

TITLE**Apparatus and Method for Mitigation of Scour Around Seabed Installations**5 **FIELD OF THE INVENTION**

The present invention is related to mitigation and/or prevention of scour which would otherwise occur around seabed installations such as wind turbine towers or other offshore installations and more particularly is related to removing or at
10 least reducing the need for traditional rock dumping around such installations.

BACKGROUND OF THE INVENTION

15 The rise of offshore wind turbine tower monopile installations (particularly the most popular monopile being a suction pile), and other offshore seabed installations (including mooring points, subsea suction buckets or suction jackets, energy production or processing facilities (including either electricity distribution or oil or gas exploration or production platforms) and any other seabed
20 installation – hereinafter referred to as either monopile or “seabed installation”) has resulted in a significant problem occurring in that flow of water (due to e.g. oncoming currents and waves) around the base of the monopile or subsea installation itself can cause a number of different scour effects caused by a respective number of different vortices/flow characteristics such as (but not
25 limited to):-

- Downflow vortices;
- Horseshoe vortices;
- Lee-wake vortices;
- 30 • Accelerated flow.

Any one or combination of two or more of these (or other) vortices/flow characteristics is likely to result in shear bed stress occurring which will (if above

a critical value) would cause material (e.g. sand or rocks or other material) to move from the location around the junction of the subsea installation and the seabed, thus causing scour (i.e. causing a scour hole) to occur around the said junction which would then have the highly undesirable effect of undermining the foundation of the subsea installation.

Figure 1 of "The effect of scour on monopile lateral behaviour" technical paper published during "Proceedings of the XVII ECSMGE-2019 "Geotechnical Engineering foundation of the future" conference (ISBN 978-9935-9436-1-3) (currently available at

https://www.ecsmge-2019.com/uploads/2/1/7/9/21790806/0775-ecsmge-2019_bayton.pdf)

is reproduced here in order to show the scour hole resulting from these vortices around the base of a monopile (similar effects will occur around other subsea installations):-

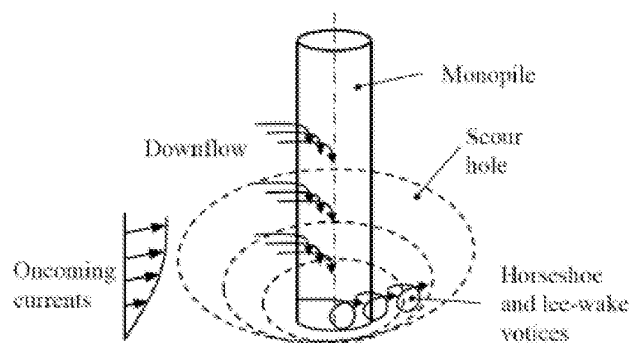


Figure 1. Local scour hole formation

Such a scour hole results in potentially significant erosion occurring of the foundations around the base of a monopile or other subsea installation and therefore causes a significant reduction in the strength of the foundation of such a monopile or other subsea installation.

Conventionally, the main method of mitigating such scour damage to the foundations of the monopile or other subsea installation is to lay or dump a large amount of rock around the base of the monopile or other subsea installation but such a conventional method can be relatively expensive and/or difficult to install the rocks, particularly if the monopile or other seabed installation has a relatively large diameter. In addition, the rocks are typically irregularly sized and therefore don't provide a uniform surface nor provide a uniform flow channel to the water which can then cause additional problems to the flow of water. In addition, such a prior art method (which typically comprises a disc around the bottom of the monopile or seabed installation) typically needs to have the disc of rocks which extends from the outer circumference of the monopile or seabed installation to the far edge of the disc of rocks of between 4 to 5 times the diameter of the monopile or seabed installation), which can therefore mean a relatively long distance that the disc of rocks needs to extend. That therefore means that the amount of electrical export cable exposed to the water (which is typically between the point of exit from the monopile or seabed installation at/towards its base and the outer edge of the disk of rocks – at which point the electrical export cable is then buried in a trench for protection) is relatively long which means that fatigue experienced by the cable in its operational working life will be greater than desired.

Another more recent conventional method of mitigating such scour damage to the foundations of the monopile or other subsea installation is provided by SPT Offshore by virtue of their Scour Protection System (ScPS)[™] (disclosed in EP3228754 and/or WO/2022/194891) and which provides a flexible matt having strips of fabric provided on its upper surface and which mimic seaweed and therefore acts to some degree to provide a number of flexible obstacles to the water to somewhat slow down the flow of sea water flowing over the ScPS[™]. Other prior art patent documents that may be useful for understanding the background of the present invention include GB1134154A, KR102624682, CA1046296, CN117230843 and CN116145712.

It is an object of the present invention to provide a scour protection apparatus and a method of preventing scour occurring which assists in reducing shearbed stress, preferably to below a critical value that would otherwise cause material (e.g. sand or rocks or other material) to move from the location around the junction of the subsea installation and the seabed, and thus assist in preventing scour from occurring and thus assists in protecting the foundation of the subsea installation.

10 **SUMMARY OF THE INVENTION**

According to the present invention, there is provided a scour protection apparatus adapted for immersion in a body of water, the scour protection apparatus comprising:-

- 15 an inner throughbore which in use is located around the outer circumference of a substantially tubular shaped subsea installation;
- a lower most substantially planar shaped surface adapted in use to rest upon the seabed surface;
- an outermost perimeter; and
- 20 an upper most surface substantially impervious to water, wherein at least a portion of the upper surface comprises at least two flow diversion means provided thereon and each flow diversion means being separated from each adjacent flow diversion means by a groove arrangement,
- wherein the scour protection apparatus in use reduces seabed scour occurring around a junction of the substantially tubular shaped subsea installation and the seabed.

According to the present invention, there is also provided a method of preventing scour around the foundations of a substantially tubular shaped subsea installation, the method comprising:-

30 providing a scour protection apparatus adapted for immersion in a body of water, the scour protection apparatus comprising an inner throughbore which in use is located around the outer circumference of a substantially tubular shaped

subsea installation, a lower most substantially planar shaped surface adapted in use to rest upon the seabed surface, an outermost perimeter and an upper most surface;

5 wherein at least the upper surface of the scour protection apparatus is substantially impervious to water, and at least a portion of the upper surface is provided with at least two flow diversion means thereon and each ring of repeating shapes are separated from each adjacent ring by a groove arrangement and each shape within a ring being separated from adjacent shapes by at least one groove,

10 and

arranging the scour protection apparatus around the outer circumference of the substantially tubular shaped subsea installation at a junction of the substantially tubular shaped subsea installation and the seabed.

15 Preferably, each flow diversion means comprises a shape such that at least a portion of the upper surface of the apparatus comprises at least two repeating shapes provided thereon and more preferably comprises at least two rings of repeating shapes provided thereon and each ring of repeating shapes are separated from each adjacent ring by a groove arrangement and each shape within a ring preferably being separated from adjacent shapes by at least one groove.

20 Preferably, the lower most planar shaped surface is a lower most planar disc shaped surface.

25 Typically, the outermost perimeter comprises an outermost generally elliptical circumference or more preferably an outermost generally circular circumference.

30 Preferably, the depth of the scour protection apparatus increases from the outermost perimeter towards the throughbore, such that the depth at the throughbore is typically greater than the depth at the outermost perimeter. Typically, the upper surface of the scour protection apparatus tapers upwardly from the outermost perimeter towards the said throughbore, such that the depth

of the scour protection apparatus increases from the outermost perimeter towards the throughbore.

5 Preferably the scour protection apparatus is generally cone shaped and more preferably is generally frusto-conical shaped around a central throughbore extending along its central longitudinal axis.

10 Preferably, the scour protection apparatus may be formed from two or more sub-elements or sections. Preferably, said two or more sections comprise two or more interconnecting sections which when connected together form the scour protection apparatus. Preferably, there may be three sections which each circumscribe 120 degrees and which when brought together envelope, around the throughbore, a typically relatively short vertical height of the lower installed end of the monopile or other subsea installation. Each of the three sections
15 preferably comprise at least one and more preferably at least two strap and/or lifting padeyes or the like to assist transportation of each of the sections whilst on land and/or whilst being transported through the water from the surface of the water to the installation location on the seabed around the outer circumference of the substantially tubular shaped subsea installation secured within the seabed.

20 Alternatively, the scour protection apparatus may be formed from two or more sub-elements or sections and which are arranged to be connected together to form the generally cone shaped element prior to transportation on land or more preferably prior to transportation through the water from the surface of the water to the installation location on the seabed around the outer circumference of the substantially tubular shaped subsea installation secured within the seabed, such
25 that the generally cone shaped element is lowered down the outer circumference of the substantially tubular shaped subsea installation secured within the seabed until it reaches the seabed.

30 Preferably the one piece unit is formed from two or more segments which are preferably two or more interconnecting segments which when connected together form the one piece scour protection apparatus.

Preferably the or each section is/are formed from two or more segments which are preferably two or more interconnecting segments which when connected together form each section of the scour protection apparatus.

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Typically, each pair of segments comprise a connection means to connect them together. The connection means may comprise any suitable connection mechanism such a screw means or a bolting means and more preferably a flexible connection mechanism but more preferably comprises a strapping arrangement and most preferably the strapping arrangement comprises a suitable connecting strap, chain, wire or the like (hereinafter collectively referred to as "strap") arranged to be passed through a radially directed (with reference to the radial direction of the scour protection apparatus 1R when it is formed) substantially linear channel formed at least partially through one portion of the segment and more preferably through the spigot and where the connecting strap also preferably passes (at least partially) through at least one channel formed within the socket of the adjacent segment in order to couple the two adjacent segments together with one another (i.e. via the connecting strap). The two said channels of the adjacent segments are preferably arranged such that, when the respective two segments are brought together, the two channels are in radial alignment such that the connecting strap is linearly arranged such that the two portions thereof which pass through the said channels are radially aligned with one another.

The connecting strap can be secured to lock the two adjacent segments together by wrapping the connecting strap around the rest of the outer perimeter or circumference (in the radial direction) of the joint between the adjacent segments, and the two ends of the connecting strap can be secured to one another by a suitable locking means. The flexible connection mechanism preferably comprises a flexible strapping arrangement which securely locks two adjacent segments together and thus prevents them from separating apart from one another but which also permits one segment to flex, bend or twist with respect to the other segment such that the flexible connection mechanism allows

for articulation such that each of the segments can conform to a non-standard (i.e. non-flat) seabed. Accordingly, the flexible connection mechanism allows for the scour protection apparatus to accommodate an undulating seabed as well as conforming to said undulating seabed to ensure full contact with the seabed during service and most preferably can conform to changes to the seabed during the life of the installation of the scour protection apparatus if underpinning is observed during said life of the installation of the scour protection apparatus. That therefore provides the advantage that underpinning, due to water flowing underneath the scour protection apparatus which would otherwise result in water digging out a section of the seabed, is prevented.

Preferably, there may be three sections which each circumscribe 120 degrees and which when brought together envelope, around the throughbore, a typically relatively short vertical height of the lower installed end of the monopile or other subsea installation.

Preferably, the two or more rings of repeating shapes re-directs the flow path of water flowing through the respective grooves and/or forces the water striking the repeating shapes to enter the respective groove and thereby creates significant turbulence in the water which further slows down the flow of the water. This has the distinct advantage of providing greater scour protection than conventional methods. Moreover, the repeating shapes (which preferably are protruding repeating shapes projecting upward from the upper face and comprise one or more channel(s) therebetween) disrupt and/or deflect flow to reduce far field shear bed stress. This provides the significant advantage that, unlike prior art scour protection systems (which for example can comprise rocks arranged in a disc around the bottom of the monopile or seabed installation) which typically need to have a disc of rock installed which extends from the outer circumference of the monopile or seabed installation to the far edge of the rock of between 4 to 5 times the diameter of the monopile or seabed installation), the protruding shapes on the upper face of embodiments of the present invention significantly reduces the distance that the said embodiments need to extend out to around 2 to 2.5 times the diameter of the monopile or seabed installation. That reduction in

the distance for embodiments of the present invention provides the significant advantage that the amount of electrical export cable that is exposed to the water (which is typically between the point of exit from the monopile or seabed installation at/towards its base and the edge of the embodiment of the scour protection apparatus) is significantly reduced and that in turn significantly reduces the fatigue that will be experienced by the cable in its operational working life). In addition, the benefit in the reduction of the diameter of the embodiments of scour protection apparatus in accordance with the present invention compared with the prior art systems will be especially significant for the bigger wind turbine towers, monopile or seabed installations that are being installed offshore in recent years and in the future (turbine towers as time goes on are getting bigger and bigger because that can provide for a vertically higher up turbine & therefore longer blades which means more wind is experienced and higher up winds are experienced - which means significantly higher power turbines can be used which results in significantly more power being produced). Preferably, the repeating shapes are solid/rigid/non-flexible shapes.

Preferably, each of the repeating shapes within each ring is identical. This has the advantage of maximising the number of shapes within each ring.

Preferably, each ring provided on the upper surface comprises identical repeating shapes to the shapes of each other ring, such that all of the shapes provided on the upper surface are identical.

The shapes may be triangles, circles, squares, rectangles or pentagons but most preferably the shapes are hexagonal. This provides the advantage of maximising the total number of shapes for a given surface area provided on the upper surface. Most preferably, the said given surface area comprises a hexagonal tessellation. This provides the further advantage that the hexagonal patterns produce a more favourable flow pattern which improves the disruption to flow of the water passing through the grooves and therefore improves the flow suppression efficiency; there are several reasons for this but one of the main or

most important reasons is that the hexagonal patterns and surrounding groove arrangement provide a plurality of flow re-direction points.

5 Optionally, the shapes may be concave shapes such that they provide dimples or the like in the upper surface and therefore which project into the depth of the scour protection apparatus from the upper surface. More preferably, the shapes are convex shapes such that they project upwardly and outwardly from the tapered upper surface and therefore which increase the depth of the scour protection apparatus at their respective locations compared with the grooves
10 therebetween.

Preferably, the majority of the upper surface and optionally the entire upper surface comprises a hexagonal tessellation in which each three adjacent hexagons meet at each adjoining vertex and the rest of the hexagons repeat that
15 arrangement across the majority of the upper surface and more preferably across the majority or whole of at least the tapered upper surface of the scour protection apparatus.

Typically, the vertex between two adjacent sides of each shape, preferably each
20 hexagon shape, comprises a radius and preferably not a sharp corner.

Typically, the arrangement of repeating shapes are arranged in rings co-axially arranged with respect to one another, wherein they are co-axially arranged such that each respectively further outer ring is arranged further downwards on the tapered upper surface. Preferably, each ring comprises the same number of
25 repeating shapes as its adjoining inner or outer ring and typically the shapes within all of the rings are identically sized and more preferably, the groove surrounding an outer ring comprises a greater width than the width of the groove surrounding the next inner ring, such that the width of the grooves preferably
30 increases as the rings get further distant from the throughbore. This has the advantage of increasing the effect of the disruption caused by the plurality of flow re-direction points as the water flows from the outer circumference up the tapered upper surface towards the throughbore.

Additionally, the arrangement of hexagons on the upper surface around a ring can be considered to be in the form of staggered columns equi-spaced around the diameter of the upper surface, where any one column closely fits with the next adjacent column (albeit which is staggered by half the width of a hexagon when compared with the first column) and so on for other columns circumscribing the upper surface.

The skilled person will understand that the upper surface having such a hexagonal tessellation provided thereon, where the hexagons project outwardly and generally upwardly from the upper surface due to the groove arrangements, provide the great advantage of maximising the number of shapes within each ring and/or column and/or over the whole of the upper tapered surface and this therefore has the great advantage of providing the most efficient fluid disruption possible to the scour protection apparatus.

Preferably, the scour protection apparatus is adapted to be placed around a substantially tubular shaped subsea installation which in use is secured within the seabed in a body of water such as an ocean or sea or other water body, where the substantially tubular shaped subsea installation may be a tower such as a turbine tower, a monopile including a suction pile, other offshore seabed installation (including a mooring point, subsea suction bucket or suction jacket, energy production or processing facilities (including either electricity distribution or oil or gas exploration or production platforms) or the like and any other seabed installation – hereinafter referred to as either monopile or “seabed installation”).

Preferably the method further comprises lowering the scour protection apparatus from the surface of the body of water to the junction of the substantially tubular shaped subsea installation and the seabed.

The method preferably further comprises securing the scour protection apparatus around the outer circumference of the substantially tubular shaped subsea

installation at the junction of the substantially tubular shaped subsea installation and the seabed.

5 The scour protection apparatus may be lowered as a one piece unit from the surface of the body of water to the junction of the substantially tubular shaped subsea installation.

10 Alternatively, the two or more sections of the scour protection apparatus may be lowered separately from the surface of the body of water to the junction of the substantially tubular shaped subsea installation and further may be coupled and/or secured together around the outer circumference of the substantially tubular shaped subsea installation at the junction of the substantially tubular shaped subsea installation and the seabed.

15 Preferably the method further comprises transporting the scour protection apparatus from a manufacturing and/or storage location to an edge of the body of water and the method may further comprise transporting the two or more sections of the scour protection apparatus from the manufacturing and/or storage location to the edge of the body of water separate from one another.

20 The accompanying drawings illustrate presently exemplary embodiments of the disclosure and together with the general description given above and the detailed description of the embodiments given below, serve to explain, by way of example, the principles of the disclosure.

25 In the description that follows, like parts are marked throughout the specification and drawings with the same reference numerals, respectively. The drawings are not necessarily to scale. Certain features of the invention may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and
30 conciseness. The present invention is susceptible to embodiments of different forms. Specific embodiments of the present invention are shown in the drawings and herein will be described in detail, with the understanding that the present

disclosure is to be considered an exemplification of the principles of the invention and is not intended to limit the invention to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to
5 produce the desired results.

The various aspects of the present invention can be practiced alone or in combination with one or more of the other aspects, as will be appreciated by those skilled in the relevant arts. The various aspects of the invention can
10 optionally be provided in combination with one or more of the optional features of the other aspects of the invention. Also, optional features described in relation to one embodiment can typically be combined alone or together with other features in different embodiments of the invention. Additionally, any feature disclosed in the specification can be combined alone or collectively with other features in the
15 specification to form an invention.

Various embodiments and aspects of the invention will now be described in detail with reference to the accompanying figures. Still other aspects, features and advantages of the present invention are readily apparent from the entire
20 description thereof, including the figures, which illustrates a number of exemplary embodiments and aspects and implementations. The invention is also capable of other and different embodiments and aspects, and its several details can be modified in various respects, all without departing from the scope of the present invention.

25 Any discussion of documents, acts, materials, devices, articles and the like is included in the specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters formed part of the prior art base or were common general knowledge in
30 the field relevant to the present invention.

Accordingly, the drawings and descriptions are to be regarded as illustrative in nature and not as restrictive. Furthermore, the terminology and phraseology

used herein is solely used for descriptive purposes and should not be construed as limiting in scope. Language such as "including", "comprising", "having", "containing" or "involving" and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. In this disclosure, whenever a composition, an element or a group of elements is preceded with the transitional phrase "comprising", it is understood that we also contemplate the same composition, element or group of elements with transitional phrases "consisting essentially of", "consisting", "selected from the group of consisting of", "including" or "is" preceding the recitation of the composition, element or group of elements and vice versa. In this disclosure, the words "typically" or "optionally" are to be understood as being intended to indicate optional or non-essential features of the invention which are present in certain examples but which can be omitted in others without departing from the scope of the invention.

All numerical values in this disclosure are understood as being modified by "about". All singular forms of elements, or any other components described herein including (without limitations) components of the apparatus described herein are understood to include plural forms thereof and vice versa.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1a is perspective view of a first embodiment of a scour protection apparatus adapted for immersion in a body of water, the scour protection apparatus being profiled and arranged in use to reduce seabed scour occurring around a junction of the substantially tubular shaped subsea installation and the seabed, in accordance with the present invention, where the scour protection apparatus is shown in three separate sections, each of which is formed from 5 sub elements or sections, where three separate sections:-

can be connected together (to form the scour protection apparatus) at the surface of the body of water around the outer circumference of a substantially tubular shaped subsea installation and can be lowered in one section down to the installation location at a junction of the substantially tubular shaped subsea installation and the seabed or;

the three separate sections of the scour protection apparatus can be separately lowered down through the water column of the body of the water and can be connected together (to form the scour protection apparatus) around the outer circumference of the substantially tubular shaped subsea installation at the installation location at the junction of the substantially tubular shaped subsea installation and the seabed;

Fig. 1b is perspective view of the first embodiment of the scour protection apparatus of Fig. 1a but is now shown with the three separate sections having been connected together (either at the surface of the body of water or at the installation location at the junction of the substantially tubular shaped subsea installation and the seabed although the substantially tubular shaped subsea installation is not shown in Fig. 1b);

Fig. 1c is perspective view of the first embodiment of the scour protection apparatus of Fig. 1b and is shown with the three separate sections having been connected together either at the surface of the body of water around the upper end of the substantially tubular shaped subsea installation (which in Fig. 1c is the upper end of a suction bucket) prior to lowering the scour protection apparatus to the installation location at the junction of the suction bucket and the seabed;

Fig. 2 is perspective view of a second embodiment of the scour protection apparatus and is shown as a one piece unit formed from a plurality of interconnecting segments being connected together and being shown at the surface of the body of water around the upper end of the substantially tubular shaped subsea installation (which in Fig. 2 is the upper end of a suction bucket) prior to lowering the one piece unit of scour protection apparatus to the installation location at the junction of the suction bucket and the seabed;

Fig. 3 is a perspective view of a first embodiment of a single segment of the scour protection apparatus of Figs. 1a, 1b, 1c (but not Fig. 2), where the single segment of Fig. 3 is provided with a cruciform clearance through hole

through which a pendant crucifix or other lifting coupling point can be inserted to provide a lifting point for a crane wire/rope/chain or the like in order to permit lifting or lowering of the segment and individual section or one piece scour protection apparatus, and the single segment of Fig. 3 is also provided with a fully notched clearance on its left hand side (as viewed in Fig. 3) in order to allow the fully notched clearance to pass over a spigot of the adjacent segment to assist with the last connection to be made up in order to form the scour protection apparatus of Figs. 1a, 1b, 1c, and where there is only one of the segments of Fig. 3 included in the scour protection apparatus of Figs. 1a, 1b, 1c (and the segment of Fig. 3 is colour coded to distinguish it from the other segments);

Fig. 4 is a perspective view of a second embodiment of a single segment of the scour protection apparatus of Figs. 1a, 1b, 1c, and Fig. 2, where the segment of Fig. 4 is provided with a partially notched socket to assist in connection with a spigot of the adjacent segment, where there are eleven of the segments of Fig. 4 included in the scour protection apparatus of Figs. 1a, 1b, 1c and twelve of the segments of Fig. 4 included in the scour protection apparatus having 15 overall segments of Fig. 2 (although it should be noted that the total number of individual segments and total number of overall segments is variable depending upon the application, location of installation and other factors and so may be determined on a case by case basis);

Fig. 5 is a perspective view of a third embodiment of a single segment of the scour protection apparatus of Figs. 1a, 1b, 1c (but not Fig. 2), where the single segment of Fig. 3 is provided with a cruciform clearance through hole though which a pendant crucifix (also shown in Fig. 5 in an exploded view) can be inserted to provide a lifting point for a crane wire/rope/chain or the like in order to permit lifting or lowering of the segment and individual section or one piece scour protection apparatus, where the segment of Fig. 5 is provided with a partially notched socket to assist in connection with a spigot of the adjacent segment, and where there are five of the segments of Fig. 5 included in the scour protection apparatus of Figs. 1a, 1b, 1c, and where there are three of the segments of Fig. 5 included in the scour protection apparatus of Fig. 2;

Fig. 6 is a perspective view of two of the segments of Fig. 4 being brought together (such that the spigot of one is lowered into the partially notched clearance or socket of the other) and which shows the segments of Fig. 4 having an underside cut out and which can be varied during manufacture to provide for mass or weight control and also provides access for lifting through holes;

Fig. 7 is a further perspective view from a slightly different angle of the segment of Fig. 3;

Fig. 8 is a further perspective view from a slightly different angle of the segment of Fig. 5 but with the pendant crucifix installed to provide a lifting point for a crane wire/rope/chain or the like in order to permit lifting or lowering of the segment and individual section or one piece scour protection apparatus;

Fig. 9 is a perspective view from the right hand side of a fourth embodiment of a segment and which is somewhat similar to the segment of Fig. 4 except that the segment of Fig. 9 is integrally formed with upperside padeyes which project upwardly and outwardly from the upper side of the segment and lowerside padeyes which project downwardly and outwardly from the lower side of the segment of Fig. 4 where the padeyes provide a lifting point for a crane wire/rope/chain or the like in order to permit lifting or lowering of the segment and individual section or one piece scour protection apparatus;

Fig. 10 is a further perspective view from above of the segment of Fig. 9 showing the upper side of the segment from the spigot end;

Fig. 11 is a further perspective view from below of the segment of Fig. 9 showing the lower side of the segment;

Fig. 12 is a perspective view from the right hand side (having the spigot) of a fifth embodiment of a segment and which is somewhat similar to the segment of Fig. 9 except that the segment of Fig. 12 is integrally formed with one or more (two are shown) encapsulated straps which are accessible when the segment is inverted or is upright and which project outwardly from the left hand side having the partially notched socket and from the right hand side having the projecting spigot and where the encapsulated straps permit and aid lifting and handling of the segment;

Fig. 13 is a further perspective view of the segment of Fig. 12 but from a different angle and also shows the respective ends of the pair of lifting straps

having been gathered together and raised upwards in preparation for lifting of the segment by a crane or the like;

Fig. 14 is a perspective view of a sixth embodiment of fourteen segments having been arranged in a ring, with the last (fourteenth) segment being lowered into place, where this sixth embodiment of segment is somewhat similar to the segment of Fig. 4 except that the segment of Fig. 14 is formed with flat sides (and therefore doesn't have the spigot nor the partially notched socket of the segment of Fig. 4) but which instead has holes formed through its sides for fixings such as bolts to pass therethrough to connect each segment to its adjacent segment and this sixth embodiment of segment is shaped such that all segments in the scour protection apparatus being formed in Fig. 14 are identical;

Fig. 15 is a perspective view of a yet further embodiment of scour protection apparatus which has alternate, uneven spacing between segments and which is comprised of seven segments being a seventh embodiment of segment and seven segments being an eighth embodiment of segment, where the seventh embodiment of segment comprises a spigot at each side and the eighth embodiment of segment comprising a partially notched socket at each of its sides to assist in connection with the spigot of the adjacent seventh embodiment of segment;

Fig. 16 is a perspective view of a yet further embodiment of scour protection apparatus which has even spacing between segments but which is otherwise similar to the scour protection apparatus of Fig. 15 and which is therefore comprised of seven segments being the ninth embodiment of segment and seven segments being the tenth embodiment of segment;

Fig. 17 is a perspective view of a yet further embodiment of scour protection apparatus which is formed from fifteen segments being a eleventh embodiment of segment where the eleventh embodiment of segment comprises connecting strap arrangement where a connecting strap is secured at one end to an end of a channel formed at one side of the segment and where the connecting strap passes through said channel and exits said channel and further extends around the outer perimeter of the segment and enters into a similarly located channel formed within the adjacent segment and is secured at its other end

within said channel of the adjacent segment in order to strap each segments to each adjacent segment;

Fig. 18 is a further perspective view of the scour protection apparatus of Fig. 17 but which shows a partial cross section through five of the segments at the front of Fig. 17 in order to show the internal arrangement of the straps within the channels;

Fig. 19 is a further perspective line drawing view of two of the segments of the scour protection apparatus of Fig. 17;

Fig. 20 is a perspective view of a yet further embodiment of scour protection apparatus which is formed from fifteen segments being a twelfth embodiment of segment where the tenth embodiment of segment is similar to the second embodiment of segment shown in Fig. 4 except that the twelfth embodiment of segment comprises an indented or concave part-spherical dimple texture or arrangement of shapes formed in the upper surface of the segment, where the dimple provides an alternative flow disruption mechanism to the projecting hexagon arrangement of the first to eleventh embodiments of segment;

Fig. 21 is a further perspective view of one of the segments of Fig. 20 but from a different angle;

Fig. 22 is a further perspective view of the segment of Fig. 21 but shown in cross section to illustrate the indented texture of the dimples in the upper surface of the segment;

Fig. 23 is a perspective view of a yet further embodiment of scour protection apparatus which is formed from fifteen segments being an thirteenth embodiment of segment where the thirteenth embodiment of segment is similar to the twelfth embodiment of segment shown in Fig. 20 except that the thirteenth embodiment of segment comprises an outwardly projecting or convex domed texture or arrangement of shapes formed on the upper surface of the segment, where the domed texture provides an alternative flow disruption mechanism to the projecting hexagon arrangement of the first to eleventh embodiments of segment;

Fig. 24 is a further perspective view of one of the segments of Fig. 23 but from a different angle;

Fig. 25 is a further perspective view of the segment of Fig. 24 but shown in cross section to illustrate the outwardly projecting or convex domed texture formed on the upper surface of the segment;

5 Fig. 26 is a perspective view of a yet further embodiment of scour protection apparatus which is formed from fifteen segments being an fourteenth embodiment of segment where the fourteenth embodiment of segment is similar to the thirteenth embodiment of segment shown in Fig. 23 except that the fourteenth embodiment of segment comprises an outwardly projecting hexagonal texture or arrangement of shapes formed on the upper surface of the segment, 10 where the outwardly projecting hexagonal arrangement of shapes increases in height as each ring progresses inwardly such that the height of the ring of outwardly projecting hexagonal shapes is smallest in height for the outer ring compared with being highest for the inner ring, with each outwardly projecting hexagonal shape providing a flow disruption mechanism;

15 Fig. 27 is a perspective view of one of the segments of Fig. 26 in isolation from the other segments of Fig. 26;

Fig. 28 is a perspective view of a yet further embodiment of scour protection apparatus which is formed from fifteen segments being a fifteenth embodiment of segment where the fifteenth embodiment of segment is similar to 20 the thirteenth embodiment of segment shown in Fig. 23 except that the a fifteenth embodiment of segment comprises an outwardly projecting triangular texture or arrangement of shapes formed on the upper surface of the segment, with each outwardly projecting triangular shape providing a flow disruption mechanism;

25 Fig. 29 is a perspective view of one of the segments of Fig. 28 (in isolation from the other segments of Fig. 28) showing the partially notched socket on its left hand side;

Fig. 30 is a different perspective view of the segment of Fig. 29 showing the spigot projecting from the right hand side of the segment on its right hand side;

30 Fig. 31(a) is a perspective part line drawing view of two most preferred segments which can form part of a yet further embodiment of scour protection apparatus, where the two segments are a sixteenth and most preferred embodiment of segment where the fourteenth embodiment of segment

comprises a most preferred connecting strap arrangement where a connecting strap is arranged to be pushed, pulled, passed, threaded or is otherwise arranged through a channel formed at least partially through one portion of the segment which in this case is preferably through the spigot and where the connecting strap also passes (at least partially) through at least one channel formed within the adjacent segment (preferably at one side thereof) and exits said channels and further preferably extends around the outer circumference (in the radial direction of the annular substantially disc shaped annular ring of the scour protection apparatus) of the relevant pair of segments each end of the connecting strap is secured (preferably together) in order to strap each segment to each adjacent segment;

Fig. 31(b) is a further perspective part line drawing view of the two most preferred segments of Fig. 31(a), but viewed from within the throughbore of the scour protection apparatus of Fig. 31(a) and particularly showing the two ends of the connecting strap being shackled together; and

Fig. 31(c) is a further perspective part line drawing view of two of the segments of Fig. 31(a).

20 **DETAILED DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION**

Fig. 1a shows a first embodiment of a scour protection apparatus 1 adapted for immersion in a body of water (not shown) such as the sea or an ocean or the like, the scour protection apparatus 1 being profiled and arranged in use to reduce seabed scour occurring around a junction (not shown) of a substantially tubular shaped subsea installation 5 which may comprise any subsea installation such as either:-

- a monopile (i.e. a single tubular structure extending up from its foundation in the subsea surface through a water column); or
- a jacket foundation which comprises a framework having typically 3 or 4 suction buckets at its lower end, where the suction buckets are piled into the subsea surface and thereafter support the jacket foundation; and

the seabed (not shown) in accordance with the present invention, where the subsea installation 5 may support a further structure located above the sea surface (such as a wind turbine tower or offshore platform etc.).

5

The scour protection apparatus 1 is shown in three separate sections 3a, 3b, 3c, each of which is formed from five sub elements or segments 10, where three separate sections 3a, 3b, 3c:-

can be connected together by a suitable connection mechanism and which is much more preferably a flexible connection mechanism (to form the scour protection apparatus 1 having a throughbore 2) as shown in Fig. 1c at the surface of the body of water around the outer circumference of the substantially tubular shaped subsea installation 5 and can be lowered in one fully connected and combined arrangement by means of a crane wire, chain or rope of the like being connected to each of six pendant crucifixes 12 (which project upwardly from the upper surface 22 of the of scour protection apparatus 1 and which provide wire or rope connection points or shackle connection points if that is more suitable (particularly if a chain is being used)) down to the installation location at a junction of the substantially tubular shaped subsea installation 5 and the seabed; or

the three separate sections 3a, 3b, 3c of the scour protection apparatus 1 can be separately lowered down through the water column of the body of the water as shown in Fig. 1a by means of the crane wire, chain or rope of the like being connected to each of the two pendant crucifixes 12 (where each section 3a, 3b, 3c comprise one pendant crucifix 12 at each end thereof) and once lowered, can be connected together as shown in Fig. 1b (to form the scour protection apparatus) around the outer circumference of the substantially tubular shaped subsea installation 5 at the installation location at the junction of the substantially tubular shaped subsea installation 5 and the seabed.

30

Fig. 2 is perspective view of a second embodiment of the scour protection apparatus 20 and is shown as a one piece unit 20 formed from a plurality of interconnecting segments 10 being connected together and being shown at the

- surface of the body of water around the upper end of the substantially tubular shaped subsea installation (which in Fig. 2 is the upper end of a wind turbine tower having either e.g. an arrangement of suction buckets 5 or a monopile 5 at its lower end) prior to lowering the one piece unit 20 of scour protection apparatus 20 (by means of the crane wire, chain or rope of the like being connected to each of the three pendant crucifixes 12 provided in the one piece unit 20) to the installation location at the junction of the suction bucket 5 and the seabed.
- Fig. 3 is a perspective view of a first embodiment of a single segment 10A of the scour protection apparatus of Figs. 1a, 1b, 1c (but not Fig. 2), where the single segment 10A of Fig. 3 is provided with a cruciform clearance through hole 11A through which a pendant crucifix 12 (shown in Fig. 5) or other lifting coupling point can be inserted to provide a lifting point for a crane wire/rope/chain (not shown) or the like in order to permit lifting or lowering of the segment 10A and individual section 3a, 3b, 3c or one piece scour protection apparatus 20, and the single segment of Fig. 3 is also provided with a fully notched clearance 13 on its left hand side (as viewed in Fig. 3) in order to allow the fully notched clearance 13 to pass over a spigot 14 of the adjacent segment to assist with the last connection to be made up in order to form the scour protection apparatus 1 of Figs. 1a, 1b, 1c, and where there is only one of the segments 10A of Fig. 3 included in the scour protection apparatus 1 of Figs. 1a, 1b, 1c (and the segment 10A of Fig. 3 is colour coded to distinguish it from the other segments 10).
- Each of the segments 10 of Figs. 1a, 1b, 1c and Fig. 2 comprise a lower most planar shaped surface 9A such that when they are all connected together to form the scour protection apparatus 1, they provide the scour protection apparatus 1 with a lower most substantially or partially planar shaped surface 9.
- In addition, each of the outer perimeter 19A of the segments 10 of Figs. 1a, 1b, 1c and Fig. 2 comprises a part circumferential perimeter 19A having a substantially constant radius such that when they are all connected together to form the scour protection apparatus 1, they provide the scour protection

apparatus 1 with an outermost generally elliptical circumference or more preferably an outermost generally circular circumference 16A and therefore provide the scour protection apparatus 1 with a lower most substantially or partially planar disc shaped surface 9.

5

Each of the segments 10 of Figs. 1a, 1b, 1c and Fig. 2 is tapered downwardly along its upper surface 22A in a substantially linear manner from its throughbore 2A to its outer perimeter 16A such that when they are all connected together to form the scour protection apparatus 1, they provide the scour protection apparatus 1 with a depth that increases from the outermost generally circular circumference 16A towards the throughbore 2A, such that the depth at the throughbore 2A is greater than the depth at the outermost perimeter 16. In other words, the upper surface 22A of the scour protection apparatus 1 tapers upwardly from the outermost circumference 16A towards the said throughbore 2A, such that the depth of the scour protection apparatus 1 increases from the outermost perimeter towards the throughbore 2A.

The scour protection apparatus 1, 20 is therefore generally frusto-conical shaped with a central throughbore 2 extending along its central longitudinal axis 8. This in use provides the advantage that water flowing over the scour protection apparatus 1, 20 will be forced to flow up the tapered upper surface 22 which will therefore act (in addition to the flow disruption caused by the various shapes 15 as will be described subsequently) to at least partially slow down the velocity of the water due to the force of gravity acting thereon. In addition, the frusto-conical shape assists to prevent flow of the water from accelerating around the subsea installation 5 and in particular the foundations thereof and/or the apparatus 1, 20 itself because the frusto-conical shape decreases the hydrodynamic drag of the scour protection apparatus 1, 20 within the water column and this ensures the hydrodynamic loads at the edge (i.e. the outermost generally circular circumference) of the scour protection apparatus 1, 20 drop to ambient level thus minimising the occurrence of scouring (and thus providing protection against scouring of the foundations of the subsea installation 5).

Each of the segments 10 of Figs. 1a, 1b, 1c and Fig. 2 comprise a plurality of shapes 15 provided on its upper surface 22 and preferably are a plurality of repeating shapes 15 and for the embodiment of Figs. 1 to 19 most preferably are a plurality of spaced apart hexagonal outwardly projecting shapes 15A having channels or grooves 21 therebetween. Each of the plurality of shapes 15 project upwardly from the tapered upper surface 22 and the channels or grooves 21 therebetween lie on the upper surface 22 of the frusto-conically shaped scour protection apparatus 1, 20. The skilled reader will realise that the size and/or number of shapes 15 provided on each of the segments 10 of Figs. 1a, 1b, 1c and Fig. 2 can be varied depending upon the application, project, location of installation and/or other factors and so may be determined on a case by case basis by the supplier of the scour protection apparatus 1, 20 and/or the operator and/or the installer and/or any other relevant party involved in a particular application or project.

15

The plurality of shapes 15 of all embodiments described herein are arranged in rows (typically with two shapes 15 per row) such that when the segments 10A are brought together firstly into their sections 10 and secondly to form the disc shaped scour protection apparatus 1, the shapes 15 are arranged in 20 or more rings 7 and in the preferred embodiments disclosed herein, there are preferably three rings 7A, 7B, 7C, where:-

inner ring 7A is closest to the longitudinal central axis 8 of the disc shaped scour protection apparatus 1 (and therefore ring 7A has the smallest diameter of all of the rings 7)

outer ring 7C is furthest from the longitudinal central axis 8 of the disc shaped scour protection apparatus 1 (and therefore ring 7C has the greatest diameter of all of the rings 7); and

middle ring 7B is intermediate rings 7A and 7C (and therefore ring 7B has a smaller diameter than ring 7C but a larger diameter than ring 7A).

30

Thus, there are preferably the same number of shapes 15 in each ring 7 and more preferably the shapes 15 within each of the rings 7 are all identically sized and more preferably, the groove 21 surrounding the outer ring 7C has a greater

width than the width of the groove 21 surrounding the middle ring 7B, such that the width of the grooves 21 preferably increases as the rings 7 get further distant from the throughbore 2.

- 5 This has the advantage of increasing the effect of the disruption caused by the plurality of flow re-direction points as the water flows from the outer circumference up the tapered upper surface towards the throughbore 2.

10 The grooves 21 are preferably all arranged lie on a substantially frusto-conical shaped uppermost surface 22 of the scour protection apparatus 1, 20 such that water making contact with the upper surface 22 of the scour protection apparatus 1, 20 is deflected into the grooves 21 and flows upwards from the side of entry and either around the lateral sides of the scour protection apparatus 1, 20 or around the outer circumference of the monopile or seabed installation. The
15 scour protection apparatus 1, 20 is preferably formed from an impervious or impermeable material such as concrete or metal and therefore the lower surface of the grooves 21 is typically solid in order to ensure that the water is directed along the groove 21 such that no water can pass through the upper surface of the scour protection apparatus 1, 20 and this provides the advantage over prior
20 art arrangements (such as that shown in GB1134154 or CA1046296 which disclose having fabric sheets possibly with holes formed therein) that the water is substantially prevented from making contact with the seabed in the immediate vicinity around the junction of the lower end of the monopile or seabed installation and the seabed and therefore provides significant scour protection to
25 that area of the sea bed.

In addition, each segment 10 is provided with connection means in the form of a flexible connection mechanism to enable each segment 10 to be connected and more preferably securely connected to its two adjacent segments, one adjacent
30 segment on each side. In the embodiment of segment 10A shown in Fig. 3, the segment 10A comprises a circumferentially extending spigot 14A (on its right hand side as shown in Fig. 3) and a fully notched clearance 13A (on its left hand side as shown in Fig. 3), where the circumferentially extending spigot 14A

comprises a co-operatively and is correspondingly shaped to act like a plug when it is inserted into the co-operatively and correspondingly shaped fully notched clearance 13A which will act like a socket and accept the insertion of the circumferentially extending spigot 14A. Preferably, the circumferentially extending spigot 14A and fully notched clearance 13A are arranged to have at least a clearance fit therebetween in use. Thus, whilst the circumferentially extending spigot 14A and the fully notched clearance 13A do not provide a secure coupling therebetween in the vertical or lateral direction, they do provide a secure coupling therebetween in the radial direction and thereby assist in the building of the scour protection apparatus 1 into its frusto—conical shape.

The various segments 10 therefore are building blocks which can be built up into either or both of separate sections 3a, 3b, 3c or can further be built up into a one piece unit 20 depending upon how the installer of the scour protection apparatus 1, 20 plans to install the scour protection apparatus 1,20.

The segment 10A further comprises one or more lifting thru' holes 24A (in addition to the cruciform clearance through hole 11) and in the embodiment shown in Fig. 3, the segment 10A comprises 4 lifting thru' holes 24A which are preferably arranged along the central radial axis having the midpoint or centre of gravity coincident therewith such that when suitable lifting assistance means such as hooks (not shown) are secured into the lifting thru' holes 24A, a crane wire, chain or rope or the like can be coupled to the hooks and the segment 10A can be safely lifted from e.g. a transportation device such as a vehicle trailer or flatbed to an assembly location.

The segment 10A further comprises one or more securing holes 25A formed vertically all the way through the spigot 14A through which a suitable fixing device such as a bolt (not shown) can be inserted (and which as will be described subsequently, the suitable fixing device can further extend into a securing hole 26B formed through the bottom portion of the partially notched clearance or socket 13B such that the spigot 14 of the adjacent segment 10 and socket 13B of the segment 10B can be secured to one another).

Fig. 4 shows a second embodiment of a single segment 10B of the scour protection apparatus of Figs. 1a, 1b, 1c, and Fig. 2, where the segment 10B of Fig. 4 differs from the segment 10A in that it 10B is provided with a partially notched socket 13B to assist in connection with a spigot 14 of the adjacent segment 10, where there are eleven of the segments 10B of Fig. 4 included in the scour protection apparatus 1 of Figs. 1a, 1b, 1c and twelve of the segments of Fig. 4 included in the scour protection apparatus of Fig. 2.

It will however be appreciated by the skilled reader that:-

- the number of different embodiments of segment 10 that are utilised in a particular scour protection apparatus 1, 20 in accordance with the present invention;
- the total number of individual segments of a particular embodiment of segment 10 utilised in a particular scour protection apparatus 1, 20 in accordance with the present invention; and
- the total number of overall segments 10 utilised in a particular scour protection apparatus 1, 20 in accordance with the present invention

is variable depending upon the application, project, location of installation and/or other factors and so may be determined on a case by case basis by the supplier of the scour protection apparatus 1, 20 and/or the operator and/or the installer and/or any other relevant party involved in a particular application or project.

The segment 10B of Fig. 4 further differs from the segment 10A in that it 10B doesn't have a cruciform clearance through hole 11 but it does have a securing hole 26B formed vertically through the bottom portion of the partially notched clearance or socket 13B such that the spigot 14 of the adjacent segment 10 and socket 13B of the segment 10B can be secured to one another once they are aligned and inserted together. Otherwise, the rest of the features of the segment 10B of Fig. 4 are similar to those of the segment 10A and are shown with the suffix B instead of the suffix A.

Fig. 5 shows a third embodiment of a single segment 10C of the scour protection apparatus of Figs. 1a, 1b, 1c and Fig. 2, where the single segment 10C of Fig. 5 is similar to the segment 10A of Fig. 3 (it also has a cruciform clearance through hole 11C through which a pendant crucifix 12 shown in Fig. 5 in an exploded view can be inserted to provide a lifting point for a crane wire/rope/chain or the like in order to permit lifting or lowering of the segment 10C and individual 3a, 3b, 3c or one piece scour protection apparatus 20), where the segment 10C of Fig. 5 is provided with a partially notched socket 13C (identical to that 13B of the segment 10B of Fig. 4) to assist in connection with a spigot 14 of the adjacent segment 10, and where there are five of the segments 10C of Fig. 5 included in the scour protection apparatus of Figs. 1a, 1b, 1c. Otherwise, the rest of the features of the segment 10C of Fig. 5 are similar to those of the segment 10A and are shown with either the same reference number without a suffix or with the suffix C instead of the suffix A.

Fig. 6 shows two of the segments 10B of Fig. 4 being brought together (such that the spigot 14B of one is lowered into the partially notched clearance or socket 13B of the other) and which shows the segments 10B of Fig. 4 having an underside cut out 28, where the size of the cut out 28 can be varied during manufacture of the segments 10 to provide for mass or weight control and also provides access for the lifting thru' holes 24B.

Figs. 9 to 11 show a fourth embodiment of a segment 10D and which is somewhat similar to the segment 10B of Fig. 4 except that the segment 10D of Fig. 9 is integrally formed with upperside padeyes 27U (instead of lifting thru holes) which project upwardly and outwardly from the upper surface 22 of the segment 10D and lowerside padeyes 27L which project downwardly and outwardly from the lower surface 17 of the segment 10D of Fig. 4 where the padeyes 27U, 27L provide a lifting point for a crane wire/rope/chain or the like in order to permit lifting or lowering of the segment 10D and individual section 3 or one piece 20 scour protection apparatus. Otherwise, the rest of the features of the segment 10D of Figs. 9 to 11 are similar to those of the segment 10B and are

shown with either the same reference number without a suffix or with the suffix D instead of the suffix B.

5 Figs. 12 and 13 show a fifth embodiment of a segment 10E and which is somewhat similar to the segment 10D of Fig. 9 except that the segment 10E of Fig. 12 is provided with a different form of a flexible connection mechanism, wherein the segment 10E is integrally formed with one or more (two are shown) encapsulated straps 29 (instead of padeyes) which are accessible when the segment 10E is inverted or is upright and which project outwardly from the left
10 hand side having the partially notched socket 13E and from the right hand side having the projecting spigot 14E and where the encapsulated straps 29 permit and aid lifting and handling of the segment. Otherwise, the rest of the features of the segment 10E are similar to those of the segment 10D and are shown with either the same reference number without a suffix or with the suffix E instead of
15 the suffix D.

Fig. 14 shows a sixth embodiment of fourteen segments 10F having been arranged in a ring to provide another example of a scour protection apparatus 1F, with the last (fourteenth) segment 10F being lowered into place, where this
20 sixth embodiment of segment 10F is somewhat similar to the segment 10B of Fig. 4 except that the segment of Fig. 14 is formed with flat sides 30 (and therefore doesn't have the spigot nor the partially notched socket of the segment of Fig. 4) but which instead has side holes 31 formed through its sides for suitable fixings such as bolts (not shown) to pass therethrough to connect each
25 segment 10F to its adjacent segment 10F and this sixth embodiment of segment 10F is shaped such that all segments 10F in the scour protection apparatus 20F being formed in Fig. 14 are identical. The sixth embodiment of fourteen segments 10F does also differ from the previous embodiments in that, due to the lack of the spigot and partially or fully notched socket, some of the shapes 15FH
30 are halved compared to the rest of the shapes 15F but those half shapes 15FH match up to a corresponding half shape 15FH when the segments 15F are connected together. Otherwise, the rest of the features of the segment 10F are

similar to those of the segment 10B and are shown with either the same reference number without a suffix or with the suffix F instead of the suffix B.

5 Fig. 15 shows a seventh and eighth embodiment of fourteen segments 10H which when combined together form another example of a scour protection apparatus 1H. The scour protection apparatus 1H has alternate, uneven spacing between two different types of segments 10H which are comprised of:-

10 i) seven male segments 10HM being a seventh embodiment of segment 10HM which comprises a spigot 14H projecting laterally outwards from each side thereof; and

15 ii) seven female segments 10HF being an eighth embodiment of segment 10HF which comprises a partially notched socket 13H formed in each of its sides to assist in connection with the spigot 14H of the adjacent seventh embodiment of segment 10HM.

20 This arrangement of segments 10HM and 10HF results in even spacing 32 between each segment but uneven spacing between some of the grooves 21 compared to others – for example, groove 21HA is 1.8 times the width of groove 21HB.

25 Otherwise, the rest of the features of the segment 10H are similar to those of the segment 10F and are shown with either the same reference number without a suffix or with the suffix H instead of the suffix F.

30 Fig. 16 shows a ninth and tenth embodiment of fourteen segments 10K which when combined together form another example of a scour protection apparatus 1K. The scour protection apparatus 1K has alternate, uneven spacing between two different types of segments 10K which are comprised of:-

i) seven male segments 10KM being a ninth embodiment of segment 10KM which comprises a spigot 14K projecting laterally outwards from each side thereof; and

ii) seven female segments 10KF being an eighth embodiment of segment 10KF which comprises a partially notched socket formed in each of its

sides to assist in connection with the spigot 14K of the adjacent seventh embodiment of segment 10KM.

5 This arrangement of segments 10KM and 10KF results in uneven spacing 34A versus 34B between respective segments 10K.

Otherwise, the rest of the features of the segment 10K are similar to those of the segment 10H and are shown with either the same reference number without a suffix or with the suffix K instead of the suffix H.

10

Figs. 17 to 19 show an eleventh embodiment of fifteen segments 10L which when combined together form another example of a scour protection apparatus 1L. The scour protection apparatus 1L has 15 identical segments 10L each of which comprise a connecting strap arrangement 36 where a connecting strap 38
15 is secured at one end 39 to an end of a channel 40 formed at one side (the left hand side shown in Figs. 17 to 19) of each segment 10L from the inner throughbore 2L to the outer perimeter 19L. The connecting strap 38 passes through said channel 40 and exits said channel 40 at the outer perimeter 19L and further extends around the outer perimeter 19L of the segment 10L from left to
20 right as shown in Figs. 17 to 19 all the way along the outer perimeter 19L of that segment 10L and crosses over the joint 42 with the adjacent segment 10L and enters into a similarly located channel 40 formed within the adjacent segment 10L and is secured at its other end 39 within the inner end of said channel 40 of the adjacent segment 10L in order to secure each segment 10L to each adjacent
25 segment 10L.

Otherwise, the rest of the features of the segment 10L are similar to those of the segment 10K and are shown with either the same reference number without a suffix or with the suffix L instead of the suffix K.

30

Fig. 20 shows a twelfth embodiment of fifteen segments 10M (shown in more detail in Figs. 21 and 22) having been arranged in a ring to provide another example of a scour protection apparatus 1M, where this twelfth embodiment of

segment 10M is somewhat similar to the segment 10B of Fig. 4 except that the segment of Fig. 20 is formed with an indented or concave part-spherical dimple shapes 44 forming a dimpled texture or arrangement of part spherical dimple shapes 44 formed in the upper surface 22M of the segment 10M (instead of the
5 hexagonal projecting shapes 15B of the segment 10B of Fig. 4), where the dimples 44 provide an alternative flow disruption mechanism to the projecting hexagon arrangement of the first to eleventh embodiments of segments 10.

Otherwise, the rest of the features of the segment 10M are similar to those of the
10 segment 10B and are shown with either the same reference number without a suffix or with the suffix M instead of the suffix B.

Fig. 23 shows a thirteenth embodiment of fifteen segments 10N (shown in more detail in Figs. 24 and 25) having been arranged in a ring to provide another
15 example of a scour protection apparatus 1N, where this thirteenth embodiment of segment 10N is somewhat similar to the segment 10B of Fig. 4 except that the segment 10N of Fig. 24 is formed with an outwardly projecting or convex part-spherical dome shapes 46 formed on the upper surface 22N of the segment 10N (instead of the indented or concave part-spherical dimple shapes 44 of the
20 segment 10M of Fig. 21), where the domes 46 provide an alternative flow disruption mechanism to the projecting hexagon arrangement of the first to eleventh embodiments of segments 10.

Otherwise, the rest of the features of the segment 10N are similar to those of the
25 segment 10B and are shown with either the same reference number without a suffix or with the suffix M instead of the suffix B.

Fig. 26 shows a fourteenth embodiment of fifteen segments 10P (shown in more detail in Fig. 27) having been arranged in a ring to provide another example of a
30 scour protection apparatus 1P, where this fourteenth embodiment of segment 10P is somewhat similar to the segment 10B of Fig. 4 except that the segment 10P of Fig. 24 is formed with a series of rings of hexagonal projecting shapes 15P formed on the upper surface 22P of the segment 10P which increase in

height as each ring progresses inwardly such that the height of the ring of outwardly projecting hexagonal shapes 15PO is smallest in height for the outer ring 15PO compared with the highest height for the inner ring 15PI (therefore with the height of the middle ring 15PM being greater than the height of the smallest (outer) ring 15PO but being smaller than the height of the tallest (inner most) ring 15PI), with each ring of outwardly projecting hexagonal shapes 15P providing an alternative flow disruption mechanism to the projecting hexagon arrangement of the first to eleventh embodiments of segments 10.

10 Otherwise, the rest of the features of the segment 10P are similar to those of the segment 10B and are shown with either the same reference number without a suffix or with the suffix P instead of the suffix B.

15 Fig. 28 shows a fifteenth embodiment of fifteen segments 10Q (shown in more detail in Figs. 29 and 30) having been arranged in a ring to provide another example of a scour protection apparatus 1Q, where this fifteenth embodiment of segment 10Q is somewhat similar to the segment 10N of Fig. 24 except that the segment 10Q of Fig. 28 is formed with an outwardly projecting convex triangular shape 48 formed on the upper surface 22Q of the segment 10Q (instead of the
20 indented or convex part-spherical domed shapes 46 of the segment 10N of Fig. 23), where the triangular shape 48 provide an alternative flow disruption mechanism to the projecting domed shapes 46 of the thirteenth embodiments of segments 10N. Also, the outwardly projecting convex triangular shapes 48 may be arranged with the triangles pointing upwards 48U as shown in Fig. 29 or
25 pointing downwards as shown in Fig. 30.

Otherwise, the rest of the features of the segment 10Q are similar to those of the segment 10N and are shown with either the same reference number without a suffix or with the suffix Q instead of the suffix N.

30

Figs. 31(a) to 31(c) show a sixteenth embodiment of two most preferred segments 10R which, when combined with a suitable number (to form a suitable total number of segments 10R such as fourteen or fifteen segments 10R) of other

similarly shaped segments 10R, can form part of a yet further embodiment of scour protection apparatus 1R.

5 The two segments 10R are a sixteenth and most preferred embodiment of segment 10 where the sixteenth embodiment of segment 10R is most similar to the eleventh embodiment of segment 10L disclosed in Fig. 17, in that it also includes a connection strap arrangement 50 comprising at least one (and as shown in Figs. 31 (a) to (c)), a doubled over) connecting strap 51 which is arranged to be pushed, pulled, passed, threaded or is otherwise arranged
10 through a radially directed (with reference to the radial direction of the scour protection apparatus 1R when it is formed) substantially linear channel 53 formed at least partially through one portion of the segment 10R which in this case is preferably through the spigot 14R (which like the other spigots 14 extends circumferentially from one lateral side of the segment 10R) and where the
15 connecting strap 51 also passes (at least partially) through at least one channel 54 formed within either of the fully notched clearance socket 13R or partially notched clearance socket (not shown in Figs. 31 (a) to (c) but this could replace the fully notched clearance socket 13R that is shown in Figs. 31 (a) to (c)) in order to couple the two adjacent segments 13R together with one another (i.e.
20 via the connecting strap 51). The two channels 53, 54 are preferably arranged such that, when the respective two segments 10R are brought together, the two channels 53, 54 are in radial alignment such that the connecting strap 51 is linearly arranged such that the two portions thereof which pass through the channels 53, 54 are radially aligned with one another (i.e. they are on the same
25 generally radially directed axis as one another).

The connecting strap 51 can then be secured to lock the two adjacent segments 13R together by wrapping the connecting strap around the rest of the outer perimeter or circumference (in the radial direction) of the joint between the
30 adjacent segments 10R. In other words, if when the segments 10R are connected together into the disc shaped scour protection apparatus 1R having a throughbore 2R, and the disc shaped scour protection apparatus 1R is considered to be in the approximate shape of a torus (such that the outermost

generally circular circumference 16R is equivalent to the toroidal direction), the connecting strap 51 is secured in place by wrapping the connecting strap 51 around the outer perimeter or circumference in the poloidal direction of the joint between the adjacent segments 10R. The two ends 52 of the connecting strap 51
5 can be secured or locked to one another 52 by a suitable locking means 55 such as a shackle 55 or the like.

Otherwise, the rest of the features of the segment 10R are similar to those of the segment 10L and are shown with either the same reference number without a
10 suffix or with the suffix R instead of the suffix L.

Overall, each of the embodiments of scour protection apparatus 1, 20 described herein are arranged to envelope, around their throughbore 2, a typically relatively short vertical height such as in the range of 0.5 metre to 5 meters or so of the
15 lower installed end of the monopile or other subsea installation 5 and may have an outer diameter which ranges from 8 to 20 metres or so.

In addition to the above-mentioned advantages of the embodiments 1, 20 of the present invention described herein, the geometries of the shapes 15, 44, 46, 48
20 and most preferably the hexagonal projecting shapes 15 provided on or within the upper surface 22 of the respective embodiments assist to prevent the formation of horse shoe vortices which would otherwise occur if the shapes 15 weren't present. As will be appreciated by the skilled reader, the repeating shapes 15, 44, 46, 48 and most preferably the hexagonal projecting shapes 15
25 provided on or within the upper surface 22 of the respective embodiments are solid/rigid/non-flexible shapes 15, 44, 46, 48 which further assists in preventing the formation of horse shoe vortices which would otherwise occur if the shapes 15 weren't solid and non-flexible.

30 In addition to the above mentioned advantages of the embodiments 1, 20 of the present invention described herein, the flexible connection mechanism disclosed herein not only securely lock two adjacent segments 10 together and thus prevents them from separating apart from one another but which also permits

- one segment 10 to flex, bend or twist to a certain extent with respect to the connected segment 10 such that the flexible connection mechanism allows for articulation of the two segments 10 with respect to each other such that each of the segments 10 can conform to a non-standard (i.e. non-flat) seabed.
- 5 Accordingly, the flexible connection mechanisms disclosed herein allow for the scour protection apparatus 1, 20 to accommodate an undulating seabed as well as conform to said undulating seabed to ensure full contact with the seabed during service and most preferably can conform to changes to the seabed during the life of the installation of the scour protection apparatus 1, 20 if underpinning is
- 10 observed during said life of the installation of the scour protection apparatus 1, 20. That therefore provides the advantage that underpinning, due to water flowing underneath the scour protection apparatus 1, 20 which would otherwise result in water digging out a section of the seabed, is prevented.
- 15 Embodiments 1, 20 in accordance with the present invention may be made from any suitable impervious or impermeable material, including but not limited to:-
- Concrete;
 - Rebar reinforced concrete;
 - Glass reinforced plastic; and/or
 - 20 ○ Suitable fibre filled epoxy material.

Embodiments 1, 20 of the present invention provide *a solution to* mitigate scour about seabed installations 5, removing or drastically reducing the need for traditional rock dumping (dependent on environmental parameters). The various

25 embodiments of segments 10 in accordance with the invention are also arranged with consideration of road transportation.

Embodiments 1, 20 of the present invention have the advantage of considerably reducing the scour that would otherwise occur around the junction of wind turbine

30 tower monopile installations 5 (particularly the most popular monopile 5 being a suction pile 5), and other offshore seabed installations 5 (including mooring points, subsea suction buckets or suction jackets, energy production or processing facilities (including either electricity distribution or oil or gas

exploration or production platforms) and any other seabed installation 5, in that they significantly reduce the effect that flow of water (due to e.g. oncoming currents and waves) around the base of the monopile or subsea installation 5 itself causes, including a number of different scour effects such as (but not limited to):-

- Downflow vortices;
- Horseshoe vortices;
- Lee-wake vortices;
- 10 • Accelerated flow; and
- Assists in reducing shearbed stress below a critical value that would otherwise cause material (e.g. sand or rocks or other material) to move.

Moreover, the repeating shapes 15 of the various embodiments disclosed herein (which preferably are protruding repeating shapes 15 projecting upward from the upper surface 22 and comprise one or more groove(s) 21 therebetween) disrupt and/or deflect flow of the current or waves of water contacting the scour protection apparatus 1, 20 and in doing so reduce far field shear bed stress. This provides the significant advantage to such embodiments that, unlike prior art scour protection systems (which for example can comprise rocks arranged in a disc around the bottom of the monopile or seabed installation 5) which typically need to have a foundation in the form of a disc of rocks installed which extends from the outer circumference of the monopile or seabed installation 5 to the far edge of the disc of rock of between 4 to 5 times the diameter of the monopile or seabed installation 5), the protruding repeating shapes 15 on the upper surface 22 of embodiments of the present invention significantly reduces the distance that the said embodiments need to extend out to around 2 to 2.5 times the diameter of the monopile or seabed installation 5. That reduction in the distance for embodiments of the present invention provides the significant advantage that the amount of electrical export cable that is exposed to the water (which is typically between the point of exit from the monopile or seabed installation 5 at/towards its base and the edge of the embodiment of the scour protection apparatus 1, 20 – because it is then buried in a trench for protection) is

significantly reduced and that in turn significantly reduces the fatigue that will be experienced by the cable in its operational working life).

5 Embodiments of the present invention may be used with monopiles or other subsea installations 5 having the substantially cylindrical element profile, as disclosed in PCT Patent publication number WO2019/077370, provided there around (i.e. around the actual monopile or cylindrical structure 5 that extends upwards from the seabed) in order to reduce vortex induced vibration (VIV) and/or drag acting upon the monopile or other subsea installation 5.

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Modifications and improvements may be made to the embodiments hereinbefore described without departing from the scope of the invention.

15

CLAIMS:-

1. A scour protection apparatus adapted for immersion in a body of water,
the scour protection apparatus comprising:-
 - 5 an inner throughbore which is adapted in use to be located around the
outer circumference of a substantially tubular shaped subsea installation;
a lower most substantially planar shaped surface adapted in use to rest
upon the seabed surface;
an outermost perimeter; and
 - 10 an upper most surface substantially impervious to water, wherein at least
a portion of the upper surface comprises at least two flow diversion means
provided thereon and each flow diversion means being separated from each
adjacent flow diversion means by a groove arrangement,
wherein the scour protection apparatus in use reduces seabed scour
 - 15 occurring around a junction of the substantially tubular shaped subsea
installation and the seabed.
2. A scour protection apparatus according to claim 1, wherein the lower most
planar shaped surface is a lower most planar disc shaped surface and wherein
20 the outermost perimeter comprises an outermost generally circular
circumference.
3. A scour protection apparatus according to either of claims 1 or 2, wherein
the depth of the scour protection apparatus increases from the outermost
25 perimeter towards the throughbore, such that the depth at the throughbore is
greater than the depth at the outermost perimeter and the upper surface of the
scour protection apparatus tapers upwardly from the outermost perimeter
towards the said throughbore.
- 30 4. A scour protection apparatus according to any preceding claim, wherein
the scour protection apparatus is generally generally frusto-conical shaped
around a central throughbore extending along its central longitudinal axis.

5. A scour protection apparatus according to any preceding claim, wherein the scour protection apparatus is formed from two or more interconnecting sections which when connected together form the scour protection apparatus.

5 6. A scour protection apparatus according to claim 5, wherein the or each section is formed from two or more interconnecting segments which when connected together form each section of the scour protection apparatus.

10 7. A scour protection apparatus according to claim 6, wherein each pair of segments comprise a connection means to connect them together.

15 8. A scour protection apparatus according to claim 7, wherein the connection means comprise a flexible connection mechanism which securely locks two adjacent segments together and prevents them from separating apart from one another but which also permits one segment to move with respect to the other segment such that the flexible connection mechanism allows for articulation between said two adjacent segments.

20 9. A scour protection apparatus according to claim 8, wherein the flexible connection mechanism comprises a strapping arrangement which includes a strap arranged to be passed through a radially directed substantially linear channel formed at least partially through one portion of the segment and through a spigot formed in a segment and where the connecting strap also passes (at least partially) through at least one channel formed within a socket of an adjacent segment in order to couple the two adjacent segments together with one another and the two said channels of the adjacent segments are arranged such that, when the respective two segments are brought together, the two channels are in radial alignment such that the connecting strap is linearly arranged such that the two portions thereof which pass through the said channels are radially aligned with one another.

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10. A scour protection apparatus according to claim 9, wherein the connecting strap is secured to lock the two adjacent segments together by wrapping the

connecting strap around the rest of the outer perimeter or circumference (in the radial direction) of the joint between the adjacent segments, and the two ends of the connecting strap are secured to one another by a locking means.

- 5 11. A scour protection apparatus according to any preceding claim, wherein the at least two flow diversion means provided on at least a portion of the upper surface comprise at least two rings of repeating shapes.
- 10 12. A scour protection apparatus according to claim 11, wherein each ring of repeating shapes are separated from each adjacent ring by a groove arrangement and each shape within a ring being separated from adjacent shapes by at least one groove.
- 15 13. A scour protection apparatus according to claim 12, wherein the two or more rings of repeating shapes re-directs the flow path of water flowing through the respective grooves and thereby creates significant turbulence in the water which further slows down the flow of the water.
- 20 14. A scour protection apparatus according to any of claims 11 to 13, wherein each of the repeating shapes within each ring is identical and each ring provided on the upper surface comprises identical repeating shapes to the shapes of each other ring, such that all of the shapes provided on the upper surface are identical.
- 25 15. A scour protection apparatus according to any of claims 11 to 14, wherein the majority of the upper surface comprises a hexagonal tessellation in which each three adjacent hexagons meet at each adjoining vertex and the rest of the hexagons repeat that arrangement across the majority of the upper surface of the tapered upper surface of the scour protection apparatus.
- 30 16. A scour protection apparatus according to any of claims 11 to 15, wherein a vertex between two adjacent sides of each shape comprises a radius.

17. A scour protection apparatus according to any of claims 11 to 16, wherein the arrangement of repeating shapes are arranged in rings co-axially arranged with respect to one another, such that each respectively further outer ring is arranged further downwards on the tapered upper surface and each ring
5 comprises the same number of repeating shapes as its adjoining inner or outer ring and the shapes within all of the rings are identically sized and the groove surrounding an outer ring comprises a greater width than the width of the groove surrounding the next inner ring, such that the width of the grooves increases as the rings get further distant from the throughbore.

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18. A scour protection apparatus according to any of claims 11 to 17, wherein the arrangement of hexagons on the upper surface around a ring are in the form of staggered columns equi-spaced around the diameter of the upper surface, where any one column closely fits with the next adjacent column and so on for
15 other columns circumscribing the upper surface.

19. A scour protection apparatus according to any preceding claim, wherein the scour protection apparatus is adapted to be placed around a substantially tubular shaped subsea installation which in use is secured within the seabed in a
20 body of water.

20. A method of preventing scour around the foundations of a substantially tubular shaped subsea installation, the method comprising:-

providing a scour protection apparatus adapted for immersion in a body of
25 water, the scour protection apparatus comprising an inner throughbore which in use is located around the outer circumference of a substantially tubular shaped subsea installation, a lower most substantially planar shaped surface adapted in use to rest upon the seabed surface, an outermost perimeter and an upper most surface; wherein at least the upper surface of the scour protection apparatus is
30 substantially impervious to water, and at least a portion of the upper surface is provided with at least two flow diversion means thereon and each ring of repeating shapes are separated from each adjacent ring by a groove

arrangement and each shape within a ring being separated from adjacent shapes by at least one groove, and

arranging the scour protection apparatus around the outer circumference of the substantially tubular shaped subsea installation at a junction of the substantially tubular shaped subsea installation and the seabed.

21. A method according to claim 20, wherein the method further comprises lowering the scour protection apparatus from the surface of the body of water to the junction of the substantially tubular shaped subsea installation and the seabed.

22. A method according to either of claims 20 or 21, wherein the method further comprises securing the scour protection apparatus around the outer circumference of the substantially tubular shaped subsea installation at the junction of the substantially tubular shaped subsea installation and the seabed.

23. A method according to any of claims 20 to 22, wherein the method further comprises lowering the scour protection apparatus as a one piece unit from the surface of the body of water to the junction of the substantially tubular shaped subsea installation.

24. A method according to any of claims 20 to 22, wherein the method further comprises lowering the scour protection apparatus as two or more sections separately from the surface of the body of water to the junction of the substantially tubular shaped subsea installation and further comprises coupling and securing said two or more sections together around the outer circumference of the substantially tubular shaped subsea installation at the junction of the substantially tubular shaped subsea installation and the seabed.

25. A method according to claim 24, wherein the method further comprises transporting the scour protection apparatus from a manufacturing and/or storage location to an edge of the body of water separate from one another.