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(54) CONCRETE SEGMENT

(71) I, JUNICHI TSUZUKI, of 30-8, Seijo 6-chome, Setagaya-ku, Tokyo, Japan, a citizen of Japan, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to a concrete segment primarily, but not exclusively, intended for use as a wall of a tunnel for underground water, sub-way or the like.

The details of the concrete segment of the present invention are generally as described in the specification of my U.K. Patent No. 1,502,207 (to which the reader is referred), but the segment is modified in the manner described hereinafter.

In general, concrete segments are coupled together both in the circumferential direction and in the lengthwise direction of a tunnel which has been made by a shielding process.

This type of tunnel however poses many problems due to the fact that stresses produced by earth pressure tend to be concentrated on joints between adjoining segments, and thus, if the case comes to the worst, the metal joint pieces are deformed, or the segment itself is subjected to local failure. Cracking in the segment can lead to leakage of underground water into the tunnel and lowered strength thereof.

Hitherto, metal joint pieces to be built in the joint surfaces of segments have been manufactured according to bending and welding processes, with an expenditure of much time and effort, thus lowering the manufacturing efficiency.

According to a first aspect of the present invention, there is provided a concrete segment, comprising: a concrete member curved in an arcuate form and having a plurality of cavities in the joint surfaces of said concrete member, each of said cavities being open from the inner surface as well as from one of said joint surfaces of said concrete member; metal joint pieces positioned in said cavities and having bolt-holes therein, said bolt-holes being exposed from the respective joint surfaces of said concrete

segment; and a steel frame member or members embedded in said concrete member and oriented in a substantially circumferential direction, at least those of said metal joint pieces which are in the circumferentially opposite end surfaces of said concrete member comprising a body portion and a back plate, said back plate being attached to said body portion and to said steel frame member or at least one of said steel frame members, and said body portion and said back plate being of substantially U-shaped section with the respective U's being concave towards each other. The provision of such back plates can improve the joint strength of such concrete segments, and can provide additional advantages such as simplicity in manufacture, low manufacturing cost and toughness.

In accordance with various preferred embodiments, each of said back plates is directly attached to the respective frame member or members; said back plates may be of cast iron; and said joint pieces may be provided with steel anchor bars.

According to a second aspect of the present invention, there is provided a concrete segment, comprising: a concrete member curved in an arcuate form and having a plurality of cavities in the joint surfaces of said concrete member, each of said cavities being open from the inner surface as well as from one of said joint surfaces of said concrete member; and metal joint pieces positioned in said cavities and having bolt-holes therein, said bolt-holes being exposed from the respective joint surfaces of said concrete segment, at least one of said metal joint pieces having at least one generally rearwardly extending steel anchor bar and at least one generally laterally extending steel reinforcing bar at least a portion of which lies in a plane which is substantially normal to said generally rearwardly extending anchor bar; and a steel frame member or members embedded in said concrete member and oriented in a substantially circumferential direction, at least those of said metal joint pieces which are in the circumferentially opposite end surfaces of said concrete

member being attached to said steel frame member or members. Such metal joint pieces having such steel anchor bars can further improve the strength of the respective joint pieces of the concrete segments.

In one preferred embodiment, at least one of said generally laterally extending steel anchor bars is generally of U-shape, with the base of the "U" attached to the respective metal joint piece, and with the legs of the "U" extending laterally from the metal joint piece and crossing over each other. In another preferred embodiment, at least one of said generally laterally extending steel anchor bars is generally of U-shape, with the free ends of the legs of the "U" attached to the respective metal joint piece.

Said at least one joint piece may include a first said generally rearwardly extending steel anchor bar and a second said generally rearwardly extending steel anchor bar, said first and second anchor bars being on opposite sides of said metal joint piece and being angled towards each other so that they cross it at a point, at which point they are attached to each other.

The following features are desirably incorporated into a concrete segment in accordance with either of the aforementioned aspects of the present invention.

1. Cut-away portions may be provided on edges of the inner peripheral surface of the concrete member, said cut-away portions being such that, when a plurality of such concrete segments are assembled to form a tubular structure, the cut-away portions provide grooves between the adjoining segments, which grooves may be filled with a filling material. Such an arrangement can be used to prevent, in a simple manner, leakage of underground water.

2. For reasons which will be explained later, at least those of the metal joint pieces which are in the circumferentially opposite end surfaces of the concrete member are preferably of cast iron. The metal joint pieces may all be of cast iron, or, in an alternative embodiment, the metal joint pieces in the circumferentially opposite end surfaces of the concrete member only may be of cast iron, the metal joint pieces in the widthwise opposite side surfaces of the concrete member being of plain steel. Preferably those metal joint pieces which are of cast iron are of ductile cast iron.

3. The metal joint pieces may be embedded in the concrete member at a given depth from the inner peripheral surface towards the outer peripheral surface of the concrete member. Such an arrangement can help shield the metal joint pieces from the environment, to reduce corrosion of the joint pieces.

4. The or each steel frame member may consist of two parallel steel plates curved at

substantially the same curvature as that of said concrete member, and spacers interposed between said two parallel steel plates at a given spacing along the length of said steel frame member. Such an arrangement can reinforce the concrete segment in an efficient manner.

In order that the invention may be more fully understood, some preferred embodiments in accordance therewith will now be described with reference to the accompanying drawings, wherein:-

Fig. 1 is a front view, half of which shown in cross section, of a concrete segment according to the aforementioned first aspect of the present invention;

Fig. 2 is a plan view of Fig. 1;

Figs. 3 and 4 are enlarged, partial perspective views of metal end joint pieces of the concrete segment shown in Fig. 1;

Fig. 5 is an enlarged, partial, perspective view of a metal end joint piece of the concrete segment shown in Fig. 1 coupled to a steel frame;

Fig. 6 is an enlarged, partial front view of a metal end joint piece, as viewed towards the end joint surface of a segment;

Fig. 7 is a transverse cross-sectional view of Fig. 6;

Fig. 8 is a longitudinal cross sectional view thereof;

Fig. 9 is an enlarged, partial, longitudinal cross-sectional view showing a pair of circumferentially adjoining concrete segments which are coupled together;

Fig. 10 is a perspective view of a metal side joint piece;

Fig. 11 is a view of a metal side joint piece secured to a concrete segment, as viewed towards the side joint surface of the segment;

Fig. 12 is a transverse cross-sectional view of Fig. 11;

Fig. 13 is a longitudinal cross-sectional view of Fig. 11;

Fig. 14 is a longitudinal cross-sectional view showing a pair of axially adjoining concrete segments which are coupled together;

Fig. 15 is a front view showing concrete segments assembled into a ring form for providing a wall of a tunnel;

Fig. 16 is an enlarged, partial, perspective view of a metal end joint piece having another type of a backing plate, which is coupled to a steel frame;

Fig. 17 is an enlarged, partial, front view of a metal end joint piece, as viewed towards the end joint surface of a concrete segment;

Fig. 18 is a transverse cross-sectional view of Fig. 17;

Fig. 19 is a longitudinal cross-sectional view of Fig. 17;

Fig. 20 is a longitudinal cross-sectional view showing a pair of circumferentially adjoining concrete segments which are coupled together using the metal end joint

pieces, according to the present invention; and

Figs. 21 to 29 show several metal joint pieces for use in a concrete segment according to the aforementioned second aspect of the present invention.

Referring firstly to Figs. 1 and 2, a concrete segment (hereinafter referred to as a segment) is shown at 1. The segment 1 essentially consists of a curved precast concrete body or member 2 having a given curvature, metal joint pieces 3, 4 provided respectively in the circumferentially opposite end surfaces (joint surfaces) and widthwise opposite side surfaces (joint surfaces) of the segment, and steel frame members 5 and steel bars 6 embedded in the concrete member 2. For the sake of clarity, the frame members 5 and bars 6 are omitted from Figs. 3 and 4.

As shown in Fig. 2, a plurality of open cavities 7 are provided at a given spacing in the circumferentially opposite end surfaces and widthwise opposite side surfaces of the concrete member 2, with metal joint pieces 3, 4 being fitted therein, with their front surfaces exposed from the concrete member 2. The metal joint pieces are embedded in the concrete member 2 at a given depth from the inner peripheral surface of the concrete member 2. In addition, cut-away portions 8 (seen most clearly in Figs. 3 and 4) are provided on the entire edges of the inner peripheral surfaces of the concrete member 2, and filled with a filling material, upon assembly of adjoining segments.

The metal joint pieces 3, 4 are made of cast iron. However, at least metal joint pieces 3 provided in the circumferentially opposite end surfaces of the concrete member 2 should be made of cast iron. As shown in Fig. 5, each metal joint piece 3 comprises a body portion 9 of a 'U' shaped cross section, and attaching portions 10, 10 provided on the opposite sides of the body portion 9. A bolt inserting hole 11 is provided in a bottom portion of the body portion 9, while bolt holes 12, 12 are provided in the attaching portions 10, 10, respectively. Provided in the upper or lower edge of the body portion 9 is a shoulder portion 13 continuous with the cut-away portion 8 in matching relation.

A back plate 14 made of a steel and having a 'U' shaped cross section is attached to the back surfaces of the attaching portions 10, 10 of the metal joint piece 3, and the back plate 14 is fastened to the metal joint piece 3 by means of an auxiliary steel anchor bars 15 and nuts 16.

The steel frame member 5 is welded by means of an attaching auxiliary metal piece 17 (which is part of the frame 5) having a 'U' shaped cross section to the back surface of the back plate 14, so that the metal joint piece 3 is directly coupled to the steel frame

The metal joint piece 4 should preferably be made of cast steel, but may be made of a plain steel. As shown in Fig. 10, the metal joint piece 4 is of a shape similar to that of the metal joint piece 3. The metal joint piece 4 consists of a body portion 18 of a 'U' shaped cross section, and attaching portions 19 provided on the opposite sides of the body portion 18. Anchor bars (steel) 21 extend through the attaching portions 19 and are tightened with nuts 20. The steel anchor bars 21 are embedded in the concrete member 2.

The metal joint pieces 3, 4 should preferably be made of ductile cast iron, for strength.

The steel frame member 5, as shown in Figs. 1, 2, and 5, consists of upper and lower parallel steel plates 22, 22 which are curved through a given curvature along the circumferential surface of the concrete member 2, and a plurality of spacers 23 which are interposed between the upper and lower steel plates 22, 22 at a given spacing in the lengthwise direction of the steel frame member 5. Attaching auxiliary metal piece 17 is welded to the ends of the upper and lower steel plates 22, 22.

Molding of a segment is carried out in such a manner that the steel frame member 5 and steel bars 6 are assembled beforehand and then metal joint pieces 3, 4 are secured thereto, after which the thus prepared framework is placed in a mold, or the respective members are assembled within a mold, and a reinforcing metal screen 24 is attached thereto, as required, for reinforcement. Then, mortar and concrete are filled into the mold, and the concrete segment thus formed is removed therefrom after hardening. The metal screen 24 serves, during manufacture of the segment to prevent local failure of the segment at its end portions, due to stress concentration.

Figs. 9 and 14 show the procedure of coupling one segment 1 to another. The respective joint surfaces of the segments 1, 1 are mated with each other, and then bolts 26 are inserted through the bolt holes 11, 11 or 25, 25 in the metal joint piece 3, or 4, followed by tightening in each case by a nut 27. Shown at 28 is a continuous groove into which is filled anti-freezing material. Then, the filling material 30 is filled into a groove 29 defined by the cut-away portions 8, 8. The provision of filling material 30 in the groove 29 permits the exposed surface of the metal joint piece 3 or 4 to be shielded from the ambient atmosphere, when assembled, so that corrosion of the metal joint piece 3 or 4 may be prevented to a large extent. In this manner, the segments 1, 1 are coupled to each other in the circumferential direction into a ring form, while segments 1, 1 are also coupled to each other in a direction which is lengthwise of the tunnel being built.

Shown at 31 in Fig. 15 is an auxiliary segment which is to be fitted in a gap between segments at the completion of the assembly of segments.

5 Figs. 16 to 20 show a metal joint piece 3 having a modified type of back plate 32, and the manner in which it is incorporated in the concrete member 2, and the manner in which segments containing it are coupled together.

10 The back plate 32 in this embodiment is made of cast iron as in the preceding embodiment. However, the depth of the open cavity in the back plate is increased, with a corresponding increase in the internal volume of the cavity 7, as compared with the corresponding cavities in the preceding embodiment, so as to provide easier access for tightening nuts and bolts, when making the joints between circumferentially adjacent segments.

20 As is apparent from the foregoing description of the concrete segment according to the present invention, the metal joint pieces are preferably made of cast iron, and thus the manufacture of metal joint pieces may be simplified, thereby avoiding the expenditure of much time and effort in the manufacture of metal joint pieces. The metal joint pieces should preferably be made of a ductile cast iron for increased joint strength.

30 In addition, the metal joint pieces are exposed from the joint surface of a segment and thus are vulnerable to corrosion. However, cast iron is less vulnerable to corrosion than a plain steel which has been machined, so that corrosion in the metal joint pieces according to the invention may be prevented further effectively, in cooperation with the corrosion resisting property of the cast iron.

40 In addition, the use, in accordance with the invention, of a U-section back plate attached to the back of the U-section body portion can result in an increase in strength of the joints.

45 Accordingly, the present invention presents a concrete segment which is tough and economical.

Turning now to Figs. 21 to 29 of the accompanying drawings, shown therein are several metal joint pieces having at least one generally rearwardly extending steel anchor bar and at least one laterally extending steel reinforcing bar at least a portion of which lies in a plane which is substantially normal to said anchor bar, for use in a concrete segment according to the aforementioned second aspect of the present invention. The latter drawings do not show the remaining integers of the concrete segment, and in particular do not show other metal joint pieces, not being as described in the previous sentence, which may be present in the concrete segment, since the remaining integers are preferably as described above in connection with the aforementioned first aspect of the invention and/or described in the aforementioned

specification of my Patent No. 1 502 207.

In Fig. 21, there is shown a metal joint piece 41 which is of cast iron, is generally U-shaped in cross section, and is provided with flanges 42 on both sides thereof. Steel anchor bars 43 rearwardly extend through the flanges 42 and are secured by nuts 44. In accordance with the aforementioned second aspect of the present invention, laterally extending steel reinforcing bars 45 are placed across the nuts and secured thereto by welding: thus, the steel reinforcing bars 45 lie in planes which are substantially normal to the steel anchor bars 43. Further, each steel reinforcing bar 45 has its ends crossing each other so as to improve its resistance to bending. A steel reinforcing bar 45 is provided at the front and at the back sides of the flange 42, respectively (accordingly, there are two steel reinforcing bars 45 on each flange). However, more or fewer steel reinforcing bars may be provided.

Fig. 22 is a front view of the metal joint piece 41 shown in Fig. 21.

In Fig. 23, the steel reinforcing bars 45 at the front side of the metal joint piece 41 are bent in the same direction as the main steel anchor bars 43. Thus, only the steel reinforcing bars 45 at the rear side of the metal joint piece 41 lie in planes which are substantially normal to the steel anchor bars 43.

In Fig. 24, the steel reinforcing bars 45 on either one of the flanges both have their initial portions lying in planes which are substantially normal to the steel anchor bars 43, and the terminal portions of these reinforcing bars 45 are bent rearwardly of the metal joint piece.

In Fig. 25, the steel reinforcing bars 45 on both flanges all have their initial portions lying in planes which are substantially normal to the steel anchor bars 43, and the terminal portions of the reinforcing bars 45 are bent rearwardly of the metal joint piece.

In Fig. 26, the steel reinforcing bar 45 is attached to the metal joint piece 41 by the use of a metal fixing means 46. The metal fixing means 46 engages the main steel anchor bar 43 and is secured thereto by bolt and nut means 47.

In Fig. 27, projections 48 for attaching U-shaped steel reinforcing bar 45A are provided at the back surface of the end portion of the flange 42. The ends of the U-shaped steel reinforcing bars 45A are secured by nuts to the projections 48, respectively.

In Fig. 28, flanges 42 laterally extend from the end of the metal joint piece but are angularly offset towards the rearward direction. The generally laterally extending steel reinforcing bars 45 are fixed on the projections 48 in the same manner as mentioned above. On the other hand, the generally rearwardly extending main steel anchor bars 43 extend through their respective flanges 42, and are

secured, by nuts, at right angles to the corresponding flange 42, so that the reinforcing bars 45 lie in planes which are normal to the anchor bars 43. The steel anchor bars 43 cross at a point rearwardly spaced from the metal joint piece 41 and are welded at that point.

In Fig. 28 the projection 48 has a cut-off portion at the top thereof in which the steel reinforcing bar 45 is engaged. In the alternative arrangement shown in Fig. 29, the projection 48A is in the general shape of an annulus through which the steel reinforcing bar 45 extends. These two types of projection will be effective. The projections are formed in the same manner as mentioned above in connection with Fig. 27.

The use of metal joint pieces such as shown in Figs. 21 to 29, having at least one generally laterally extending steel reinforcing bars at least a portion of which lies in a plane which is substantially normal to at least one generally rearwardly extending anchor bar, in concrete segments as described above can further improve the strength of the respective joint portions of the concrete segments.

WHAT I CLAIM IS:-

1. A concrete segment, comprising:
a concrete member curved in an arcuate form and having a plurality of cavities in the joint surfaces of said concrete member, each of said cavities being open from the inner surface as well as from one of said joint surfaces of said concrete member;
- metal joint pieces positioned in said cavities and having bolt-holes therein, said bolt-holes being exposed from the respective joint surfaces of said concrete segment;
- and a steel frame member or members embedded in said concrete member and oriented in a substantially circumferential direction, at least those of said metal joint pieces which are in the circumferentially opposite end surfaces of said concrete member comprising a body portion and a back plate, said back plate being attached to said body portion and to said steel frame member or at least one of said steel frame members, and said body portion and said back plate being of substantially U-shaped section with the respective U's being concave towards each other.

2. A concrete segment, according to claim 1, wherein each of said back plates is directly attached to the respective steel frame member or frame members.

3. A concrete segment according to claim 1 or claim 2 wherein said back plates are of cast iron.

4. A concrete segment according to any one of claims 1 to 3 wherein said metal joint pieces are provided with steel anchor bars.

5. A concrete segment comprising: a concrete member curved in an arcuate form and having a plurality of cavities in the joint

surfaces of said concrete member, each of said cavities being open from the inner surface as well as from one of said joint surfaces of said concrete member; and metal joint pieces positioned in said cavities and having bolt-holes therein, said bolt-holes being exposed from the respective joint surfaces of said concrete segment, at least one of said metal joint pieces having at least one generally rearwardly extending steel anchor bar and at least one generally laterally extending steel reinforcing bar at least a portion of which lies in a plane which is substantially normal to said generally rearwardly extending anchor bars; and a steel frame member or members embedded in said concrete member and oriented in a substantially circumferential direction, at least those of said metal joint pieces which are in the circumferentially opposite end surfaces of said concrete member being attached to said steel frame member or members.

6. A concrete segment according to claim 5, wherein at least one of said generally laterally extending steel anchor bars is generally of U-shape, with the base of the "U" attached to the respective metal joint piece, and with the legs of the "U" extending laterally from the metal joint piece and crossing over each other.

7. A concrete segment according to claim 5, wherein at least one of said generally laterally extending steel anchor bars is generally of U-shape, with the free ends of the legs of the "U" attached to the respective metal joint piece.

8. A concrete segment according to any one of claims 5 to 7, wherein said at least one metal joint piece includes a first said generally rearwardly extending steel anchor bar and a second generally rearwardly extending steel anchor bar, said first and second anchor bars being on opposite sides of said metal joint piece and being angled towards each other so that they cross at a point, at which point they are attached to each other.

9. A concrete segment according to any one of claims 1 to 8, wherein cut-away portions are provided on edges of the inner peripheral surface of said concrete member, said cut-away portions being such that, when a plurality of such concrete segments are assembled to form a tubular structure, the cut-away portions provide grooves between the adjoining segments, which grooves may be filled with a filling material.

10. A concrete segment according to any one of claims 1 to 9, wherein at least those of the metal joint pieces which are in the circumferentially opposite end surfaces of the concrete member are of cast iron.

11. A concrete segment according to any one of claims 1 to 10, wherein the metal joint pieces which are in the circumferentially opposite end surfaces as well as those which



secured, by nuts, at right angles to the corresponding flange 42, so that the reinforcing bars 45 lie in planes which are normal to the anchor bars 43. The steel anchor bars 43 cross at a point rearwardly spaced from the metal joint piece 41 and are welded at that point.

In Fig. 28 the projection 48 has a cut-off portion at the top thereof in which the steel reinforcing bar 45 is engaged. In the alternative arrangement shown in Fig. 29, the projection 48A is in the general shape of an annulus through which the steel reinforcing bar 45 extends. These two types of projection will be effective. The projections are formed in the same manner as mentioned above in connection with Fig. 27.

The use of metal joint pieces such as shown in Figs. 21 to 29, having at least one generally laterally extending steel reinforcing bars at least a portion of which lies in a plane which is substantially normal to at least one generally rearwardly extending anchor bar, in concrete segments as described above can further improve the strength of the respective joint portions of the concrete segments.

WHAT I CLAIM IS:-

1. A concrete segment, comprising:
a concrete member curved in an arcuate form and having a plurality of cavities in the joint surfaces of said concrete member, each of said cavities being open from the inner surface as well as from one of said joint surfaces of said concrete member;
metal joint pieces positioned in said cavities and having bolt-holes therein, said bolt-holes being exposed from the respective joint surfaces of said concrete segment;
and a steel frame member or members embedded in said concrete member and oriented in a substantially circumferential direction, at least those of said metal joint pieces which are in the circumferentially opposite end surfaces of said concrete member comprising a body portion and a back plate, said back plate being attached to said body portion and to said steel frame member or at least one of said steel frame members, and said body portion and said back plate being of substantially U-shaped section with the respective U's being concave towards each other.

2. A concrete segment, according to claim 1, wherein each of said back plates is directly attached to the respective steel frame member or frame members.

3. A concrete segment according to claim 1 or claim 2 wherein said back plates are of cast iron.

4. A concrete segment according to any one of claims 1 to 3 wherein said metal joint pieces are provided with steel anchor bars.

5. A concrete segment comprising: a concrete member curved in an arcuate form and having a plurality of cavities in the joint

surfaces of said concrete member, each of said cavities being open from the inner surface as well as from one of said joint surfaces of said concrete member; and metal joint pieces positioned in said cavities and having bolt-holes therein, said bolt-holes being exposed from the respective joint surfaces of said concrete segment, at least one of said metal joint pieces having at least one generally rearwardly extending steel anchor bar and at least one generally laterally extending steel reinforcing bar at least a portion of which lies in a plane which is substantially normal to said generally rearwardly extending anchor bars; and a steel frame member or members embedded in said concrete member and oriented in a substantially circumferential direction, at least those of said metal joint pieces which are in the circumferentially opposite end surfaces of said concrete member being attached to said steel frame member or members.

6. A concrete segment according to claim 5, wherein at least one of said generally laterally extending steel anchor bars is generally of U-shape, with the base of the "U" attached to the respective metal joint piece, and with the legs of the "U" extending laterally from the metal joint piece and crossing over each other.

7. A concrete segment according to claim 5, wherein at least one of said generally laterally extending steel anchor bars is generally of U-shape, with the free ends of the legs of the "U" attached to the respective metal joint piece.

8. A concrete segment according to any one of claims 5 to 7, wherein said at least one metal joint piece includes a first said generally rearwardly extending steel anchor bar and a second generally rearwardly extending steel anchor bar, said first and second anchor bars being on opposite sides of said metal joint piece and being angled towards each other so that they cross at a point, at which point they are attached to each other.

9. A concrete segment according to any one of claims 1 to 8, wherein cut-away portions are provided on edges of the inner peripheral surface of said concrete member, said cut-away portions being such that, when a plurality of such concrete segments are assembled to form a tubular structure, the cut-away portions provide grooves between the adjoining segments, which grooves may be filled with a filling material.

10. A concrete segment according to any one of claims 1 to 9, wherein at least those of the metal joint pieces which are in the circumferentially opposite end surfaces of the concrete member are of cast iron.

11. A concrete segment according to any one of claims 1 to 10, wherein the metal joint pieces which are in the circumferentially opposite end surfaces as well as those which

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are in the widthwise opposite side surfaces of said concrete member are of cast iron.

12. A concrete segment according to any one of claims 1 to 10, wherein the metal joint pieces in the circumferentially opposite end surfaces of said concrete member are of cast iron, and the metal joint pieces in the widthwise opposite side surfaces of said concrete member are of plain steel.

10 13. A concrete segment according to any one of claims 1 to 12, wherein those of said metal joint pieces which are of cast iron are of ductile cast iron.

15 14. A concrete segment according to any one of claims 1 to 13, wherein said metal joint pieces are embedded in said concrete member at a given depth from the inner peripheral surface towards the outer peripheral surface of said concrete member.

20 15. A concrete segment according to any one of claims 1 to 14, wherein the or each said steel frame member consists of two parallel steel plates curved at substantially the same curvature as that of said concrete member, and spacers interposed between said two parallel steel plates at a given spacing along the length of said steel frame member.

30 16. A concrete segment substantially as herein described with reference to, and as illustrated in, Figures 1 to 14 of the accompanying drawings.

35 17. A concrete segment according to claim 16, modified substantially as described with reference to, and as illustrated in, Figures 16 to 20 of the accompanying drawings.

18. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Figs. 21

and 22 of the accompanying drawings.

19. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 23 of the accompanying drawings.

20. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 24 of the accompanying drawings.

21. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 25 of the accompanying drawings.

22. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 26 of the accompanying drawings.

23. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 27 of the accompanying drawings.

24. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 28 of the accompanying drawings.

25. A concrete segment according to claim 5, and substantially as described with reference to, and as illustrated in, Fig. 29 of the accompanying drawings.

26. A tubular structure whenever constructed by assembly of a plurality of concrete segments in accordance with any one of claims 1 to 25.

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