March 11, 1958 K. O. VARTIA 2,826,157

ROOF STRUCTURE

Filed July 17, 1953

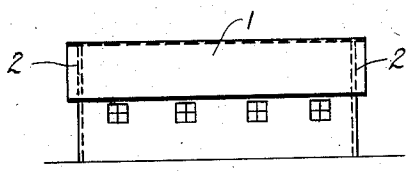


Fig. 1

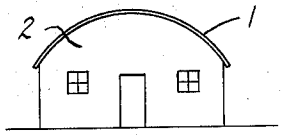


Fig. 2

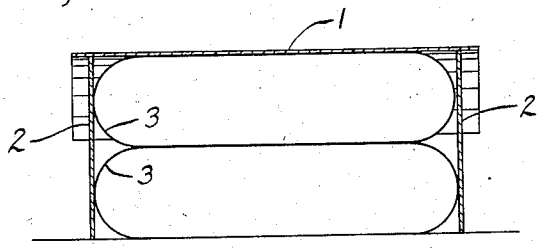


Fig. 3

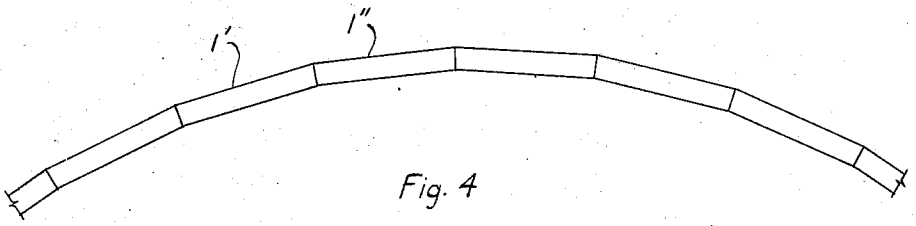


Fig. 4

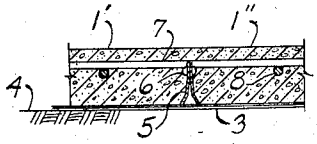


Fig. 5

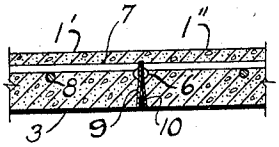


Fig. 6

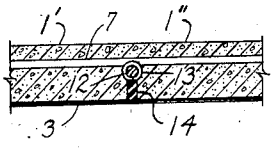


Fig. 7

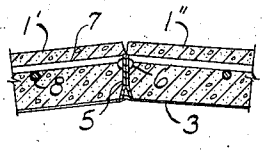


Fig. 8

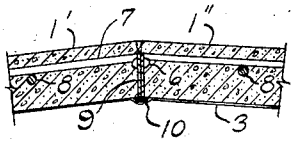


Fig. 9

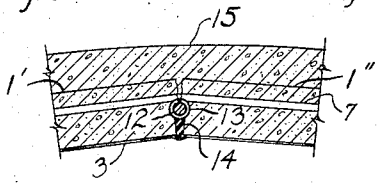


Fig. 10

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INVENTOR.

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2,826,157

ROOF STRUCTURE

Karl O. Vartia, Austin, Tex.

Application July 17, 1953, Serial No. 368,733

8 Claims. (Cl. 108—1)

My invention relates to so-called barrel-shell roofs, wherein a relatively thin structure of portland-cement concrete or the like is able to span a relatively great distance between supports because a transverse curvature converts the shell into a deep beam with portions of the shell acting as tension and compression areas and the remaining area as connecting web section. Such roofs are economical of material, but with the usual methods of construction this economy is offset by the expense of erecting and supporting a curved form at an elevated level, placing a thin layer of concrete upon this curved form, and after the concrete has gained sufficient strength, removing the form. Where a large area is to be roofed with many spans it is, of course, possible to design movable forms which can be re-used many times, but a construction schedule is then slowed by the necessity of waiting for each shell to become self-supporting before the form may be removed to a new location.

By use of my invention the shell is formed as a substantially flat slab structure at ground level or wherever it may be most convenient to provide the forming area. Prior to forming the structure, one or more deflated containers of thin but durable material, and capable of containing air or the like at moderate pressure with little or no stretching, are spread out flat upon the forming area to substantially the developed area of the shell. As will be more fully described hereinafter, upon inflation these containers provide both a supporting means during the conversion of the flat slab into an approximation of a barrel shell and a lifting means to position and place the resulting shell upon supports which will make of it a usable structural element. Reinforcing steel, to be prestressed or not as desired, and edge forms are then placed, along with longitudinal slab weakening devices as described hereinafter. The concrete or other slab material is then placed upon the deflated container or containers and around both the reinforcing and the slab weakening devices. After the slab material has gained sufficient strength, the edge forms are removed and the container or containers then inflated. If the edges of the containers have been placed exactly along the edges of the slab, at the instant of the slab becoming airborne the whole slab will be so uniformly supported that there will be little or no bending moment within the slab. As inflation is continued and the increasing volume of air within the container causes the slab to be lifted away from the underlying surface, the fabric along the edges takes a circular form between lines of tangency with the separating surfaces. Obviously, outside the line of tangency, where the fabric no longer contacts the slab, there is no longer an upward supporting force on the under side to balance the downwardly acting weight of the slab and a definite bending moment is created within the slab. At some stage of the inflation process, as defined by the weight of the slab and the actual strength of the lines of weakness, this bending moment cracks the slab along the lines of weakness, and causes the slab to assume a transversely curved shape

as the joints deflect. Should the container or containers be originally placed short of extending to the edges of the slab, no stage of completely uniform support will occur, since at the initial point of being airborne the slab will already have an outwardly extending unsupported portion and a consequent bending moment. Should the containers initially extend somewhat beyond the edge of the slab, a reverse bending moment will occur at the instant the slab becomes airborne. This is because the fabric of the container or containers outside the edge of the slab will be ballooned upwardly with a consequent upward line loading at the edge of the slab in addition to the uniform air pressure support against the under side of the slab. If the outward extent of the container or containers is limited so that the strength of the weakened lines in the slab is not exceeded by the reverse moment, there may be a certain advantage in the arrangement in that a larger container will enable a greater height of lift within any given limits of slab overhang, or container pressure and fabric stress. After the slab has cracked and deflected the transverse curvature greatly increases the ability of the deflected slab to overhang the supporting container at the ends, and inflation may be continued until sufficient clearance is obtained to permit transverse end supports to be placed under the curved slab. The containers will then be deflated sufficiently to transfer the weight of the slab to the supports, after which the container or containers will be completely deflated and removed.

If desired, the shell thickness may be increased by placing upon it an additional layer of material after it has been raised and its weight transferred to the supports 2. The articulated shell thus acts as a form and support for the second layer of concrete or the like until it hardens and becomes an integral part of the shell.

The method in general of forming a unit of a structure upon a deflated container and then raising the unit by inflating the container is disclosed and claimed in application Ser. No. 295,702, filed by applicant on June 26, 1952, now Patent No. 2,749,592.

To more particularly describe this invention, reference is had to the attached drawings.

Fig. 1 is a side elevation and Fig. 2 an end elevation of a building having a barrel-shell roof 1, supported on transverse end frames or diaphragms 2.

Fig. 3 is a longitudinal section on a larger scale through the building shown in Fig. 1. In addition to the roof 1 and transverse supports 2, there are shown a pair of inflated air containers 3, which are at a stage of inflation where the weight of roof 1 is supported in part at least on transverse members 2.

Fig. 4 is an end view of a portion of roof 1 on a still larger scale to show that it consists of a series of articulated segments such as 1' and 1'' which are deflected with respect to each other so as to approximate a transversely curved section.

Figs. 5, 6 and 7 show various arrangements for providing a joint between roof segments 1' and 1'' that will permit a limited amount of deflection, and Figs. 8, 9 and 10 show these same joints in the deflected position. In addition, Fig. 8 shows the crack that opens in the upper surface still unfilled, Fig. 9 shows the crack filled with mortar to the level of the adjacent surfaces, and Fig. 10 illustrates the case wherein an additional layer of material is placed over the whole area of the roof.

Referring again to Fig. 5, upon a suitably level surface 4 are placed one or more deflated containers 3, upon which in turn there will be formed the slab structure to be described. As previously indicated the slab and underlying containers should be substantially coextensive if it is desired to have minimum lifting pressure and minimum bending moment in the slab at the time of initial

lifting. While, of course, I do not limit my invention to the use of such material, vinyl plastics have been found suitable for some applications, sheet material of a thickness providing adequate tensile strength and surface toughness still being sufficiently thin to form even large containers without their becoming so heavy as to be difficult to handle while being spread out on the forming area or being removed after they have served their purpose. Also, the smooth surface of the plastic prevents its adhering with any firmness to the concrete. Upon the containers 3 is placed a joint weakening assembly comprising a pair of diverging strips 5, preferably of metal, secured together by a series of rivets 6. Upon this assembly there may be placed transverse reinforcing 7. If desired, slots may be provided in the upper edges of strips 5 to accommodate reinforcement 7 at a lower level. Also, if desired, longitudinal reinforcing 8 may be provided, but the strips 5 may easily be proportioned to provide adequate longitudinal reinforcement. The rounded heads of rivets 6, by keying into the concrete on both sides of the joint, help to provide any necessary shear transfer across the joint after the slab concrete above the strip assembly has been cracked by deflection. Later filling of the crack with mortar will re-establish the shear strength of the concrete. The more widely divergent lower portions of the strips 5 serve both to give added stability to the assembly during the forming process and to provide a recess into which container 3 may project without being caught in the joint as it closes. This is illustrated in Fig. 8.

Fig. 6 is essentially similar to Fig. 5 except that the strips 9 do not have the widely divergent lower portions, but, instead, a mastic or slow setting cement 10 is placed between the strips 9 prior to setting them up on the containers 3. When the joint is caused to deflect, at least some of the still soft material 10 squeezes out at the bottom and prevents pinching of the container 3. This latter condition is illustrated in Fig. 9. In addition, Fig. 9 shows the crack above the joint filled with mortar.

Fig. 7 illustrates another form of joint in which adjacent segments rotate about a longitudinal rod 12 which has preferably been oiled before the placing of concrete in order to facilitate the required rotation. The rod 12 is provided with annular projecting ribs 13 to provide shear transfer into the adjacent slab segments, and is supported upon a longitudinal strip 14 of rubber or other yielding material having sufficient supporting properties to maintain the assembly in the proper position during the placing and hardening of the slab. Fig. 10 shows this joint in the deflected position and also shows an additional layer 15 of concrete or the like. While the container 3 is still shown in contact with the underside of the slab it would preferably have been deflated and removed before placing the additional layer 15 upon the articulated slab to form the completed shell. It is possible, however, to maintain pressure in the containers 3 to provide additional support during the hardening of the additional layer 15. By this procedure a lesser thickness, or a lesser amount of reinforcement might be required in the articulated slab, or the placing of the additional layer might be accomplished at an earlier time while the slab material had not yet hardened sufficiently to be fully supporting.

Referring again to Fig. 7, the yielding strip 14, alone, may be made to serve as both slab weakener and as the bearing between adjacent slab segments. If the rod 12 is eliminated and the strip 14 is made sufficiently firm, it will both permit deflection, with the consequent cracking of the slab over the strip, and yet provide a connection between segments with a determinable amount of shear strength. The bond between the strip 14 and the adjacent slab surfaces could be increased if necessary by appropriate ribs or depressions or both in the vertical surfaces of strip 14.

I do not limit myself to any specific number of segments in the articulated slab. Any two adjacent segments upon deflection gain in longitudinal beam strength. Transversely, the slab segments are supported by upward components of force at the deflection points and the more widely spaced these points are, the thicker or stronger the slab is required to be. Conceivably, a gabled roof of only two flat segments might be constructed by means of my invention, with the outer edges of the slab either adequately strengthened to span between end supports, or designed to be supported upon side supports such as the side walls of the building shown in Figs. 1 and 2. The side supports could be placed during the erection procedure in the same fashion as end supports 2.

I do not limit myself to a slab formed by placing relatively fluid concrete or the like to the prescribed lines. Without departing from the spirit of my invention, at least some portions of the articulated slab could be formed or fabricated from precast or preshaped units assembled and appropriately secured together to function as described.

The invention herein described and claimed may be manufactured and used by or for the Government of the United States of America for governmental purposes without payment of royalties thereon or therefor.

I claim:

1. The method of forming a barrel-shell roof which comprises forming upon a deflated container a substantially flat slab provided with substantially parallel lines of weakness extending the length of the slab, inflating said container to cause the slab to be lifted and to be deflected along the lines of weakness by a withdrawal of support along the edges so that the slab takes a shape approximating a section of a cylinder, placing supports beneath the ends of said deflected slab, and then deflating and removing said container.

2. The method of constructing a roof which comprises forming upon a deflated container a relatively thin slab of substantially the length and developed width of the roof, said slab to be constructed with at least one line of longitudinal weakness, inflating said container to cause said slab to be lifted and to be deflected along the line of weakness by a relative withdrawal of support along the edges, placing supports beneath said deflected slab, and then deflating said container to transfer the weight of said slab to said supports.

3. A method of constructing a roof which comprises forming upon a deflated container a relatively thin slab of substantially the length and developed width of the roof, said slab to be constructed with lines of longitudinal weakness, inflating said container to cause said slab to be lifted and to be deflected along the lines of weakness, placing supports beneath said deflected slab, and then deflating said container to transfer the weight of said slab to said supports.

4. The method of constructing a roof which comprises forming upon a deflated container a relatively thin slab of substantially the length and width of the roof, said slab to be constructed with lines of longitudinal weakness, inflating said container to cause said slab to be lifted and to be deflected along the lines of weakness, placing supports beneath said deflected slab, deflating said container to transfer at least part of the weight of said slab to said supports and placing upon said slab an additional layer of concrete or the like to become an integral part of said slab.

5. The method of forming a barrel-shell roof which comprises forming upon a plurality of deflated containers a substantially flat slab provided with substantially parallel lines of weakness extending the length of the slab, said containers jointly being capable when first inflated of providing substantially uniform support through fluid pressure to the under side of said slab and so arranged that upon further inflation the support is gradually withdrawn from beneath the longitudinal edges of said slab, inflating said containers to cause the slab to be lifted and to be deflected along the lines of weakness into a shape approximating a section of a cylinder, placing sup-

ports beneath the ends of said deflected slab, and then deflating and removing said containers.

6. The method of constructing a roof which comprises forming upon a plurality of deflated containers a relatively thin slab of substantially the length and developed width of the roof, said containers jointly being capable when first inflated of providing substantially uniform support through fluid pressure to the under side of said slab and so arranged that upon further inflation the support is gradually withdrawn from beneath the longitudinal edges of said slab, said slab to be constructed with at least one line of longitudinal weakness, inflating said containers to cause said slab to be lifted and to be deflected along the line of weakness, placing supports beneath said deflected slab, and then deflating said containers to transfer the weight of said slab to said supports.

7. A method of constructing a roof which comprises forming upon a plurality of deflated containers a relatively thin slab of substantially the length and developed width of the roof, said slab to be constructed with lines of longitudinal weakness, said containers jointly being capable when first inflated of providing substantially uniform support through fluid pressure to the under side of said slab and so arranged that upon further inflation the support is gradually withdrawn from beneath the longitudinal edges of said slab, inflating said containers to cause said slab to be lifted and to be deflected along

the lines of weakness, placing supports beneath said deflected slab, and then deflating said containers to transfer the weight of said slab to said supports.

8. The method of constructing a roof which comprises forming upon a plurality of deflated containers a relatively thin slab of substantially the length and developed width of the roof, said slab to be constructed with lines of longitudinal weakness, said containers jointly being capable when first inflated of providing substantially uniform support through fluid pressure to the under side of said slab and so arranged that upon further inflation the support is gradually withdrawn from beneath the longitudinal edges of said slab, inflating said containers to cause said slab to be lifted and to be deflected along the lines of weakness, placing supports beneath said deflected slab, deflating said containers to transfer at least part of the weight of said slab to said supports and placing upon said slab an additional layer of concrete or the like to become an integral part of said slab.

References Cited in the file of this patent

UNITED STATES PATENTS

312,897	Rapp	Feb. 24, 1885
1,393,699	Purcell	Oct. 11, 1921
1,898,943	Fischer	Feb. 21, 1933