

AN ARTIFICIAL REEF AND A METHOD OF CONSTRUCTING AN ARTIFICIAL REEF

The present invention relates to an artificial reef assembly and a method of constructing an artificial reef.

BACKGROUND TO THE INVENTION

Multi-purpose reefs and offshore breakwaters are used for coastal protection and/or recreational purposes, such as surfing. They are typically built in water depths of 2-15 m around 100-400 m offshore from the low tide line. However, this may vary in some locations.

The design of the reef is normally established from numerical and physical laboratory studies which determine the optimum seabed shape that produces the required quality of the wave. Different seabed shapes create different types of wave.

A problem with these sophisticated computer generated shapes is that techniques are not available to construct them accurately.

In the past, breakwaters have been built by simply dropping large rocks to form the barrier. However, these rocks are dangerous for surfers and they have large undulations in the surface that can destroy the quality of the surfing wave. In one attempt to improve construction quality, geotextile containers up to 3-5 m diameter and about 20 m long were adopted. These were filled in the hull of a dredge and then dropped to the seabed to form the reef. Over 300 containers may be dropped.

The lack of accuracy in this method, however, also led to large variations and undulations in the reef surface and a reduction in the quality of the surfing wave. Laboratory tests have shown that irregular reef shapes cause "boils" on the water surface or the "tube" of the wave partially or wholly collapses, degrading the surfing ride.

Other methods that have been adopted include using divers and ropes to place geocontainers, also known as mega-containers, on the seabed, and then filling each geocontainer in position. The cost of doing this with a large number of individual containers is high, particularly if careful placement of each is required.

Another problem occurs if there are gaps between the mega-containers. The constant wave action can lead to erosion of sand between the containers and eventual sinking of the reef into

the sand. Thus, accurate placement of the containers is highly important for the quality of the surfing wave, and for the future durability of the reef shape.

The term "seabed" is used herein to denote the floor of a body of water, whether sea, lake, manmade or otherwise.

The term "artificial reef" as used herein includes any man-made construction that is positioned in a body of water and is adapted or intended to alter the wave pattern in a body of water, such as man-made breakwaters as well as artificial reefs, and may be completely submerged or only partially submerged.

Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise", "comprising" and the like, are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense, that is to say, in the sense of "including, but not limited to".

OBJECT OF THE INVENTION

It is an object of the present invention to provide an artificial reef and/or a method of constructing an artificial reef which will allow the reef to be deployed more easily and with greater accuracy than the artificial reefs of the prior art.

It is an alternative object of the invention to provide an artificial reef assembly and/or a method of constructing an artificial reef assembly and/or an artificial reef and/or a method of constructing an artificial reef which will overcome one or more of the problems of the prior art, or will at least provide a useful choice.

Other objects of the present invention may become apparent from the following description, which is given by way of example only.

SUMMARY OF THE INVENTION

According to a first aspect of the present invention, there is provided an artificial reef assembly including a plurality of containers adapted to receive a filler material, each said container connected to at least one other said container by connecting means, wherein in use, the

connecting means hold the plurality of containers in a required configuration and the containers are filled with a required amount of filler material to form a required shape of the reef.

According to a second aspect of the present invention, there is provided an artificial reef assembly comprising at least one reef element and a support structure, the at least one reef element being coupled to the support structure, and the support structure being adapted to support the at least one reef element while being transported to an installation location and to be secured to the seabed to locate the at least one reef element on the seabed in a desired location to form at least a portion of an artificial reef.

Preferably, the artificial reef assembly further comprises coupling means connected to the support structure, the coupling means being adapted to couple the support structure to the seabed.

According to a third aspect of the present invention, there is provided an artificial reef assembly comprising at least one reef element and coupling means to couple the reef element to the seabed while the reef element is at the surface and to subsequently enable the at least one reef element to be moved to the seabed using the coupling means.

Preferably, the reef assembly further comprises a support structure, the at least one reef element being coupled to the support structure and the support structure being connected to the coupling means.

Preferably, the artificial reef assembly comprises a number of reef elements.

In one example of the invention, two or more reef elements are coupled to one support structure. However, alternatively, one support structure could be provided for each reef element.

According to a fourth aspect of the present invention, there is provided an artificial reef including a plurality of containers filled with a required amount of filler material, each said container connected to at least one other said container by connecting means, wherein the connecting means hold the plurality of containers in a required configuration such that the containers form a required shape of the reef.

According to a fifth aspect of the present invention, there is provided a method of constructing an artificial reef assembly comprising:

- i) determining a required shape for an artificial reef to be created from the reef assembly;
- ii) determining a required configuration of a plurality of containers to create the required shape when filled with a required amount of filler material;
- 5 iii) connecting the plurality of containers together with connecting means, such that each said container is connected to at least one other said container, wherein the connecting means are adapted to hold the plurality of containers in the required configuration when in use.

10 According to a sixth aspect of the present invention, there is provided a method of constructing an artificial reef, the method comprising:

- (i) coupling a coupling means to a reef element located at the surface of a body of water;
- (ii) securing the coupling means to the seabed while the reef element is located at
15 the surface; and
- (ii) moving the reef element from the surface to the seabed using the coupling means.

20 Preferably, the reef element is attached to a support structure and the coupling means is attached to the support structure.

 According to a seventh aspect of the present invention, there is provided a method of constructing an artificial reef, the method comprising:

- (i) attaching a reef element to a support structure;
- 25 (ii) transporting the support structure and the attached reef element to a location on the surface of a body of water above an installation location on the seabed;
- (iii) securing the support structure to the seabed using a coupling means while the support structure and the reef element are at the surface location; and
- (iv) moving the support structure and the reef element to the installation location on
30 the seabed using the coupling means.

 Preferably, the method further comprises determining a required shape for the artificial reef.

 Typically, the size and shape of the reef element may be determined from the required shape.

35 Preferably, the reef element may comprise a container, which is preferably flexible and may be formed from a fabric material, such as geotextile material. Typically, the container is a

megacontainer.

Typically, the reef element may have a volume of between 30m^3 to 1600m^3 .

Typically the reef element may have a length of from 10m to 80m and preferably from 30m to 60m.

Typically, the cross-sectional area of the reef element may be from 1m^2 to 25m^2 . Preferably the cross-sectional area is substantially constant along the length of the reef element.

However, it is possible that the cross-sectional area could vary along the length of the reef element.

Preferably, the support structure is in the form of a web that supports the reef element(s).

Where the reef element is a container, the container is filled with a filler material. Preferably the container is filled with the filler material when the container is located at the installation location on the seabed.

Preferably, the artificial reef is constructed from a number of reef elements.

In one example of the invention, one reef element is attached to one support structure. However, in an alternative example of the invention two or more reef elements are attached to the support structure. The artificial reef may be constructed from a number of reef elements and support structures, for example, one reef element per support structure or a number of support structures with two or more reef elements per support structure.

According to an eighth aspect of the present invention, there is provided a method of constructing an artificial reef, the method including:

- i) determining a required shape for the artificial reef;
- ii) determining a required configuration of a plurality of containers to create the required shape when filled with a required amount of filler material;
- iii) connecting the plurality of containers together with connecting means, such that each container is connected to at least one other said container, wherein the connecting means are adapted to hold the plurality of containers in the required configuration when in use;
- iv) moving the containers into the required configuration at a required location;
- v) filling each container with the required amount of filler material.

Preferably, the filling step may be preceded by the step of temporarily fastening at least one of said plurality of containers to an anchor means anchored adjacent the required location.

5 Preferably, the connecting means may be provided with attachment lines and the method may include the step of anchoring a plurality of anchor means adjacent the required location and using the anchor means as pulley means for the attachment lines.

Preferably, at least one of the connecting means may be elongate flexible connecting means.

10

Preferably, the connecting means may include rope and/or strapping and/or chains and/or steel cables.

Preferably, a plurality of the connecting means may be connected to form a web.

15

Preferably, each said container may be a flexible container. However, it is possible that the containers could be rigid or semi-rigid. It is also possible that any combination of flexible, rigid and semi-rigid containers could be used on the same reef assembly or to construct one artificial reef.

20

Preferably, a mat may be provided and attached to the connecting means. This feature has the advantage of preventing or minimising sinkage of the containers and/or leakage of sand.

25

Further aspects of the invention, which should be considered in all its novel aspects, will become apparent from the following description given by way of example of possible embodiments of the invention.

BRIEF DESCRIPTION OF THE FIGURES

30

Examples of an artificial reef assembly and a method of constructing an artificial reef in accordance with the invention will now be described with reference to the accompanying drawings, in which:

35

Figure 1 is a diagrammatic plan view of a first example of a support structure in the form of a web of connecting means for an artificial reef;

Figure 2 is a diagrammatic plan view of a first example of a reef assembly using the support structure shown in Figure 1;

Figure 3 is a diagrammatic isometric view of a section of the artificial reef assembly of Figure 2 prior to installation;

Figure 4 is a diagrammatic plan view of an artificial reef formed from the reef assembly of Figure 2;

Figure 5 is a diagrammatic isometric view of a section of the artificial reef of Figure 3 as viewed along the line AA of Figure 3;

Figure 6 is a plan view of the reef assembly located at an installation location on the seabed and showing an arrangement of anchors;

Figure 7 is a diagrammatic cross-section of the artificial reef of Figure 3 through the line AA; and

Figure 8 is a diagrammatic plan view of a second example of an artificial reef assembly with a second example of a support structure.

DESCRIPTION OF POSSIBLE EMBODIMENTS OF THE INVENTION

Figure 1 shows a support structure formed from a plurality of connecting means 1 which are connected together to form a web or network, generally referenced 100. In this example, the connecting means 1 is webbing or fabric tape. However, the connecting means could be any suitable material, such as rope or cable. Attached along the peripheral edges of the web 100 are a number of coupling means 4 in the form of ropes.

A first example of an artificial reef assembly 300 is shown in Figures 2 and 3. The reef assembly 300 is formed by attaching containers 2 to the web 100 in a configuration which is such that when the web 100 is held in a required position and the containers 2 are filled with a required or predetermined amount of filler material, a predetermined required reef shape, generally referenced 200 is formed, as shown in Figures 4, 5 and 7. It is to be understood that although the containers 2 are shown diagrammatically in Figure 5 as having a round cross-section, in practice the containers will typically adopt an oval cross-section as shown in Figure 7.

Each container 2 is connected to at least one other container 2 by the connecting means 1. Typically the containers 2 are flexible containers and may be manufactured from a geotextile material. The containers 2 may be any size but are preferably mega-containers. Typically, the containers 2 have a length of from 10m to 80m, preferably 30m to 60m. The containers may

have a volume in the range from 30m^3 to 1600m^3 . The containers may have a cross-sectional area in the range 1m^2 to 25m^2 . However, any suitable material could be used for the containers and the containers could be any suitable size, which may depend on the particular location of an artificial reef and any installation requirements.

5

The breaking strains of the various connecting means 1 may vary depending on the anticipated load on each particular connecting means 1 when in use.

10

The containers 2 are attached to the web 100, preferably by means of tags 3 affixed, for example by being sewn, along their sides, to form the reef assembly. The tags 3 may preferably be spaced between 1m and 10 m apart, although other spacings may be suitable.

15

Manufacture of the reef assembly may be done on shore, thereby saving time and reducing costs. Figure 3 shows the reef assembly prior to installation with the containers 2 empty and folded.

20

In use, the reef assembly, generally referenced 300, is transported to a desired location folded up, preferably on a barge or other flat surface ready for deployment. The web 100 is then stretched out, preferably on the water surface by attachment lines 4 which are connected to the web 100 at predetermined intervals. Winches (not shown) may be used to stretch out the web 100.

25

Other ropes or lines (not shown) may be used to tie the containers 2 more securely to the web 100 in order to provide stability for the containers 2 under wave action. These additional ropes or lines may be later untied during or after the containers 2 are filled with filler material.

30

An array of suitable anchor means, for example anchors 5, are anchored into the seabed adjacent the required location of the reef. The attachment lines are fed through the anchors 5 and the anchors are used as pulley means to pull the reef assembly down onto the seabed and into its required location. The attachment lines 4 may be fed through the anchors 5, and then up to a surface vessel such as a barge, so that the lines can be tensioned by suitable tensioning means on the barge, thereby enabling the reef assembly to be pulled into its installation location on the seabed. The anchors 5 may be used as permanent anchors for the reef and/or as attachment points to temporarily hold the reef assembly 300 in position before the containers 2 are filled.

35

Tensioned straps (not shown) may also be laid across the reef assembly 300 in case of wave action to improve stability prior to filling of the containers. Temporary sand bags (not shown) may also be placed on top of the reef assembly 300 if the swell conditions require them.

5 With the web 100 in position on the seabed, the containers 2 are held in a predetermined required configuration by the connecting means 1. The containers 2 are then filled with filler material by any suitable means.

10 As can be seen from Figures 4 and 7, the containers 2 may be positioned on the web 100 such that they overlap, thereby minimising the hollow formed between adjacent containers 2 when oval cross-section flexible containers 2 are used. An overlap of up to around $1/8^{\text{th}}$ of the maximum filled width of the containers 2 may be suitable. This also helps to ensure that there are no gaps between the containers 2.

15 To prevent a container 2 from rolling over when filling due to the force of its filled neighbour, every second container 2a is preferably filled first and then the intermediate containers 2b (see Figure 7) are filled.

20 In many embodiments the artificial reef, generally referenced 200, will be stable under its own weight and the anchors 5, if used, can be removed once the containers 2 have been filled.

25 If required, a mat (not shown) may be provided between the web 100 and the containers 2. The mat may prevent leaking of sand from between the containers 2 which might otherwise result in the containers 2 sinking into the seabed.

If required, a further row of tags (not shown) may be provided above the first row of tags. This may strengthen the connection between the containers 2 and the web 100, and may also assist in reducing the tendency of the containers to move around when empty or partially filled.

30 A second example of a reef assembly 500 is shown in Figure 8. In this case a second example of a support structure in the form of a web 600 is used. The web 600 is fabricated in the same manner as the web 100 from connecting means 1. However, in this example only one container 602 is attached to the web 600. The container 602 is attached to the web 600 in the same way as the containers 2 are attached to the web 100. That is, by using tags 3 (not shown in Figure 8).

35

In this example, the reef assembly 500 may be used where only one container is required to construct an artificial reef. However, the reef assembly 500 also has applications where the installation is in an area of high currents, large swell or other difficult environmental conditions which make it difficult or impossible to construct the artificial reef using a single web 100 with multiple containers 2. In this case, a number of reef assemblies 500 may be installed to construct the artificial reef. This has the advantage that surface time, installation time and filling time is reduced which makes it easier to install the reef assembly and fill the container 602 in difficult environmental conditions. The reef assembly 500 may also have applications where space for construction of the reef assembly and/or deployment of the reef assembly is restricted.

It is also possible that a number of reef assemblies could be used to construct an artificial reef, each reef assembly comprising one support structure with one or more containers (or reef elements) attached to the respective support structure.

Materials

- The containers 2 could be made of any suitable durable material. Examples include geotextiles, heavy-duty polypropylene, durable plastic or concrete.
- The containers could be tube-shaped and may be circular, oval, rectangular, triangular or any other suitable shape in plan or cross-section.
- The containers may be flexible, rigid or partially rigid (for example semi-rigid).
- Filling material is preferably sand, but it could be mud, stones, cobbles etc.
- Preferably at least one of the connecting means 1 is an elongate flexible connecting means, which may be any suitable material including rope, strapping, chains, steel cables. In alternative embodiments some of the connecting means may be substantially rigid.
- Tags could be made of strapping or any suitable material and tied with strapping, ropes, shackles
- The mat could be made of canvas, polypropylene, geotextile or any other suitable material.

While the connecting means have been shown in the form of a web in the embodiment shown, in some embodiments the containers may be sufficiently strong, or may be reinforced, so that the connecting means connect only adjacent containers.

Those skilled in the art will appreciate that the invention presented herein is a novel method to improve the accuracy of construction of an artificial reef, while also keeping down the cost of construction. Standard mega-containers may be used but much of the construction can be done on land, thereby significantly reducing the expensive sea-based costs and minimizing the dependence on periods of low waves for work to be undertaken.

With this method, the containers may be deployed:

- Accurately relative to each other;
- Simultaneously; and
- More rapidly, thereby saving on diver and at-sea time

The method does not require many low swell days and therefore the whole reef may be completed in a single period of low swell. Safety for divers is also greatly improved without the requirement for many dead-man weights to be placed and moved on the seabed. The reef may be deployed in one period as one unit, although the reef could also be deployed in stages, on separate sections of web.

Where in the foregoing description, reference has been made to specific components or integers of the invention having known equivalents, then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example and with reference to possible embodiments thereof, it is to be understood that modifications or improvements may be made thereto without departing from the spirit or scope of the invention.

CLAIMS

1. An artificial reef assembly including a plurality of containers adapted to receive a filler material, each said container connected to at least one other said container by connecting means, wherein in use, the connecting means hold the plurality of containers in a required configuration and the containers are filled with a required amount of filler material to form a required shape of the reef.

2. An assembly according to claim 1, wherein the container has a volume of between 30m^3 to 1600m^3 .

3. An assembly according to claim 1 or claim 2, wherein the container has a length of from 10m to 80m.

4. An assembly according to claim 3, wherein the container has a length of from 30m to 60m.

5. An assembly according to any of the preceding claims, wherein the container has a cross-sectional area of from 1m^2 to 25m^2 .

6. An assembly according to any of the preceding claims, wherein the reef element has a cross-sectional area that is substantially constant along the length of the reef element.

7. An artificial reef assembly comprising at least one reef element and a support structure, the at least one reef element being coupled to the support structure, and the support structure being adapted to support the at least one reef element while being transported to an installation location and to be secured to the seabed to locate the at least one reef element on the seabed in a desired location to form at least a portion of an artificial reef.

8. An assembly according to claim 7, further comprising coupling means connected to the support structure, the coupling means being adapted to couple the support structure to the seabed.

9. An artificial reef assembly comprising at least one reef element and coupling means to couple the reef element to the seabed while the reef element is at the surface and to subsequently enable the at least one reef element to be moved to the seabed using the coupling means.

10. An assembly according to claim 9, further comprising a support structure, the at least one reef element being coupled to the support structure and the support structure being connected to the coupling means.

5

11. An assembly according to any of claims 7 to 10, wherein the artificial reef assembly comprises a number of reef elements.

10

12. An assembly according to claim 11 when dependent on claim 7 or claim 10, wherein two or more reef elements are coupled to the support structure.

13. An assembly according to claim 11, when dependent on claim 7 or claim 10, or claim 12, wherein there are a number of support structures.

15

14. An assembly according to claim 13, wherein one reef element is coupled to each support structure.

15. An assembly according to any of claims 7 to 14, wherein the reef element has a volume of between 30m^3 to 1600m^3 .

20

16. An assembly according to any of claims 7 to 15, wherein the reef element has a length of from 10m to 80m.

25

17. An assembly according to claim 16, wherein the reef element has a length of from 30m to 60m.

18. An assembly according to any of claims 7 to 17, wherein the reef element has a cross-sectional area of from 1m^2 to 25m^2 .

30

19. An assembly according to any of claims 7 to 18, wherein the reef element has a cross-sectional area that is substantially constant along the length of the reef element.

20. An assembly according to any of claims 7 to 19, wherein the reef element comprises a container adapted to be filled with a filler material.

35

21. An assembly according to any of claims 1 to 6 or 15, wherein the container is flexible.

22. An assembly according to claim 21, wherein the container is formed from a fabric material.

23. An assembly according to claim 22, wherein the container is formed from a geotextile material

24. An assembly according to any of claims 1 to 6 or 20 to 23, wherein the container is a megacontainer.

25. A method of constructing an artificial reef assembly comprising:

- iv) determining a required shape for an artificial reef to be created from the reef assembly;
- v) determining a required configuration of a plurality of containers to create the required shape when filled with a required amount of filler material;
- vi) connecting the plurality of containers together with connecting means, such that each said container is connected to at least one other said container, wherein the connecting means are adapted to hold the plurality of containers in the required configuration when in use.

26. A method of constructing an artificial reef, the method comprising:

- (i) coupling a coupling means to a reef element located at the surface of a body of water;
- (ii) securing the coupling means to the seabed while the reef element is located at the surface; and
- (ii) moving the reef element from the surface to an installation location on the seabed using the coupling means.

27. A method according to claim 26, further comprising attaching the reef element to a support structure and attaching the coupling means to the support structure.

28. A method according to claim 27, further comprising transporting the support structure with the reef element attached to the support structure to the location at the surface of the body of water.

29. A method of constructing an artificial reef, the method comprising:

- (i) attaching a reef element to a support structure;
- (ii) transporting the support structure and the attached reef element to a location

on the surface of a body of water above an installation location on the seabed;

(iii) securing the support structure to the seabed using a coupling means while the support structure and the reef element are at the surface location; and

(iv) moving the support structure and the reef element to the installation location on the seabed using the coupling means.

30. A method according to any of claims 26 to 29, further comprising determining a required shape for the artificial reef.

31. A method according to claim 30, wherein the size and shape of the reef element is determined from the required shape.

32. A method according to any of claims 26 to 31, wherein the reef element comprises a container and the container is filled with a filler material.

33. A method according to claim 32, wherein the container is filled with filler material when the reef element is at the installation location on the seabed.

34. A method according to any of claims 26 to 33, wherein the reef element has a volume of from 30m^3 to 1600m^3 .

35. A method according to any of claims 26 to 34, wherein the reef element has a length of from 10m to 80m.

36. A method according to claim 35, wherein the reef element has a length of from 30m to 60m.

37. A method according to any of claims 26 to 36, wherein the cross-sectional area of the reef element is from 1m^2 to 25m^2 .

38. A method according to any of claims 26 to 37, wherein the reef element has a cross-sectional area that is substantially constant along the length of the reef element.

39. A method according to any of claims 26 to 38, wherein the artificial reef is constructed from a number of reef elements.

40. A method according to any of claims 26 to 39, wherein one reef element is attached to

one support structure.

41. A method according to any of claims 26 to 39, wherein two or more reef elements are attached to the support structure.

42. A method according to any of claims 26 to 41, wherein the artificial reef is constructed from a number of reef elements and a number of support structures.

43. A method according to any of claims 27 to 29 or any of claims 30 to 42 when dependent on any of claims 27 to 29, wherein the support structure comprises connecting means.

44. A method of constructing an artificial reef, the method including:

- vi) determining a required shape for the artificial reef;
- vii) determining a required configuration of a plurality of containers to create the required shape when filled with a required amount of filler material;
- viii) connecting the plurality of containers together with connecting means, such that each container is connected to at least one other said container, wherein the connecting means are adapted to hold the plurality of containers in the required configuration when in use;
- ix) moving the containers into the required configuration at an installation location;
- x) filling each container with the required amount of filler material.

45. A method according to claim 44, wherein the filling step is preceded by the step of temporarily fastening at least one of said plurality of containers to an anchor means anchored adjacent the installation location.

46. A method according to any of claims 43 to 45, wherein the connecting means may be provided with attachment lines and the method may include the step of anchoring a plurality of anchor means adjacent the required location and using the anchor means as pulley means for the attachment lines.

47. A method according to any of claims 43 to 46, wherein the connecting means comprises an elongate flexible connecting means.

48. A method according to claim 47, wherein the connecting means may include rope and/or strapping and/or chains and/or steel cables.

49. A method according to any of claims 43 to 48, wherein the connecting means are connected to form a web.

50. A method according to any of claims 32, 33, 44, 45, any of claims 34 to 43 when
5 dependent on claims 32 or 33 or any of claims 46 to 49 when dependent on any of claims 32, 33, 44 or 45, wherein the container is flexible.

51. A method according to claim 50, wherein the container is formed from a fabric material.

10 52. A method according to claim 51, wherein the container is formed from a geotextile material.

53. A method according to any of claims 32, 33, 44, 45, 50 to 52, any of claims 34 to 43
15 when dependent on claims 32 or 33 or any of claims 46 to 49 when dependent on any of claims 32, 33, 44 or 45, wherein the container is a megacontainer.

54. A method according to any of claims 44, 45 or any of claims 46 to 53 when dependent
on any of claims 44 or 45, wherein a mat is provided between the connecting means and the
containers.

20 55. A method according to any of claims 27 to 29 or any of claims 30 to 43 when dependent
on any of claims 27 to 29, wherein a mat is provided between support structure and the reef
elements.

25 56. An artificial reef including a plurality of containers filled with a required amount of filler
material, each said container connected to at least one other said container by connecting
means, wherein the connecting means hold the plurality of containers in a required
configuration such that the containers form a required shape of the reef.