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SHELL CUPOLA

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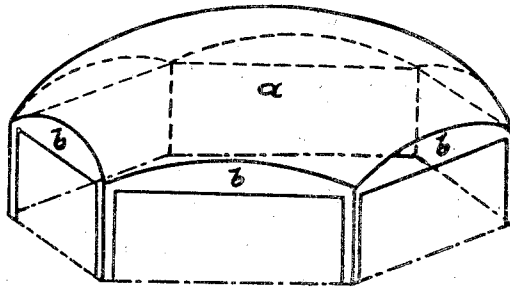


Fig. 1.

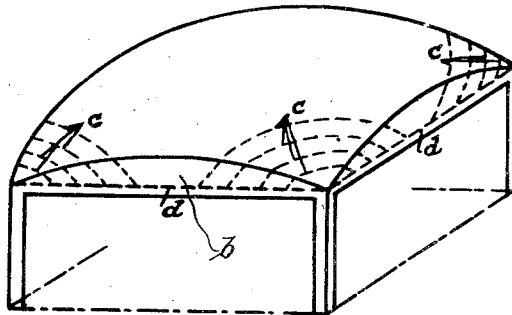


Fig. 2.

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SHELL CUPOLA

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and in Germany May 5, 1930

2 Claims. (Cl. 108—1)

I have filed an application in Germany, May 5, 1930; in France, October 20, 1931; in Belgium, October 20, 1931; and in Italy, October 26, 1931.

This invention refers to the use, construction and design of shell-like roofs formed of or embodying thin, curved members such as plates or slabs, bordered or stiffened by vertical members, sometimes marginal, such as eaves members or diaphragms which may be positioned between columns, if the roof is supported by columns, and the invention, therefore, has for one object to provide means whereby the shell together with the stiffening members, marginal or otherwise, acts as a structure of unified bending action and carries the loads to widely spaced columns or other supporting members or parts.

It is well known that rotation shells, that is, shells such as the shell of a dome, generated by revolving a line, usually a curved line, about a central axis, can be used for large spans with great economy. Heretofore such doubly curved shells or domes could be used for large buildings of circular or elliptical plan but could not be used for buildings of other plan, such as polygonal or rectangular. They could not be used for ordinary large building construction without intermediate supporting walls. Another disadvantage of the old dome form is, that wide column spacing was not possible, because the tension ring at the eaves of the shell was not strong enough to carry the load from the dome over long spans. With this invention wide column spacing is possible.

Both these defects are overcome by the present invention, since the shell of the dome is bordered by vertical integral members which together with the shell act like uniform beams.

The vertical members by which the shell is bordered make it possible to build structures of polygonal or rectangular plans. Any desired plan of a hall can be effected. Joining the marginal members with the shell to obtain a uniform beam action makes the dome capable of carrying the loads over large spans to distant columns.

My invention is illustrated more or less diagrammatically in the accompanying drawing, in which:—

Figure 1 is a perspective drawing of a dome or cupola of hexagonal plan; and

Figure 2 is a similar view of a dome of rectangular plan.

Figure 1 shows a perspective drawing of a dome formed by a doubly curved shell over a hexagonal plan area, where the borders of the shell "a", lying in the vertical plane of two ad-

joining columns, are connected with marginal members such as members "b", thus combining shell and member into an integral structural unit with combined bending action, which may carry the loads to widely spaced columns or supports. For the spherical shell, as shown in Fig. 1, there could be substituted the shell of an ellipsoid, or of almost any other shape. The members bordering the shell can form the circumference of any polygonal or rectangular shaped plan area. The members, together with the shell, act between the columns like a T-beam of large section modulus. The wider the column spacing, the larger is the contributing width of the compression flange supplied by the shell. For example, column spacing of 250 feet can be used.

The shells of rotation (viz., shells generated by revolving a line about an axis) of former days had their principal stresses, if symmetrically loaded, in the direction of the meridians and of the rings only. In the dome of the present invention, the combination of dome action and bending action in the shell involves a decided change in direction and magnitude of the stresses. In a shell embodying the present invention, the principal stresses at the crown or upper portion are of the same character as in a dome, being meridional and in circles normal to the meridians. As the eaves or boundaries of the shell herein described are approached the stresses change and are directed laterally across the corners near the columns. The maximum change is to be found at the eaves line where the shell is connected to the eaves members. There the eaves members and the shell may by analogy be described as having the effect or action of a T-beam with a curved or domed flange, the curvature rendering the whole structure substantially rigid. The T-beam actions of adjacent members merge into each other or overlap, it being of course, impossible to resolve the structure into separate beams. In contrast to the true dome of earlier periods, the tensional ring stresses are eliminated.

In Fig. 2 the shell "a" again is combined with eaves members to form a structural unit. The shell may be constructed of reinforced concrete. The uniform bending action of the shell with the eaves members "d" is secured by a system of reinforcing bars "c", which, near the corners of the shell cupola, are placed in the direction of the principal tensional stresses across the corners of the shell, as shown in Fig. 2. These bars are anchored in adjoining members "b" and by their tensile action transfer stresses from the shell to

the members, thus conveying their stress to the reinforcement "d" of the members and forming of shell and members a structural unit acting similarly to a T-beam, to resist bending between the columns.

Although the T-beam analogy is helpful in explaining the carrying action of the dome, it must not be taken too literally. The structure is a statically undetermined system and its stress computation must be treated according to the theory of elasticity as found in text-books on analytical mechanics.

Whereas the shell as described will usually be made of concrete, the invention may also be carried out in other materials. The invention is not limited to the construction of roofs but can be applied to various other types of structures as, for instance, hanging domes, tanks, etc. Depending on structural and economical considerations, a marginal member may either be constructed as a truss, a diaphragm, a beam, an arch or any other suitable frame construction, and although it is not essential, any other part of the construction or many other parts of the construction may be reinforced.

Where I have used the words "doubly curved", I include structures, or the formation of structures, in which the shell is formed as a spherical dome or as a part of a spherical dome, and also one in which it may be replaced by a different doubly curved shell, whether it be a shell of revolution or a shell of non-revolution form, like a dome where the parallel plan circles of revolution are replaced by ellipses or by other curved forms. Cupolas and domes, however made, are generally spherical or are substantially circular in plan. My invention may be applied to a dome other than spherical and to one whose plan is other than circular. The words "doubly curved"

as used herewith, include domes other than spherical.

Where the term "peripheral" is employed, as in the claims, it will be understood that I do not wish to limit myself to a too precise meaning of the word. The supports, for example, may be near and yet not precisely at the outer edge or periphery of the shell. Where members are described as vertical it will be understood that a reasonable deflection from the vertical which does not involve a substantial change in result is intended to be included within the term "vertical" as it appears in the claims.

I claim:

1. In combination, a doubly curved shell body, a plurality of circumferentially spaced supports for the shell body, the shell body, between the supports, being bordered by generally vertical peripheral members, the shell, together with the vertical members, forming between each pair of supports, a structure of unified bending resistance, the shell having reinforcements extending in the direction of principal stresses across the corners adjacent the supports.

2. In combination, a doubly curved shell body, a plurality of circumferentially spaced supports for the shell body, the shell body, between the supports, being bordered by generally vertical peripheral members, the shell, together with the vertical members, forming between each pair of supports, a structure of unified bending resistance, the shell having reinforcements extending in the direction of principal stresses across the corners adjacent the supports, the peripheral members including reinforcing members in operative relationship with the first mentioned reinforcements.

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