fragmentary sectional view of a slab anchor member shown in Fig. 78;

Adaptation and application of the structural systems described to concrete paving sections, as for roads, is shown by Figure 71, being a plan view and Figure 72, a section.

Fig. 73 is a modification of the structure shown in Fig. 72;

Fig. 74 is another modification of the structure shown in Fig. 72;

Fig. 75 is a plan view showing the reinforcing members;

Devices for placing and securing the special reinforcement for the system of reinforced concrete described, are shown by the various views.

Fig. 76 is an elevational view partially in section of a concrete pedestal construction;

Fig. 77 is a plan view of a foundation to be supported;

Fig. 78 is a plan view of the foundation shown in Fig. 77 combined with a structure embodying my invention;

Fig. 79 is a view in elevation of the base shown in Fig. 78 and partially in section;

Fig. 80 is a plan view of a reinforced road paving slab embodying my invention;

Fig. 81 is a sectional view of the slab shown in Fig. 80;

Fig. 82 is a plan view of a partition slab embodying my invention;

Fig. 83 is a sectional view of the partition shown in Fig. 82;

Fig. 84 is an enlarged sectional view on line XXIX—XXIX of Fig. 82;

Fig. 85 is a plan view of a general assembly of reinforcement;

Fig. 86 is a detail elevation of radial support bars of the reinforcement shown in Fig. 85;

Fig. 87 is a detail perspective view of an auxiliary device for supporting the radial bar; and

Fig. 88 is an elevational view of a connecting link bar for the reinforcement shown in Fig. 85.

The term "concrete" shall be taken to mean any solid substance, either homogeneous or conglomerate, regardless of whether its solidity is acquired by setting, drying, cooling, chemical change or otherwise, and usually, but not necessarily having its compressive strength greater than its tensile strength.

The term "reinforced" shall be taken as descriptive of the use of "reinforcement", which latter term shall be taken to mean any material of metallic or equivalent nature having strength characteristics differing from the concrete but usually superior thereto in tensile characteristics and to an equal or less extent in compressive characteristics.

The several structural systems adapted to central single column support being self-sufficient units are classified as compound rotational systems, which are subdivided as natural form compound rotational system, modified compound rotational system and modified compound wave reinforced rotational system; simple rotational system which is subdivided into natural form and wave reinforced systems; multiple rotational systems, which are subdivided into natural form and modified form.

In the accompanying drawings main features are designated as numbered figures; sub-features are designated by capital letters, as for segments of a plan; and detail elements are designated by numerals; all like features or elements are designated by like characters.

The Figure 1 shows a plan view of a typical structure such as an element of the floor of a building, the quadrant segments designated A, B, C, and D showing the varied conditions for

articulation with the sectional elevation Figures 2 and 3.

In Figure 1 the limit of the essential structure is indicated by the broken line designated 1, which encloses a surface which may, and in this case does, turn down at the center to form the hollow of the column, designated 1a in Figures 2 and 3.

Figures 2 and 3 show half sectional elevation views on a diameter and a tangent, the lower surface of the slab turning down to form the exterior surface of the column, both being integral and designated 2.

The natural form compound rotational system is disclosed by the quadrant designated A of Figure 1, and by the sectional elevation Figure 2. In Figure 1, quadrant A, the reinforcement designated 3, 4, and 5 indicate the general extent and preferred arrangement of bands of reinforcement which must be placed near the top of the slab. This is all of the reinforcement required but inequalities of concrete strength characteristics may be partially compensated for by the additional radial reinforcement, designated 6, shown in Figure 1, quadrant B, this reinforcement being placed near the bottom of the slab. It may terminate as shown or be extended inward and down into the outer shell of the column.

The movement of the slab under load is increased in its elements and neutralized in its aggregate, relatively, as follows: The outer rim stresses are most intense in the lower part of the slab and are both radial and circumferential, the dominant stress depending upon the load conditions as a whole, the stresses in the band 3 are both radial and circumferential with radial stress being compressive and the circumferential stress tensile, the highest intensity of the circumferential stress being at the top of the slab, the reinforcing therefore being placed near the top; the radial stresses are maximum at the bottom of the slab but are partially neutralized by the rotation of the band as a whole. The transference of the stresses to and from this band are by means of natural wave stresses of more or less regularity, the action of which will be made clear in connection with the modified compound wave reinforced rotational system. Within the band itself, each ring from one reinforcement ring to the next is subject to rotation, each ring being subject to an accumulation of motion, and therefore of stress which increases circumferentially near the top outward and radially near the bottom inward.

The band between bands of reinforcement designated 3 and 4 of Figures 1, 2, and 3 is subject to a combined radial and circumferential compressive stress in which the circumferential stress predominates and is of maximum intensity near the bottom but with variation dependent upon the conditions of loading. The radial stress is compressive with intensity varying with loading, and providing an intermittence of intensity as induced by the wave stresses previously referred to.

The individual rings of band 4 are subject to rotation individually, intensities being of the same progressive intensity and detail character in general as described relative to band 3.

Band between reinforcement bands designated 4 and 5 is subject to both radial and circumferential compression in which the circumferential stress predominates in the outer edges and the radial stress in the central portion, additional wave stresses taking place as previously referred to.

Similarly the band of reinforcement 5 is subject to the conditions of band of reinforcement 4 while the band between reinforcement bands 5 and 6 corresponds to that between bands 4 and 5.

The reinforcement band designated 6 in the same figures is in general and subdivided rotation as the other bands, the reinforcement rings being in tension of progressive increase of intensity, the circumferential reinforcement being placed near the top of the slab as before.

The area of this reinforcement band has radial tension at the top of the slab but this is most effectively absorbed by the circumferential tension reinforcement. The radial stress is compressive on the diagonal downward and near the bottom at which point its intensity is maximum, gradually turning to a predominantly vertical stress in the column itself, the ultimate stress character being treated hereinafter.

The essential principles of the system of construction described as the natural form compound rotational system are that the complete load and resulting stresses are carried to the center, converging to a single support; that there is produced a series of general and internal rotation of rings; that the predominant stresses are intermittently radial and circumferential; that the radial stresses are produced by curve line and straight line stresses in either or both horizontal and vertical planes; that the form is adapted to formation of natural wave stresses; that the form is adapted to relatively large local motion partially compensating as a whole; that the form is adapted to an interplay of movement in a manner to partially neutralize stresses and relieve accumulation of high stress intensities; that, while the foregoing stress conditions are designed primarily to articulate with loads and the effect of gravity, they also are compensating as regards such stresses as induced by contraction and expansion and as induced by temperature changes, shrinkage stresses, and stresses due to chemical developmental changes. The progressive thickening of the slab from the circumference to the center is made to conform to shearing stress limitations.

The modified compound rotational system is shown by Figure 1, being a plan, and Figure 2, being a half section and half elevation. In Figure 1 the reinforcement is shown in quadrants C and D, in which quadrant D shows the circumferential steel placed in the top of the slab, indicated 3, 13, 4, 14, 5, 15, and 6, in which like numerals and like reinforcement bands from quadrant A are identical.

The additional reinforcement rings indicated 13, 14, and 15 are all in tension under some conditions of loading and are proportioned in size corresponding to the size of the next outer corresponding band.

Reinforcement rings above referred to are supported near the top of the slab by radial bars, indicated 7a of Figure 1, segment D. These bars not only act as supports but are subject to intermittent compressive and tensile stresses and to a greater degree to shearing stresses, serving to articulate with the natural wave stresses, hereinafter described.

For this system, it is necessary to provide intermittent bands of circumferential compression steel near the bottom of the slab, indicated 9, 10, 11, and 12 of Figures 1 and 3. The group arrangement of each band, as most clearly indicated in band 12, is desirable in order to articulate with the natural wave stresses.

The function of these bands of circumferential

compression steel is to induce in the slab, as cut by a radial plane, an equivalent axis or effective plane of pressure similar to that provided naturally by the former system as shown in Figure 2.

Additional radial bars, indicated 8 (and retaining the radial bars indicated 7) are provided near the bottom of the slab, their purpose being to progressively increase the radial resistance compressive moment of the concrete in the spaces between the bottom bands of circumferential steel, and at the crossing of these bands to provide additional horizontal shearing resistance and so tend to stabilize the natural wave stresses. These radial bars of reinforcement should continue down into the column or should effect a lap splice with bars arising from the column and continuing into and through the column head area of the slab surrounding the column, as more clearly shown by the later included column description.

The object of the additional reinforcement in this slab is to provide a variable strength factor and as a nearly uniform stress in the slab in such manner that its effective plane of resistance or strength will coincide with the natural form required to articulate with the character of stresses which in turn articulate with the motion produced by the alternation of relative strength and weakness.

The advantages of this modified compound rotational system are that it permits of a regular under surface, within the limitations shown, and a level top surface, the depression and opening at the center being optional. It also provides a more uniform strength factor at the critical sections due to the superior uniformity of steel or metallic reinforcement over concrete.

A further advantage in this system is that upon assembly of a number of slab elements into a combined structure, the tendency of one slab unit to tilt, from the uneven loading of one side, is counteracted by an uplift effort exerted by it upon the slabs adjacent to the unloaded sides, thus partially relieving the intensity of stress induced in the column of the slab which is unevenly loaded. Slabs subject to such uplift, have their stresses reversed, areas and elements that have been in compression being subject to tension and those formerly in tension being subject to compression.

Further clarification may be effected by noting that the depressions on the top surface as shown by Figure 2 are filled up in Figure 3. The relative location of this additional material as related to its center or axis of rotation is such that its effect is nullified. Its use has the advantage of offsetting the loss of sectional area due to raising of the projections of the under side of the slab.

In the foregoing descriptions, the shearing stress factor is provided with suitable limits by the progressive increase in thickness of the slab approaching the support.

A more complete disclosure of how my newly discovered systems are novel will become apparent in the following description of the modified compound wave reinforced system.

In this last named system, Figure 4 is a plan view showing a quarter of the slab, Figure 5 is a half section on a radial line and Figure 6 is an enlarged view of the outer or circumferential portion of Figure 5, while Figure 6—A shows arrangement if sectional form is natural.

In these figures, the reinforcement elements are identical with corresponding elements in Figures 1, 2, and 3, and indicated by identical characters. Also the segment 2—C corresponds to the quadrant C, showing the same radial and circumferential reinforcement as before and in addition the circumferential reinforcement indicated 9*a*, 10*a*, 11*a*, and 12*a*, its primary function being to secure or provide facilities for securing in place the reinforcing waves, or rings, shown in all other segments, and designated 17, 18, 18*a*, 19, 19*a*, 19*b*, 20, 20*a*, 21, 21*a*, 22, and 22*a*, all of which are placed near the bottom of the slab directly on the circumferential reinforcement referred to. The waves, or rings, 17 are placed directly upon the circumferential reinforcement bands 9*a* and in turn support the rings 18 and 18*a*. The rings 19, 19*a*, and 19*b* are placed directly upon the supporting circumferential reinforcing bars, but in a continuous overlap, each series of rings having one side resting on and the opposite side under the adjacent series of rings. The same arrangement is followed for rings 20 and 20*a*, 21 and 21*a*, 22 and 22*a*. The arrangement of rings in relation to each other is most clearly shown by the segment indicated 5—C, their relation to supports by segment 4—C, and to top tension circumferential reinforcement by segment 2—D.

The function of these rings is to produce or induce stress surges, thereby equalizing the stress vibrations and preventing the accumulation of excessive stresses. The primary basic principle of the discovery claimed resides in the ratio of the overlap of the primary rings indicated 17, 18, 19, 21, 22, and the secondary rings indicated 20*a*. I term this the minor ratio, being the quotient of the length of the common cord of the overlapped circles divided by the divergence of the overlapped arcs, having a substantially numerical value of 3.4 for the waves indicated 18 and 22, and a value of 3.04 for the waves indicated 19 and 20*a*. It is the protection of the ratio that is the function of rings 18*a*, 19*a*, 19*b*, 20, 21*a*, and 22*a*, these latter rings being desirable theoretically but practically they may be readily dispensed with where the structural material is good concrete except that there should be retained the rings 18*a*, 19*a*, 19*b*, and 20*a*, unless the load conditions are very mild or the span (that is the slab diameter) relatively small.

The secondary basic principle of the discovery is the relative distance radially and spacing of the circumferential bands of reinforcement, both for compressive and tensile stresses and the corresponding wave contour of the radial section, which I term the minor radii.

It is apparent from the foregoing description and the figures referred to that the stresses of this system are fully determined in their character, location and direction, it only remaining for the design for a particular span (or diameter) and load to govern their intensity.

All of the stresses in the wave (or ring) reinforcement described are compressive, but the relative intensity of compression between the primary and secondary ring is subject to variation.

The modified compound wave reinforced rotational system may have its system of wave reinforcement used without the modified form as shown by Figure 6—A, corresponding parts being identically numbered. In this case the substantial difference is that the center line of the slab section conforms to the required plane of pressure and therefore the compression reinforcement of circumferential bands are not required nor are the corresponding supplemental tension

bands, indicated 16, 14 and 15. Also the wave ring reinforcement should lie in the plane of pressure, or the center line of the slab, and therefore must conform to its curved surface. This description is sufficient to disclose the use of the wave reinforcement in the natural form and show its principles as more completely and lucidly disclosed by the modified form compound wave reinforced rotational system.

Having disclosed the inherent principles of the several systems described, I now show the modifications which preferably should be made in any of them to meet the conditions imposed by use of a half slab, as may be desirable either for independent or assembled use of the elementary slabs.

Figure 7 shows a plan view of a partial quadrant of a slab in which is shown and indicated by like characters the essential reinforcement of the modified form compound wave reinforced rotational system, but the essential modifications as shown apply to all of the foregoing systems and to those that follow.

Figure 8 shows a sectional view of the slab and elevation of the half beam, section being taken on line III. Figure 9 shows similar section modified to show special reinforcement as for line IV. Figure 10 shows a fragmental section of the slab as taken on line IV.

The new and hereinbefore undescribed elements of reinforcement as contained in the slab are those shown in all of the several figures and are indicated 23, 24, and 25, being here shown as three elements but which may be combined into one element or divided into a greater number.

The essential function of this reinforcement is to assume a continuous tensile stress of varied intensity, transmitting the accumulated compression of the several compression bands as concentrated in the lower convolutions of the plane of pressure to the tension bands in the upper convolutions of the plane of pressure, thus swinging from bottom to top as shown by Figure 9.

In order to articulate with this reinforcement, and prevent the progressive action of destructive stresses, the cut or straight side of the slab should be terminted as a beam, shown in sectional plan in Figure 7 and in elevation by Figure 8. The unbalanced moment transmitted to the column is provided for in its tension element by the vertical column reinforcement indicated 30 and the compression element indicated 31, both as shown by Figures 7 and 8.

Reduction in the intensified radial stress in the slab due to its unbalanced condition from lack of continuity is effected by the use of the essentially elliptical column formation with its circular eccentric opening, 1a of Figure 7, shifted inward, the normal column having its center on or about the inner face of the beam, to which center of slab reinforcement and convolution are related.

Coming now to the column head, in which the slab is merged into the column, the stresses assume a high complexity, the ultimate co-ordination of which is attained from a development of the modified form compound wave reinforced rotational system, which affords the ideal stress organization for any of the systems hereinbefore and hereinafter disclosed.

The column shaft is formed to articulate with the natural flow of stresses from the column head which is a unit of construction common to both the slab and column shaft in which the two are co-joined. Therefore both elements are treated jointly.

The ideal column, including the elements of the head and shaft are shown by Figure 11 which is a half plan of the column head showing a half section of the column shaft and the contiguous portion of the slab, Figure 12 which is a half section and half elevation of the column shaft and head taken on line V, Figure 13 which is a secondary fragmental elevation of the column neck (connecting the head proper and the shaft). Figure 14 which is a sectional plan of the column shaft on line VI, and Figure 15 which is a sectional elevation of the column shaft seat taken on line VII, the two last figures disclosing the adaptation of the individual floor columns to a supporting core column of structural steel.

In Figure 11 the various elements of surface and reinforcement are identical with and are identically designated as previously shown and described in corresponding preceding figures, and previously shown circumferential compression reinforcement indicated 12 of Figures 11 and 12, while an integral part of the slab is an even more fundamental element of the column head and should be used for other related systems of construction hereinafter disclosed. The same is true of the wave reinforcement 22 and 22a (but particularly 22) of Figures 11 and 12 and preceding figures.

The reinforcement bars 34 of Figures 11 and 12 provide for circumferential compression due to the rotation of the head, and to accommodate them the surface of the column should be bulged into the neck formation indicated 2a of Figures 12 and 13. These circumferential rings should be placed on both the outside and the inside of the principal vertical reinforcement of the column, indicated 32 of Figures 11 and 12.

This vertical reinforcement should extend outward along the bottom surface of the column head and into the slab proper, forming support of inner circumferential tension reinforcement ring 5 of Figures 11 and 12. This is the most important of all the column head and shaft reinforcement, and their number is important, being either 16 or preferably 32 bars, equally placed in reference to the column head waves, either natural or preferably reinforced.

The reinforcement bars indicated 33 of Figures 11 and 12, are provided primarily to hold other reinforcement being the internal spiral later described and to support and hold in place the top tension reinforcement rings of the slab, indicated 6, 15 and 5 of Figures 11 and 12, for which purpose alternate bars bend out while the intervening bars indicated 36, project through the column seat, 16 of Figures 11 and 12, in case there is provided a column seat for a superimposed column. These bars serve no particular purpose as reinforcing of the column head except in case of inherent weakness in the concrete for which they afford a slight compensation, bars 32 and slab bars supplementing the connective action of bars 36.

In Figures 11 and 12 the spiral reinforcement indicated 35 is in conformity to standard current practice, but the use of the internal spiral indicated 38 is a part of my discovery that it is needed to permit the most effective development of stresses and of motion in the column shaft. It is used in connection with my discovery that the natural organization of stresses in a cylinder are such that the movements propagated in the central quarter of the gross area are such as to impose a bursting tendency upon the outer shell comprising three fourths of the area of the col-

umn, so that a column of a given diameter will have its strength increased by the omission of this central core, while the internal ring of the shell preferably should be protected against circumferential stress (produced by the shell) by the use of the internal spiral 15.

The vertical bars used in conjunction with this inner spiral, if used at all, should be square and placed outside of the spiral.

It should be understood that all of the elements disclosed and reinforcement provided previous to that designated 32, 33, and 38 are the essentials of the solid column which may be used in conjunction with my special new neck and head column construction.

Apart from the novel type of hollow shaft and funnel head for reinforced concrete columns as regards their stress characteristics, I disclose as a new development the use of hollow concrete columns in their provision for the conveyance of pipe, conduit and service lines and in their provision for column neck discharge openings, indicated 39 of Figures 11, 12, and 13; also the depressed column seat, 1*b*, articulating with the column shaft base discharge opening, 43 of Figures 11 and 12.

Due to the enormous floor areas reaching up 6,000 square feet which it is practical to carry on one column by the use of my systems of construction, there is accumulated at one column location, if the building is a number of stories in height, a load of immense magnitude so that in such cases it is desirable to restrict the space occupied by the column to less than is feasible with the use of concrete as a primary support. Therefore, I have devised and invented a new type of composite column as shown by Figure 14, being a plan section for a condition of location similar to line VI on Figure 12, and further shown in sectional elevation by Figure 15, as taken on line VII of Figure 14, and combining pipe cylinders as further shown in elevation by Figure 13.

In these figures, the outer and inner surface of the column shaft shell are indicated 2 and 1*a* respectively; the structural steel fabricated column, 40; the seat brackets, 41; the bearing seat (consisting of a circular plate with circular opening), 42; the column interior surface spread open to a funnel surface, 1*a*, providing access to allow for the passage of pipe lines from the floor into the column tubes indicated 37. The exact detail of construction of the column shell interior is not essential as the tubes shown circular may be in the shape of the letter D with the straight side against the web member of the structural column, the curved side forming the mould or shield for the concrete core, in conjunction with the flange of the column section, but adequate insulation for the structural steel is desirable.

Having disclosed the nature of the elements of the structure, it must be understood that their assembly may be as entirely independent units without even contact between them. The circle formation may be extended to form a circumscribed hexagon, the area added between the circle and the hexagon being treated as a succession of rotating ring segments, indicated 3*a* of Figures 4 and 16.

The usual practical assembly of the structural elements of the floor and roof slabs and supports, and one which articulates best with the structural form, is shown by Figures 16, being fragmentary plan of the contiguous hexagonal arrangement as for the corner of a building, Figure 17 which is a sectional elevation of said plan on line VIII, Figures 16—A and 16—B which are enlarged scale detail plan views, and Figure 18, which is a sectional view of Figure 16—B on line IX.

In Figure 16 the circles indicated 9 and 10 identify the locations of the bands of reinforcement as similarly indicated on preceding figures, the bands indicated 9 being placed substantially tangent to each contiguous like band, thus producing a nested arrangement similar to the cells in a honey comb. The result of this is to leave a minimum of area between the structural units to be supported therefrom, and to produce a minimum of variation in the intensity of the load transmitted to the main structural element.

A suitable method of supporting this area of the slab in the simple continuance of the circumferential reinforcement in the top of the slab elsewhere designated 3 and here designated for the continuance as 3*a*. This should always be used where expansion joints are provided.

Another method, which is the preferred method, is indicated 44 of Figures 16 and 16—A, is the single use of straight reinforcement in the bottom of the slab utilizing the generally accepted principle of moments as for a non-continuous, simply and freely supported slab. The actual fixity of the slab at the main element is neutralized by the rotational tendency of its outer rim, which articulates with the moment slab deflection in such manner as to extend the stress and point of support back toward the more stable bands of the slab.

The reinforcement referred to should extend to the point of tangency of the main structural elements, serving as a tie, useful in transmitting stress from shrinkage, contraction, and variation of loading. In connection with the last consideration, it is preferable that the short bars toward the point of tangency be elevated to the center level of the slab thickness.

The variation of this reinforcement to meet conditions at similar areas adjacent to the perifeter of the structure is indicated 45, which shows the modified direction and the progressive spacing of reinforcement.

A further system of filler reinforcement in the use of this last system modified is shown by 46 of Figure 16 and the enlarged views shown as plan by Figure 16—B, and a sectional view in Figure 18.

The straight reinforcement is placed as before but the more central bars are omitted and a double ring is placed near the bottom of the slab as indicated 46*a* and 46*b* of Figures 16—B and 18. In the latter figure the straight reinforcement is indicated 46*c*.

Openings in slabs should be confined to the spaces between structural slab elements to the extent possible in which case the opening may include the entire area. Openings in other locations must not alter or cut the critical stress lines and the loss of strength from material omitted or removed must be compensated for by additional reinforcement or otherwise where the stress character or intensity demands.

The perifeter of the slab assembly, forming either open or enclosed line of the building, should be finished by beams or girders cast integrally with the slab structural elements and in no case should there be used rigid auxiliary supports or columns.

The girder indicated 47 of Figure 16 should be designed as previously described and shown by Figures 7 and 8. The extension of girder 47 indicated 47*a* should be reasonably flexible and may

be modified in form as indicated 47*ab* or in location either toward or from that indicated 47*c*.

A modification and adaptation of the several structural systems hereinbefore described and also adapted to those hereinafter described, is shown by Figure 19 which is a plan of a quarter of the structural unit.

Figure 20 which is a complete plan of two complete units assembled, Figure 21 which is a sectional elevation of which the section is taken on line X of Figure 19, and Figure 22 which is a section taken on line XI of Figure 19.

This modification is designed particularly to serve as units of elevated viaducts as for elevated streets to relieve the traffic congestion of cities, for elevated roads over rough and irregular terrain and for bridges.

In the case of elevated streets, there may be provided a succession of superimposed levels for slow and fast traffic, some of which may connect to structures designed as elevated automobile parking areas or garage buildings.

In any case where the need requires it, the column may be expanded to provide an opening of such size as to enclose a spiral stair or elevator connecting to other levels. In normal cases the column hollow will serve as a pipe space for electric conduit and for drainage.

This design of structure is suitable for any of the systems of construction hereinbefore or hereinafter described.

Figure 19 shows the arrangement and location of reinforcement, indicated by numerals as previously used, as intended for the adaptation of the natural form compound rotational system combined with the modified form. The use of the modified form for the band indicated 10 is preferable while its use for the inner bands is entirely optional, the selection being dependent upon the number of units to be constructed. For example, if only a few units are to be used as for a bridge, the use of reinforcement to create the modified form would show greater economy, while if there are a great many identical units the standardized moulds, or forms, for the natural form would be economical.

The primary reinforcement bands of tension steel, indicated 3*a*, 3, 4, 5, and 15, are similar to like bands previously described except that, with the exception of bars indicated 15 which are truly circular, the bars are arranged in the form of an ellipse, which is true to form for the inner bars but progressively bulged for the outer bars which reach the maximum bulge in bars 3*a*.

Tension reinforcement referred to is placed near the top of the slab as used for modified form and near the center of the slab as used for the natural form, with a gradual transition in position where the two forms are combined.

The circumferential compression reinforcement indicated 10, 11, and 12, is required only with the use of the modified form, but it is desirable to use light bars in the edge position, as indicated 12, even with the natural form, in all cases the vertical location being near the bottom of the slab.

The radial reinforcement, indicated 7 and 8 of Figure 19, should retain its angular segmental arrangement as formerly, serving the same function. This action is improved and general construction facilitated by the use of radial bars 7*a* and 8*a* in the top of the slab also.

Wave reinforcement is not shown on the drawings but may be used to advantage as previously described, in which case the wave rings should be proportionately reduced in diameter as the minor axis of the ellipse is approached so as to maintain their several relationships, except that the standard uniformity should be adhered to for the band over reinforcement indicated 12.

In Figures 20 and 21, the girder indicated 49 is essentially a balustrade and may be omitted to any extent.

In case of the natural form type, it is necessary, and in the case of the modified form type it is preferable, that the structural slab be covered with a layer of earth, sand, or cinders indicated by numeral 52 of Figures 21 and 22. The fill should preferably be finished with a suitable traffic surface or a paving slab indicated 53 of Figures 20, 21, and 22.

Drainage is provided for by the column hollow 1*a* and the outlet pipe 50 below the grade line 51 of Figures 21 and 22. Access from the driving surface may be through a drainage grating at the center or sides or seepage through the fill material.

The column shaft, indicated 2 (being an extension of the underside of the slab also indicated 2, since the entire structure is a single entity) may be of any suitable length.

The foundation indicated 48 of Figures 21 and 22 may be of any type but preferably of one of those hereinafter described, and of such spread or size as will insure stability of the structure as related to both its size and height.

Connection and interaction between the structural units should be confined to an interlocking slip joint, and by the alternate recession and extension of the beam balustrades shown in the several figures and indicated 49.

Coming now to the simple rotational systems, these may be disclosed best in conjunction with their applications, as shown by Figures 23, 24, 25, 26, 27, 28, and 29.

The simple rotational system is in principle similar to the compound rotational system, the essential difference being that there are fewer alternations of stresses and therefore fewer segmental divisions, being 8 instead of the former 32 double divisions.

This system is divided into the natural form simple rotational system and the modified form rotational system, both of which may be wave reinforced. As the economical applications of both are largely confined to foundations or similar structures, its description is here embodied in its typical applications first pointing out the essential considerations. The ratio of wave overlap, hereinbefore designated the inner and outer minor ratio is maintained as before and the minor radii are determined thereby as before.

Foundations embodying the principles outlined in the foregoing inventions of the several systems are here described. While any of the slab systems previously described may be inverted and used as footings of either connected or isolated character, it is recognized that this will be economical only where the accumulated load of the structure is very great or where the supporting value of the soil is very low. For normal or usual conditions and practice the foundation should follow the general design shown by Figures 23 and 28 inclusive.

Due to the requirement for greater relative resistance to shear, the slab portion of the foundation must be relatively thick as compared to its diameter, with a resulting reduction of flexibility, thus reducing the number of bands of stress whirls. In Figures 23 and 24, stub bars are in-

dicated as 32*a*, these being in accord with general practice as regards the portion projecting into the column, but new as regards the spreading curvature within the foundation itself and its loop back endless bottom. In these figures, a new element is introduced in the bell core spiral indicated 32*a*, this being a distinct departure from the cylindrical spirals commonly used in columns both because of the difference in shape and because the stress in this bell core changes from the tensile stress of the cylinder at the top to a progressively increasing compressive stress at the bottom.

Bar 54 of these figures and corresponding bars 55 and 56 are circular, continuous, metallic, welded or lap spliced, the smaller circles being in compressive and the larger circles in tensile stress.

The wave stress rings 57 and 57*a* of these figures should preferably follow the number and proportional size and lap arrangement shown, the larger ring having the inner minor ratio as regards included lap width to included lap length. The stresses in all circular bars 54 will be compressive, tensile for bars 55, and compressive for bars 56.

Stub bars 32*a* may be omitted if the foundation is designed to support a metal or other than concrete column.

A variation of the foregoing foundation designed for simpler forming is shown by Figures 25, a plan, and 26, a half elevation and half section on line XII, in which stub bars of any suitable shape are indicated by 32*b*, these being omitted if foundation is for other than a reinforced concrete column. Circular rings made continuous by either metallic weld or lap splice are designated 54, 55, and 56. The stress in these rings is compressive, tensile and compressive respectively. Wave rings 58 are used for the same purpose as in all previously described construction and act in like manner.

An effective inversion of the first described foundation, Figures 23 and 24, is shown by Figures 27, a plan, and 28, a half elevation and half section on line XIII, but with the character of stresses of the reinforcing members exactly reversed. In this case the wave rings 64 are spaced for a lap of inner minor ratio but may be increased in number as shown by Figure 23. In the Figures 27 and 28, bars indicated 62 and 63 correspond to similar bars indicated 56 for Figures 23 and 24, but the stresses described are reversed. The contour of the bottom surface is extremely efficient in transmitting the load to the soil and affords a simple profile for excavation, but where it is desired to conform more closely to past practice the sectional profile may be that indicated 65 of Figure 28. This form of foundation is very advantageous because it minimizes the excavation necessary and forms a flat level surface conforming to the floor and in many cases may be utilized as a part thereof.

A novel adaptation of this foundation structure is disclosed by Figure 29, being a half-elevation, half-section, and of which Figure 27 is substantially typical as a plan view. Its use is as a support for roof structures, one application of which is later set forth. The column element may be solid or hollow, the latter being indicated by Figure 29, the inside being indicated by 66, the outside by 67, the roof conductor opening by 68 and access openings by 69 and 70. Structural elements and character of stresses are identical with identically numbered elements of Figures 27 and 28.

All of the foundation designs described have concrete stresses conforming to the reinforcement stresses described and in all cases a large portion of the actual stresses is carried by the concrete, due to the large volume of this required to resist the shearing stresses. Due to this fact, as well as natural processes previously referred to, the wave rings may be dispensed with and such omission will be less disadvantageous than is the case for ordinary slabs. However, such omission should not be made around openings such as shown by 68 of Figure 29.

The novel and useful system of construction now described is designated as the multiple rotational system. The principles of this system are disclosed by Figure 30 which is a half plan view of slab, Figure 31, which is a vertical sectional view of slab and integral column, on line XIV, Figure 32, which is a plan view of slabs assembled and connected, and Figures 33, 34, and 35, which illustrate variations of the system as used for foundations.

The controlling principle of this system is the assembly, about and concentric with a support or column structure, of a series of concentric rings, each of which is designed for independent stresses and stable within itself to a greater or lesser degree.

The outer limit of the column slab plate and nearly coincidently the outer ring of reinforcement are designated by 71 and 72 respectively of quadrant E, Figures 30 and 31, similar successive included bands being similarly designated. All of these bands are placed near the top of the slab and are all in tension within certain limits of load magnitude and above certain load limits the bands of reinforcement at and near the circumference become compressive, a condition which usually should be avoided and is usually avoided by the progressive reduction of the pitch, or distance between successive bands as the column is approached, often combined with a simultaneous progressive increase in the sectional area of each successive included reinforcement ring, or band.

A further method of protection is that of pitching the bottom surface, 2X, down as the column is approached partially used in Figure 31, indicated 2X, this serving the double purpose of reducing the unit shearing stress below what it otherwise would be by the resulting thickening of the slab and partially compensating for the progressive increase of shear producing load.

Another method, particularly adapted to roof structures, is combining with the downward slope of the lower surface, a somewhat less downward slope of the top surface, indicated 1X in quadrant F of Figure 31, as the column is approached. This serves to reduce or almost eliminate the circumferential compressive stress which otherwise increases rapidly toward the edge.

Compensation for this increased stress toward the edge, together with provision of a super factor of safety, is afforded by placing similar reinforcement rings near the bottom of the slab for the outer portion of the area as indicated by 77 of quadrant F of Figures 30 and 31, showing the bottom layer of reinforcement. This also facilitates use of convex slabs as later referred to.

The mechanical principle of this construction is the tendency of each successive ring of concrete to roll over its next inner ring, but being restrained by its own enclosing reinforcement ring.

As a result there is produced a series of multiple moments, the couple of which is independent of the spacing of columns or rather of the distance from the column center to the ring under consideration, but is determined by the ratio of the pitch (or distance between the reinforcing ring considered and the next enclosed reinforcing ring), to the proper proportion of the depth accepted (usually denoted in reinforced concrete formulae as *jd* and approximating 7/8 of the distance from the center of the top ring to the bottom of the slab), the primary compressive stress in the concrete being radial and the tensile stress in the concrete being circumferential.

As this ratio is extremely small as compared with the couple ratio for the usual lineal moments, the compressive stress is very low, particularly as the breadth factor is the entire circumference of the ring considered. The area of reinforcement required is only a small fraction of that theoretically required to balance the concrete compressive stress due to the fact that this reinforcement constantly renews its strength by reason of the combined factors of its curvature and band stress.

For these reasons this system is particularly advantageous for half and quarter plates adjacent to walls as shown by the assembly drawings, Figure 32, and at the same time is well adapted to assembly without exterior columns, the wall beam indicated 1—2 of Figure 32, and wall being carried on the circumference of the slab plate in place of the columns as here shown.

Radial compression of the concrete must be transformed into circumferential compression of circumferential concrete areas and circumferential reinforcement bars placed near the bottom of the slab and indicated by 80 of Figures 30 and 31.

Due to this circumferential conversion, columns may be either solid or hollow as shown by 76, Figures 30 and 31. However, the residual radial compression and supporting, or shear, load is carried into the column by radial bars 78 and 79, of Figures 30 and 31.

Designs for adaptation to foundations are shown by Figures 33, 34, and 35. A half-elevation, half-section view is shown of the normal type footing with reinforcement indicated 72 in a flat plane, the plan view thereof being shown by the left quadrant 83 of the plan view, Figure 34. An inverted footing, designed to minimize excavation and provide a level floor area, is shown in plan by the quadrant 84 of Figure 34 and in elevation by Figure 35. In this case the reinforcement rings are arranged in the plane of a spherical segment, 85, and the protruding concrete may be eliminated so that a section of the footing conforms to the shape line 86.

The interstices between the slab plates 81, 82, 83, may be reinforced by any of the methods indicated, being similar to the methods previously described for similar conditions.

A further variation of the concentric ring system is the use of a continuous spiral, much of which may be of wire for the usual slab. There is no structural or stress virtue in the continuous spiral and its use is merely that of convenience. The individual rings of reinforcement are either metallic welded or lap spliced with the use of bond stress from the concrete.

The Figures 30 and 31 indicate clearly the several opportunities for practical simplification of this general system of multiple rotation as used for natural form multiple rotation system and for modified form multiple rotational system, the sectional view proper showing the latter type.

For any practical structure, the slab immediately surrounding the column must be thickened in order to provide sufficient area to meet the requirements for shearing resistance. However, the unit shear in this or any of the rotational systems may be high as compared with the usual lineal moment systems.

A fundamental principle in this system is that the radial reinforcement (indicated 78 of Figures 30 and 31) near the column as well as away from it, is placed near the bottom of the slab in contrast to the usual location near the top. Also that the area of this reinforcement, in its relation to the concrete area and actually if desired, diminishes away from the column and toward the center of the slab span distance between columns.

The use of radial reinforcement near the bottom of the slab lends itself naturally to the creation of an equivalent plane of pressure diverging downward from the natural plane of pressure as the column is approached, and so to a flattening of the under side of the slab.

The logical depression and curvature of the radial reinforcement of the slab to form vertical reinforcement of the column produces a direct pressure condition which supplements the shearing stress at the line of transition from slab to column.

The radial reinforcement from the center of the column, indicated 79 of Figures 30 and 31, by reason of its effect on the resulting plane of pressure has the effect of making the slab tend toward the convex forms indicated by line 74 of Figure 31.

Where no radial reinforcement is used in the bottom of the slab, it is particularly desirable either to make the actual form of the slab convex on its lower surface actually, or to effect a similar tendency by a progressive reduction in the pitch of the successive circumferential bars of reinforcement (indicated 72) as the column is approached, or to provide the circumferential compression reinforcement near the bottom of the slab as shown in Figures 30 and 31, indicated 77.

It is obvious from the foregoing description that the structural area at the conjunction of the slab and column support, notwithstanding the simple arrangement of reinforcement, is subjected to a major rotational effort as a whole and therefore is subject to the organization of stresses more accurately organized by the column head shown by Figures 11 and 12 hereinbefore described. The use of that column head in conjunction with this slab system is wholly satisfactory, and highly preferred.

Externally supported slab structures of the natural form compound rotational system, modified form compound rotational system, including that of wave reinforced, are shown by Figures 36, 37, 38, and 39, reinforced elements of which are indicated by numerals identical with those used for members of similar shape for similar structure of the center supported application, but of stress character hereinafter stated.

Use of the wave reinforced element, while always contributing to the strength and economy of concrete as heretofore explained, is of lesser importance where the sectional contour follows Figures 38 and 39, than for sectional contour

shown by Figure 37, all taken on line XV of Figure 36.

Obviously the intensity of the stresses is reversed as compared with the center supported slab, being higher as the circumference is approached, and so adapted to a relatively lower increase of unit stress.

Character of reinforcement stresses, whether tensile or compressive, depends upon the contour of the section used. In Figure 37, band denoted **9** is in compression, **10** in tension, **11** in compression, **12** in tension, **6** in compression, and **6a** in tension.

In Figure 38, band **9** is in compression, **10** in tension, **11** in compression, **12** in tension, **6** omitted except for temperature and shrinkage reinforcement, and wave rings **22** and **22a** may be omitted readily, while all wave rings may be dispensed with if radial temperature reinforcement is used.

In Figure 39, band **9** is in tension, **10** in compression, **11** in tension, **12** in compression, **6** in tension and **6a** omitted, except for temperature and shrinkage reinforcement.

This structural system is suitable for any structural plane supported actually or approximately for its entire circumference, intermittent support, as for example, octagonal, being suitable also.

Typical applications are for entire floors or roofs of any type building where the total elimination of columns is desirable, its use being economical for any reasonable span, such as for large auditoriums and applications hereinafter stated.

The externally supported multiple rotational system is disclosed by Figures 40, 41, 42, 43, 44, 45, 46, and 47, in which Figure 40 is a composite plan view of a half slab and the other figures are sectional views taken on line XVI of Figure 40, of which the bottom reinforcement is shown in the quadrant indicated G, and the top reinforcement in the quadrant indicated H. The outer limit of the slab is shown by **87** of Figures 40 and 47 inclusive and for all such figures bottom reinforcement bars are indicated by **88**, and top reinforcement bars are indicated by **89**.

The function of the bottom bar is to withstand the tensile stress incident to the rotational effort of its included or enclosed ring or band of concrete. As this effort becomes less toward the center, the pitch spacing of the concentric circular bars is increased or their size reduced or both. This is the only adjustment required and only the bottom bands are necessary for sections such as are shown by Figures 42, 43, and 44, except that it is preferably that all types provide the heavy top reinforcement indicated **92** of Figures 40, 41, 42, 43, and 44, the function of which is to receive the circumferentially converted radial compression induced by the bottom circumferential bands **88**.

Flat sections or sections of top concavity if loaded beyond a certain relative limit, induce a circumferential compression as the circumference is approached and this should be compensated for by corresponding concentric bars near the top of the slab, indicated **89**, of Figures 40 and 41.

Slab structures having center openings, including such as are shown by Figures 45 and 46, disclosing a spiral ramp suitable for use as a driveway, walkway or stair support, and Figure 47 disclosing a theatre balcony, should have both top and bottom bars, both being progressively increased in size and decreased in pitch or spacing as both inner and outer circumferential limits are reached.

Special reinforcement to be known as ripple ring reinforcement is to be used in all open center slabs where the opening is to large to come within the bands indicated **92**, these rings being indicated **90** of Figures 40 and 41, their external diameter indicated by their internal limit designated **91**. The preferred stress surge in the circumferential bars and preferred stress transference is produced by three equally spaced concentric ring groups, the outer rings having a contact pitch, or spacing equal to their radius. The diameter of the innermost smallest ring is such as to have a lap of the outer minor ratio, referred to hereinbefore. The plane of these ripple rings should be tilted downward toward the radial center as much as the slab thickness will permit for both flat and top concaved slabs, and a reverse tilt for top convex slabs, whether the surface be conical or spherical.

Support of the slab system here described should preferably be continuous, but may be limited to any number of straight line polygonal supports not less than four sides for all conditions except those having openings too large to come within the top compression band indicated **92**. The shape of supports should preferably be symmetrical but may vary somewhat therefrom. In any case, the area outside of the shortest dimension should be designed by an abrupt or progressive large increase in strength factor, preferably obtained by sharp increase in thickness and also by increase in sectional area of reinforcement with relative small pitch.

The essential principle of this system and its modifications is that circumferential bottom tension is balanced by radial compression which in turn is converted into circumferential top compression, utilizing either a single conversion or a succession and that the inner portion included by the conversion band may be open.

In the case of the use of ripple ring reinforcement, which may be used in any case, it is possible to provide relatively very large center openings, the rings being tilted downward toward the center thus producing a tensile stress surge at the unsupported edge and a compressive stress surge at the supported edge.

A novel and useful application of any of the externally supported slabs or any other structural surface is combined in a novel way with the previously and hereinafter described column forms or any other column structure, together with a novel main supporting structure, the combination being new and each individual component thereof being new, including the suspension principle in reinforced concrete and the reinforced arch used either in conjunction therewith or otherwise, is shown by Figures 48, 49, 50, 51, 52, 53, and 54, all designed to provide a roof enclosure.

Figure 48 is a fragmental sectional-elevation of Figure 49 which is a plan view, at a reduced relative scale, showing a roof structure for any type building but particularly suitable for a building used for manufacturing, assembling, or sorting. The first object accomplished is to provide for the admission of daylight from any or all directions and so distribute it as to produce an even and uniform intensity of light within. The oval or elliptical shape of the structural opening, **93** of Figures 48, 49, and 50, produces an interlocking or compensating effect between the adjacent sides, **96** of Figures 48 and 49, of the elevated portion of the roof, **94** of Figures 48, 49, and 50, and **95** of the same figures, thus each opening admits a maximum of daylight at the center with a pro-

gressive reduction toward the ends as the adjacent sides of the monitor approach each other. The shape may be of any suitable form desired for these openings, but that shown is most advantageous for forming the soffit or contour of the arch, 97 of Figures 48, 49, and 50, and the contour of the suspension member, 98 of Figures 48, 49, and 50.

The flat portion of the roof, 94 of Figures 48, 49, and 50, is supported by the upper arch of wall 96 of Figures 48, 49, and 50, on each of four sides, the load of this arch being supported and the arch thrust restrained by the lower portion of said wall designed to act as the tower of the suspension structure formed by the lower middle portion of said wall. The tower portion of said suspension member is in turn supported by the column head, 105 or 106 respectively of Figures 48, 49, 51, and 52, and that in turn by columns 107 or 108 respectively of Figures 48, 49, 50, 51, 52, and 53, being adaptations of new structural systems hereinbefore described, or by any suitable form of support.

Details of column features are shown by Figures 51, 52, and 53, openings for conductors for roof drainage being designated 109 and 110, other features being consistently indicated.

The lower connecting portion of the roof, designated 95 of Figures 48, 49, 50, 51, 52, and 54, may be of any kind of structure but preferably of reinforced concrete using the moment principle for a one way reinforced slab fixed at the supports, said supports being the lower part of the wall 96 of Figures 48, 49, and 50. Thus this slab forms the floor element of a structure similar to a suspension bridge.

Reinforcement details of the suspension and arch structure are shown by Figure 50, and designated 100, 101, 102, 103. Reinforcement of the arch performs the ordinary functions for such conditions, the novelty consisting in the application of the arch to the roof of the monitor structure, its inclined position of plane, and its support on what are in effect the towers of what is essentially a suspension bridge structure. Reinforcement 102 serves as the tension suspension cable, 103 as tension element in distributing the load of the bridge slab element and 101 as tension supports of the bridge element, said members being extended, if desired, across slab floor and up into arch, being in that case interrupted by the opening 93. The tower of the bridge element may have cast therein roof conductors similar to 110 in the column 108 of Figures 48, 49, and 50, or the water may overflow directly to the low roof portion, either over the entire top portion of wall 96 (forming a parapet or curb), or through suitable depressions or openings, it being advantageous to utilize the beveled intersection of walls 96, as shown in detail by Figure 51, as a concaved channel for such overflow, waterproofing treatment or material of roof being carried over parapet 96a, formed by wall 96 of Figures 48, 49, and 50.

A further advantageous and novel adjunct of this roof structure which is here described and claimed new for any overhead structure, whether roof or floor, is the duct provision shown by Figure 54, in which there is constructed under the roof valleys and/or between columns a passageway or duct for conveying and distributing air for ventilating or conditioning the air of the enclosed or other area. In Figure 54, 111 indicates the form of duct when it is further used as an overhead passage or observation gallery, while one of any suitable modifications is shown by its modification indicated 111a. One of its modified forms when used for air transmission or pipe concealment is shown by 112. These ducts, channels, or passages may be connected to the opening of hollow columns or extend around or enlarge to include and enclose either hollow or solid columns. Access thereto may be through the column interior or by any suitable structure or opening. Natural air discharge is or may be through the vent opening 104 of Figure 49.

Individual structures, here described, include structures supported from a single support at the center whether that support is solid, hollow, or subdivided, and whether consisting of a roof only or foundation and/or floors combined therewith. Such a structure particularly adapted for use as a vending station such as a gasoline filling station is shown in plan by Figure 55 and in section by Figure 56, (taken on line XVIII of Figure 55), in which 113 designates the overhanging roof slab, 114 is the outer edge of the foundation, 117 is the column shell expanded to provide sufficient hollow or enclosed area to serve as the office, or attendants' housing, the column shell constituting the walls thereof with slits in same to serve as door and window opening. The column shaft is covered by a slab 18, while the office floor, 115, serves also as a part of the foundation. The outer part of the foundation, 114, serves as the elevated vending floor and the covered area, 116, indicating the surface of the grade or paving, used as vehicle space. Any of the structural systems covered by these inventions may be used for the structure but the figures show the center supported multiple rotational system for the outer roof, 113; also for the outer foundation, 114. The same type system circumferentially supported is used for the inner part of the foundation, 115, and roof, 118. Architectural decorative treatment may be applied circumferentially as indicated by 119 of Figure 56.

A multi-story structure suitable for vending or amusement or recreational or other purposes is shown by Figure 57, which is a sectional elevation on equivalent line XVIII, in which 114a indicated a circumferentially supported floor and foundation slab, 120 a similar slab but providing for load of reverse application from the foundation; 122, is a similar type slab of modified section used for the roof; 123 is the supporting walls thereof; 121 is the internally supported slab carried by the expanded column shell, 124, forming the walls of the first story. The surrounding level of surface 125 may be used as covered space for any purpose. Openings should be limited to the center of the several slabs where the size of opening is large. The system of construction may be any of those disclosed by these inventions but the figures show the multiple rotational systems and if large openings are provided, there should be added the ripple ring reinforcement.

Floating structures embodying my novel concrete construction are shown by Figures 58 to 64 inclusive. Figure 58 is a sectional view of a circular structure, therefore showing any section on any diameter through a circular plan. This structure is suitable for a surface or submerged reservoir used for any liquid but primarily designed for water or sewage disposal plants. The interior, 126, shows a curvature departing toward the circumference from the exterior surface, 127, but the degree of departure, or reversed curvature, is determined by the predominant pressure, whether from within or without. Any of the systems described may be used.

Tanks for water or fluid or other substance are shown by Figures 65, 66, 67, 68, and 69. Such tanks are suitable for any type of tank structure but are primarily adapted to use for railroad water and coal supply containers, and such uses where the capacity rather than extreme height is the dominant consideration.

Column structures of reinforced concrete applicable to any system of construction and which is novel and is a new invention is now described as shown by Figure 58, a plan view, and Figure 59 which is a fragmental elevation and section taken on line XXIII.

The column structure is based on the discovery of the organization of stresses within the column shaft, which causes the interior of the column to produce a lateral, radial, bursting pressure from within the column. This may be relieved by having the center area of the circular shaft (representing about one fourth the total area) hollow, the opening being indicated **155** and the outer circumference **156** of Figures 58 and 59. Outside the opening **155** there is indicated an inside spiral reinforcement, **158**, and inside the circumference is the usual outside spiral reinforcement, **157**. Inside of this spiral is placed the main vertical reinforcement, **159**, and adjacent to and circumferentially outside the inner spiral, **158**, is the secondary vertical reinforcement, **160**. The concrete area between the outer spiral and the opening should be used as a basis of computation. If the inner spiral is omitted, then the area adjacent to the opening and equal to one eighth the gross total area should be computed at a lower unit stress. The opening shown and described is minimum and may be indefinitely larger, this invention being for use in any system of construction whatever.

Slotted columns are shown by Figure 60, which is a plan-section, and Figure 61, which is an elevation, the portion above and below the slots, **161**, being treated as a hollow column, the areas between the slots, **162**, being considered as individual columns, and may be solid as shown, **162**, with rectangular spaced and tied reinforcement, or as shown at **163** with a spirally reinforced core, or may have a structural steel core forming either a composite column or an encased metal column as indicated **164**.

Precast slabs of reinforced concrete are herein described as my invention being an adaptation of any of the structural systems hereinbefore described but more particularly the combination shown by the Figure 40, a plan view and Figure 41, which is a sectional view, modifications of which are shown by Figure 62, which is an isometric view of a slab having one corner cut away to show its preferred formation.

A simpler adaptation of the same general type of slab is shown by the isometric view, Figure 75, while details of construction and setting common to both forms are shown by Figures 64, 65, 66, 67, 68, 69, and 70.

The Figure 62 shows the under side and two edges, together with a section view from the removal of a corner, of a slab adapted to precasting and supporting on beams along all four edges. The central surface area, indicated **167**, shows a sinkage from the bottom side, its area being substantially thinner than the surrounding area extending to the edge of the slab indicated **165**.

The object of this sinkage is to reduce the weight and amount of material used as the circular area may be designed and proportioned upon the basis of continuous support and for a span equal to the circle diameter, which is slightly less than the side of the supporting square. This outer area must be designed upon the basis of a span equal to the diagonal of the square and so is thickened. This type of slab is most desirable for very large spans as for example the spacing of beams exceeding sixteen feet.

The corners may be cut out at any or all corner locations, to permit the clearance around columns or pipes; also the center of the slab may be left open as indicated **168**, or **168*a***, for passage of any device or equipment, including that hereinafter referred to.

A simplified form of this slab is shown by Figure 63, showing the slab tilted up revealing the bottom, **167**, and two edges, indicated **165**. Similar corner cuttings are similarly indicated **166** and **166*a***. The dotted line indicated **173** marks the location of a circle inscribed with reference to the supports and marking the location of special top circumferential reinforcement shown in section by Figure 65 and indicated **173**.

This last sectional figure is cut on the line XXIV of the tilted plan view Figure 63 and is also applicable to a similar section of Figure 62. This section shows also the normal bottom reinforcement, **171**, and the extra heavy reinforcement indicated **174**, as used in connection with the modified form multiple rotational system.

The cut out center, indicated **168** of Figure 62, is shown in detail section on a diameter by Figure 64, the slab being indicated **167**, the opening **168**, the slab reinforcement **171**, and the cast cover plate filler **169**, this being reinforced with a single circumferential ring, which in case the plate is unduly large is supplemented with a succession of included rings or otherwise.

The setting of these slabs is shown by Figure 79 which shows a fragmental sectional elevation of column and beam intersection as commonly used in steel frame of buildings. The slab of either type described is hoisted into position over the beams provided to support it, is lowered upon them and grouted with suitable mortar or material to insure a firm and continuous support.

In order to provide simple and effective means of handling and setting the precast slabs described, I have invented and applied a cable device and anchorage, for use in the center or corner openings or elsewhere about the slabs, as shown by Figure 66, which is a fragmentary plan of a corner of said slabs, but typical for the center opening or other location.

This cable anchorage is placed near the bottom of the slab, the anchor itself being indicated **176**, and is engaged with the reinforcement indicated **171**, **173**, and **174**, all of which is the more effectively united by the band anchors of reinforcement indicated **175**.

Figure 68 represents a vat into which the concrete is poured or cast in layers, the figure showing said vat in isometric view with two sides removed and the concrete slabs shown in the interior before their removal. The vat floor is indicated **180**, the slabs **165**, and the waterproof membrane **182**, which is any suitable material such as a double thickness of impervious paper or fibre board or metal.

The cut out corners to allow for columns are indicated **166**, the open center **168**, the slab surface **165**, the anchors **176**, the filler blocks **177**, and the vat sides **181**.

Further facilities for this casting are shown

by Figure 70 which is a sectional view on line XXV through the cable anchor shown in plan by Figure 66. The anchor is indicated 176, the general corner opening being filled by the three ply fibre material indicated 177, 178, and 179. These plies are loosely attached about the anchor, the whole is placed in the corners or center of the bin or vat in conjunction with the reinforcement, serving as void form blocks and as gauge blocks for the thickness.

The operation in use is to lay the completely or sectionally fabricated reinforcement, placing the anchor cables (fibre encased), and pouring a layer of concrete which is tamped and struck to a level. Either immediately thereafter, or when partially set, this surface is covered with the separating elements indicated 182, and the process repeated to produce a laminated block of concrete from which the successive slab plates are lifted after full strength from setting is attained.

Additional devices as used are invented as shown in Figure 69 which is a fragmental plan adjacent to two contiguous columns of a building. There is provided a succesison of strips (such as wood or metal), indicated 183, which in their aggregate become the equivalent of the vat walls hereinbefore described and indicated 181. Adjacent to the column or pier is provided fibre encased cable anchors indicated 177. The placing of the anchors 177 and the dividing strips 183 in conjunction with one another in any basement or lower floor of a building produces a continuous but divided mould which has a complete unit of reinforcement placed in each and the entire area poured over with concrete, struck off flush with the top of the mould strips. Upon this surface is placed the separating membrane, another series of divisions with reinforcement and the pouring repeated. In this manner the builder can, while the structural steel frame is being erected, cast all roof and floor slabs in the basement, using gravity dumps for the concrete and avoiding expensive hoisting and distributing. When the steel frame is complete, the floor plate slabs will be ready to be placed. A hoist cable can then pick up the top slab, raise it in a tilted position turned diagonally across the frame opening, and place it on the roof. This cable is then passed down through the center opening of the set slab and lowered to hoist the slab for the top floor, this process being continued until all floors are placed, and all slabs are then grouted solidly to the supporting beams and to each other.

I claim as new not only the system of construction and its application, but the devices and appurtenances used therewith and the process and method of said use, construction and setting.

A further application of the adaptation of the several structural systems to pre-cast slabs is my invention of pre-cast foundations or footings including the types shown by Figures 71, 72, 73, 74, 75, and 76. I claim as new and my invention the construction of any type of foundation or footing for piers, columns or walls, regardless of their design but describe specifically the following.

Figure 71 shows a plan view of a circular footing and Figure 72 shows a half elevation and a half section as taken on the line XXVI. This footing is particularly well adapted to setting on a bed of fresh grout or mortar. Its essential reinforcement consists in the several circular rings, 186 being placed near the conjunction of the outer circumference indicated 184 and the top surface 184*a* and being in compression; ring 187 placed well inside of the latter and near the bottom surface indicated 184*b* and being in tension; the group of four rings indicated 188 and placed well inside the former and near the top surface 184*a*. The center of the slab should preferably contain a recess or metal insert adapted for a lifting connection, in this case shown as a threaded iron insert indicated 185.

A variation of the footing as described is shown by Figure 73, which is a half elevation and half section on line XXVI of plan view Figure 71 to which it also applies, the corresponding members being identically indicated, and the reinforcement being subject to stress of like character but higher intensity.

A further variation is shown by Figure 74 which is a half elevation and half section taken on line XXVI of plan view Figure 71, to which it also applies. The corresponding elements are identically indicated but the stresses in the reinforcement are somewhat altered, ring 186 being in compression, 187 and the four rings indicated 187*a* being in tension.

A further variation is shown by the half plan shown by Figure 75 and the half elevation, half section shown by Figure 76, as taken on the diameter, section line XXVII. The circumference of the footing is indicated 184*cd*, the top surface 184*c* and the bottom surface 184*d* of the two figures. The reinforcement indicated 187*b* is all in tension. The insert for picking up is indicated 185 as before.

The adaptation of my systems of construction is shown by the Figures 77, 78, and 79. Figure 77 is a plan of an ordinary pier as it exists, Figure 78 is a plan of the same pier with its footing clipped off at the corner to provide an octagonal shape, the pier in both figures being indicated 190 and the original footing 189.

In the Figure 78 the original footing has been surrounded by a reinforced concrete ring or collar, as more effectively shown by Figure 79, the half elevation and half section, taken on line XXVIII of Figures 78 and 77.

In all figures the outer limit of the concrete ring is indicated 190, its top surface 190*a* and its bottom surface 191*b*. The reinforcement rings, of any number but preferably not more than 3, are placed near the outer bottom and indicated 187*b*, their stress being tensile. The reinforcement ring 188*b* is placed near the inner top of the ring and its stress is compressive.

While the invention has been described particularly in connection with concrete structures it will be seen that the principles disclosed are applicable to all solids. By shaping structural material of any kind to develop the circumferential stress bands described, the desired strength for lateral resistance to force may be secured with a great saving of weight.

Minor changes may be made in the physical embodiments of the invention within the scope of the appended claims without departing from the spirit thereof.

I claim:

1. In a concrete structure forming a self-sufficient unit, the combination of a supporting column, a substantially horizontal portion formed integrally with the sides of said column and radiating therefrom, said radiating portion varying progressively in thickness from the column walls to the periphery of said horizontal portion, the material in said horizontal portion being proportioned so as to produce successive circumferential stress band sections, compressive stress in one of

said bands and tensile stress in an adjacent band under normal distributed load.

2. A concrete structure of the character designated in claim 1, comprising a column in which the side walls diverge radially to form a substantially horizontal top portion constituting a supporting surface.

3. A concrete structure of the character designated in claim 1, having circumferentially disposed reinforcing elements in certain of said stress bands.

4. A concrete structure of the character designated in claim 1, in which the horizontal portion comprises a series of concentric wave formations, each of said wave formations including a stress band section.

5. A concrete structure of the character designated in claim 1, including reinforcing members extending radially of the axis of said column and circumferentially disposed reinforcement members spaced radially from the axis of said column and coinciding substantially with certain of said stress band sections in the horizontal portion of said structure.

6. A concrete structure of the character designated in claim 1, including reinforcing members disposed circumferentially and spaced radially from the axis of certain of said columns, said members coinciding substantially with certain of said stress band sections.

7. A concrete structure of the character designated in claim 1, including a plurality of reinforcing members extending circumferentially and spaced radially from the axis of said column to coincide with alternate stress band sections, and other ring reinforcing members positioned adjacent to each other and having their centers substantially in the curved axis of a stress band section.

8. A concrete structure of the character designated in claim 1, including a plurality of reinforcing members extending circumferentially and spaced radially from the axis of said column to coincide with alternate stress band sections, and other ring reinforcing members positioned adjacent to each other and having their centers positioned in a plane substantially parallel to the plane of said circumferential reinforcing members and in the curved axis of a stress band section.

9. A concrete structure of the character designated in claim 1, including a plurality of reinforcing members extending circumferentially and spaced radially from the axis of said column to coincide with alternate stress band sections, and other ring reinforcing members positioned adjacent to each other in overlapping relation so that their centers shall lie substantially in the curved axis of a stress band, the area of reinforcing material in a particular stress band being proportioned to the stress developed in that particular band.

10. A concrete structure of the character designated in claim 1, including a plurality of continuous reinforcing members extending radially from the axis of the column to the periphery of said horizontal top portion, other continuous reinforcing members extending circumferentially of the axis of said column and spaced radially from the axis of said column, certain circumferential reinforcing members being located in alternate stress band sections whereby a compressive stress in one band section and a tensile stress in an adjacent band section is transmitted circumferentially of said structure.

11. In a concrete structure of the character designated, a plurality of supporting columns in adjacent spaced relation, each of said columns having a horizontal top portion formed as an integral part of said column walls and radiating therefrom to tangentially engage an adjacent column top, said radiating portion varying progressively in thickness from the column walls to the periphery of said top portion, the material in said top portion being proportioned so as to produce successive stress band sections, compressive stress in one of said bands and tensile stress in an adjacent band under normal distributed load and means for uniting the peripheral edges of adjacent horizontal column top portions.

12. In a concrete structure, a hollow supporting column, the walls of the upper end of said column diverging radially to form a substantially horizontal top portion, the thickness of the horizontal top portion varying progressively from the column to the periphery thereof, the material in said horizontal portion being proportioned so as to produce successive concentric stress band sections, compressive stress in one of said bands and a tensile stress in the adjacent band under normal distributed load, radially disposed reinforcing members in said column, the upper portion of said members diverging radially into said bottom portion and intersecting said stress band sections, and circumferential reinforcing members concentric to the axis of said column and spaced radially therefrom, certain of said circumferential reinforcing members being located in different areas of a stress band section, whereby all stresses developed in said band sections are transmitted to said column.

13. In a concrete structure, a hollow supporting column, the walls of the upper end of said column diverging radially to form a substantially horizontal top portion, the thickness of the horizontal top portion varying progressively from the column to the periphery thereof, the material in said horizontal portion being proportioned so as to produce successive concentric stress band sections, compressive stress in one of said bands and a tensile stress in the adjacent band under normal distributed load, a plurality of longitudinally disposed openings formed in the walls of said column, radially disposed reinforcing members in said column and located between said openings, the upper portion of said members diverging radially into said bottom portion and intersecting members concentric to the axis of said column and spaced radially therefrom, certain of said circumferential reinforcing members being located in different areas of a stress band section, whereby all stresses developed in said band sections are transmitted to said column.

14. In a concrete structure of the character designated, a slab comprising a plurality of circumferentially disposed concentric reinforcing elements, said elements alternating in position relative to the top and bottom of the slab, in one or more alternations.

15. In a concrete structure of the character designated, a slab comprising a plurality of circumferentially disposed concentric reinforcing elements, said elements alternating in position relative to the top and bottom of the slab, the area of individual reinforcing members in each alternation increasing toward the peripheral edge of the structure.

16. In a concrete structure of the character

designated, a slab comprising a plurality of circumferentially disposed concentric reinforcing elements, said elements arranged in groups and alternating in position relative to the top and bottom of the slab, the area of individual groups of reinforcing members in each alternation increasing toward the peripheral edge of the structure.

17. In a concrete structure of the character designated, a slab comprising a plurality of circumferentially disposed concentric reinforcing elements, said elements arranged in groups and alternating in position relative to the top and bottom of the slab, the area of individual groups of reinforcing members in each alternation increasing toward the peripheral edge of the structure, and radially disposed reinforcing members spaced circumferentially.

18. In a reinforced concrete structure, the combination of a supporting column having a substantially horizontal top portion the material in said top portion being proportioned so as to produce successive stress band sections, compressive stress in one band and tensile stress in an adjacent band under normal distributed load, concentric overlapping ring reinforcing members located in each band section and having their centers in the curved axis of the corresponding band section, and radially extending reinforcing members projecting from the axis of said column and intersecting the stress bands.

19. In a reinforced concrete structure, the combination of a supporting column having a substantially horizontal top portion the material in said top portion being proportioned so as to produce successive stress band sections, compressive stress in one band and tensile stress in an adjacent band under normal distributed load, concentric overlapping ring reinforcing members located in each band section and having their centers in the curved axis of the corresponding band section, and radially extending reinforcing members projecting from the axis of said column and forming the median line of certain overlapping ring members in certain stress bands.

20. In a reinforced concrete structure, the combination of a supporting column having a substantially horizontal top portion, the material in said top portion being proportioned so as to produce successive stress band sections, compressive stress in one band and tensile stress in an adjacent band under normal distributed load, concentric overlapping ring reinforcing members located in each band section and having their centers in the curved axis of the corresponding band section and radially extending reinforcing members projecting from the axis of said column, intersecting the stress bands and forming the diameters of certain ring members in other stress band sections.

21. In a reinforced concrete structure, the combination of a supporting column having a substantially horizontal top portion, the material in said top portion being proportioned so as to produce successive stress band sections, compressive stress in one band and tensile stress in an adjacent band under normal distributed load, concentric overlapping ring reinforcing members located in each band section and having their centers in the curved axis of the corresponding band section and radially extending reinforcing members projecting from the axis of said column and forming the median line of certain overlapping ring members in certain stress bands, and circumferential reinforcing rings spaced radially from the axis of said column and located adjacent to certain sections.

JAMES MINOR WORKMAN.