Dec. 1, 1959 A. HOYDEN ET AL 2,914,783

BRIDGE CONSTRUCTION

Filed April 7, 1954 2 Sheets-Sheet 1

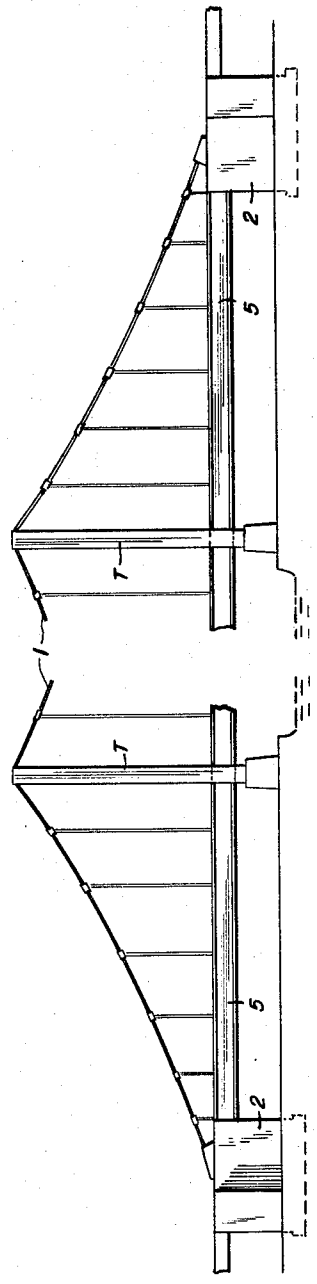

FIG. 1

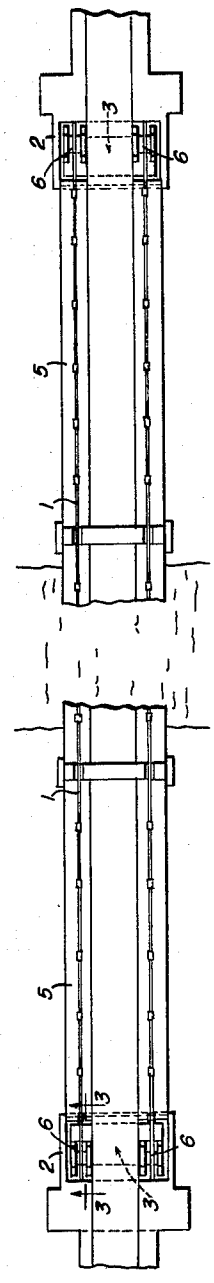

FIG. 2

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Dec. 1, 1959 A. HOYDEN ET AL 2,914,783

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Filed April 7, 1954 2 Sheets-Sheet 2

FIG. 3

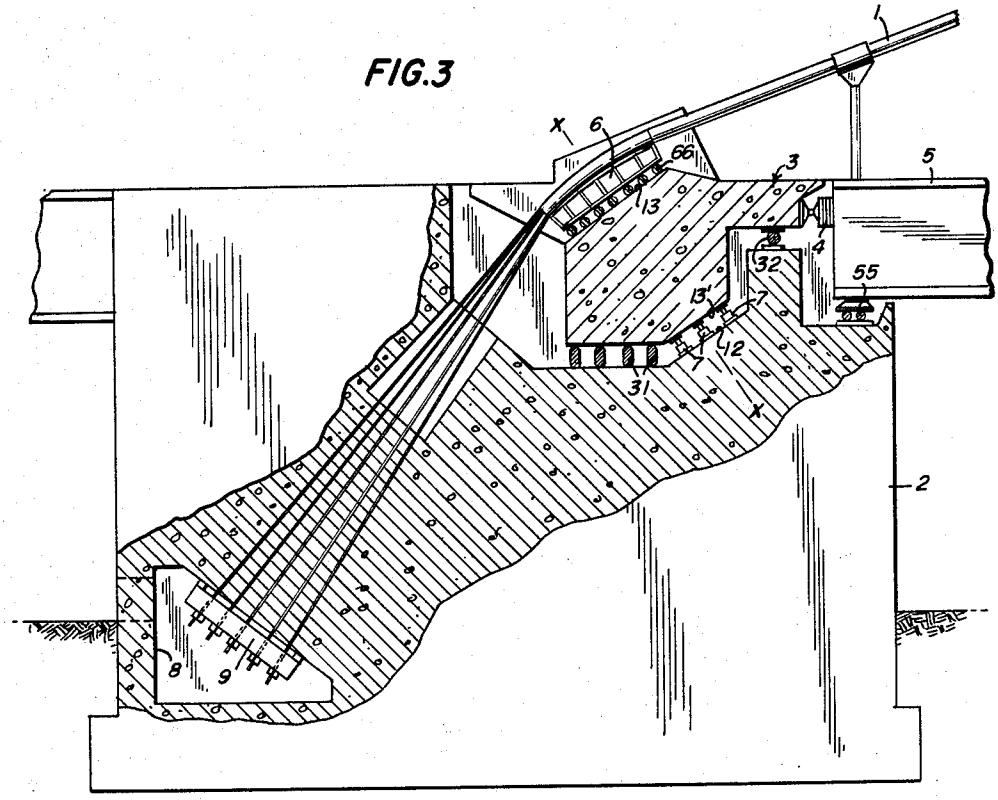


FIG. 4

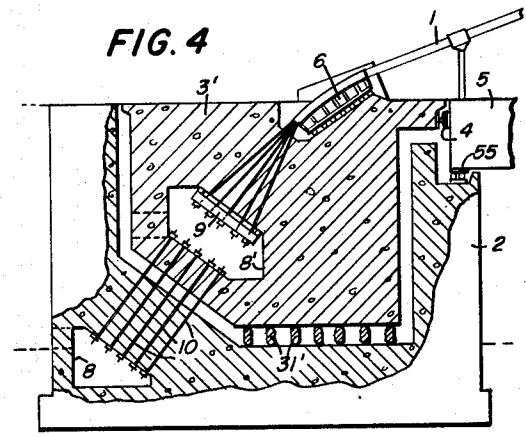
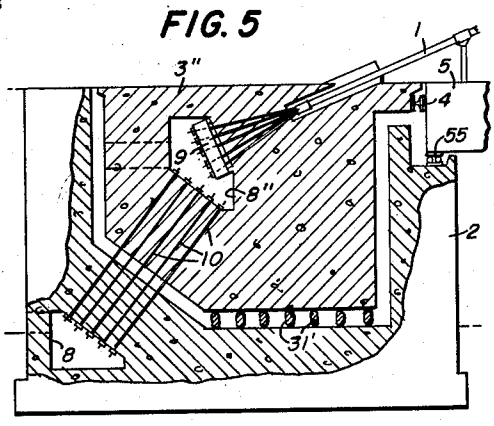


FIG. 5



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BRIDGE CONSTRUCTION

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The present invention relates broadly to the art of bridge construction.

More particularly this invention relates to construction of suspension bridges and is further concerned with a method and apparatus for building a partly anchored suspension bridge or a suspension bridge that is rigid in itself.

The invention is particularly concerned with the anchoring of the suspension cables at the opposite ends of the bridge.

The construction of a ground anchored suspension bridge is dependent upon the provision of a sufficiently firm foundation for the abutments because the abutments must withstand the entire and generally large pulling force exerted by the supporting cables. In this foundation structure and in order to transmit the horizontal components that represent a considerable part of the pulling force of the cable to the ground, it occasionally arises, that a sliding post or coffer foundation is required.

Furthermore, in cases in which it is not possible to directly anchor the supporting cables in the ground or to a connection that resists push and pull, usually special abutment bodies, thus preferably an anchorage in natural rock, there has been provided an abutment body of such dead or inherent weight that the same, diminished by the vertically upwardly directed component of the cable pull, is sufficient to create on the foundation the necessary friction for opposing the horizontal component of the cable pull. The cable ends in this type arrangement are usually trained about what is termed a reversing bearing or cable saddle and extend in a steeper direction or angle downwardly and are anchored in the respective abutment bodies. In this connection it has been proposed to construct the anchoring body as a tiltable body and arrive at an arrangement in the nature of a lever-arm structure propped against a stationary foundation in such fashion that either the resultant of the cable pull and the weight of the tilted body passes through this supporting point or a part of the horizontal component is transmitted to the stiffening girders for the bridge.

The present invention is concerned with systems for transmitting at least a part of the horizontal component of force resulting from the pull of the cable to the stiffening girders of partly anchored suspension bridges as well as ones that are fully rigid, that is a suspension bridge that carries the entire horizontal force. Such types of construction are of great practical importance for it frequently happens that the ground conditions are not suited for the building of a ground anchored suspension bridge, even if special counter-weight bodies are used.

The known bridge arrangements along the aforementioned lines suffer from certain defects. On the one hand, if the abutments are constructed as what are termed tiltable abutments and include uniform counterweight masses, changeable traffic loads on the bridge

will result in up and down motions of the roadbed on the bridge. On the other hand, it had previously been necessary, in connection with facilitating the construction of the stiffening girders and for erection of the bridge superstructure, to arrange joints adjacent the bridge openings which due to the transmission of the horizontal force had to be large and heavy.

It is therefore an object of the present invention to eliminate the aforementioned defects and to provide for simple and expeditious construction of a fully anchored or partly anchored and stiffened suspension bridge in a manner which will eliminate or materially diminish the necessity for assembling scaffolds in the middle opening.

Accordingly the invention has for an object to provide a method in the construction of suspension bridges in which during the assembly of the bridge the horizontal force of the supporting cables, depending upon the arbitrary selected reversing angle of the cables, is borne by means of special components termed push or pull members which provide a temporary ground anchoring system whereupon by a subsequent removal or yielding of the push or pull members the horizontal force of the cable is partly or wholly transmitted to the stiffening girders.

Another object the invention provides, for the accomplishment of the aforestated method of transmitting horizontal cable forces, a laterally movable force transmitting body that is supported in or on the stationary foundation and movable in the direction of the horizontal components of force generated by the cables.

As a particular object this aforementioned body is of pistol shape in cross section.

Consistent with the aforestated objects and in order to temporarily accommodate the whole or any arbitrary portion of the horizontal force of the cables between the slidable pistol shaped body and the foundation the invention provides adjustable supporting means operable to maintain the movable pistol body out of contact with the horizontal girders or supporting structure of the bridge until such time as it is desired that the horizontal components of force developed by the cables in their anchoring be transmitted to the horizontal girders or bridge supports.

As a specific object the supporting means are adjustable and in this connection the adjustability further comprehends an arrangement in which the supporting means can be removed and additionally includes the provision of adjustable anchoring cables between the horizontally movable body and the fixed or stable foundation.

In the latter instance the invention provides an arrangement in which the suspension cables can be anchored in the horizontally movable body either in a direct line as regards the downward inclination from the towers or at a larger angle of inclination by an arrangement which will include cable bends.

Other and more specific objects and advantages of the present invention will become apparent from the following description of several embodiments of the invention as illustrated diagrammatically in the accompanying drawing. The drawings omit all structural parts that are not necessary for complete understanding of this invention.

In the drawings,

Figure 1 is a fragmentary side elevation of a suspension bridge,

Figure 2 is a top plan view of the arrangement shown in Figure 1,

Figure 3 is an enlarged scale sectional view taken on line 3—3 of Figure 2,

Figure 4 is a view similar to Figure 3 and illustrating a modification utilizing tensionable members in temporary ground anchoring, and

Figure 5 is a view similar to Figure 4 and of a slightly modified form of the invention in which the suspension cables are not provided with cable bends adjacent their lower ends.

In the arrangement illustrated in Figures 1 and 3, the supporting cables 1 of the suspension bridge are suspended over towers T and anchored in a foundation body 2. This foundation body 2 is of a cast concrete structure that is firmly embedded in the ground. Means are provided for putting a bend in the suspension cables so that they extend at a steeper angle within the foundation body than the angle formed with the horizontal at the upper level of the bridge. The foundation body 2 has a socket or recess in the upper part thereof that is open upwardly and within this socket is mounted a substantially smaller concrete body 3 of the general shape of a pistol. This concrete body 3 is supported on a group of bearings as at 31 and a further bearing arrangement at 32 and is thus slidably mounted for movement in the direction of the horizontal component of force generated by the suspension cables. The movable concrete body 3 bears against contact bearings 4 provided on the stiffening girders 5 when the bridge is completed.

The guiding of the suspension cables 1 includes training the same through special guiding or bearing means 6, a cable saddle of known construction and supporting these bearing means by means of rolling contact bearing members 66 on an upper angular surface 13 of the concrete body 3. This upper angular surface 13 is perpendicular to the line x—x which bisects the angle formed by the bend in the cables as they pass over saddles 6. Further, the foundation body 2 includes a lower angular surface 12 that is parallel with the surface 13. The movable concrete body 3 includes another angular surface 13' that is spaced from and parallel with the surfaces 13 and 12. Between the surfaces 12 and 13' which are perpendicular to the bisector line x—x are mounted adjustable spacer or bracing members 7. These bracing members 7 are removable or adjustable so as to control the spacing between surfaces 12 and 13'. The spacer or bracer members 7 have been diagrammatically illustrated as jack means. Conventional hydraulic or screw action jacks can be utilized, also devices known in the mining art as pit props can be interposed between the surfaces 12 and 13'. Further, the invention contemplates shims or any other means which can exert a pushing force against the bodies 3 to hold the same stationary relative to the end of the girders 5 until it is desired to release said holding force. The cable ends, as is conventional, are separated into their individual strands and in the recess 8 provided in the foundation body 2 they are connected to an adjusting anchor support 9. In this support body 9 the cables, as required, may be tensioned or slackened. The details of the cable anchoring so that they may be tensioned or slackened are not shown but any arrangement well known in the art for this purpose could be utilized. During assembly of the superstructure cables, which are temporarily ground anchored in the member 9, the pistol 3 is prevented from movement to the right in the figure by the bracing members 7. Thus the horizontally movable body or pistol 3 is supported on its rolling contact bearing members 31, 32 and the side bearings 4 on the horizontal girders have not yet been contacted by the pistol so that the stiffening girders 5, which at that stage of construction are still in the process of assembly, are not as yet subjected to any horizontal components of force generated by the cables. At the proper time, that is, when the horizontal girders 5 and the superstructure is completed, the bracing members or elements 7 are shortened or entirely removed so that the pistol or movable body 3 can slide toward the right on bearing members 31, 32 and thus through bearing elements 4 can exert horizontal pressure against the completed girders 5. The portion of the horizontal force exerted on the girders 5 depends on the angle of bend of the cables and thus can be arbitrarily determined. In a ground anchoring arrangement in which the cables are anchored without any bends therein there is no horizontal component or force generated and in a ground anchoring arrangement in which the cables are vertical in their anchoring relation the horizontal pressure equals the entire horizontal component of force of the cable pull. The latter instance would concern a suspension bridge that is fully braced. Between these two limits, that is, the zero limit and the fully braced limit, there are various possibilities of partly anchored suspension bridge systems. An important consideration which must be borne in mind in this connection embodies the intentional distribution of the force that has to be resisted by the foundation body during temporary anchoring in the ground. These forces are considerably lower in a system including temporary anchoring than one in which the cables were permanently anchored in the ground initially, since in the latter instance during completion of the bridge, until any horizontal force is transmitted to the stiffening girders, a considerable part of the bridge weight, that is, roadway, rails and all traffic loads are lacking.

In other words, by the present invention the bridge cables are anchored and the horizontal component of force generated thereby is resisted by the bracing of the movable body 3 to retain that body immovable until necessary. The superstructure, rails, roadways and the like are embodied in the bridge and when these components have been completed, then, by shortening or removing the bracing members 7, the horizontal component of force generated by the anchored cables is transmitted to the girders 5 to stiffen the bridge. In order to allow for expansion and contraction movements occasioned by changes in temperature, the cable guide block construction at 6 is supported on rolling contact bearing members 66 and the ends of the horizontal girders are further supported on rolling contact bearing members 55.

Therefore as regards Figure 3, the invention provides a method and apparatus for, in effect, storing a horizontal component of force during completion of a suspension bridge and then applying that force to the horizontal components of the bridge to rigidify the bridge.

In the arrangement of Figure 4, the movable concrete body 3' is larger and heavier. Additionally, it is provided with a recess 8' within which the anchoring supports 9 for the cables 1 are arranged. In this modification, the cables 1 after passing over cable saddles 6 are anchored in the pistol or movable body 3' which in turn is supported on a set of rolling contact bearing members 31' and is anchored by means of adjustable cables 10 extending between the interior of the recess 8' and a recess 8 provided in the foundation body 2. During the assembly of the bridge the cables 10 are tensioned to such an extent that the movable body or pistol 3' does not bear against the bearings 4 on the stiffening girders 5. It is only when the bridge structure is substantially completed that the cables 10 are slackened so that, as in the case in the arrangement of Figure 3, the body 3' moves to the right to transmit a predetermined portion of the horizontal component of force to the girders 5.

In Figure 5 is illustrated a further embodiment in which the anchoring cables 1 are anchored to a cable support 9 mounted in a recess 8' without being bent over a cable guide block. Otherwise the structural components are identical with that form shown in Figure 4 and includes the supporting bearings 31'. In the arrangement of Figure 5 the special anchoring cables 10 are tightened so that the concrete body 3' is held from movement to the right until such time as desired whereupon the cables 10 are

slackened and the concrete body 3' moves to the right to apply the horizontal force to the girders 5.

It is further to be pointed out that the angular relationship to the horizontal of the anchoring cables 10 is not to be limited to the particular direction shown in Figures 4 and 5. These cables 10 may extend at a greater or less inclination to the horizontal. In this connection, however, care should be taken that the vertical force or cable pull is balanced unless the dead weight of the concrete body or pistol suffices therefore.

It is thus clear that this invention provides an anchoring arrangement for the suspension or supporting cables of bridges which permits a temporary ground anchoring of the cables pending completion of the superstructure of roadways and other bridge components and which temporary anchoring absorbs or resists the horizontal components of force generated by the anchored cables. The arrangement includes means for subsequently releasing the temporary anchoring with the ground or foundation so as to transmit the horizontal components of force of the cable pull to the horizontal stiffeners or girders of the bridge to increase the stability thereof.

It is believed clear that from the arrangement of Figures 3 to 5 the system includes a laterally movable concrete body that is supported on rolling contact bearing members. In Figure 3, adjustable bracing means prevent lateral movement of this body in a direction toward the bridge until this movement is desired, whereas in Figures 4 and 5 additional cable means or hold backs prevent this transmission of force.

With all embodiments before mentioned the supporting cables 1 of the suspension bridge are anchored on both ends in the same manner. There are two foundation bodies 2 on the abutment points of the river banks, each body provided with the special characteristics illustrated in the forms of invention shown in Figures 3 to 5.

It is therefore to be particularly pointed out that the invention embodies an improvement in bridge construction relating to bridges of the type having horizontal girders and supporting cables which includes initially anchoring the ends of the cables in a fashion to prevent transference of any horizontal components of force developed by the anchored cables to the girders so that the assembly of the bridge, that is, completion thereof, may be accomplished and subsequently and independently of the anchoring of the cables the method comprehends transferring at least a part of the horizontal components of force developed by the anchored cables to the girders. In accomplishing the aforementioned improvement, the invention includes interposing a movable force transmitting element between anchored cables having bends therein and the girders of the bridge. Furthermore, the invention includes the application of force in opposition to the horizontal component of force developed by the anchored cables until such time as it is desired to apply this horizontal component of force to the girders to stiffen the same.

What is claimed is:

1. The method of applying horizontal force to an end of roadway stiffening girders in a suspension bridge in which the stiffening girders are suspended from suspension cables and in which one end of each stiffening girder is freely supported on a foundation body, comprising positioning a horizontally movable body on said foundation body, said horizontally movable body having an end portion adapted to contact the one end of each stiffening girder and being in supporting contact with the corresponding end portion of the suspension cables whereby the horizontal component of force of the cable pull is exerted on said movable body, applying a force between said movable body and the foundation body to hold said movable body out of contact with said stiffening girders until they are ready to be stressed and releasing said force to allow movement of said movable body to apply said cable pull component to the end of said stiffening girders.

2. The method of applying horizontal force to each end of roadway stiffening girders in a suspension bridge comprising constructing spaced foundation bodies, suspending stiffening girders from suspension cables with the opposite ends of the girders freely supported on said foundation bodies, positioning a horizontally movable body on each foundation body outwards of the adjacent ends of the girders in supporting contact with the corresponding end portions of the suspension cables and with an end portion of each movable body in a position to make contact with the respective adjacent ends of the girders whereby the horizontal component of force of the cable pull is exerted on said movable bodies, applying a force between each movable body and foundation body to hold the end portions of the movable bodies out of contact with the ends of the stiffening girders until they are ready to be stressed and releasing said force to allow movement of said horizontally movable bodies towards the ends of the girders to contact the respective end portions of the movable bodies with the opposite ends of the girders so that said horizontal component of force of the cable pull is applied to the ends of the stiffening girders.

3. In a suspension bridge including a foundation body at each end of the bridge, roadway stiffening girders, and suspension cables suspending said stiffening girders, means for applying horizontal force to at least one end of said girders, said means including a horizontally movable body supported on at least one foundation body, one end of each stiffening girder being freely supported on said foundation body, said horizontally movable body having an end portion adapted to contact said one end of each stiffening girder, means establishing a supporting contact between said horizontally movable body and the corresponding end portion of the suspension cables whereby the horizontal component of force of the cable pull is exerted on said horizontally movable body, and means for releasably applying a force between said horizontally movable body and the foundation body to hold said movable body out of contact with said stiffening girders until they are ready to be stressed, whereupon a releasing of said force will allow movement of said horizontally movable body so as to apply said cable pull component of force to said one end of said stiffening girders via said end portion of the horizontally movable body.

4. A suspension bridge including a primary anchoring foundation embedded on opposite sides of the space to be spanned, cable supporting tower means intermediate said foundations, a secondary foundation body supported on each primary foundation for horizontal movement thereon, each secondary body having an abutment means on the side thereof facing said tower means, longitudinally extending girder means arranged between the foundations, said abutment means being adapted to engage the ends of the girder means, supporting cable means suspended over said tower means and including opposite anchored ends, means suspending said girder means from said supporting cable means, said secondary foundation bodies being in supporting contact with the corresponding end portions of said cable means whereby a horizontal component of force is exerted in said secondary foundation bodies tending to move said secondary bodies toward one another and releasable means arranged between each primary anchoring foundation and each secondary body for preventing movement of the respective bodies relative to the ends of the girder means until it is desired to transfer the horizontal force applied on said bodies by the cable means to the ends of the girder means to effect engagement of the abutment means with the girder means.

5. A suspension bridge as claimed in claim 4 in which said last-mentioned means comprise additional cable means adjustably connected between the primary anchoring foundations and respective secondary foundation bodies to exert a pulling force on said secondary bodies in a direction away from said girder means.

6. A suspension bridge as claimed in claim 4 and said last-mentioned means comprising means arranged between said primary foundations and said secondary bodies on the side of the secondary bodies that is adjacent the ends of the girder means for exerting a pushing force on said secondary bodies.

7. A suspension bridge as claimed in claim 4 and bearing means interposed between the respective primary anchoring foundations and secondary foundation bodies and said bearing means having foundation-engaging surfaces constituted by surfaces of revolution.

8. A suspension bridges as claimed in claim 4 and cable guide means mounted on said secondary foundation bodies for changing the angle of bend of the cable means so that they extend at a steeper inclination to the horizontal, said primary foundations and said secondary foundation bodies having respective facing surfaces extending perpendicular to a line that bisects the angle of bend of the

cables, and the means arranged between each foundation and each secondary body for preventing movement of the respective bodies comprising bracing means extending between said facing surfaces.

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