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(54) OPEN BOTTOM FIBER REINFORCED PRECAST CONCRETE ARCH UNIT

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(52) **U.S. Cl.** **52/380**

(57) **ABSTRACT**

A one-piece open bottom fiber reinforced precast concrete arch unit is buried in compacted soil and has an arcuate top wall portion integrally connecting arcuate side wall portions. The fiber reinforced wall portions have a configuration which provides ductility and flexure strength for effectively utilizing the surrounding compacted soil to resist deflection of the unit in response to a load and to redistribute stresses in the unit. Each of the side wall portions of the unit has a reducing wall thickness towards its bottom and has a radius of curvature greater than the rise of the unit and at least twice the radius of curvature of the top wall portion. A fiber reinforced end arch unit includes an integrally precast and fiber reinforced vertical collar connected to fiber reinforced wing walls by bolts extending through the collar and into anchor nuts embedded in the wing walls.

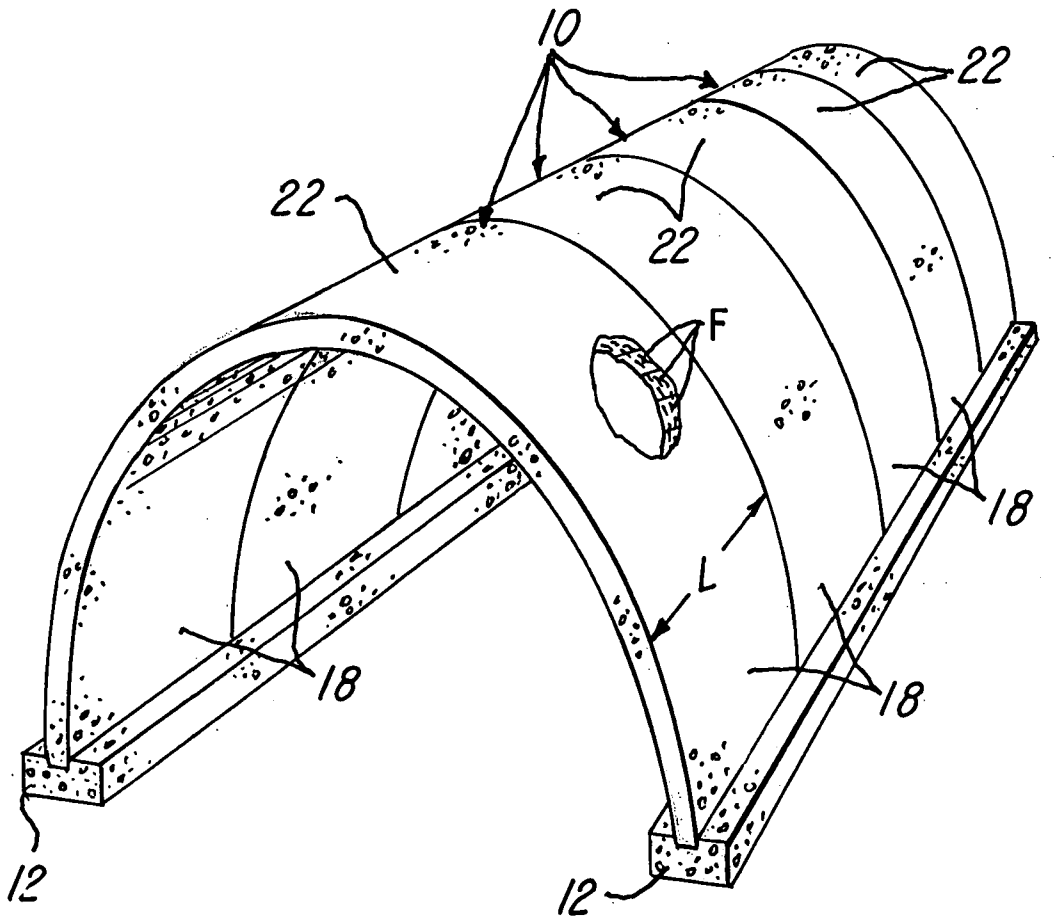


FIG-1

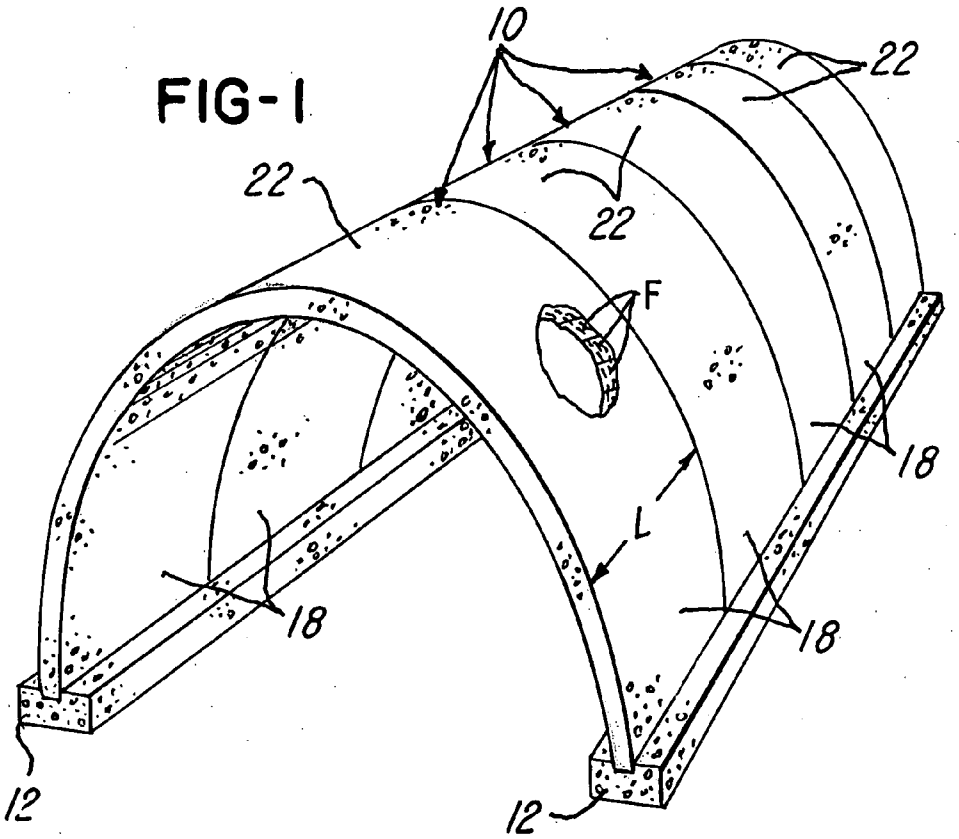


FIG-2

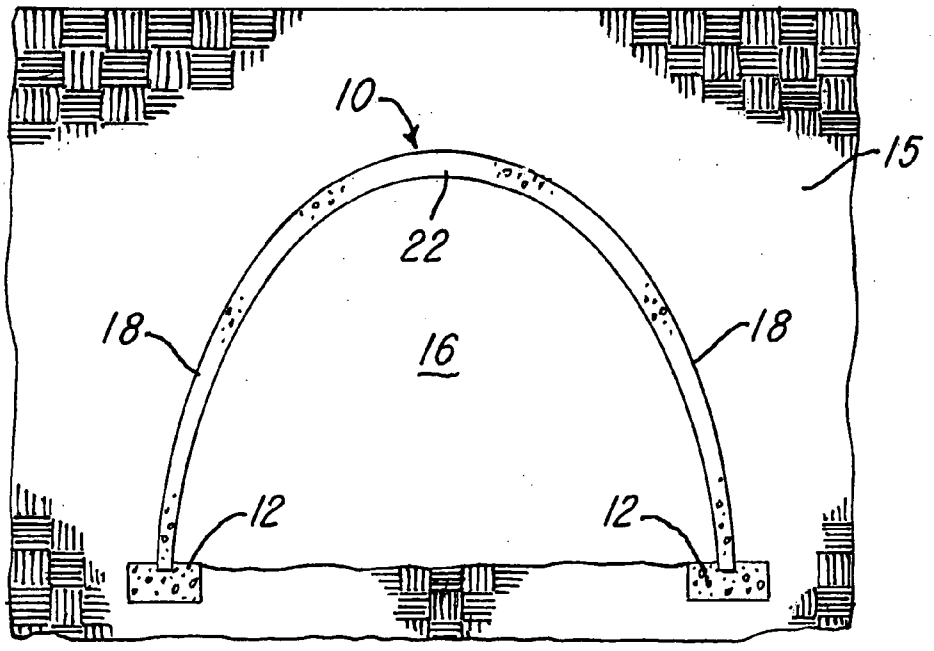


FIG-3

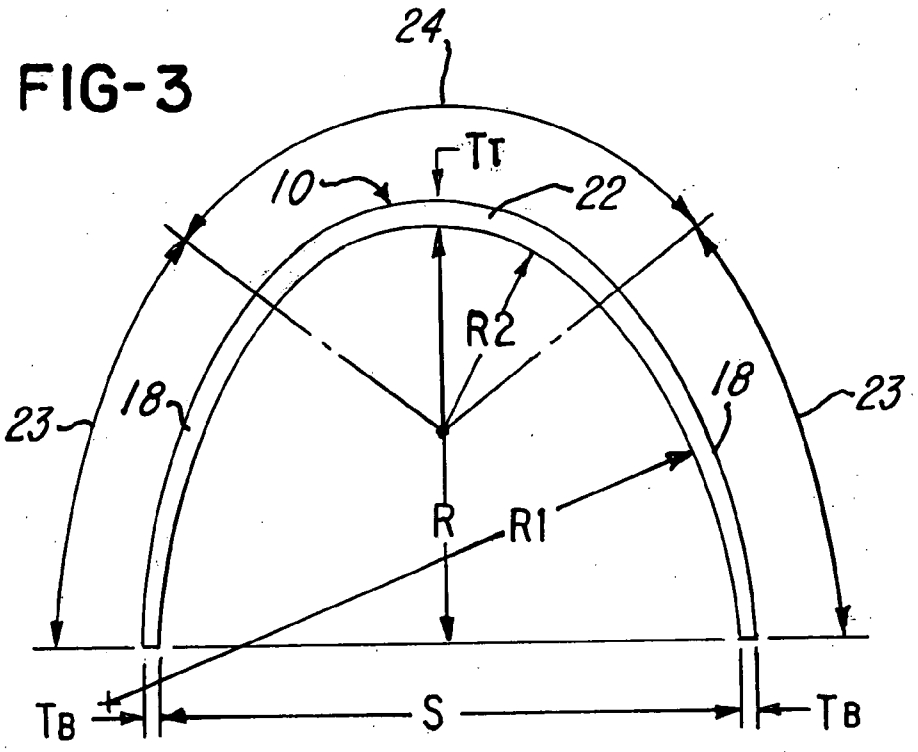


FIG-4

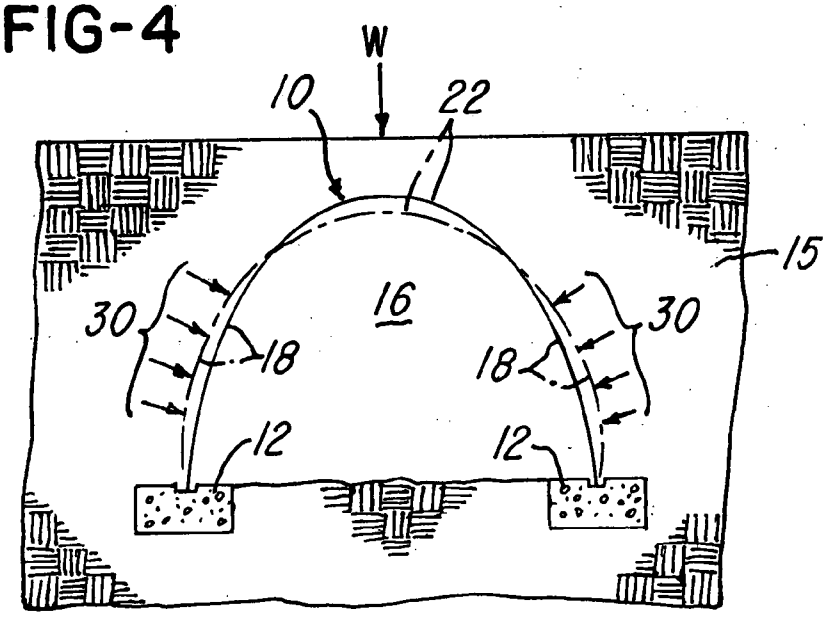


FIG-5

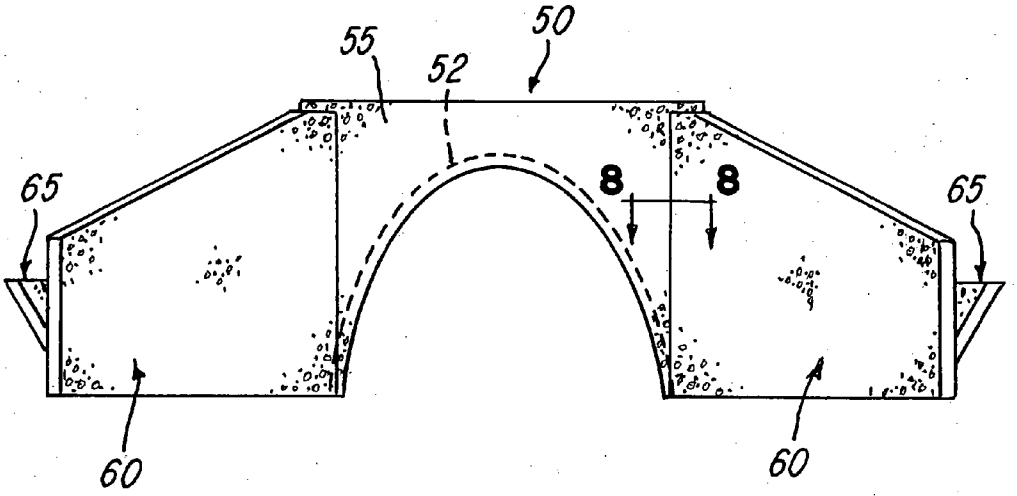


FIG-6

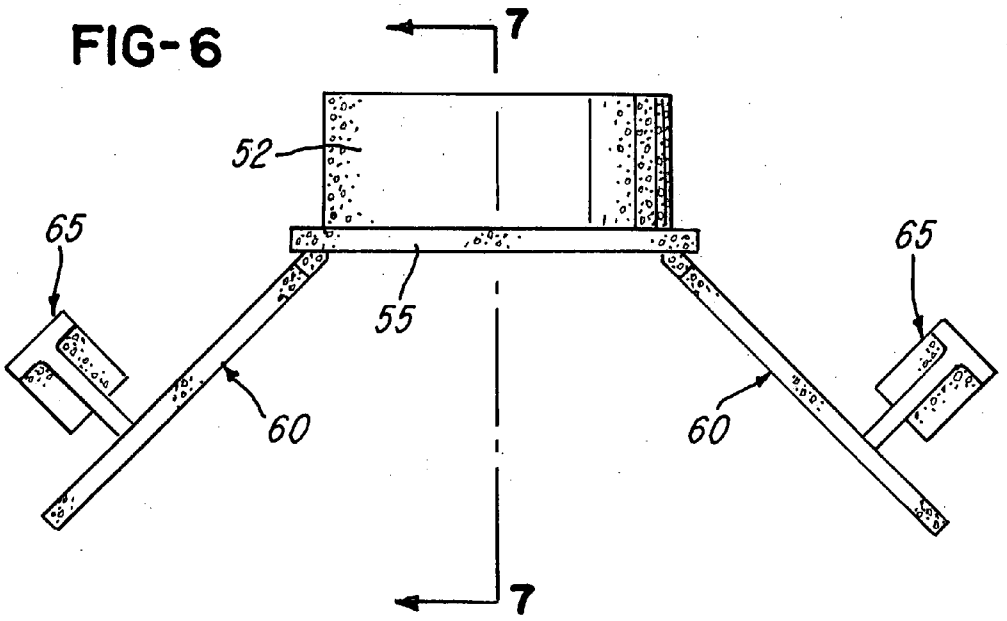


FIG-7

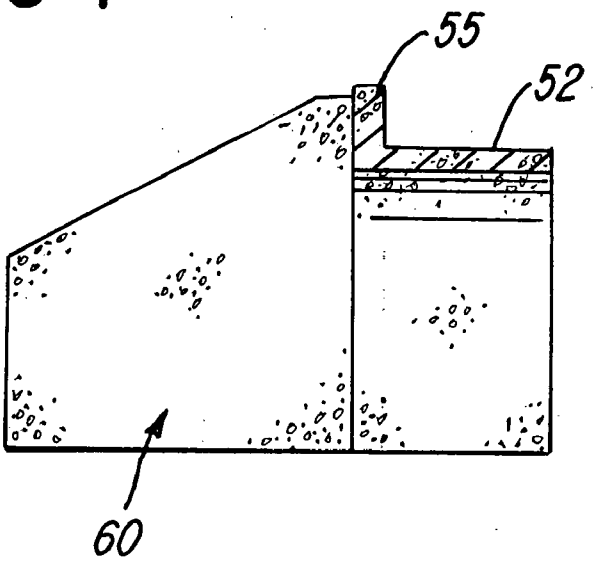
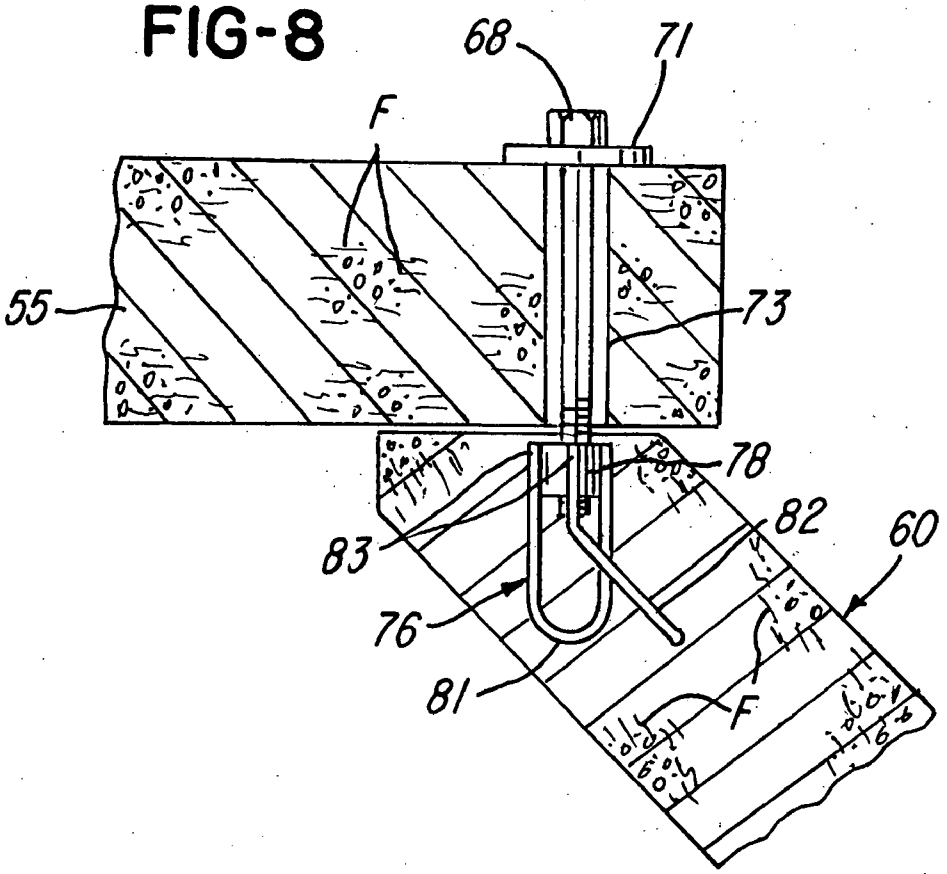


FIG-8



OPEN BOTTOM FIBER REINFORCED PRECAST CONCRETE ARCH UNIT

RELATED APPLICATION

[0001] This application is a continuation-in-part of patent application Ser. No. 11/074,488, filed Mar. 8, 2005.

BACKGROUND OF THE INVENTION

[0002] This invention relates to open bottom precast concrete arch units of the type constructed to be buried in the ground or soil and as generally disclosed, for example, in U.S. Pat No. 3,482,406, U.S. Pat. No.4,558,969, U.S. Pat. No.5,281,053, U.S. Pat. No.6,161,342, U.S. Pat. No.6,205,717, U.S. Pat. No.6,406,220, U.S. Pat. No.6,408,581 and U.S. Pat. No.6,640,505. Such precast concrete arch units are produced in various sizes and spans, for example, by Bebotech Corporation in Middletown, Ohio who offers part elliptical and part circular shapes and as a single or one-piece casting or as a twin or two-piece casting with spans from 12 feet to 84 feet. In such precast concrete arch units, it is common to have a wall thickness of 8 to 14 inches and to have embedded in the concrete walls steel reinforcing bars or rods which may be in the form of a mesh. The steel reinforcing bars or rods provide the concrete arch unit with sufficient strength to support the soil above the arch unit and any load which may be applied to the arch unit, for example, by the wheels of a vehicle on a road passing over the arch unit.

[0003] It is desirable to minimize the weight of a precast concrete arch unit without sacrificing strength for supporting a load in order to reduce the construction cost of the unit and the costs for handling, transporting and installing the unit at a construction site. Thus it is desirable to reduce the volume of concrete and the volume of reinforcing steel within a precast concrete arch unit in addition to reducing the labor required to precast the unit. Furthermore, when a one-piece open bottom precast concrete arch unit is used, it is desirable for the unit to be transported while resting on one end and be nested with other similar arch units for efficiently transporting a plurality of the arch units on a semi-trailer bed. While an arch unit may be precasted in two or more sections to facilitate transportation, substantial additional time and labor is required to assemble and connect the sections at the site where the arch units are installed.

SUMMARY OF THE INVENTION

[0004] The present invention is directed to an improved one-piece open bottom precast concrete arch unit which is designed for underground use and to be buried in compacted soil. The arch unit of the invention provides all of the desirable features mentioned above and is effective to utilize the surrounding soil mass efficiently as a resistance support for the arch unit and thereby minimize the production cost of the arch unit by substantially reducing the volume and weight of concrete and the weight of reinforcement within the arch unit. The arch unit of the invention eliminates the use of steel reinforcing bars or rods and thus eliminates the labor required to position steel reinforcement bars or rods between the forms which are used to precast the arch unit.

[0005] In accordance with one embodiment of the invention, a one-piece arch unit is precast with opposite arcuate side wall portions integrally connected by an arcuate top wall portion. The side wall portions have a radius of curvature substantially greater than the radius of curvature of the top wall section, and the radius of curvature of the top wall portion is substantially less than the vertical height or rise of the arch unit and also substantially less than the span of the arch unit between the bottoms of the side wall portions. The precast concrete arch unit of the invention is reinforced with a predetermined volume of reinforcing fibers such as steel fibers which provide the arch unit with substantial ductility and flexure strength in order to utilize the resistance forces produced by the compacted soil mass surrounding the arch unit. Utilizing the compacted soil to resist bulging of the side wall portions of the arch unit enables a substantial load to be supported by the top wall portion.

[0006] The interaction between the arch unit of the invention with the surrounding soil in combination with the fiber reinforcement not only provides for eliminating steel reinforcement bars and rods, but also provides for substantially reducing the wall thickness of the precast concrete arch unit. The reduction in the wall thickness of the arch unit further increases the ductility of the unit and facilitates the transfer of loads and stresses within the arch unit. Additional economies are achieved by varying the wall thickness of the side wall portions to proportion the strength provided by the arch unit to the applied loads and stresses for the varying conditions around the perimeter of the arch unit. Tapering of the side wall portions also reduces the volume of concrete required to cast the arch unit, thereby further reducing the weight and production cost of the arch unit. In a modification of the invention, a fiber reinforced end unit has an integrally formed fiber reinforced vertical wall or collar which is connected to fiber reinforced wing walls by bolts extending through the collar and threaded into anchors within the wing walls.

[0007] Other features and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a perspective view of a plurality of underground open bottom precast arch units constructed in accordance with the invention and shown supported by parallel spaced concrete footers;

[0009] FIG. **2** is an end view of the arch unit of FIG. **1** and shown buried in compacted soil;

[0010] FIG. **3** is an end view of only the arch unit shown in FIG. **2** and illustrating the radii of curvature for the side and top wall portions of the arch unit along with the span, rise and wall thicknesses of the unit;

[0011] FIG. **4** is a diagrammatic view of the arch unit shown in FIG. **2** and illustrating, in exaggerated form, the deflection of the side and top wall portions in response to an applied downward load;

[0012] FIG. **5** is an end view of a precast fiber reinforced concrete end arch unit connected to fiber reinforced precast concrete wing walls in accordance with the invention;

[0013] FIG. **6** is a top view of the end arch unit and wing walls shown in FIG. **5**;

[0014] FIG. **7** is a section taken generally on the line **7-7** of FIG. **6**; and

[0015] FIG. **8** is an enlarged fragmentary section taken generally on the line **8-8** of FIG. **5**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] FIG. **1** illustrates a plurality or series of longitudinally aligned one-piece open bottom fiber reinforced precast concrete arch units **10** constructed in accordance with the invention and supported by parallel spaced elongated concrete footers **12** which may be cast in place at the construction site or be part of a poured concrete floor. The arch units **10** are buried in compacted soil **15** (FIG. **2**) and define a passage **16** through which pedestrians, vehicles or water may pass. The arch units may also be provided with end walls to define a chamber in which water may be temporarily stored, for example, run-off water received from a large parking lot.

[0017] Referring to FIGS. **1** & **3**, each of the precast concrete arch units **10** has a length L, for example, eight feet, and includes a pair of curved or arcuate opposite legs or side wall portions **18** integrally connected by a curved or arcuate top wall portion **22**, and the arcuate length of each portion **18** and **22** may be generally the same, as shown by the lines **23** and **24**. The arch unit **10** has a height or rise R from the bottom surfaces of the side wall portions **18** to the top inner surface of the top wall portion **22**, and the arch unit has a span S between the bottom inner surfaces of the side wall portions **18**.

[0018] Each of the side wall portions **18** has an inner radius of curvature R**1**, and the top wall portion **22** has an inner radius of curvature R**2**. Preferably, the radius R**1** is greater than twice the radius R**2**, and the rise R is less than the radius R**1**. The radius R**2** is also greater than 20 percent of the span S and less than 45 percent of the span. Thus the radius R**2** is substantially smaller than the rise R, and the radius R**1** may be greater than the span S, as shown in FIG. **3**. When desired, the arcuate length of each side wall portion **18** may be shortened to reduce the rise R by relocating or inserting end walls within the arcuate forms used to precast the arch unit **10**.

[0019] Each of the precast concrete arch units **10** is poured with a predetermined volume of reinforcing fibers F (FIG. **1**) which are preferably steel with each fiber having a length preferably within a range of 0.25 inch to 3 inches and a length at least fifty times the cross-sectional thickness of the fiber. The density of the fibers as they are thoroughly mixed into the concrete before pouring the precast concrete arch unit **10** is preferably within a range of 0.25 and 2.0 percent by volume. One source of steel fibers which has provided satisfactory results are produced by Polytorx, LLC in Ann Arbor, Mich. and sold under the trademark HELIX. The twisted steel fibers of this Company are disclosed in U.S. Pat. No. 6,060,163. However, other fibers also provide satisfactory results, such as the steel fibers produced by Bekaert Corporation and sold under the trademark DRA-MIX. Synthetic or non-metal fibers may also be used, for example, fibers sold by Nycon, Inc. under the trademark NYCON.

[0020] Each of the arch units **10** does not have any embedded steel reinforcing bars or rods, but has a relatively thin wall thickness to provide the fiber reinforced side wall portions **18** and top wall portion **22** with ductility and flexure strength. As shown in FIG. **3**, the side wall portions **18** may also be tapered along its arcuate length from the top wall portion **22** which has a uniform thickness T_T. The thickness T_T of the top wall portion **22** may thus be greater than the thickness T_B at the bottom or base of the side wall portions **18**. Preferably, the thickness T_B is within the range of 1.5 percent to 3.5 percent of the span S and within a range of 0.5 to 0.9 of the top wall thickness T_T. For example, in an arch unit **10** having a span S of 16 feet, the top wall thickness T_T may be within the range of 5 inches to 7.5 inches while the bottom wall thickness T_B may be in the range of 2.5 inches to 4 inches.

[0021] Referring to FIG. **4**, an open bottom precast concrete arch unit **10** buried within the soil **15** is diagrammatically illustrated by a single line. When a downward load W is applied to the soil above the arch unit **10**, for example, by the wheels of a heavy vehicle, the top wall portion **22** tends to deflect downwardly, causing the side wall portions **18** to deflect or bulge outwardly, as greatly exaggerated in FIG. **4**. However, the resistance forces produced by the compacted soil **15**, as indicated by the arrows **30** substantially eliminates or minimizes the bulging of the side wall portions **18** with the result that the deflection of the top wall portion **22** is substantially eliminated or minimized. As a result, the possibility of cracking the fiber reinforced precast concrete arch unit **10** in response to a load W is substantially reduced.

[0022] Referring to FIGS. **5** and **6**, a fiber reinforced precast concrete end arch unit **50** includes an arch structure or portion **52** having the same arch configuration and construction as the arch unit **10** described above in connection with FIGS. **1-4**, but with a shorter length, for example, four feet. The end unit **50** also includes a vertical end wall or collar **55** which is precast integrally with the arch portion **52** and is also fiber reinforced in the same manner as the arch portion **52** and the arch units **10**. Attached to the precast concrete collar **55** are a pair of precast concrete wing walls **60** which are reinforced with fibers F in the same manner as the arch units **10** and **50** are reinforced. The wing walls may also be constructed as disclosed in U.S. Pat. No. 7,001,110 which issued to the assignee of the present invention, and the disclosure of which is herein incorporated by reference. Each of the wing walls **60** is provided with one or more anchor members **65** constructed and attached, for example, as also disclosed in the '110 Patent.

[0023] Referring to FIG. **8**, each of the wing walls **60** is connected or attached to the outer end face of the collar **55** by a set or at least two vertically spaced bolts **68** each of which extends through a plate washer **71** and a corresponding oversized hole **73** in the collar **55**. Each bolt **68** is threaded into a corresponding anchor member **76** embedded in the wing wall **60** and including a cylindrical anchor **78**. The anchor member **76** also includes a horizontal U-shaped metal rod **81** welded to opposite sides of the anchor **78** and a second U-shaped metal rod **82** having bent end portions **83** welded to the top and bottom of the anchor **78**.

[0024] As apparent from the drawings and the above description, an open bottom fiber reinforced precast concrete arch unit and end arch unit constructed in accordance with the invention provides desirable features and advantages. For example, by eliminating conventional reinforcing bars

and rods and using reinforcing fibers within the arch units and substantially reducing the wall thickness of each arch unit, the arch unit is provided with ductility and flexure strength so that it may utilize the resistance forces exerted by the compacted surrounding soil to enable the arch unit to support a substantial load applied to the soil above the unit. In addition, the replacement of steel reinforcing bars or rods with the reinforcing fibers F and the substantial reduction in the wall thickness of the arch unit results in a substantial reduction in the volume of concrete used to form the arch unit and a corresponding substantial reduction in the weight of the arch unit. These reductions provide for a significant reduction in the cost of producing each precast arch unit as well as the cost of handling, transporting and installing each arch unit at the construction site. Moreover, by avoiding the use of steel reinforcing bars or rods, the labor required for positioning the reinforcing bars or rods between the form surfaces for the arch unit, is eliminated.

[0025] Additional economies are achieved by varying the thickness of the side wall portions **18** of each arch unit **10** and **50** to proportion the strength provided by the arch unit according to the applied load and stresses around the perimeter of the arch unit. Bending stresses caused by concentrated loads to the top of the arch unit are transformed into thrusts that can be accommodated very efficiently in the arch unit. This transfer of loads and stresses is dramatically enhanced by increasing the ductility of each arch structure. Since the bending stresses in each arch unit diminish towards the base or bottom of the arch unit, the thickness of the side wall portions may be reduced towards the bottoms of the side wall portions. As another advantage, the discontinuity of the steel fibers F prevents corrosion of the reinforcing fibers, and this eliminates the need for additional concrete to protect the reinforcement as is required to protect continuous steel reinforcing bars and rods. Also the fibers add toughness to the precast arch unit, and the toughness resists damage to the unit during handling, shipping and installing. It is also apparent that a plurality of the arch units **10** shown in FIGS. **2** and **3** may be nested during storage and shipping to provide additional economies. It is also apparent that a plurality of laterally adjacent rows of the arch units as shown in FIG. **1** may be used for an underground water storage facility. When the arch units **10** and end arch units **50** are used to form a culvert, the wing walls **60** may be quickly attached to the collar **55** at the construction site by the bolts **68** and anchors **76** in order to reduce the time for installing the culvert.

[0026] While the forms of arch units and their method of construction and use herein described constitute a preferred embodiment of the invention, it is to be understood that the invention is not limited to these precise forms of arch units and method, and that changes may be made therein without departing from the scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. An underground open bottom precast concrete end arch unit adapted to be buried in compacted soil, said arch unit comprising a one-piece inverted U-shaped wall structure having a predetermined length and arcuate opposite side wall portions integrally connected by an arcuate top wall portion, a predetermined volume of reinforcing fibers dispersed throughout said wall structure and providing said side wall portions and said top wall portion with a predetermined ductility and flexure strength adapted to utilize the resistance of the surrounding compacted soil to increase the load capacity of the unit, said wall structure having a rise defined between bottom surfaces of said side wall portions and an inner top surface of said top wall portion, said arcuate top wall portion having a radius of curvature substantially smaller than said rise, said arcuate side wall portions each having a radius of curvature greater than said rise, and said end arch unit further including a precast concrete vertical collar connected to said wall structure and having reinforcing fibers disposed throughout said collar.

2. A precast concrete end arch unit as defined in claim 1 wherein said arcuate top wall portion has a radius of curvature less than one-half of said radius of curvature of said arcuate side wall portions.

3. A precast concrete end arch unit as defined in claim 1 wherein each of said arcuate side wall portions has inner and outer curved surfaces converging together toward said bottom surface of said side wall portion and providing said side wall portion with a tapered wall configuration.

4. A precast concrete end arch unit as defined in claim 4 wherein each of said side wall portions has a bottom thickness less than ninety percent of the thickness of said top wall portion.

5. A precast concrete end arch unit as defined in claim 1 wherein said volume of reinforcing fibers within said wall structure and said collar is within a range of 0.25 and 2.0 percent by volume of said wall structure.

6. A precast concrete end arch unit as defined in claim 1 and including a pair of precast concrete wing walls attached to a vertical end surface of said collar.

7. A precast concrete end arch unit as defined in claim 1 wherein said arcuate top wall portion has a radius of curvature greater than twenty percent of the span of said unit as defined between inner bottom surfaces of said side wall portions and less than forty percent of said span.

8. A precast concrete end arch unit as defined in claim 1 wherein said reinforcing fibers within said wall structure and said collar comprise steel fibers having a length within a range of 0.25 inch and 3 inches.

9. A precast concrete end arch unit as defined in claim 1 wherein each of said reinforcing fibers within said wall structure and said collar has a length at least fifty times the cross-sectional thickness of said fiber.

10. A precast concrete end arch unit as defined in claim 1 wherein each of said wall portions of said wall structure has a bottom thickness within a range of 1.5 percent to 3.5 percent of the span of said wall structure as defined between bottom inner surfaces of said side wall portions.

11. An underground open bottom precast concrete end arch unit adapted to be buried in compacted soil, said arch unit comprising a one-piece inverted U-shaped wall structure having a predetermined length and arcuate opposite side wall portions integrally connected by an arcuate top wall portion, a predetermined volume of reinforcing fibers dispersed throughout said wall structure and providing said side wall portions and said top wall portion with a predetermined ductility and flexure strength adapted to utilize the resistance of the surrounding compacted soil to increase the load capacity of the unit, said wall structure having a rise defined between bottom surfaces of said side wall portions and an inner top surface of said top wall portion, said arcuate top wall portion having a radius of curvature substantially smaller than said rise and between twenty percent and forty

five percent of the span of said unit as defined between inner bottom surfaces of said side wall portions, said arcuate side wall portions each having a radius of curvature greaterthan said rise, and said end arch unit further including a precast concrete vertical collar integrally connected to said wall structure and having reinforcing fibers disposed throughout said collar.

12. A precast concrete end arch unit as defined in claim 11 wherein said arcuate top wall portion has a radius of curvature less than one-half of said radius of curvature of said arcuate side wall portions.

13. A precast concrete end arch unit as defined in claim 11 wherein each of said arcuate side wall portions has inner and outer curved surfaces converging together toward said bottom surface of said side wall portion and providing said side wall portion with a tapered wall configuration.

14. A precast concrete end arch unit as defined in claim 11 wherein said volume of reinforcing fibers within said wall structure and said collar is within a range of 0.25 and 2.0 percent by volume of said wall structure.

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