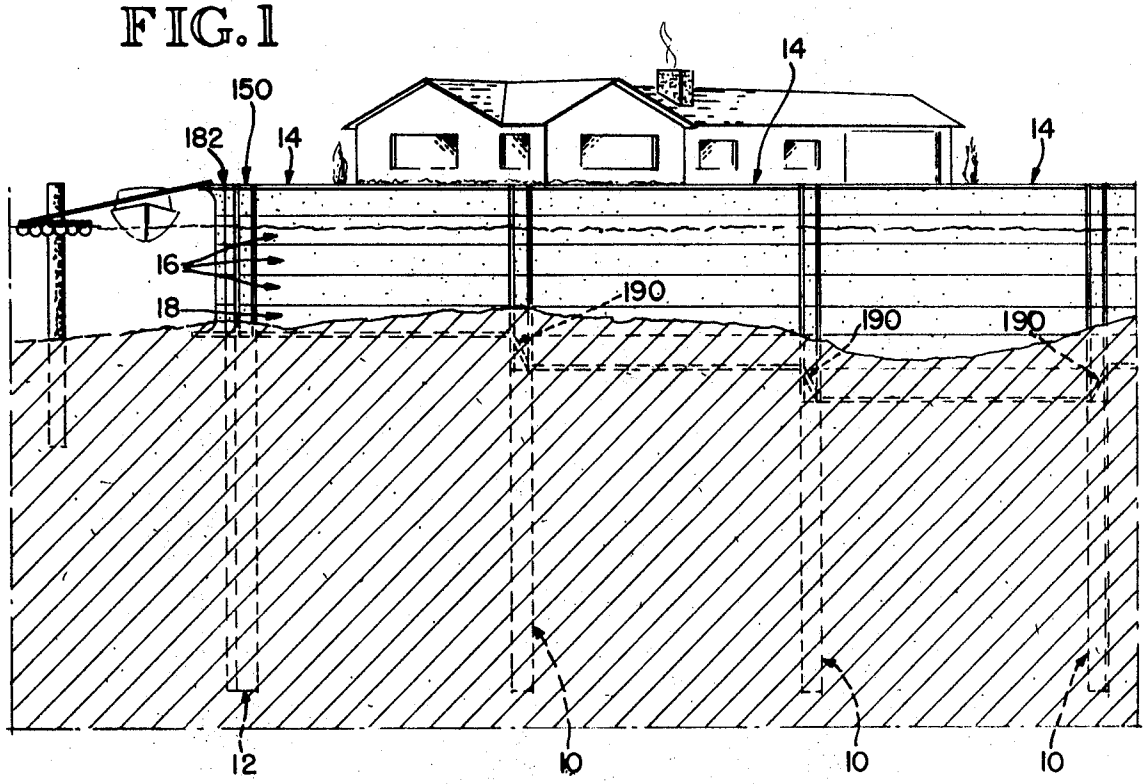
Oct. 19, 1971 B. J. DICKINSON 3,613,382

SEA WALL CONSTRUCTION

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FIG. 1



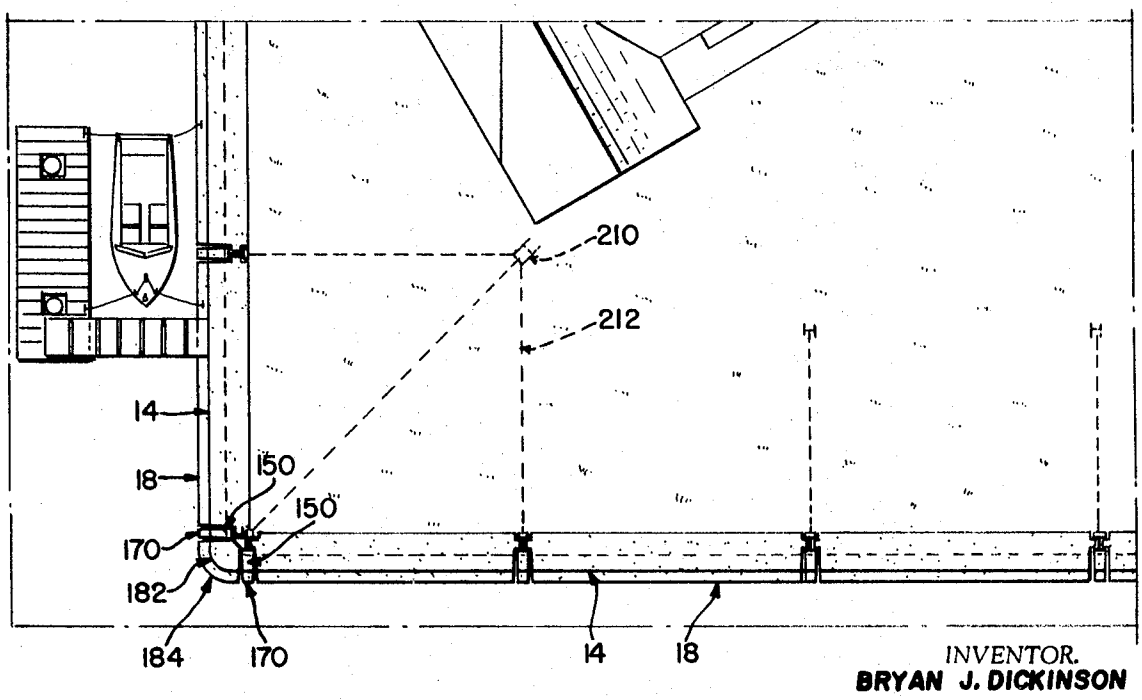


FIG. 2

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SEA WALL CONSTRUCTION

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FIG. 3

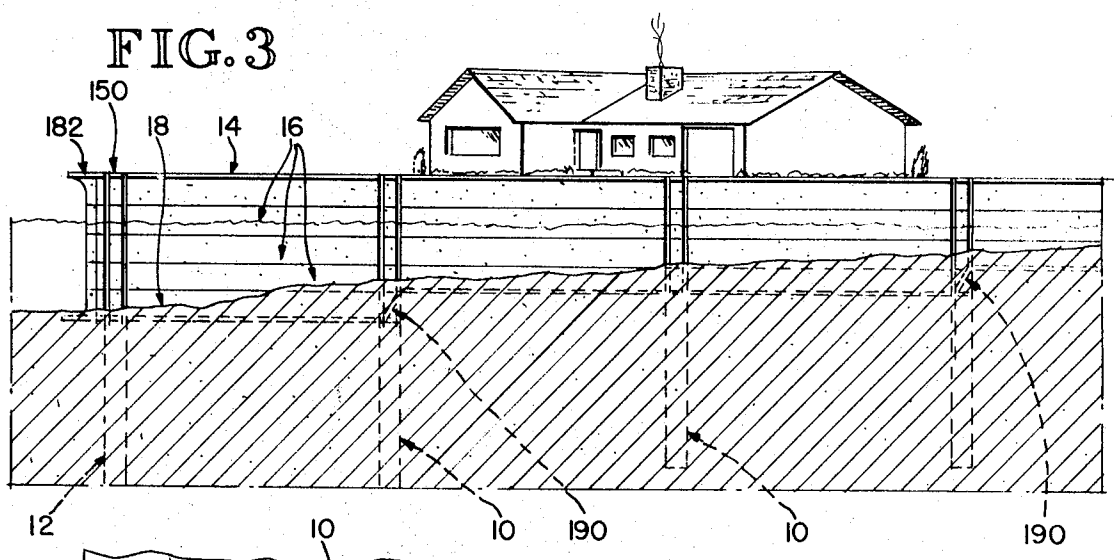
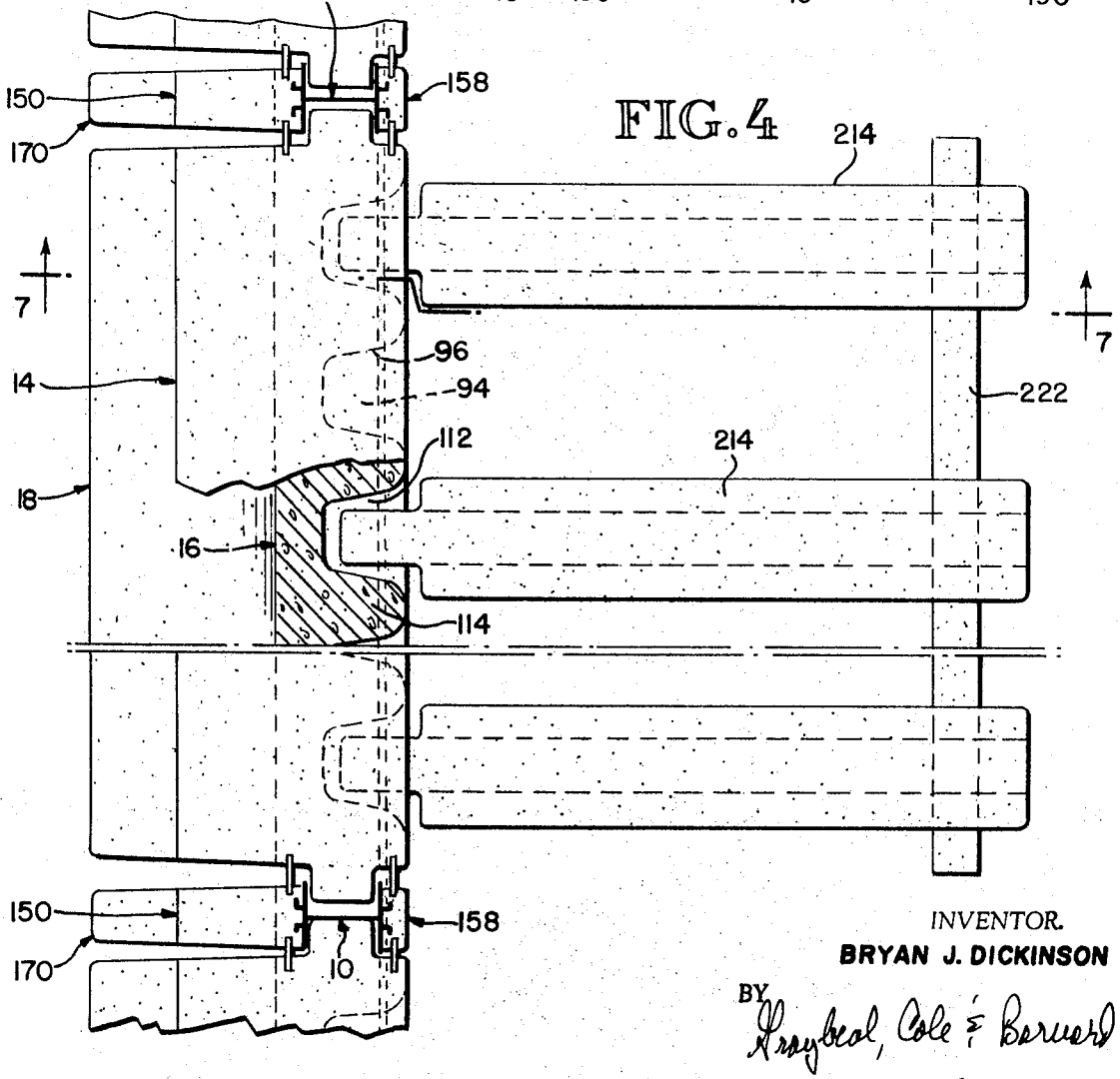


FIG. 4



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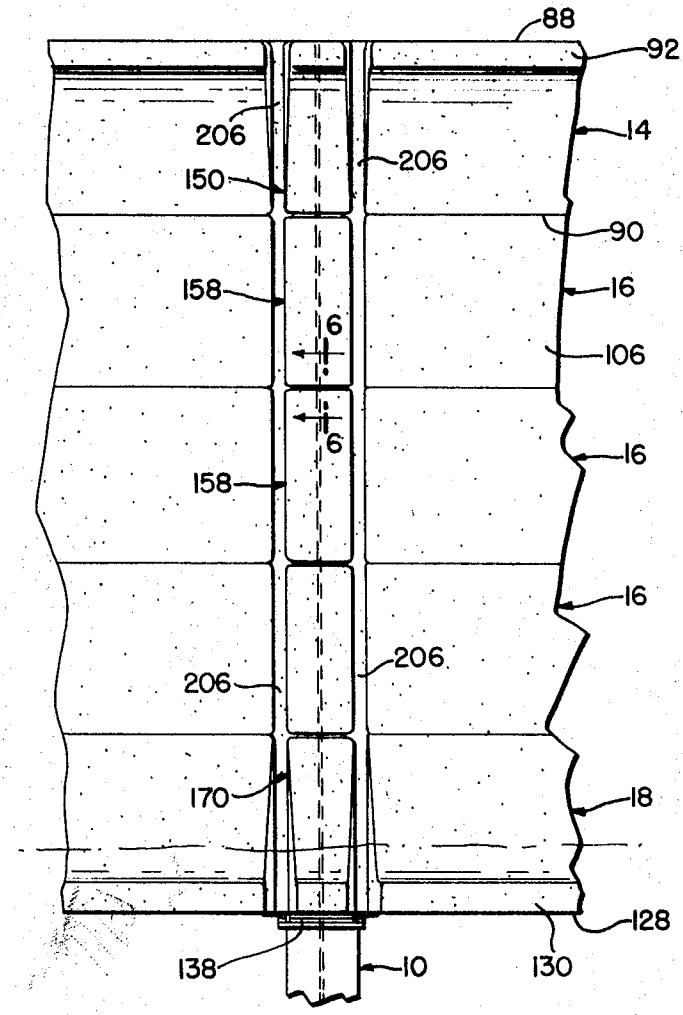


FIG. 5

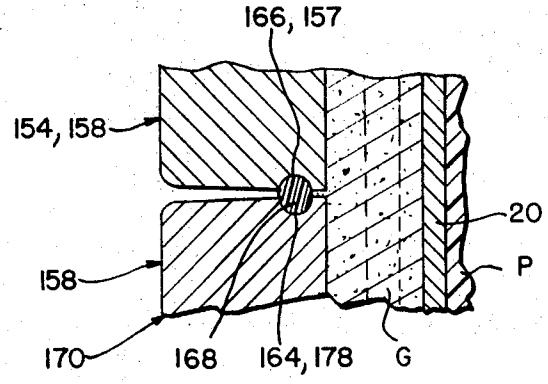


FIG. 6

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FIG. 7

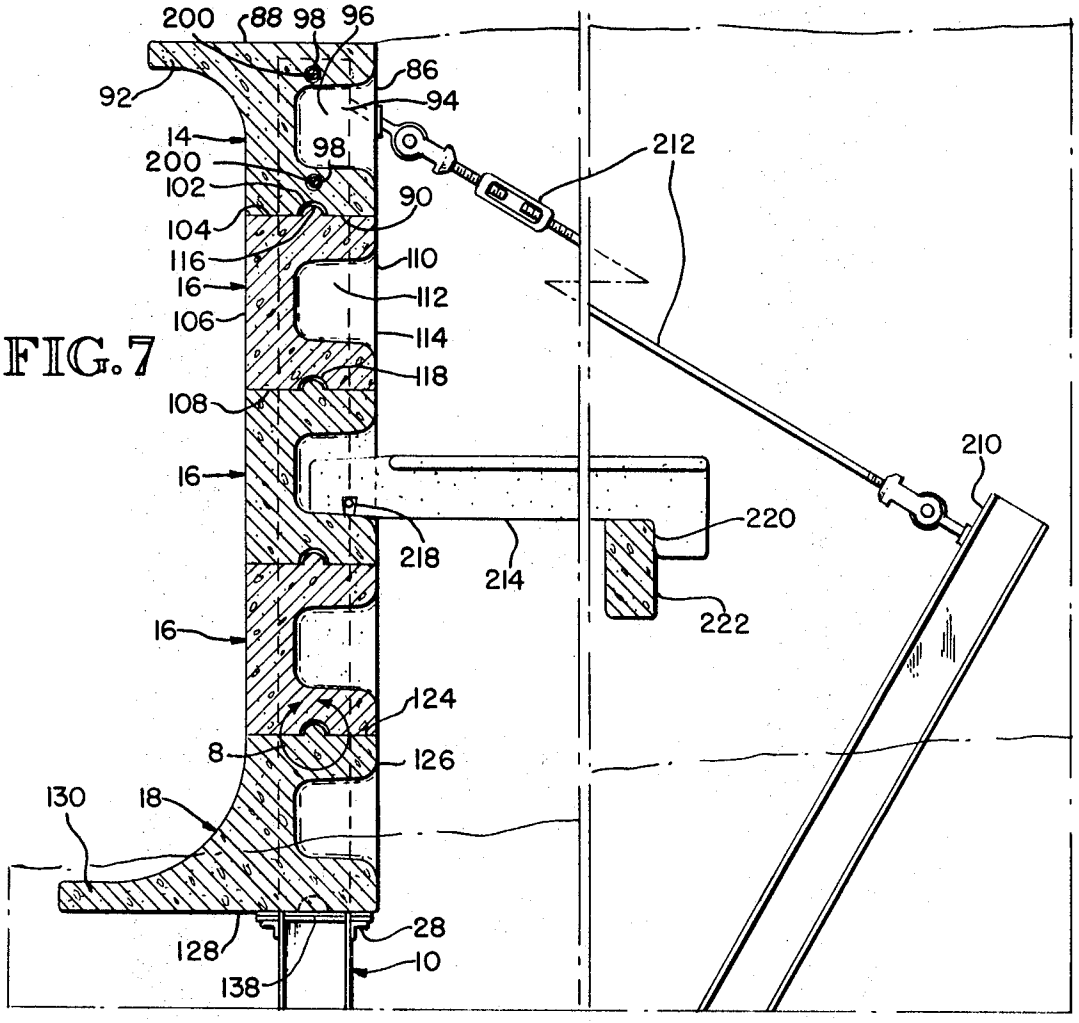


FIG. 8

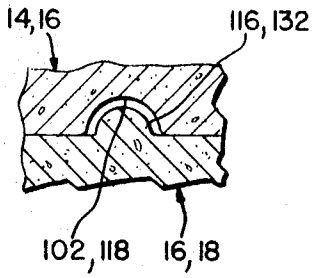
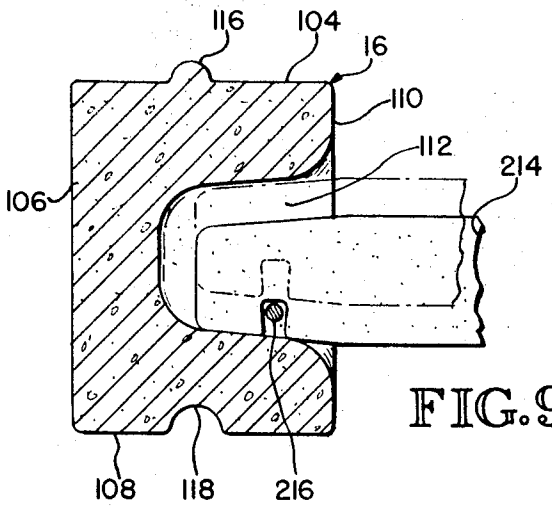


FIG. 9



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FIG. 10

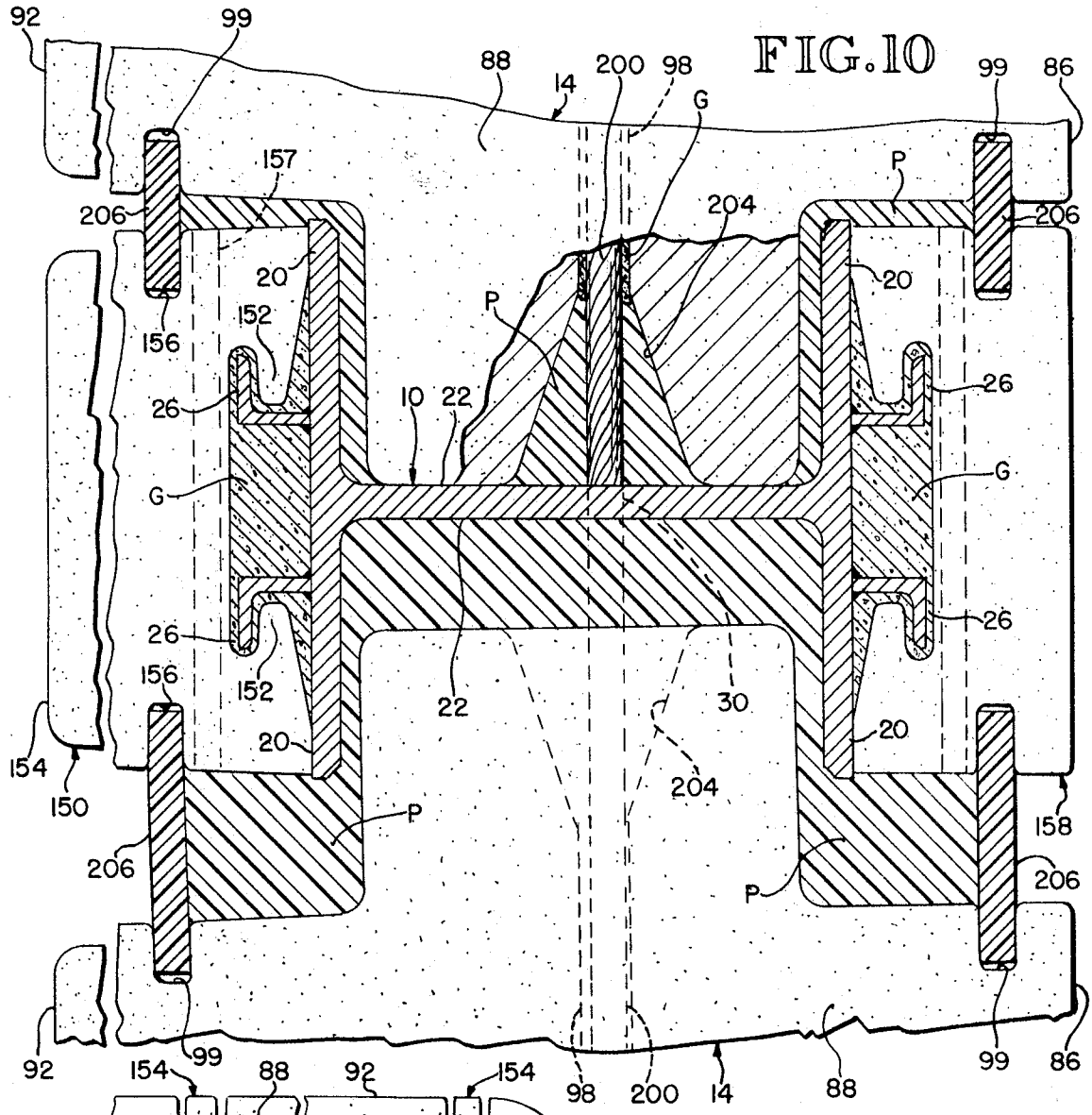
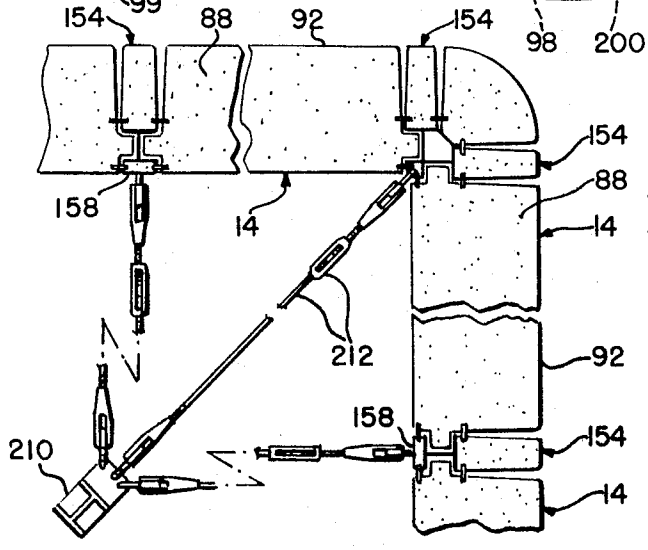


FIG. 11



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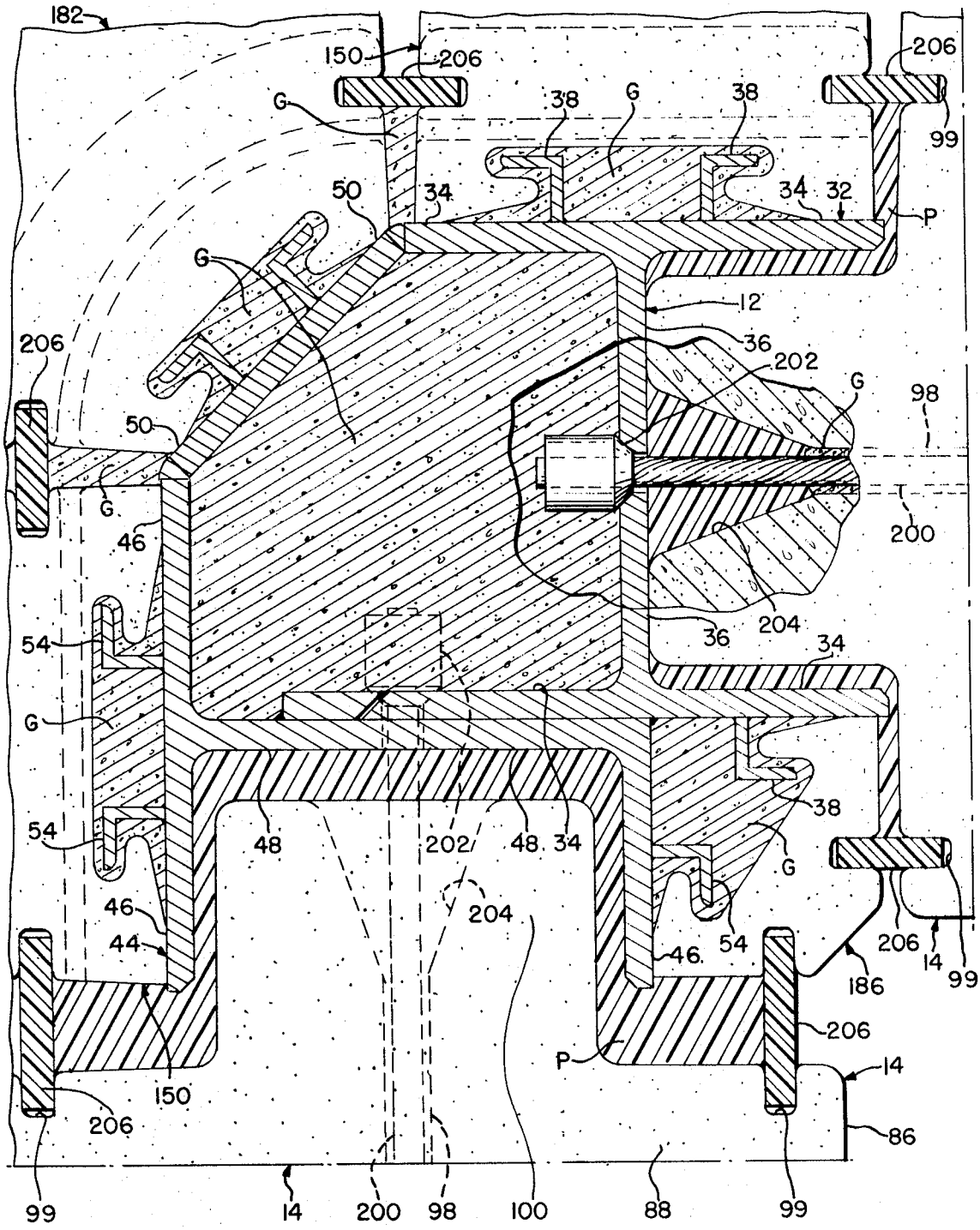


FIG. 12

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FIG.13

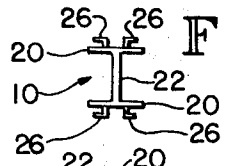


FIG.14

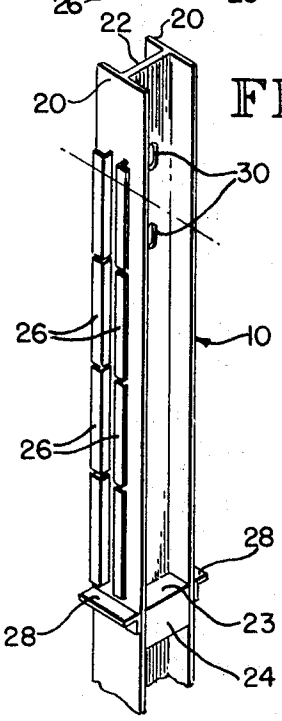
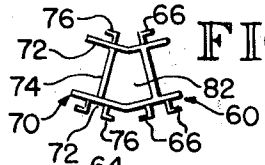


FIG.15



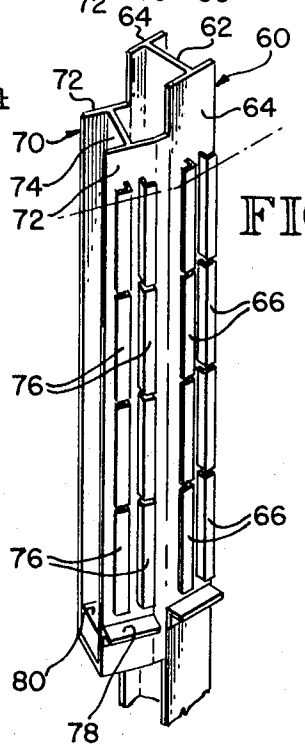


FIG.16

FIG.17

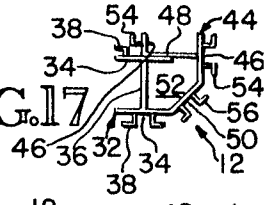


FIG.18

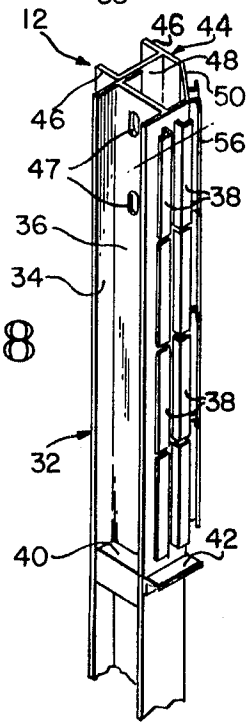


FIG.19

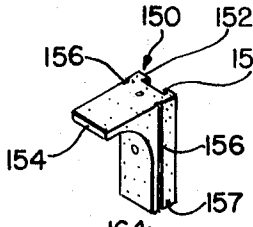


FIG.20

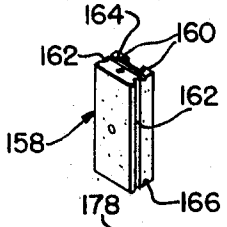


FIG.21

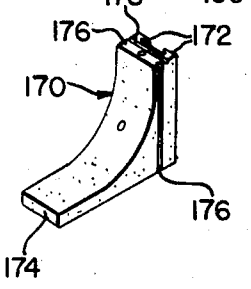
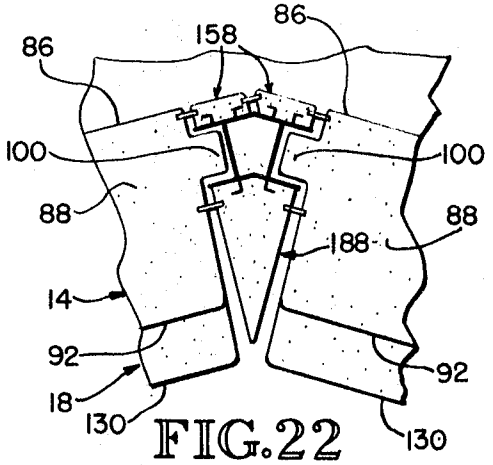


FIG.22



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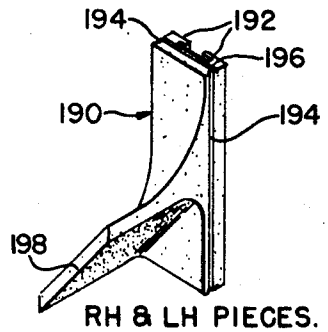
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SEA WALL CONSTRUCTION

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FIG. 23



RH & LH PIECES.
LH SHOWN

FIG. 24

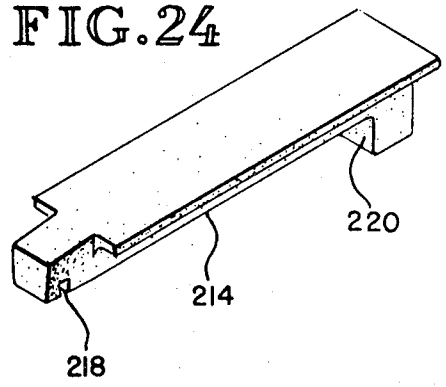


FIG. 25

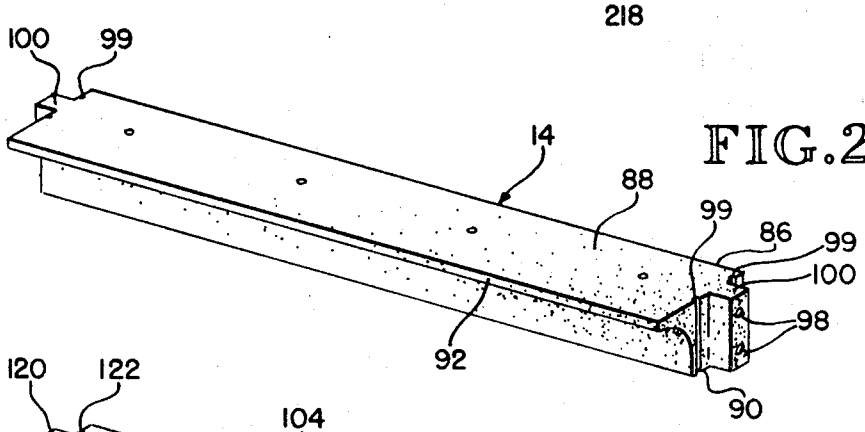


FIG. 26

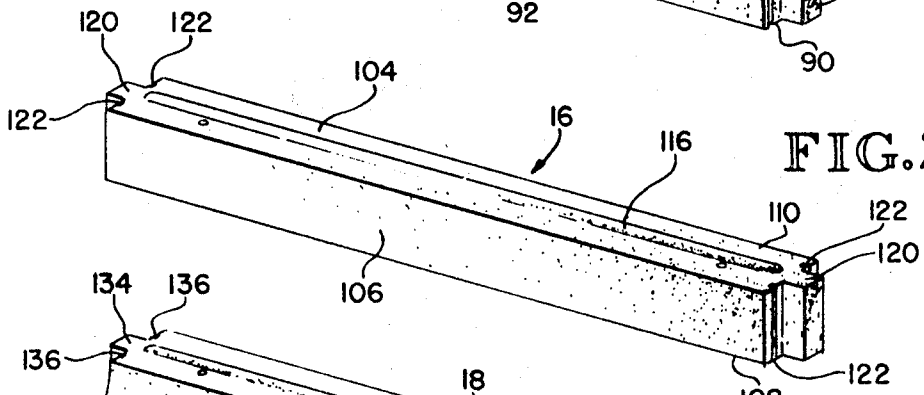
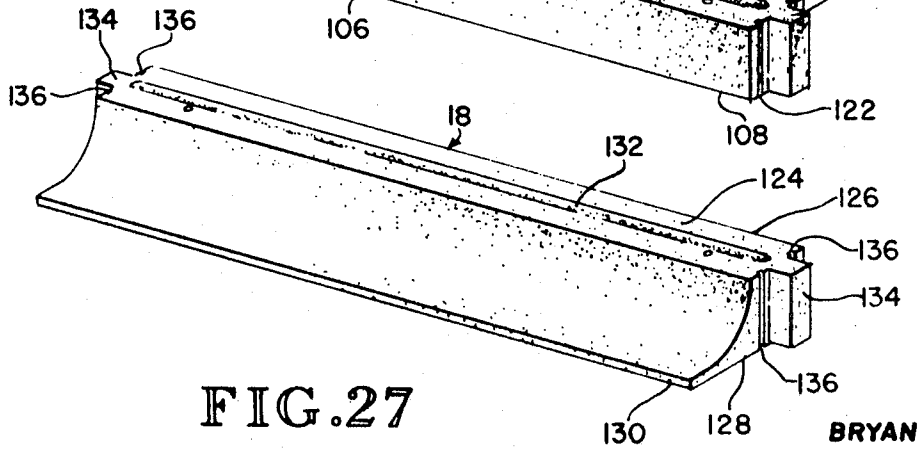


FIG. 27



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United States Patent Office 3,613,382 Patented Oct. 19, 1971

3,613,382

SEA WALL CONSTRUCTION

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Filed Aug. 6, 1969, Ser. No. 847,886
Int. Cl. E02b 3/08; E02d 5/00; E04b 2/08
U.S. Cl. 61—49 31 Claims

ABSTRACT OF THE DISCLOSURE

Modular sea wall structure utilizing steel beam bearing pilings between and on which are supported modular concrete block units. The pilings are driven as deeply as required to give firm support and the bottommost concrete block unit is positioned between and resting on two adjacent pilings at a preselected depth below or above the bottom surface. The top block is post-tensioned and the intermediate blocks are designed along with the other structural components to hold the geometry of the wall. All steel parts, namely, pilings and pretensioned cables, are sealed or isolated from the corrosive effects of water and air. Flexibility of movement is maintained between component parts such as blocks and pilings.

BACKGROUND OF INVENTION

This invention relates generally to the art of sea wall or breakwater construction and more specifically to a modular, flexible nonmonolithic sea wall structure made of steel pilings, and steel reinforced concrete block units.

All of the presently known sea wall or breakwater structures which are used to any extent have certain disadvantages. A riprap wall for instance employs a wide gravity supported base with the sides of the wall angling inwardly to the top. Materials for a riprap wall may not be available and it is not watertight. Its costs are high and because of the angling sidewalls it is not possible to tie a boat alongside. Sheet piling walls comprise metal sheets driven into the mud or bottom. The steel or metal is exposed to water and/or air corrosion making it costly to maintain within a very short period of time. Concrete walls normally are monolithic and accordingly lack flexibility. Such a structure will require a gravity supported base. A particularly large problem with concrete walls is the fact that the water must be evacuated by the use of coffer dams and pumps from the forms before any pours can be made. The high cost of in-place construction of a concrete wall renders such a structure normally not commercially feasible. Wooden pilings and planks are used but where the wood is wet most of the time, it can be destroyed by worms in as little as three years even with substantial creosote treatment prior to installation.

Often efforts to devise commercially feasible sea walls or breakwaters are found in the prior art. In general, such prior art walls have inherent disadvantages. They may be monolithic and thus lack the flexibility to adjust to stress concentrations from external forces. Other defects would include gravity support with expensive foundation footings, metal components which are not protected from corrosive effects of water and air, or the structure for some other reason is impractical.

SUMMARY OF INVENTION

The pilings of this invention are generally H-shaped steel beams driven at predetermined intervals for supporting steel reinforced precast modular concrete blocks. The pilings themselves are designed in such a way as to support the bottom of the sea wall above or below the surface of the mud or bottom at a predetermined level. Support of the precast blocks is not dependent upon a gravity based footing but rather on support means structured into the piling. The top blocks of the modular wall units are tied together with post-tensioned prestress cables and when needed one or all middle and bottom blocks can be post-stressed in the same manner as the top blocks. All steel piling and other steel components are isolated from air and water by a unique sealing and filler system in the joints between the blocks and the pilings. Both inside and outside exposed surfaces of the pilings are protected by inside and outside face pieces which are also tied into the sealing system between pilings and blocks. Filler material in the joint structure between parts moving relative to each other is nonhardenable.

Accordingly, it is among the many features of this invention to provide a sea wall which is flexible, as opposed to monolithic, making it more resistant to earthquake and seismic shock. The wall is flexible to a degree allowing blocks to move relative to blocks and relative to their supporting pilings. The pilings are tied together by post-tensioning prestress cables running through the top blocks. The post-tensioning need not be limited to the top blocks. The blocks are designed to permit a predetermined amount of relative movement both inwardly and outwardly and lengthwise of each other. Middle blocks act as a restraint against excessive movement of the pipes from the vertical. It is a tendency of the wall because of this restraint to resist distortion from square or rectangular geometry between any two adjacent pilings. The wall can be undermined and still stand because it does not rely on a footing or gravity support. The wall can be built to any height, or any length, and with a variable bottom line or top line to allow for variations in bottom and top line topography. The wall is fully capable of inside and outside corners of almost any angle. Clearance is provided between the ends of the concrete block modules and the adjacent webs of the H pile to permit longitudinal variations off a straight line if the piling should rotate during driving or if a gradual arc is desired. With the system based on a series of standard concrete modules of fixed length and design, it is possible to predesign and determine the exact number of various bearing piles and the exact number and types of the concrete modules necessary for a particular installation such as the typical structures demonstrated in the accompanying drawings. Accordingly, estimating the cost of a particular sea wall installation is more accurate. The components of the system can be manufactured at a fixed plant site and barged to the construction site. The modular, prefab construction saves greatly in labor and ultimate costs. No on-site forms either wooden or steel are required for an installation utilizing this system. The system is designed to be resistant to earthquake damage and as stated above constructed to be flexible within limits. In this way, the system resists backfill forces and pressures that will occur in different degrees along a breakwater or retaining wall creating stress concentrations that normally break rigid, nonflexible monolithic walls or breakwaters. The controlled flexibility of this system enables it to resist damage from high pressure concentrations that occur from heavy waves or waterborne objects such as deadheads, logs, floating watercraft or the like which may strike the wall in such a manner as to create localized high pressure stress concentrations. The wall can be constructed watertight or as a planned "weeping wall" as desired. The blocks can be placed to the exact desired elevation due to the shimming method of the bottom block. Seal strips between blocks and face pieces assist in retaining a nonhardenable filler in the joints and can flex without losing position by movement of the concrete modules and/or the H pile. Concrete anchor-back members may be employed as well as more conventional cables and turnbuckle tie-

backs. Damaged or cracked blocks or face pieces may be removed and replaced merely by putting a new block in place of the damaged block. The entire wall might, if desired, be later removed and relocated.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is an elevational view illustrating a proposed environmental type use for the sea wall and showing generally that the bottom line of the wall can be designed in accordance with the bottom topography;

FIG. 2 is a partial plan view of the environmental view of FIG. 1 illustrating in general how one form of tieback for the wall would appear;

FIG. 3 shows another environmental view in elevation and further illustrates how the sea wall may conform to the submerged land topography;

FIG. 4 is a partial plan view of the wall showing in greater detail one form of tieback to strengthen the wall against backfill forces on the wall;

FIG. 5 is a partial elevational view of a wall joint from the front or water side of the wall and further illustrating details thereof;

FIG. 6 is a partial cross-sectional view taken along the line **6—6** of FIG. 5 and which when taken in conjunction with other views shows details of a joint structure;

FIG. 7 is a partial cross-sectional view taken along the line **7—7** of FIG. 4 to show an elevational side view of the wall and illustrating details of construction;

FIG. 8 is a partial cross-sectional view of the tongue and groove interface between block modules as referenced by the partial section line **8** of FIG. 7;

FIG. 9 is a partial elevational cross-section view of a single block further illustrating details of one form of tieback from the wall;

FIG. 10 is a partial elevational cross-section view of a piling and block joint or seam illustrating details of construction;

FIG. 11 is a partial plan view of a form of tieback used for the wall as for instance at a corner;

FIG. 12 is a partial plan cross-section view of a corner or turn joint or seam in the wall and showing details of its construction and its similarity to the straight joint shown in FIG. 10;

FIGS. 13 and 14 taken together show a straight H piling with face plate mounting angles attached thereto, both views illustrating details of construction of a straight H piling;

FIGS. 15 and 16 taken together show a 30° angle type piling in plan and perspective illustrating details of construction;

FIGS. 17 and 18 show a 90° piling construction, reference being had to the more detailed illustration of a joint involving this piling in FIG. 12;

FIGS. 19, 20 and 21 show top, middle, and foot face pieces which are designed for mounting on the angle irons secured to the pilings and which assist to form the joints between blocks and pilings;

FIG. 22 shows for purposes of illustration a 30° inside turn of the wall as opposed to the outside turns illustrated by the pilings in FIGS. 13 through 18;

FIG. 23 shows a transition face piece as would be used to step the bottom wall lines illustrated in FIGS. 1 and 3;

FIG. 24 shows a perspective view of one form of modular anchor-back member construction as illustrated in FIGS. 7 and 9;

FIG. 25 shows a top modular block unit in perspective;

FIG. 26 shows an intermediate or middle modular block in perspective; and

FIG. 27 shows a modular foot block structure for use in the wall.

DESCRIPTION OF PREFERRED EMBODIMENTS

FIGS. 1, 2 and 3 illustrate a typical installation involving the present invention. As can be seen, the wall structure comprises generally straight vertical pilings

10, corner piling **12**, top blocks **14**, intermediate blocks **16**, foot blocks **18**, and piling face plates and other details which will be identified by reference numerals in subsequent views. Details of piling construction are best seen in FIGS. 13 through 18 in addition to FIGS. 10 and 12. It will be noted that a straight H piling (FIGS. 13 and 14) sometimes referred to as an I-beam, has flanges **20** and web **22** in accordance with standard design nomenclature. On each side of the web between the flanges will be welded an angle member having horizontal step leg **23** and vertical support leg **24**. The steps **23** on each side of the web will support the modular blocks which are shaped to have their ends extend into the area between the flanges on each side of the web for primary support of said blocks. It will be recognized that the block step on one side need not be positioned at the same level as the block step on the other side. The lower end of pile **10** is not shown because of space limitations in the drawings. It will be realized that total length of the piling will be the sum determined by how deeply the pile must be driven, that is, length below supporting step required to provide adequate foundation support plus the wall height above the step.

On the outer surface of each of the flanges will be located a series of angle irons **26** mounted back-to-back to form a hanging or holding device on which the face plates will be mounted. Angle irons **26** are attached by one leg to the flange surface so that the other leg extends outwardly and generally parallel to the flange as shown in the drawings. The angle irons will extend generally over substantially all of the length of the piling down to step **23**. Other methods of supporting the face pieces will be readily devised. In addition to block step **23** the piling will be provided on the outside of flanges **20** with plate steps **28** on which the bottommost face pieces will be supported. In addition, the piling will be provided with spaced holes **30** in web **22** near the top of the piling to allow the post-stress cables to pass through the pile. While the system preferably contemplates post-tensioned prestress cables running through the top block, it should be realized that all blocks could be post-tensioned in which event additional holes **30** would be provided in the piling web to permit passage of the stress cables through the system. It should also be mentioned that the angle irons welded as they are on the outer surfaces of the flanges increase the section modulus of the pilings to increase the strength properties of that portion of the piling which protrudes from the ground. It should also be pointed out that steps **23** on each side of the web may be placed at the same elevation in order to maintain a level or straight line bottom line, or they may be stepped one concrete modular height, or more, up or down, to allow the system to adjust for slopes or irregularities of the submerged ground topography as illustrated in FIGS. 1 and 3.

FIGS. 17 and 18 show a 90° turn piling which is also illustrated in greater detail in FIG. 12 to bring out details of the pile-block joints and the sealing features for protecting steel components form air and water. Thus when it is desired that a corner be accomplished in excess of the angle allowed by design clearances or tolerances provided between the flanges and the end of the concrete module, a section of H pilings may be welded to the driven H pile to accomplish the required angle. Thus 90° turn piling **12** as illustrated in FIGS. 17 and 18 will have driven piling section **32** with flanges **34**, a web **36**, and face plate support angle irons **38**. Said piling will have block support step **40** and face piece support step **42** consistent with the structures of FIGS. 13 and 14. There will be welded to the main driven H section **32** a partial or turn section **44** which is a modified H beam with part of one flange removed to permit its being joined to the section **32** in the manner shown. Thus, partial section **44** will extend from the top of the pile to the step level below which the main pile section **32** forms the only structure. The partial section H pile **44** will have half of one flange

46 removed to permit one flange 34 of section 32 to be welded to web 48 of section 44. A filler or spacing plate 50 is welded to edges of flange 46 of section 44 and flange 34 of section 32 to define an enclosed space 52 in the corner pile structure. Flanges 46 also support angle irons 54 and plate 50 supports angle irons 56. The cavity 52 between the sections 32 and 44 may be, but is not necessarily, closed at the lower end generally in the area of steps 42 and 40 for purposes which will be explained more completely hereinafter with reference to FIGS. 12. In like manner and to further illustrate the almost infinite range of angles at which the corners can be made, FIGS. 15 and 16 have been included. There it will be seen that main pile section 60 has web 62 and flanges 64 to which are attached face piece angle irons 66. A partial H pile section 70 with flanges 72 and web 74 is securely connected to main driven pile 60. The partial H pile section 70 will have angle irons 76 and face plate step 78 at the lower end of the flange and block support step 80 between the flanges. The two H beams joined together will form cavity 82 which may, but need not necessarily, be closed at the lower end. The main pile sections will normally be taller than the partial or turn sections since it will also be the driven section and the upper end will be damaged by the pile driver and have to be cut off. Note in this respect the dark dot lines in FIGS. 14, 16 and 18 which indicate approximately where the pile will be cut off after it is in position.

The design configuration of the main concrete blocks is best illustrated in a combination of FIGS. 4, 7, 9 and 25 through 27. The rear sides of the blocks as can best be seen in FIGS. 4, 7 and 9 are made with a series of cavities so that when a wall is assembled the back or fill side defines a waffled contact line with the back fill material. Thus top blocks 14 as best shown in FIG. 25 include a back surface 86, top surface 88, and bottom surface 90. The front of the top block is formed with a forwardly extending wave deflector 92 which is in effect an extension of top surface 88 of the block. This deflector causes water that has been deflected upwardly after striking the sea wall to be further deflected seaward. In this way the smallest amount of over-the-wall waves or splashing may occur. The back surface 86, as stated above, contains a series of cavities 94 and includes spaced vertical divider sections 96 which give the waffled appearance to the back of the wall. The purpose of the cavities and the waffle contact line with back fill, as shown in the combination of FIGS. 4, 7 and 9, is to prevent wedge separation between the wall and the back fill and to allow the weight of the back fill to rest in part on the concrete modules. It will be understood that the resultant line of force from the gravity weight of the back fill and possible pressures due to pressure sliding of the various parts of the back fill will cause resultant lines of force which will apply weight to the lower section of each cavity and thus each block. Additionally, the weight of each concrete module itself is reduced by the formation of cavities in the back wall and the reduction in weight is accomplished with a very minor loss of strength. The top module has vertically disposed seal strip cavities 99 on each side of sections 100 as seen in FIG. 25 for purposes which will be more fully explained hereinafter. Each of the top blocks 14 has the horizontally extending and protruding end support means 100 to be received between the flanges of the H piling. It will also be observed in FIGS. 7 and 8 that bottom surface 90 of the top block has an elongated groove 102 which extends along the length of the bottom surface of the module terminating a short distance from each end.

The intermediate or middle concrete modules 16 as seen in FIGS. 7, 9 and 26 are generally rectangular having top surface 104, front side 106, bottom surface 108, and back side surface 110. As with the top block, the middle module has a series of cavities 112 defined by a series of intermediate divider partition walls 114 as in FIGS. 7 and 9. Upper surface 104 has extending along most of the length thereof a tongue or ridge 116 and the bottom surface 108 has a groove 118. Where two blocks join, as for instance a top block with a middle block or a middle block with a foot block, the loose fitting tongue and groove joint will be provided. The groove in any pair of mating blocks however will be substantilly larger than its corresponding ridge or tongue as shown in FIG. 8 to provide a substantial gap or clearance. The groove will also be longer than the ridge or tongue. Thus a certain amount of forward and back shuffling or shifting between adjacent blocks is permitted. Likewise with the groove longer than the tongue there can be longitudinal shuffling or sliding movement between two blocks. The loose fitting tongue and groove joint between blocks shown in FIG. 8 not only permits the relative movement of adjacent blocks to the limits of the groove but enables seal means to be put in the tongue and groove if it is desired to make the wall watertight rather than weeping. Accordingly, if it is desired to make the wall watertight an elongated plastic seal means such as is shown in FIG. 6 could be disposed between the tongue and groove to seal the connection or joint line. Note that intermediate blocks 16 have protruding and support sections 120 to be received between the flanges of the H pilings. Note also that vertical seal grooves 122 are provided on the end surfaces for purposes which will be explained hereinafter.

Foot blocks 18 shown in FIGS. 5, 7 and 27 have top surface 124, rear surface line 126, bottom surface 128, and outwardly extending toe means 130 forming an extension of the bottom surface. The two extensions 130 of the foot block will normally be located a sufficient distance below the sand line or bottom as seen in FIGS. 3, 5 and 7 so that undermining of material from beneath the block would require a major drop in bottom line elevation or severe flow pressures beneath the wall. It will be noted that the toe of the foot block will divert water currents moving down the face of the sea wall to a horizontal or near horizontal direction, thereby diverting these forces seaward and minimizing their tendency to undermine the sea wall. In the case of a bulkhead placed above low tide line, the foot block toe will divert the incoming wave forces in an upward direction lowering the impact and also preventing undermining. Each of the foot blocks 18 will have extending along the length of upper surface 124 a ridge or tongue 132 to mate with the groove 118 on the adjacent middle block. Foot blocks will have end support sections 134 defined by offset surfaces to be received on the steps 23, 40 and 80 of the various pilings and to be received between the flanges of the H pile. The foot blocks are also provided with vertically extending seal strip grooves 136 on each end of the block and on each side of the protruding support portion 134. The foot block may be provided with a groove in its bottom surface such as is shown in FIG. 8 if other modules such as a middle block were placed under a foot block. Such a construction or combination of modules might be used to further protect against the blowout of oozy material below the toe.

FIGS. 5 and 7 show a typical wall construction and also show that shims may be used between the piling steps and the bottom blocks to achieve accurate leveling of the bottom block before the remainder of the blocks are lowered into place on top of the foot block. Thus, shims 138 can be used on top of the piling steps and also on top of the face piece steps to adjust the heights of the steps for inaccuracies of elevation if for instance the piling is overdriven. The shims for the bottom blocks may be of various thicknesses and can be fastened to the bottom ends of the bottom blocks before they are placed on the steps so as to allow underwater placement without any difficulty. The shims for the bottom face pieces likewise may be of various thicknesses and may be slid into place guided by the angle irons on the flanges of the poles. It may be desirable in some installations to elimintae the foot block and/or the top blocks. It should also be noted that the concrete modules can also be constructed with two or more parallel tongue and groove joints as shown

in FIG. 8 to accomplish greater strength of interlock or greater control of seepage if the joint is utilized as a water-weeping joint. As mentioned above, the tongue and groove joints may be sealed against water leakage by placing a plastic material strip to be squeezed into a seal in the gap between the tongue and groove. The clearance or gap in the tongue and groove joint allows a controlled amount of shifting or shuffling as may be necessary from time to time to adjust to forces or stresses. The foot blocks have a series of cavities on the rear side as in the other blocks.

The manner of protecting the exposed flange portions of the H pilings is demonstrated in numerous views of which FIGS. 19, 20 and 21 are illustrative. Essentially they are precast concrete face pieces **150**, **158**, **170** which occupy the vertical gaps between the main blocks and which cooperate with the structural modules **14**, **16**, **18** to support the joint sealing system to be described hereinafter. FIG. 19 for instance shows a top face piece for the water side of the wall which is placed on the H piling to coincide with the elevation of the main top structural module. Top face piece **150** has on the back side thereof cooperating L-shaped hanger sections **152** defining a slot which permits the top face piece **150** to slide over the angles welded to the outside faces of the piling flanges. Top face piece **150** will have an outwardly extending deflector portion **154**, vertical seal strip grooves **156** on each side, and horizontal seal strip groove **157** on the bottom end. The middle face piece **158** is also constructed and placed on the pilings to coincide in elevation with a corresponding middle block module. It has on the back side thereof cooperating L-shaped hanger sections **160** defining a slot which permits the face piece **158** to slide over the angles welded to the outside faces of the H pile flanges and also has vertical seal strip grooves **162** on each side. In addition it will include horizontal seal groove **164** on the top and horizontal seal groove **166** on the bottom so that horizontal seal strips **168** may be incorporated between face pieces. In this regard, see FIG. 6 for a slightly larger detail view. Reference to FIG. 10 for instance and top face piece **150** shows the seal line **157** mentioned above with respect to FIG. 19. Foot face piece **170** has on its back surface L-shaped hanger members **172**, outwardly extending toe section **174**, vertical seal grooves **176**, and top horizontal seal groove **178**. Where necessary a horizontal seal groove may be provided at the bottom of foot face piece **170**. The horizontal seal line is illustrated in both FIGS. 10 and 12 in dotted line as it extends through the face piece area of the wall. Face piece **158**, previously discussed as a middle face piece, is utilized as the protective covering of the steel H pile exposed flange face on the fill side in a manner similar to its use on the front or water side. Since the back side of the wall will not involve top and bottom face pieces **150** and **170**, face pieces **158** only can be used where special shapes are not required.

It will be appreciated that the face plates shown are merely representative of a great many forms or configurations which the various pieces may take in order to complete the wall structure. For instance, a right angle outside corner as shown in FIGS. 2 and 12 will have top face piece **182** and bottom or foot face piece **184**. FIG. 12 also will show a rear or fill side face piece **186** which must be specially formed to complete the wall structure. FIG. 22 illustrates that an outside face piece **188** may take a pie shape as shown in FIG. 22 because of the inside nature of the wall turn. Additionally where the bottom line of the wall is stepped as shown in FIGS. 1 and 3, a transition face piece **190** will be used such as is illustrated in FIGS. 1, 3 and 23. Transition face piece **190** has L-shaped hanger members **192**, vertical or side seal strip grooves **194** and a top horizontal seal strip groove **196**. In addition the transition face piece will have either a right or left hand outwardly extending step section **198**. The purpose of the step section is the same as with toe **130** in the main structural foot modules, that is to prevent undermining and loss of protective soil, mud or sand around the piling.

FIGS. 5, 6, 10 and 12 will be referred to in describing the joint structure which results in isolation and protection of the steel components. In the straight joint shown in FIG. 10, after the piles have been driven, modular units set in place, and face pieces attached to the pilings, the joint structure can be completed. Considerable dimensional tolerance can be permitted in center to center distances between H pilings to allow for inherent inaccuracies in placement of the pilings. Post-tensioned cables **200** in FIGS. 7, 10 and 12 extend through holes **98** in the top block and holes **30** and **47** in the pilings and are anchored by swages **202** at appropriate anchor pilings as in FIG. 12. Cables **200** may extend through a number of top blocks and pilings before being anchored in place as shown by swages **202** in FIG. 12. The cables may be prestressed to a high percentage of their yield strength as engineering practice may dictate. When the cables have been tensioned and the ends anchored, the holes **98** are pumped full of grout from grout connections as may be provided in a center cavity on the rear side of the modules up to the approximate points where the holes **98** will enlarge into cone areas **204** at each end of the top block and which cones **204** are cast into the block at the time of its manufacture. Those skilled in the art will understand that enlarging the end section of holes **98** in the form of cones **204** facilitates the threading of cables. The grout is permitted to harden and in this way it protects and seals the cable running through the top block up to approximately the inner end of each cone. Grouting the cable through most of the block length shortens the cable stretch area so that it becomes effective as an anchoring chain even though the cable may extend through a number of pilings and blocks before it is secured by a swage.

Long life neoprene seal strips **206** are inserted in the vertical seal grooves between blocks and face pieces. As mentioned above, grout is inserted in the negative areas between the hanger sections on the face pieces and the angle iron components on the flanges of the pilings. The horizontal seals **168** as shown in FIG. 6 between face blocks actually will serve as a secondary seal in the event the grout cracks to break the primary seal. Once the vertical seal strips **206** are in place, the cavities between the ends of the blocks and the pilings are filled with a non-hardenable permanently plastic material which may be mdae liquid by being heated prior to placing and which upon cooling becomes semifrigid yet flexible to form a permanent seal. Such permanently plastic material could be coal tar, asphalt, or a plastic such as certain epoxies. It will be noted that the plastic, designated by the letter P, is also injected into the cone area as well as into the voids between pilings and blocks. The seals **206** prevent any flow or migration of the plastic from between piles and blocks and face pieces.

It is believed that forces will occur from time to time from many sources, such as earthquakes, backfill pressures, wave impact pressures, large floating objects and so forth and therefore it is not economically feasible in most instances to build a wall of sufficient beam strength to avoid cracking at points of stress concentration. The instant wall has therefore been designed to allow flexibility at points of stress concentration which in the case of this design will be at the junction of the H pile in the ends of the concrete modules. In previous designs grout has been injected to protect steel piles and when the tensioned strength of the concrete grout was exceeded cracking would occur. It is clear that other design joints using grout would be rigid and that cracking would occur beginning from the tension side and breaking into the steel piling and exposing of the steel to the corrosive effects of water and oxygen. The cracking would in these prior designs, in a short time, continue through the entire concrete joint exposing the steel from either side of the sea wall or breakwater. In order to prevent exposure of the steel members a non-hardenable plastic material such as described above has been chosen for this invention. The

cavity formed by the placing of the flexible seal strips to enclose the end of the concrete modules and the ends of the blocks gives the wall a flexibility at the joints. Blocks can move relative to each other or relative to the pilings, as well as relative to face pieces.

The tongue and groove joints previously described with respect to the main structural units shown in FIGS. 25, 26 and 27 allow for some longitudinal shifting of modules if any external forces cause the pilings to change their alignment from vertical. Accordingly, by reference either to FIG. 1 or FIG. 3, it can be seen that if any two adjacent pilings shift from the vertical there would be formed a parallelogram which would require the modules to shift horizontally along their longitudinal axes. The ability to shift, within limits, allows the wall to adjust to forces greater than gravity forces and/or to back fill pressures thrusting in a horizontal direction. The restraint of movement is achieved when the tongue has moved the full groove width or the full groove length so that further shifting would force separation of the blocks. Before separation can occur, the forces must be sufficient to overcome the weight of all modules above the joint. The post-tensioned cables in the top blocks are attached and cannot shift horizontally or move upwardly vertically without transmitting the same force through the cables which tie all top blocks together. If a single piling is flexed by pressure of the back fill on the concrete modules, the bending will occur as a result of deformation within the elastic limits of the steel pile. The amount of force required to flex the piling will be in relation to its height above the sand line and its section modulus. Movement at the top of the piling will require stretching of those short sections of the prestressed cables which are not grouted within the adjacent concrete modules through the area of the cones. If a piling is twisted the plastic materials in the joint will permit the piling some amount of movement relative to adjacent modules. In short, it is the simple and compound movements on coordinate X–Y–Z axes which enable the wall to absorb ground wave seismic undulations. Cable stretch is minimal since the cables are grouted into the top modules after post tensioning. The wall is loose and moves modularly in any direction. The flexibility inherent in the wall structure allows for about a 5° turn per joint for assistance in keeping the wall straight or for forming large circles of small 5° turns.

An additional feature of the wall is the tieback capability shown in FIGS. 2, 7, 9, 11 and 24. One form of tieback is the conventional anchor post **210** and cable and turnbuckle assembly **212** attached to a piling as shown in FIG. 2. Alternatively, the depth of the effective retaining wall structure may be increased by an alternative form of tieback shown principally in FIGS. 7 and 9. In this instance a tie bar **214** can be made to engage a retaining rod **216** attached to the rear of a middle block and further designed to engage a retaining anchor means **222** running parallel to the wall and set back into the fill a desired distance. The tie back member **214** will have a groove **218** for engaging retaining rod **216** and an offset surface **220** for engaging the anchor means **222**. It is to be noted again that post stressed cables can be provided in all main blocks if desired or if extreme strengths are needed.

What is claimed is:

1. Nonmonolithic, flexing sea wall construction, comprising:

(a) a pair of spaced apart pilings each including supporting step means thereon,

(b) a plurality of generally vertically stacked pre-cast concrete blocks movably supported between said pilings by means permitting restrained shifting movement of the blocks relative to each other and the pilings, the bottom block being supported on said support step means and the remainder of said blocks being stacked on said bottom block, and

(c) post tensioned cable means extending through at least an upper one of said blocks and engaging said pilings.

2. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein abutting blocks are provided with coacting interlock means which allow abutting blocks to shift with respect to each other through a limited distance in more than one direction.

3. Nonmonolithic, flexing sea wall construction according to claim **2** and in which the interlock means comprises tongue and groove means, the groove of which is large with respect to the tongue to define a gap therebetween and permit movement between said abutting blocks.

4. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein said post tensioned cable means are grouted into said blocks over a substantial portion of the length of said blocks to limit the stretch area in said cable means substantially to the area between the ends of said blocks and adjacent pilings.

5. Nonmonolithic, flexing sea wall construction according to claim **1**, and wherein the back sides of said concrete blocks are provided with cavities so as to lighten said blocks and define a waffled contact line on the back side of said sea wall.

6. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein said step support means on which the bottom block is supported may be below, at or above ground level.

7. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein at least one of said pilings is provided with tieback means.

8. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein at least one of said modular concrete blocks is provided with anchor back means.

9. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein at least one of said pilings is provided with tieback means and at least one of said modular blocks is provided with anchor back means.

10. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein the bottommost block is provided on its front side with outwardly extending toe means.

11. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein the topmost block is provided with outwardly extending water deflector means.

12. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein said steel pilings are provided with flange means on each side of said support step means and extending upwardly therefrom generally to the top of said piling, said blocks being provided with end support sections extending between said flange means so that movement of said blocks relative to each other and to said pilings is in part limited by said piling means.

13. Nonmonolithic, flexing sea wall construction according to claim **12** and wherein a nonhardenable plastic material fills void areas between the ends of said blocks and said steel pilings to protect the steel pilings and cables from corrosion and to permit limited relative movement between said blocks and pilings.

14. Nonmonolithic, flexing sea wall construction according to claim **13** and wherein exposed flange areas of said steel pilings support and are covered by face piece means.

15. Nonmonolithic, flexing sea wall construction according to claim **14** and wherein generally vertically disposed seal means are provided between said face piece means and the ends of said concrete blocks to assist in confining said nonhardenable material generally to said area between said steel pilings and said concrete blocks.

16. Nonmonolithic, flexing sea wall construction according to claim **1** and wherein shim means are provided on said step means for accurate leveling of said wall.

17. In a nonmonolithic, flexing sea wall structure having steel pilings on which are supported the ends of modular block units, the joint structure comprising:

(a) face pieces attached to and protecting exposed portions of said pilings on front and back sides of the wall,

(b) seal means supported between said concrete blocks and said face pieces on said front and back sides of said wall to close off the area between the end of said blocks and said steel pilings,

(c) nonhardenable plastic material in said area between the ends of said blocks and said steel pilings to allow for limited relative movement between blocks and pilings and to seal exposed steel surfaces from air and water.

18. Nonmonolithic, flexing sea wall joint structure according to claim **17** and wherein said steel pilings are H-shaped having a web and flanges and wherein said steel piling supports said block units on at least one side of said web between said flanges.

19. Nonmonolithic, flexing sea wall joint structure of claim **18** and wherein said flanges are provided with hanger means on the outside surfaces thereof for supporting said face pieces.

20. Nonmonolithic, flexing sea wall joint structure of claim **19** and wherein said hanger means comprise L-shaped members with one leg secured to and extending outwardly of said flange and the other leg positioned generally parallel to said flange.

21. Nonmonolithic, flexing sea wall joint structure according to claim **19** and wherein said face piece members are supported on said hangers.

22. Nonmonolithic, flexing sea wall joint structure according to claim **21** and wherein hardenable material is inserted in the area between hangers, flanges and face pieces to seal off and protect exposed steel from corrosive elements such as air and water.

23. Nonmonolithic, flexing sea wall joint structure according to claim **22** and wherein horizontal seal means are disposed between vertically adjacent face pieces to assist in confining said hardenable material and to assist in isolating said steel from air and water.

24. Nonmonolithic, flexing sea wall structure according to claim **17** and wherein after said wall is constructed the cavities between the top of said pilings and the top surface of said top blocks is filled with nonhardenable plastic material.

25. A piling for supporting sea wall structure, comprising:

(a) an elongated structural steel member one end of which in use is driven into the ground to provide bearing beam support for other wall structure, said member having spaced apart flanges between which is received other wall structure;

(b) support step means located on said member between said flanges and at a predetermined level determining the bottom line of the supported wall structure,

(c) hanger means on the external surface of said flanges for supporting face pieces, and

(d) support step means for the face pieces are provided on said flanges generally at the level of the support step means located between said flanges for the supported wall structure.

26. The piling according to claim **25** and wherein said piling is H-shaped having a web and spaced apart flanges.

27. The piling according to claim **26** and wherein holes are provided in the web portion of said H pile above said step means for receiving post tensioned cables.

28. The piling according to claim **25** and wherein said hanger means comprises a series of generally vertically disposed L-shaped members one leg of which is secured to the external surface and extending outwardly of said flange and the other leg of which is disposed generally parallel to the surface of said flange.

29. The piling according to claim **28** and wherein said external surfaces of said flanges are provided with a double row of said L-shaped members, one leg of each being secured to said flange and extending generally outwardly from the flange parallel to each other and the other legs being parallel to the flange and extending away from each other.

30. The piling according to claim **25** and wherein shim means are provided on said flange step means for accurate leveling of face pieces to be supported on said hanger means.

31. The piling according to claim **25** and wherein a turn section piling is welded to said structural steel member at a predetermined angle of turn, said turn section also having spaced apart flanges, hanger means and step means, said turn section extending generally from about step level to about the top of said steel structural member.

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