

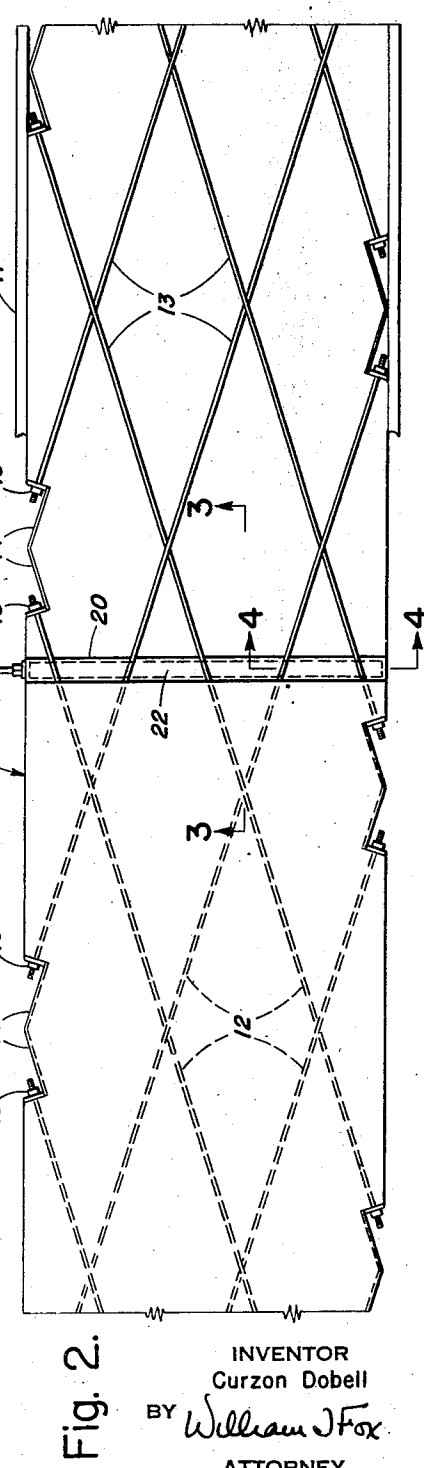
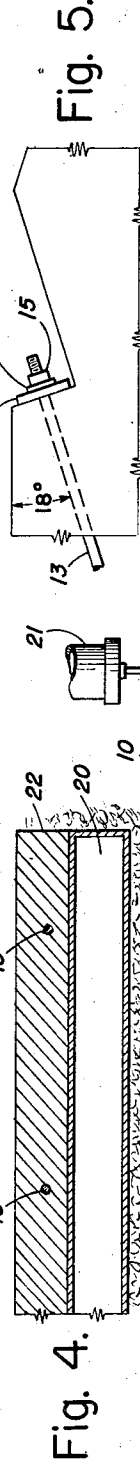
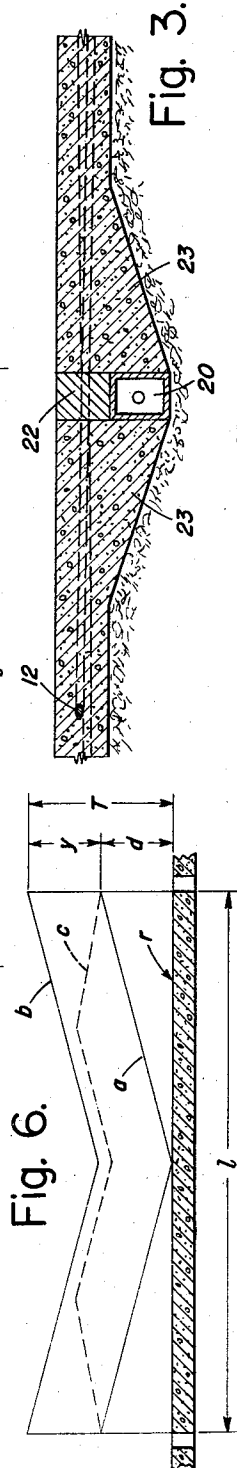
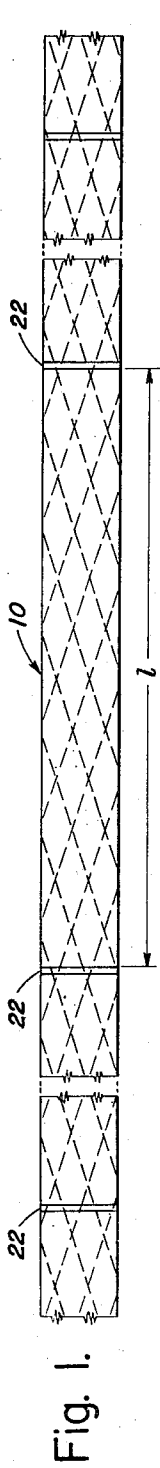
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REINFORCED PAVEMENTS

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REINFORCED PAVEMENTS

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Continuation of application Serial No. 341,770, March 11, 1953. This application November 19, 1956, Serial No. 622,896

3 Claims. (Cl. 94—22)

This invention relates to the construction of concrete surfaces resting on a sub-base, such as pavements or roadways, and more particularly to the construction of concrete roadways that are held under continuous longitudinal compression in such a way that cracking and buckling are avoided and expansion joints become unnecessary.

At present, in particular in designing runways for heavy bombers, engineers are faced with the problem of using either abnormally thick and expensive slabs of reinforced concrete to spread the load over the sub-base sufficiently so that little or no deformation will occur, or trying to find something such as asphaltic materials which will deform under the wheel loads and return to normal levels after the load has rolled on. To date, prestressed concrete is the only medium which offers both an economical slab thickness which can sustain the loadings, and a material which has elasticity enough to deform under the wheels and return to normal when the load has passed.

The common difficulties encountered in concrete roads or pavements are due to the fact that concrete tends to shrink and crack and expansion joints are necessary at frequent intervals to prevent the concrete from buckling when it expands or cracking when it contracts due to a change in temperature. Ordinary reinforcing does not eliminate these difficulties.

By reinforcing the concrete roadways with reinforcing material that is under tension and doing this a section at a time with the prestressed reinforcing wires or rods running lengthwise and crosswise of the section, ordinary cracking may be prevented. However, expansion joints are still necessary between the sections to compensate for changes in length of the sections due to changes in temperature and ordinarily these must be made quite wide in order both to provide for access to the ends of the longitudinal wires or rods so that they may be tightened after the concrete has set and to provide for thermal movement. If concrete road sections thus reinforced could be abutted end to end in practical construction, which they cannot because of the necessity for having access to the ends of the sections to tension the reinforcing, the expansion of the sections would still put the sections as a whole under compression, and at the joint between two adjacent sections serious buckling could occur.

In the use of longitudinal stressing the length of the section is determined by the loss of prestress between the ends through frictional resistance to motion between the concrete section and the sub-base. The use of a sub-base of lowered frictional resistance such as an asphaltic emulsion has been suggested but while this permits the use of longer sections, the movement at the joint is increased requiring elaborate precautions to accommodate the increased movement.

The object of the present invention is to provide a system of stressing pavements in which the slab is stressed continuously along its length and when possible continuously along its breadth without any interruptions in the stressing reinforcing for expansion joints or the like. It

is another object to create a pavement which would be a continuous slab having a uniform concrete section in compressive stress and a uniform steel section in tensile stress, both over a substantially unlimited length, with the elastic shortening caused by the compressing of the slab absorbed in increments by the use of temporary construction joints. It is yet another object to avoid and eliminate costly expansion joints between sections of pavement. And it is yet a further object to provide an easily laid roadway not requiring elaborate preparation of the reinforcing elements. It has been found that this can be done by the method and arrangement set forth in this application and that as a result cracking and buckling may be avoided.

Briefly, this invention consists in prestressing a concrete road by diagonally placed elements so that the ends of the prestressing elements can be tensioned from the edges of the slab and simultaneously providing a means and method to take up the longitudinal distance that the concrete of the road loses by reason of its being placed under longitudinal compression, by providing temporary construction joints that are later filled, allowed to set and compressed.

The result is a continuous concrete pavement under both longitudinal and lateral compression in any desired ratio evenly distributed along the length of the road in such a manner that there is no tendency of the road to buckle or crack even when the longitudinal compression is increased by increases in temperature that are restrained from causing corresponding increases in length.

It is preferred, in applying the principles of this invention, to use prestressing material of a quality such that relatively high tension may be applied to it so that after the concrete has undergone any plastic flow of which it is capable and the material of the prestressing element has taken on any permanent elongation that it will take on as a result of the forces bearing upon it, there will still be a high degree of tension in the prestressing elements and a high degree of compression in the concrete.

An understanding of both the details and the principles of this invention may best be had by an immediate reference to the drawings which illustrate the preferred mode of application of the principles of this invention and to the following detailed description of this mode of application of this invention.

In the drawings, Figure 1 is a plan view of a concrete pavement constructed in accordance with this invention; while Figure 2 shows the same in more detail;

Figure 3 is a cross section of Figure 2 taken along line 3—3; and

Figure 4 is a cross section of Figure 2 taken along line 4—4.

Figure 5 is a detail view of the end anchorage for the reinforcing rods.

Figure 6 is a diagram showing the slab compression under various conditions of compression.

Pavements or slabs on any sub-base may be constructed in accordance with the principles of this invention as shown in the drawing by molding a series of road sections generally designated as 10 and 11 in the usual way but including imbedded therein a series of diagonally-extending reinforcing elements 12 and 13, which are coated to prevent bonding with the concrete or placed in preformed holes. Balanced stresses are provided by inclining one series of elements 12 oppositely from the other series 13. It is necessary that the ends of the elements be arranged in a method to avoid interference with the tensioning device. A recess 14 is provided at each end of each of these elements so as to provide access to it for tensioning the element and a nut 15 or other appropriate means for holding the element in tension is also provided. The detail in Figure 5 shows the

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end anchorage which is a threaded bar 13 over which is placed a bearing plate 25 followed by a washer 26 and finally the nut 15. A suitable bearing plate for a 1 inch bar would be steel plate 1½ inches thick and 5 inches by 6 inches in area. Any other type of end anchorage adapted to secure the elements will be adequate. The concrete may be prevented from bonding to the elements in any of the known ways. For example, the elements may be covered with asphalt before the concrete is molded around them or they may be placed in preformed holes in the concrete.

As can be seen from Figure 2, a concrete roadway is cast in a series of spaced sections 10 and 11 but the reinforcing elements extend across the space between the sections so that some of the reinforcing elements lie partly in one section and partly in another.

After the concrete has set, the elements 12 and 13 are tensioned to place the concrete under both lateral and longitudinal compression. As a result of their compression it is natural that the length and width of each concrete section will diminish to a certain extent by elastic contraction. The length of a 500 ft. road section, for example, will decrease some three or four inches.

This invention contemplates that in order that this decrease in length takes place from the ends of the section toward the center and that it be compensated, appropriate instrument for forcing the ends apart, such as a hydraulic jack shown schematically at 20 is provided so that it will fit between the abutting ends of the adjacent sections and force their ends apart. A pump 21 is connected to the jack, and the jack, which consists of an elongated pressure chamber that is flexible so that it can expand, is put under pressure and presses against the abutting ends of the adjacent sections so as to force them apart as tension is placed on the reinforcing material. The abutting ends of the adjacent sections may be made somewhat thicker to form a haunch 23 as shown in Figure 3 so as to properly accommodate this hydraulic jack.

After the tension has been placed on the reinforcing elements and the concrete placed under compression by the combined action of this tension and the pressure of the hydraulic jack 20, the space above the hydraulic jack 20 is filled with concrete or other suitable material 22 as shown in Figures 3 and 4. The pressure may be released in the hydraulic jack 20 and the jack withdrawn after the material filling the joint has hardened sufficiently. The compression in the concrete then is transferred against the material filling between the sections and the whole section is placed under substantially equal compression.

In my scheme the jacks and tensioned reinforcing serve entirely different purposes. The concrete is placed under the required compression by the post-tensioning of the reinforcing. By post-tensioning is meant the stressing of the elements after the concrete has set. However, it would be impossible to prestress a pavement for any great length by post-tensioning the reinforcing alone without providing for some periodic adjustment of the elastic strain in the concrete due to prestressing. This adjustment would amount to some 3.5 ft. per mile at a 300 p. s. i. stress. This movement is resisted by friction between the pavement and the sub-base.

To absorb the elastic strain in the concrete due to prestressing, temporary construction joints are provided at intervals of such frequency (between 200 and 500 ft. depending on subsoil friction values), so as to reduce the friction loss between joints to a reasonable minimum. Jacks are placed between the vertical surfaces of the concrete at these joints. The prestressing is preferably placed diagonally in the slab, probably in the form of high strength bars, at any desired angle to the axis of the pavement which provides the desired ratio of longitudinal and transverse stress. These bars are coated so that they will act as "slip-rods" to avoid the cost of subsequent grouting, or may be placed in preformed holes.

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As the tensioning of the reinforcing progresses along the pavement the jacks are placed in the construction joints and are actuated to increase the gap in the joint, as measured by micrometers, by the amount of the elastic shortening of the concrete in the length of this joint. If the joint as cast was 1 inch wide and the elastic shortening in a 500 ft. slab 0.35 inch, the jack would be used to enlarge the joint from 1 inch to 1.35 inches as the prestressing progressed across the joint.

The jacks would then be used to temporarily increase the elastic shortening (such as to increase the joint to 1.7 inches), which would increase the compression in the concrete at the joint for a short period, and thus reduce the frictional loss at the mid-point between the two joints. The gap would then be relaxed back to the 1.35 inches, at which gap spacing the joint would be grouted with mortar. After the mortar has retained sufficient strength the jack would be removed, thus transferring the full force of the pre-tensioned steel across the mortared joint, and the jacks would be reused at a subsequent joint. By the use of temporary over-stressing as described, the mid-point between the joints would receive an increased compression, which would be at least partially retained after the jack was removed, resulting in a more uniform distribution of compression.

This is shown in the diagrammatic sketch of Figure 4 wherein the concrete roadbed *r* has a length *l*. If the compression which is normally expected to be maintained is applied to the roadway, the maximum compression will be realized at the ends of the slab while there will be substantially no compression at the mid-point of the slab. This is shown in line *a* with the maximum compression *d* at the slab end. If double the compression is applied, the compression over the slab will be exemplified by line *b*, showing the increment *y* due to the extra compression, and further showing the compression now existing at the mid-point of the slab. Reducing the gap or the compression back to the normally expected standard results in line *c*, wherein a more evenly smoothed out compression results across the entire length of the slab.

It has been found preferable, in this construction, to use steel wire or rods or other suitable materials having a tensile strength of at least 150,000 pounds per square inch, and to tension wires or rods initially to a tension of at least 100,000 pounds per square inch. It is preferable, but not entirely necessary, to use concrete for filling the joints, of the same type as that used in the slab in order to have a uniform material throughout.

A discussion of the haunch 23 is in order. By providing a thickened portion of the concrete slab there is provided an adequate bearing surface for the jack 20 without interrupting the continuity of the rods passing through the gap between the slabs, and without interrupting the continuity of the concrete poured in the gap to fill it after the jack has forced the sections apart. When this concrete has set and the jack tension is removed, the concrete in the gap is placed under the same compression as the rest of the pavement, and by the use of the haunch, the concrete in the gap is the same thickness as in the rest of the pavement. An alternative to the haunch is the use of a series of notches in the ends of the slabs at the joints to retain a jack set on top of the slab, with the notches being filled with grout after the jacks are removed. This, however, leaves small unstressed portions of the pavement, which might spall or otherwise fail due to temperature changes.

This application has described the stressing elements as being diagonal as this is the best embodiment now known to me. However, any arrangement of the elements that will provide the desired compression throughout the slab, is adequate if it will permit the use of the jack technique to result in a completely compressed slab, including joints.

The resultant construction is longitudinally continuous

and, having the concrete under a relatively uniform compression and the prestressing elements under a relatively uniform tension, is in a condition where it is quite stable and there is little or no tendency to buckle or crack even under relatively wide changes in temperature.

Any tendency to buckle is resisted by the prestressing elements. As these are continuous along the entire length of the roadway, there are no weak points or interruption of the section at which buckling may occur.

Many modifications and improvements that will be apparent to those skilled in the art are considered to be within the scope of the appended claims.

This application is a continuation of my application Serial No. 341,770, filed March 11, 1953, now abandoned.

I claim:

1. The method of constructing a long concrete slab resting on a sub-base which comprises forming a series of slab sections between which temporary transverse joints are provided at intervals, incorporating in the sections and across the joints high strength reinforcing elements in unbonded engagement with the sections, permitting the sections to set until they have acquired considerable strength, tensioning said reinforcing elements, increasing the width of the temporary joints by forcing them apart with an expanding means to an amount corresponding to the amount of elastic shortening which would occur in the sections if unrestrained by friction with the sub-base, filling the extender joints with a material capable of attaining sufficient strength to resist substantial compression and removing the expanding means after the joint material has attained such strength

to transfer compression from the sections to the joint material.

2. The method of constructing a long concrete slab resting on a sub-base that comprises forming a series of sections between which temporary transverse joints are provided at intervals, incorporating in the sections and across the joints high strength reinforcing elements extending diagonally across the joints and through the side edges of the sections, said reinforcing elements being in unbonded engagement with the section, permitting the sections to set until they have acquired considerable strength, separately tensioning said reinforcing elements to provide a predetermined compression in the sections causing an elastic shortening of the sections, increasing the width of the temporary joints by an amount equal to the elastic shortening of the sections at the joints while tensioning is in progress by forcing them apart with an expanding means, filling the joints while in the enlarged position with material capable of achieving a set of sufficient strength to resist substantial compressive forces, and relaxing the expanding means after the joint material has set so as to transfer the compression from the sections to the joint material.

3. A method as defined in claim 2, with the addition of forcing the sections apart at a pressure in excess of that required to create the ultimately desired compression in the roadway, holding them at the increased pressure a sufficient time to permit the compression to be distributed to the center of the sections, partially releasing the compression before filling the space between the sections with concrete.

No references cited.