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Arild et al.

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[54] **SUBMERGED TUNNEL BRIDGE**

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[52] **U.S. Cl.** **14/27,** 61/42

[51] **Int. Cl.** **E01d 15/14**

[58] **Field of Search** 14/1, 27, 18; 61/42, 72.3

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Primary Examiner—Nile C. Byers, Jr.
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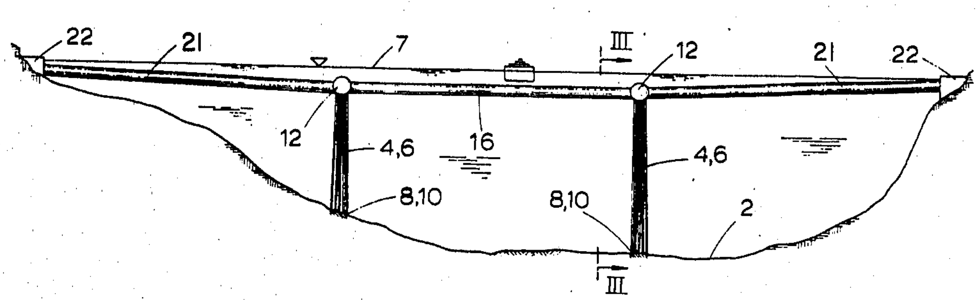
[57] **ABSTRACT**

A submerged tunnel bridge with positive buoyancy is anchored to the sea bottom. The bridge comprises spaced anchoring pontoons anchored to the sea bottom and operative to provide sufficient buoyancy for the submerged tunnel bridge, and bridge sections in the shape of tube-shaped tunnel sections mounted between the anchoring pontoons, the tunnel sections having such weight and buoyancy that net vertical force on the tunnel bridge sections with varying internal and external loads will vary in a range around zero.

7 Claims, 4 Drawing Figures



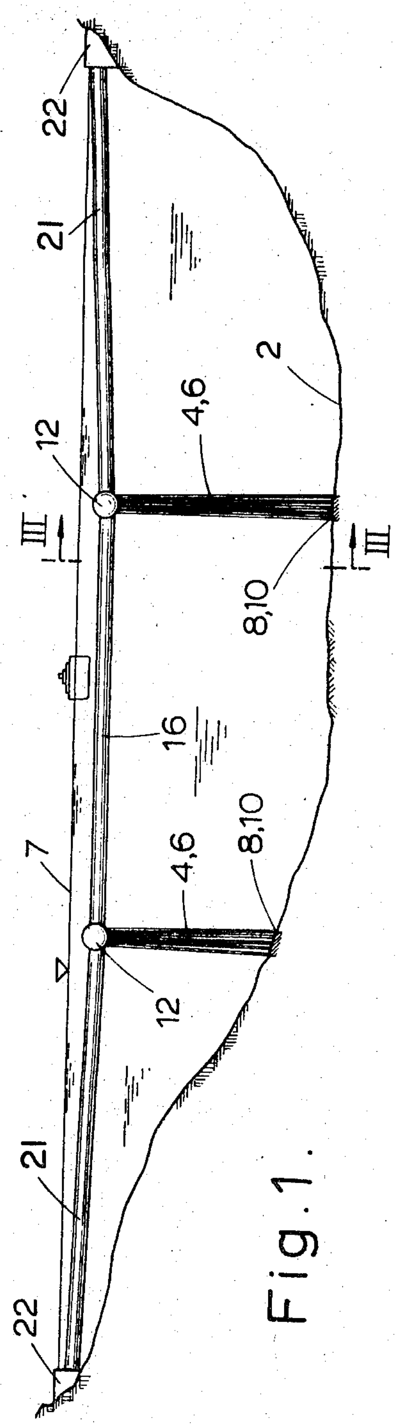

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Fig.1.

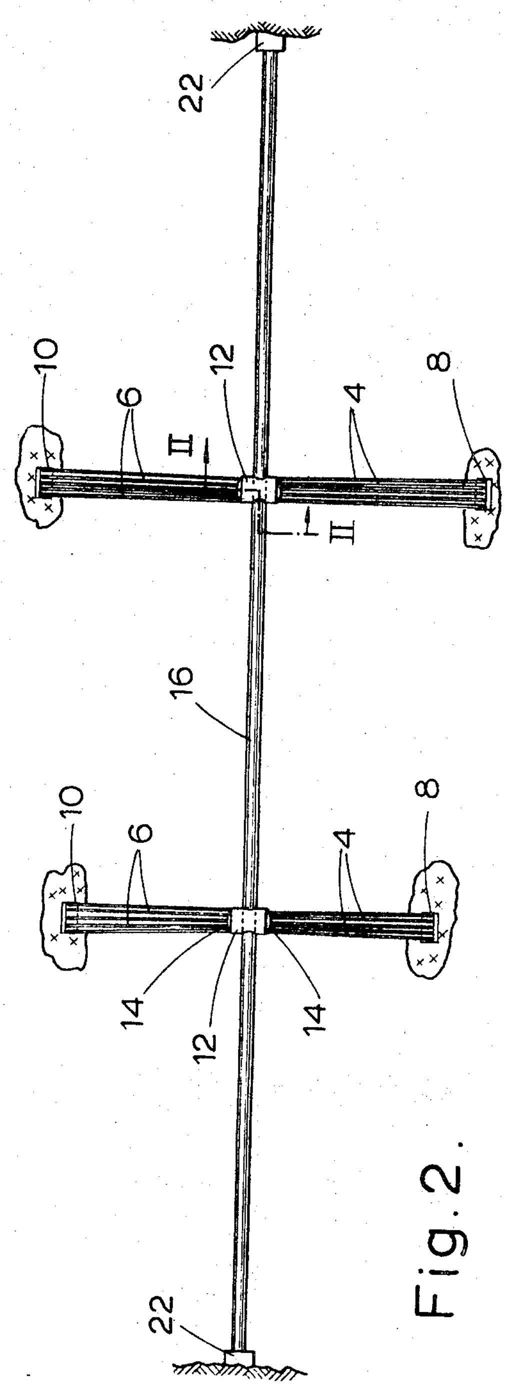
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Fig.2.

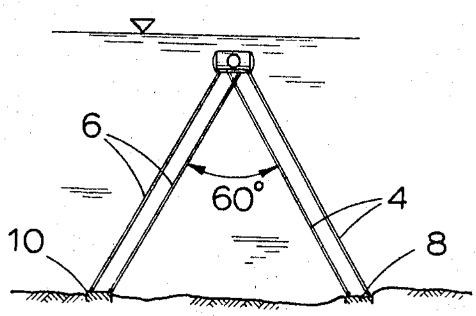

Fig. 3.

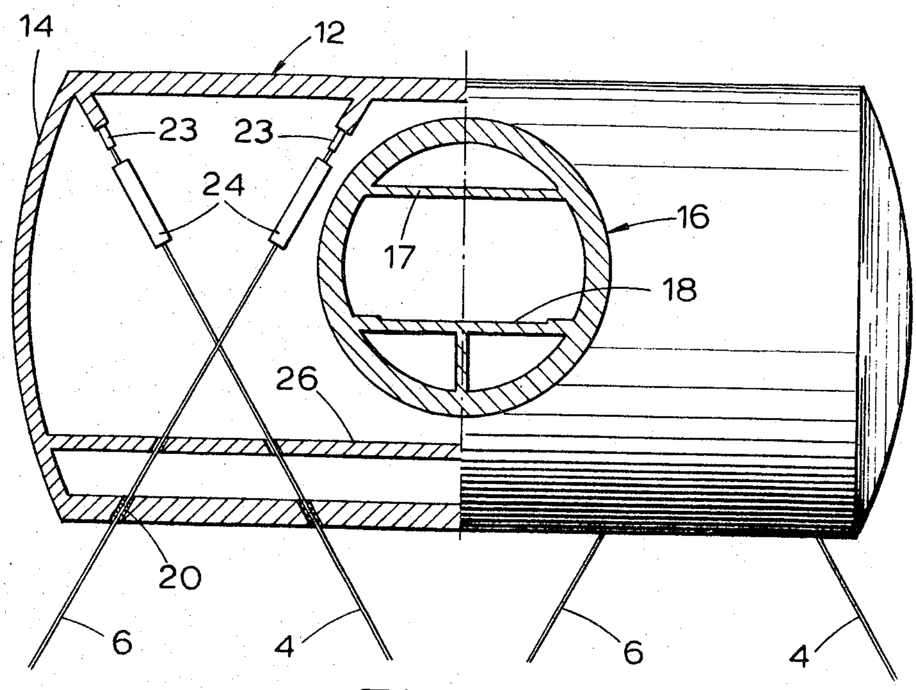

Fig. 4.

SUBMERGED TUNNEL BRIDGE

BACKGROUND OF THE INVENTION

The concept of the submerged tunnel bridge is not new. British Pat. No. 9558, Swedish Pat. No. 2095, both from 1886, and Norwegian Pat. No. 40 956 from 1924, relate to submerged tunnel bridges. In 1970 a submerged tunnel bridge was proposed as the best solution for a trafficable connection across the Strait of Messina from Sicily to the Italian mainland.

The chief advantages of a submerged tunnel bridge are partly that it can be positioned at a depth such that it cannot hinder navigation and partly that under certain conditions, it can be cheaper than either bridges or tunnels on or beneath the sea bottom.

Hitherto, however, no submerged tunnel bridges have been built, presumably because the construction and the erection problems for such bridges have been viewed as prohibitive, for instance transverse anchoring and bridge section joining pose special problems. An attempt to solve the problem of achieving lateral stability is described in Norwegian Pat. No. 120 994, wherein the entrance design comprises dividing a dual-lane roadway into two separate lanes which are anchored to a rigid abutment, thus giving the necessary transverse stability. In other proposals, transverse stability is attained by inclined restraining anchorings evenly distributed along the submerged part of the tunnel bridge. A major problem with this system is that both during and subsequent to the erection of the bridge, it is difficult to provide tension adjustments for the lateral anchoring.

In Norway, where trafficable connections are sometimes desired between points too far apart and separated by too deep waters to make conventional bridges economically feasible, submerged tunnel bridges have been considered for a long time, see: Erik Ødegård: "The anchored submerged pipe as a supporting bridge construction," Tekniske Skrifter, No. 12 N (1954) (in Norwegian).

SUMMARY OF THE INVENTION

The present invention solves the stability, anchoring and erection problems through providing most or all of the buoyancy necessary for the bridge with submerged cylindrical anchoring pontoons, the intervening bridge sections between successive pontoons having substantially zero net buoyancy. A further feature of the invention is that the submerged anchoring pontoons have provisions for adjustment and tensioning of the anchor cables, which are anchor chain or wire rope. Hence the anchoring pontoons are fixed both vertically and laterally and thereby form stable points for erecting the tunnel bridge by joining together tunnel sections. The fixing of the anchoring pontoons to the tunnel sections may be carried out prior to or subsequent to the submersion of the bridge. The anchoring pontoons have adequate space for other equipment such as pumps, emergency equipment, etc.

The tube sections of the bridge are thus designed and built such that the weight of the sections substantially corresponds to their buoyancy in submerged position, such that their submerged weights will be approximately equal to zero, preferably with a small residual buoyancy. Furthermore, the buoyancy of the anchoring pontoon shall be sufficiently large to sustain the main weight of the external and internal loads on the tunnel section. External loads shall be understood to include forces due to water currents, varying salinity, growth on the outside of the tunnel sections, etc. Internal loads shall be understood as the loads due to the traffic, that is, the weight of the vehicles, and the movement of the vehicles through the bridge. In many cases one anchoring pontoon at each end of the tunnel section will be sufficient. In other cases it may be necessary to have several anchoring pontoons, and/or to provide anchorings in addition to the pontoon anchorings, for instance at the center of a tube section, in cases where particularly large current loads are anticipated.

Bridge erection is not restricted to its being divided into equal length spans. Within reasonable limits, the pontoons and their anchorings may be positioned at the most suitable locations along the sea bed.

BRIEF DESCRIPTION OF THE DRAWINGS

An embodiment for a bridge or a bridge system in accordance with the invention is schematically illustrated in the attached drawings, wherein:

FIG. **1** comprises a lateral view of a completed submerged bridge in accordance with the invention, the bridge crossing a fjord or the like.

FIG. **2** comprises a plan view of the bridge shown in FIG. **1** (water not shown).

FIG. **3** comprises a schematic cross-sectional view in the transverse plane III—III of FIG. **1.**

FIG. **4** comprises a cross-section through the bridge system in the planes II—II of FIG. **2,** the left part showing a central cross-section through the anchoring pontoon in order further to illustrate the design of the same.

DETAILED DESCRIPTION OF THE INVENTION

Part designation numbers are the same in all four figures: Number **2** designates the sea bed across a channel, fjord or the like, having a water surface **7**; **4** and **6** designate anchor cables anchored to the sea bottom at **8** and **10,** and to the anchoring pontoons **12** at a typical incline angle of 60° as shown in FIG. **3.** A large number of cables are used to ensure dependable and stable anchoring of each pontoon, the separate cables in each anchor group being parallel with a mutual spacing such as shown in FIG. **3.** Each anchoring pontoon in the embodiment shown is cylindrically shaped and has curved end heads **14.** For example, the illustrated bridge comprises two anchoring pontoons **12,12,** between which extends one rigid tube section **16,** having a circular cross-section as shown in FIG. **4.** The tube sections are preferably cast in reinforced, pre-stressed concrete and are provided with a trafficable floor **18** and a ceiling **17** with space for ventilation channels. Each end of tube section **16** is attached to its respective anchoring pontoon in a suitable fashion. As shown in FIG. **4,** anchoring cables **4, 6** are led into the internal space of the anchoring pontoon via guides **20** in the bottom part of the pontoon. Each of the cables are fastened to an anchor **23** via adjustment- and tensioning device **24.** The anchoring pontoon **12** is, as shown, provided with a level floor **26** for installations such as pumps and other auxiliary equipment (not shown).

Until the bridge tube section and the anchoring pontoons have been finally assembled, all openings are temporarily closed. Similar bridge tube sections **21** are used between the pontoons and land. To provide constant buoyancy, the land span **21** of the submerged bridge is connected to a land tunnel **22** at a level well below the lowest water level **7**, the land connection may, however, be positioned at the depth most suitable to the incline of the slope. The bridge sectionalizing shown is symmetrical, but this choice is optional and dependent upon local conditions. The load distributions in each of the anchoring cables are controlled by means of tensioning means provided in each of the anchoring pontoons.

It will be understood that the specific design parameters for constructing a submerged tunnel bridge in accordance with the present invention will vary with each specific project and location. Specifically, one skilled in the art, upon being given a contract to build a submerged tunnel bridge in accordance with the present invention across a specific body of water between two specific locations will of course have to design the actual construction and dimensions of such individual bridge. For instance, it will of course be necessary for the project engineer to design length of the bridge. It will also of course be necessary to determine the size of the tunnel bridge sections to accommodate the anticipated traffic through the bridge. Furthermore, the project engineer will have to determine the desired depth of the tunnel bridge dependent upon the type of shipping passing through the body of water and dependent upon the specific currents and type and frequency of storms to which the specific body of water is subjected. These factors will of course be influential upon the design of the buoyancy of the pontoon sections and tunnel bridge sections, and also upon the size and strength of the anchoring cables.

As stated above, each of these specific design parameters, as well as other design parameters, will be different for each individual project. However, one ordinarily skilled in this particular art would readily understand how to design and construct a tunnel bridge in accordance with the present invention, and the specific design parameters would be readily determinable by such ordinarily skilled person.

What is claimed is:

1. A submerged tunnel bridge of the type extending from opposite land connections across a body of water below the surface thereof, said tunnel bridge comprising:

at least one buoyant anchoring pontoon positioned at a predetermined position below said surface of said body of water;

tube-shaped tunnel bridge sections positioned at said predetermined position and connected between adjacent of said anchoring pontoons and to said opposite land connections;

anchoring means connected to said anchoring pontoons and to the bottom of said body of water for submerging and maintaining said anchoring pontoons and said tunnel bridge sections at said predetermined position below said surface of said body of water;

the net buoyancy of said tunnel bridge sections at said predetermined position being approximately zero; and

the buoyancy of said anchoring pontoons at said predetermined position being sufficient to sustain the weight of internal and external loads imparted to said tunnel bridge sections.

2. A submerged tunnel bridge as claimed in claim **1**, wherein a portion of the internal space of said tunnel bridge sections constitutes a portion of the buoyancy space of said anchoring pontoons.

3. A submerged tunnel bridge as claimed in claim **1**, wherein each of said anchoring pontoons is in the form of a cylinder, the longitudinal axis of which is transverse to the longitudinal axes of the adjacent of said tunnel bridge sections; and wherein said adjacent tunnel bridge sections are connected to opposite sides of said cylinder.

4. A submerged tunnel bridge as claimed in claim **1**, wherein said opposite land connections are positioned below said surface of said body of water, the connection between said land connections and said tunnel bridge sections thus being below said surface of said body of water, the buoyancy of said tunnel bridge sections connected to said land connections thus being constant.

5. A submerged tunnel bridge as claimed in claim **1**, wherein each of said anchoring pontoons has a buoyancy space partially defined by an upper wall and a lower wall; and said anchoring means comprise cables extending through said lower wall of each of said anchoring pontoons and fixed to said upper wall thereof.

6. A submerged tunnel bridge as claimed in claim **5**, further comprising adjusting and tensioning means attached to each of said cables and positioned within said buoyancy space of each of said anchoring pontoons.

7. A submerged tunnel bridge as claimed in claim **1**, wherein said net buoyancy of said tunnel bridge sections is slightly positive, such positive buoyancy being sufficient to sustain the weight of said internal loads.

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