PATENT SPECIFICATION (11) 1 568 429

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(21) Application No. 44842/77 (22) Filed 27 Oct. 1977

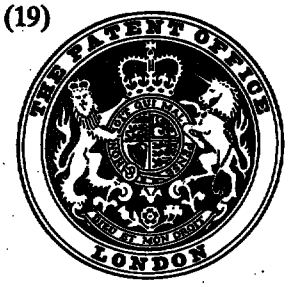
(44) Complete Specification Published 29 May 1980

(51) INT. CL.[3] E02B 3/06

(52) Index at Acceptance
E1H 740 B

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(19)



(54) IMPROVEMENTS IN OR RELATING TO BREAKWATERS

(71) We, IIDA KENSETSU KABUSHIKI KAISHA, a Japanese Corporation, of 15 - 25, Higashihie 2-chome, Hakata-ku, Fukuoka city, Japan, do hereby declare the invention for which we pray that a Patent may be granted to us, 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 breakwater which is capable of blocking a variety of waves having a wide range of wavelengths and is particularly applicable to a breakwater for a harbour wall.

It is common practice to define a dock or harbour, by a sea wall having a planar uniform vertical front surface and with such walls, an incident wave is reflected directly by the wall. Accordingly, the height of the wave in front of the wall becomes extremely large because of the overlap of the incident and the reflected waves, which is inconvenient for navigation of ships, loading, unloading, or the like. Furthermore, the impact of the wave against the wall is large.

A sea wall including a chamber with substantially vertical front and rear walls and with openings in the front wall has been proposed. However, such a wall has defects that the blocking ability is not enough against water including a variety of waves having a wide range of wave lengths.

In our copending application No. 44841/77 (Serial No. 1568428) there is described and claimed a breakwater comprising a back wall and a plurality of front walls in spaced apart relationship, said walls in use extending above and below water level, each front walls including openings therethrough, the total cross-sectional area of all the holes in each front wall decreasing from that front wall furthest from the back wall to the front wall nearest to the back wall.

The present invention seeks to provide a breakwater having effective blocking ability against a variety of waves having a wide range of wave lengths.

According to the present invention there is provided a breakwater comprising a front wall structure and a back wall spaced from the front wall structure and inclined to the front wall of said structure, the front wall structure including openings through which water can flow to and from the space between said back wall and said front wall structure, said walls being arranged, in use, to extend upwardly above and below the level of the water to be contained.

Thus the present invention is concerned with a breakwater structure having a particular relationship between the front wall structure and the rear wall.

Preferably the back wall slopes upwardly away from the front wall of the front wall structure.

Preferably the bottom of the front wall structure is spaced from the bottom of the rear wall.

In a preferred embodiment a roof connects the tops of the back wall and the front wall structure.

In a preferred embodiment the breakwater comprises a base, a perforated front wall structure upstanding from said base, a back wall upstanding from said base and having the same height as said front wall structure, and a roof slab connecting the top of said wall structure with the top of said back wall, said walls, in use, being intended to extend above and below the water level and said back wall being inclined upwardly and away from the front wall of the wall structure.

In one embodiment, the front wall structure consists of one, or at least one, vertical front wall.

Preferably the inclined back wall includes recessed surfaces and projecting surfaces alternating in the longitudinal direction of the wall.

Preferably the breakwater includes a plu-

rality of vertical partition walls, extending from the back wall to a wall in the front wall structure, spaced apart in the longitudinal direction of the breakwater.

In a preferred embodiment the front wall structure comprises a plurality of front walls which are separated from one another.

Preferably the front wall structure comprises two vertical front walls spaced apart to define a first chamber therebetween, and a second chamber between the second front wall and the back wall.

In one embodiment the transverse dimension of the first chamber is substantially the same as that of the second chamber and, in use, the upper part of the first chamber vents to the atmosphere via the holes in the first front wall, and the holes in the second front wall are all below the water level, whereby the upper part of the second chamber is isolated from atmosphere.

In relatively shallow water the base of the breakwater is conveniently seated on the sea bed but for deeper water the base may rest on, or be defined by, a base block on the water bottom.

Preferably the axes of the holes in each wall forming the front wall structure are off-set from the axes of the holes in the adjacent wall or walls whereupon, in use, water flows directly through the wall structure are avoided.

In one embodiment for a breakwater the base and roof are formed integral with the back wall and the front wall structure.

This invention will now be described further by way of example with reference to the accompanying drawings in which:-

Figure 1 is a transverse sectional view of one type of conventional sea wall,

Figure 2 graphically illustrates the blocking ability of a conventional sea wall of the type shown in Figure 1,

Figure 3 is a transverse sectional view of a breakwater according to the present invention;

Figure 4 is a sectional plan view of the breakwater of Figure 3 taken along the line IV-IV,

Figure 5 graphically illustrates the blocking ability of the breakwater shown in Figure 3;

Figure 6 is a transverse sectional view of a second embodiment for a breakwater according to the present invention,

Figure 7 is a transverse sectional view of a third embodiment for a breakwater according to the present invention,

Figure 8 is a transverse sectional view of a fourth embodiment for a breakwater according to the present invention,

Figure 9 is a transverse sectional view of a fifth embodiment for a breakwater according to the present invention,

Figure 10 is a sectional plan view of the breakwater of Figure 9 taken along the line X - X,

Figure 11 is a transverse sectional view of a sixth embodiment for a breakwater according to the present invention,

Figure 12 is a sectional plan view of the breakwater of Figure 11 taken along the line XII - XII,

Figure 13 is a transverse sectional view of a seventh embodiment for a breakwater according to the present invention,

Figure 14 is a sectional plan view of the breakwater of Figure 13 taken along the line XIV - XIV,

Figure 15 is a transverse sectional view of a still further embodiment for a breakwater according to the present invention, and

Figure 16 is a sectional view of the breakwater of Figure 15 taken along the line XVI - XVI.

Referring first to a conventional sea wall illustrated in Figure 1, the sea wall comprises a base 1 set on the sea bottom, an impermeable back wall 2 standing vertically on the base 1, its top end being higher than the water level W, a front wall 3, having a plurality of holes 5, which stands vertically on the base 1 at a certain distance ℓ from the back wall 2 and which has the same height as the back wall 2, and a roof slab 6 which extends horizontally from the top end of the back wall 2 to the top of the front wall 3. The walls 2 and 3, bottom 1 and roof slab 6 define a chamber 4 the upper part of which chamber contains air and vents to the atmosphere via holes 5 and the lower part of which chamber is under the water level W and is filled with water via holes 5.

When a wave-crest arrives at the front wall 3, as shown in Figure 1, the water level infront of the front wall 3 rises and the water rushes into the chamber 4 through the holes 5 of the front wall 3 according to the relative water level difference between the chamber 4 and the water in front of the front wall.

Then the energy of the wave is partly converted into energy of vortices A generated at the holes 5.

When the water level in the chamber 4 rises after the half period point of the wave, and the exterior water level drops, as shown in Figure 1 by two-dotted lines, the water in the chamber 4 rushes out of the chamber 4 through the holes 5, and more of the wave energy is converted into energy of the vortices A' generated at the holes 5.

Thereby the wave is blocked by the sea wall.

The amount of the energy loss of the wave due to the vortices A and A' is in proportion to the cube of the water flow speed through the holes 5. The blocking ability against the wave relates to the thickness b of the front wall 3, the diameter d of the holes 5, the ratio V of the total cross-sectional area of

the holes to the area of the front wall 3, and the width ℓ of the chamber 4.

To obtain the maximum blocking ability, that is, to minimize the height of the reflected wave, we find that the best results are obtained when the diameter d of the holes 5 is roughly the same as the wave height H_i, i.e., $d \sim H_i$, that the ratio V of the total cross sectional area of the holes to the area of front wall 3 is in a range of 20% - 35%, that the thickness b of the front wall 3 is in a range of 20% - 40% of the water depth h and the whole width X, which is the sum of the width ℓ of the chamber 4 and the thickness b of the front wall 3, is approximately 15% of the wave length L.

In view of this, if a sea wall is designed with the fixed width X, and the reflectively K_r, i.e. ratio of reflected wave height to incident wave height, is measured for waves of various wave lengths and is plotted on a graph with the reflectively K_r along the horizontal axis and the ratio X / L along the vertical axis, a graph as shown in Figure 2 results.

From this graph, it is readily understood that the reflectivity K_r is minimum when X / L is approximately 0.15. Considering that the reflectivity K_r of 0.3 or less is sufficient to obtain a desirably calm state of the water, such a sea wall exhibits remarkably good blocking ability against waves of which the wave length L is approximately X / L 0.15.

However, the range of wave lengths against which blocking ability is good is rather narrow. When the wave length becomes shorter or longer than the above-mentioned value, the reflectivity K_r increases abruptly. Consequently, it appears that the blocking ability of the conventional sea wall is not enough against a variety of waves having a wide range of wave lengths.

Referring to Figures 3 and 4 of the drawings, there is shown a breakwater including a back wall 12 which inclines at an angle α away from the sea, so that its upper part is farther from the sea than its lower part, on a base 11 on the sea bottom. The back wall 12 rises above the water level W.

A first front wall 14 and a second front wall 15, situated behind, spaced from, and parallel to the first front wall 14, stand vertically on the base 11 in front of the inclined back wall 12 and have the same height as the inclined back wall 12.

The top ends of both the first and the second front walls 14 and 15 are integrally connected by a roof slab 16.

The first front wall 14 and the second front wall 15 have a plurality of circular holes 20 and 19 respectively, which are uniformly distributed and whose axes are horizontal. The diameter d_1 of the holes 20 is larger than the diameter d_2 of the holes 19. The axes of the holes 20 are off-set to the axes of holes 19.

The shape of the holes 19 and 20 might also, in an alternative embodiment of the present invention, be polygonal.

The thickness b_1 of the first front wall 14 is larger than the thickness b_2 of the second front wall 15.

A first chamber 17 is defined by the first and the second front walls 14 and 15, the base 11 and the roof slab 16, and a second chamber 18 is defined by the second front wall 15, the inclined back wall 12, the base 11, and the roof slab 16, as shown in Figure 3.

The upper part of each of the first and the second chambers 17 and 18 is air-filled and vents to the atmosphere via the holes 14 and 15 and the lower part of each of the chambers 17 and 18 is water-filled and open to the water via the holes 19 and 20.

The width ℓ of the second chamber 18 is larger then the width b_0 of the first chamber 17, and, for example, may be several times larger.

The widths ℓ and b_0 of the first and the second chambers, the thicknesses b_1 and b_2 of the first and the second front walls and the diameters d_1 and d_2 of the holes of the first and the second front walls, mentioned above, may be changed as occasion demands.

When the wave-crest arrives at the first front wall 14, as shown in Figure 3, the water level before the first front wall 14 rises. Thus, the water rushes into the first chamber 17 through the holes 20 according to the water level difference between the first chamber 17 and the water in front of the first front wall 14. Then the water in the first chamber 17 rushes into the second chamber 18 through the holes 19. The wave energy is partly dissipated into the vortices generated at the holes 19 and 20. The water further rushes against the inclined back wall 12 and vortices turning downwards are generated according to the difference of the upper and the lower water flow speeds since the back wall inclines and the water flow speed is the highest in the upper part of the water and decreases gradually as the depth increases. Thus, the energy of the wave is further partly converted into energy of the vortices in this chamber.

When the water level in the second chamber 18 rises after the half period point of the wave, and the exterior water level drops, as shown in Figure 3 by a two-dotted line, the wave-trough arrives at the first front wall 14. The water rushes out of the second chamber 18 to the first chamber 17 through the holes 19 and then out of the first chamber 17 to the outside through the holes 20. The wave is further weakened by the vortices generated at the holes 19 and 20.

As described above, the wave is de-

energised by the vortices generated at both the sides of the first and the second front walls 14 and 15, and thereby the wave is blocked by the breakwater. Furthermore, since the holes 19 and 20 are arranged so that none of them have a common axis, the breakwater blocks a variety of waves having a wide range of wave lengths.

The inclined back wall 12 promotes the generation of vortices adjacent to the back wall 12 in the second chamber 18 and minimizes the influence of the bank pressure against the sea wall.

The measured reflectivity of the sea wall shown in Figures 3 and 4 is shown in Figure 5 in the same manner as Figure 2.

It is readily understood from Figure 5 compared with Figure 2 that the breakwater of the present invention exhibits good blocking ability not only to waves having a short wave length but also to waves having a long wave length, and its application range is much wider than that of the conventional sea wall.

That is, considering a wave having a short wave length, as apparent from Figure 5, the reflectivity K_r does not increase much and remains within a range of 0.1 - 0.2. The reflectivity K_r is generally low with respect to X / L. Consequently, it is apparent that the breakwater of the present invention has a superior blocking ability as compared with Figure 2.

On the other hand, considering a wave having a long wave length, the first and the second front walls act as a single wall having the width $b = b_0 + b_1 + b_2$ against the wave and exhibit the minimum value of the reflectivity K_r when X / L is equal to 0.12.

Accordingly, the whole width X is approximately 12% of the wave length L. The breakwater which has a shorter whole width ($X \approx 0.12$ L) than that ($X = 0.15$ L) of the conventional sea wall having a single front wall exhibits sufficient blocking ability.

Further, in the conventional sea wall having a single front wall, the energy loss is caused by the vortices generated at both sides of the front wall.

However, in the breakwater of the present invention having two front walls, the energy loss is caused by the vortices generated at both sides of both the front walls. Hence, both the thicknesses b_1 and b_2 of the first and the second front walls 14 and 15 can be formed thinner than a conventional sea wall.

From this fact, it becomes possible to reduce the amount of the material to be used for the breakwater and the weight of the same as compared with the conventional sea wall.

However, the weight reduction of the breakwater generally causes a strength drop for supporting the breakwater against the bank pressure. In the present invention this is overcome by inclining the back wall at an angle α away from the sea as described above, thereby minimising the influence of bank pressure.

For example, assuming that the angle α of inclination is 60°, the bank pressure is decreased by 40% as compared with a vertical back wall.

The width ℓ of the second chamber 18 is substantially shortened by inclining the back wall 12. However, this does not reduce the blocking ability of the breakwater. The reason is as follows: As described above, the breakwater exhibits the maximum blocking ability when the whole width X is equal to 0.12 L, in which the whole width X is measured at the calm water level, as shown in Figure 3.

The closer to the water surface, the faster the horizontal water flow speed in the second chamber 18 becomes, as described above. Hence, considering now a breakwater having a vertical back wall, vortices turning counterclockwise around the horizontal axis, as illustrated in the figure, are generated in the central upper part of the second chamber. But the lower water adjacent to the back wall does not contribute to generating the vortices which dissipate the energy of the wave. Accordingly, even if this non-contributory portion is removed by inclining the back wall away from the sea, the blocking ability of the breakwater does not change or decrease.

Referring to Figure 6, there is shown another breakwater according to the present invention.

In this case, the thickness of the second front wall 15 is in a range of 1/3 to 1/4 of that of the first front wall 14 and the ratio V of the second front wall 15 is in a range of 1/3 to 1/4 of that of the first front wall 14. The width of the first chamber 17 is almost the same as the second chamber 18. The holes 19 of the second front wall 15 are formed only at its lower part under the water level. The second chamber 18 does not vent to the atmosphere and its only exit is to the water of the first chamber 17 via the holes 19. Since the second chamber 18 is closed to the atmosphere, the air existing in the upper part of the second chamber 18 acts as a damper when the water comes in or goes out. Accordingly, the resistance the water undergoes is quite large and the energy loss of the wave is extremely large.

That is, when a wave having a wave length of $L_1 = X_1 / 0.12$ relative to the width X_1 which is from the first front wall 14 to the back wall 12 is incident, in accordance with the long wave length the water flows freely through the holes 19 of the second front wall 15 and the second chamber 18 exhibits the same extent of blocking ability as a break-

water including no second front wall.

On the other hand, when a wave having a wave length of $L_2 = X_2 / 0.12$ relative to the width X_2 which is from the first front wall 14 to the second front wall 15 is incident, according to the short wave length, the second front wall 15 exhibits a large resistance to the water flow, i.e. a similar action to a wall including no openings. Therefore, against such a wave having a short period, this breakwater exhibits the blocking ability of a breakwater having a whole width of X_2.

To block waves having a range of wave lengths from L_1 to L_2, a sea wall having uniform blocking ability over the range is provided by forming the first and the second front walls so that X_1 is approximately equal to $0.12\ L_1$ and X_2 is approximately equal to $0.12\ L_2$. For instance, when the water depth h is 8 meters, L_1 is 84 meters and L_2 is approximately 35 meters, to block waves having a period of 5 - 10 seconds. Thus, assuming that X_1 is approximately 10 meters and X_2 is approximately 4.2 meters, a breakwater which exhibits uniform blocking ability ($K_r = 0.1 - 0.2$) against such waves is constructed.

Referring to Figure 7, there is shown another breakwater according to the present invention.

The breakwater is constructed on a base block 40 having height h_2 formed on the foundation of the sea bottom.

The depth h_1 under the water level of the sea wall is greater than or equal to 30% of the sea depth h.

The base block 40 constitutes a wall for supporting the bank 13 together with the breakwater.

The breakwater is the same as the one shown in Figure 3 except that the upper part of the back wall 12 which inclines at an angle β with respect to the vertical away from the sea, bends frontwards at an angle γ with respect to the vertical at the water level.

The vertical front surface of the base block 40 is in the same plane as the vertical front surface of the first front wall 14.

In this case, since the breakwater is constructed on the base block 40, it is very easy to build the breakwater in comparison with one constructed directly on the sea bottom. Further, part of the bank pressure is supported by the base block 40 and the breakwater together with the base block 40 constitutes a rigid wall against the bank pressure.

This breakwater is conveniently constructed at a place where the water is deep.

In Figure 8 there is shown another breakwater according to the present invention. This breakwater has the same construction as the one shown in Figure 3 except that the second front wall 15 inclines at an angle δ away from the sea, so that its upper part is closer to the back wall than its lower part. It is apparent that the same results may be obtained as with the breakwater shown in Figure 3.

In addition, when the wavecrest arrives at the first front wall 14, the water rushes into the first chamber 17 through the holes 20 and then strikes against the second front wall 15. Since the second front wall 15 inclines, and the water pressure P acts perpendicular to it, the horizontal component P' of the pressure P is equal to P sin δ and the vertical component P'' of the pressure P is equal to P cos δ. The vertical component P'' contributes to the stability of the breakwater.

Referring to Figures 9 and 10, there is shown even yet another breakwater according to the present invention.

This breakwater comprises an inclined back wall 22, on a base 21, which presents a surface of the water defined by recessed surfaces 22*a* and projecting surfaces 22*b* a alternating in the horizontal direction and wall 22 has a greater height than the water level W. The breakwater further includes a front wall 24, with a plurality of holes 30, which stands vertically on the base 21 at a distance from the back wall 22 and which has the same height as the back wall 22, a support slab 26 which projects horizontally frontwards from the top end of the back wall 22 and which is integrally connected to the top end of the front wall 24, and a chamber 28 between the back wall 22 and the front wall 24.

The upper part of the chamber 28 vents to the atmosphere and the lower part of the same leads to the sea water via the holes 30.

The width l of the chamber 28 is the distance from the rear surface of the front wall 24 to the mid plane between surfaces 22*a* and 22*b* at water level.

The widths m and m' of the surfaces 22*b* and 22*a* respectively and the projecting distance n of the surfaces 22*b* forward of surfaces 22*a* may be varied.

The wave is blocked by the breakwater in the same manner as described above.

The indented back wall 22 promotes the generation of vortices in the chamber 28.

In Figures 11 and 12 there is shown another breakwater according to the present invention.

This breakwater is the same as the one shown in Figure 3 with the exception that the inclined back wall has alternate surfaces 22*a* and surfaces 22*b* as described with respect to the embodiment of Figures 9 and 10.

The results described with respect to the embodiment shown in Figures 9 and 10 can be obtained as hereinbefore described.

Referring to Figures 13 and 14 there is shown another breakwater according to the

present invention.

This breakwater comprises an inclined back wall 32 on a base 31, its top end being higher than the water level, a front wall 34 with a plurality of holes 40 which stands vertically on the base 31 at a distance from the back wall 32 and which has the same height as the back wall 32, a support slab 36 which projects horizontally frontwards from the top end of the back wall 32 and which is connected to the top end of the front wall 34, a chamber 38 between the back wall 32 and the front wall 34, and a plurality of vertical partition walls 41 which cross transversely the whole width of the breakwater at certain intervals in the longitudinal direction.

The upper part of the chamber 38 vents to the atmosphere and the lower part of the same leads to the sea through the holes 40.

The wave is blocked by the breakwater in the same manner as described above, when the incident wave is perpendicular to the breakwater, i.e. the front wall 34.

Further, when a wave incident at an acute angle such as shown in Figure 14 by an arrow *a*, or a parallel wave such as shown in Figure 14 by an arrow *b*, is incident upon the breakwater, the water surface before the breakwater repeats up and down alternately by the passing wave since the chamber 38 is separated by the partition walls 41 into compartments in the longitudinal direction. The waves are blocked by the breakwater in the same way as the perpendicularly incident waves, due to the provision of the partitions, since water cannot flow from one compartment to the next, although their oscillations are out of phase with one another. It is apparent that an inclined-angle incident wave and a parallel incident wave as well as a perpendicularly incident wave are blocked by the breakwater of the present invention.

In Figures 15 and 16 there is shown still another breakwater according to the present invention.

This breakwater has the same construction as the one shown in Figure 3 except for the addition of a plurality of vertical partition walls 41 which cross transversely the whole width of the breakwater at certain intervals in the longitudinal direction.

The same results are obtained as described above.

An inclined incident wave shown by an arrow *a* and a parallel incident wave shown by an arrow *b* as shown in Figure 16, as well as a perpendicularly incident wave, are blocked by the breakwater of this preferred embodiment of the present invention in the same way as described above.

It is readily understood as described hereinbefore that a variety of waves having a wide range of wavelengths are blocked by the breakwater according to the present invention.

The breakwater of the present invention may be constructed from prefabricated blocks, or the breakwater may be of monolithic construction made, for example, by a continuous concrete pouring system.

Further, although the present invention has been described with particular reference to a sea wall the invention is not limited thereto and it should be understood that the invention can be applied to any kind of breakwater where reduced wave impact is required.

WHAT WE CLAIM IS:-

1. A breakwater comprising a front wall structure and a back wall spaced from the front wall structure and inclined to the front wall of said structure the front wall structure including openings through which water can flow to and from the space between said back wall and said front wall structure, said walls being arranged, in use, to extend above and below the level of the water to be contained.

2. A breakwater as claimed in Claim 1 in which the back wall slopes upwardly away from the front wall of the front wall structure.

3. A breakwater as claimed in Claim 1 or 2 in which the bottom of the front wall structure is spaced from the bottom of the rear wall.

4. A breakwater as claimed in Claim 1, 2 or 3 in which a roof connects the tops of the back wall and the front wall structure.

5. A breakwater comprising a base, a perforated front wall structure upstanding from said base, a back wall upstanding from said base and having the same height as said front wall structure, and a roof slab connecting the top of said wall structure with the top of said back wall, said walls, in use, being intended to extend above and below the water level and said back wall being inclined upwardly and away from the front wall of the structure.

6. A breakwater as claimed in Claim 1, 2, 3, 4 or 5, wherein the front wall structure consists of one or at least one vertical front wall.

7. A breakwater as claimed in Claim 1, 2, 3, 4, 5 or 6, wherein the inclined back wall includes recessed surfaces and projecting surfaces alternating in the longitudinal direction of the wall.

8. A breakwater as claimed in any one of Claims 1 to 6 inclusive further including a plurality of vertical partition walls extending from the back wall to a wall on the front wall structure, spaced apart in the longitudinal direction of the breakwater.

9. A breakwater as claimed in any preceding claim, wherein the front wall structure comprises a plurality of front walls

present invention.

This breakwater comprises an inclined back wall 32 on a base 31, its top end being higher than the water level, a front wall 34 with a plurality of holes 40 which stands vertically on the base 31 at a distance from the back wall 32 and which has the same height as the back wall 32, a support slab 36 which projects horizontally frontwards from the top end of the back wall 32 and which is connected to the top end of the front wall 34, a chamber 38 between the back wall 32 and the front wall 34, and a plurality of vertical partition walls 41 which cross transversely the whole width of the breakwater at certain intervals in the longitudinal direction.

The upper part of the chamber 38 vents to the atmosphere and the lower part of the same leads to the sea through the holes 40.

The wave is blocked by the breakwater in the same manner as described above, when the incident wave is perpendicular to the breakwater, i.e. the front wall 34.

Further, when a wave incident at an acute angle such as shown in Figure 14 by an arrow *a*, or a parallel wave such as shown in Figure 14 by an arrow *b*, is incident upon the breakwater, the water surface before the breakwater repeats up and down alternately by the passing wave since the chamber 38 is separated by the partition walls 41 into compartments in the longitudinal direction. The waves are blocked by the breakwater in the same way as the perpendicularly incident waves, due to the provision of the partitions, since water cannot flow from one compartment to the next, although their oscillations are out of phase with one another. It is apparent that an inclined-angle incident wave and a parallel incident wave as well as a perpendicularly incident wave are blocked by the breakwater of the present invention.

In Figures 15 and 16 there is shown still another breakwater according to the present invention.

This breakwater has the same construction as the one shown in Figure 3 except for the addition of a plurality of vertical partition walls 41 which cross transversely the whole width of the breakwater at certain intervals in the longitudinal direction.

The same results are obtained as described above.

An inclined incident wave shown by an arrow *a* and a parallel incident wave shown by an arrow *b* as shown in Figure 16, as well as a perpendicularly incident wave, are blocked by the breakwater of this preferred embodiment of the present invention in the same way as described above.

It is readily understood as described hereinbefore that a variety of waves having a wide range of wavelengths are blocked by the breakwater according to the present invention.

The breakwater of the present invention may be constructed from prefabricated blocks, or the breakwater may be of monolithic construction made, for example, by a continuous concrete pouring system.

Further, although the present invention has been described with particular reference to a sea wall the invention is not limited thereto and it should be understood that the invention can be applied to any kind of breakwater where reduced wave impact is required.

WHAT WE CLAIM IS:-

1. A breakwater comprising a front wall structure and a back wall spaced from the front wall structure and inclined to the front wall of said structure the front wall structure including openings through which water can flow to and from the space between said back wall and said front wall structure, said walls being arranged, in use, to extend above and below the level of the water to be contained.

2. A breakwater as claimed in Claim 1 in which the back wall slopes upwardly away from the front wall of the front wall structure.

3. A breakwater as claimed in Claim 1 or 2 in which the bottom of the front wall structure is spaced from the bottom of the rear wall.

4. A breakwater as claimed in Claim 1, 2 or 3 in which a roof connects the tops of the back wall and the front wall structure.

5. A breakwater comprising a base, a perforated front wall structure upstanding from said base, a back wall upstanding from said base and having the same height as said front wall structure, and a roof slab connecting the top of said wall structure with the top of said back wall, said walls, in use, being intended to extend above and below the water level and said back wall being inclined upwardly and away from the front wall of the structure.

6. A breakwater as claimed in Claim 1, 2, 3, 4 or 5, wherein the front wall structure consists of one or at least one vertical front wall.

7. A breakwater as claimed in Claim 1, 2, 3, 4, 5 or 6, wherein the inclined back wall includes recessed surfaces and projecting surfaces alternating in the longitudinal direction of the wall.

8. A breakwater as claimed in any one of Claims 1 to 6 inclusive further including a plurality of vertical partition walls extending from the back wall to a wall on the front wall structure, spaced apart in the longitudinal direction of the breakwater.

9. A breakwater as claimed in any preceding claim, wherein the front wall structure comprises a plurality of front walls

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(14)

which are separated from one another.

10. A breakwater according to Claim 9, wherein the front wall structure comprises two vertical front walls spaced apart to define a first chamber between the first and second front walls, and a second chamber between the second front wall and the back wall.

11. A breakwater according to Claim 10, wherein the transverse dimension of the first chamber is substantially the same as that of the second chamber and, in use, the upper part of the first chamber vents to the atmosphere via the holes in the first front wall, and the holes in the second front wall are all below the water level whereby the upper part of the second chamber is isolated from the atmosphere.

12. A breakwater according to any preceding claim, wherein the base of the breakwater is seated upon a base block on the water bottom.

13. A breakwater as claimed in Claims 9, 10 or 11 in which the axes of the holes in each wall forming the front wall structure are off-set from the axes of the holes in the adjacent wall or walls whereupon, in use, water flows directly through the wall structure are avoided.

14. A breakwater as claimed in Claims 5 to 13 inclusive in which the base and roof are formed integral with the back wall and the front wall structure.

15. A breakwater as claimed in Claim 1 and substantially as hereinbefore described with reference to and as illustrated in Figures 3 and 4, Figures 6, 7 or 8, Figures 9 and 10, Figures 11 and 12, Figures 13 and 14 or Figures 15 and 16 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office,
by Croydon Printing Company Limited, Croydon, Surrey, 1980.
Published by The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

