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(54) CONCRETE ARMOR UNIT TO PROTECT COASTAL AND HYDRAULIC STRUCTURES AND SHORELINES
BEWEHRUNGSELEMENT AUS BETON ZUM SCHÜTZEN VON KÜSTEN- UND WASSERBAUWERKEN SOWIE KÜSTEN
UNITE D’ARMATURE EN CIMENT DESTINEE A PROTEGER LES STRUCTURES COSTALES ET HYDRAULIQUES AINSI QUE LES RIVAGES

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The Kaneko et al. patent discloses a polyprop block comprised of at least three integral pillar-shaped parts joined in an alternatively crossed relationship. Hence, the block has at least six appendages which interlock with other blocks so that a large number of blocks can be arranged to form tightly assembled combinations. A primary drawback of the Kaneko et al. design is that the pillar-shaped members are joined together with a minimum amount of shared surface area. This provides tremendous stress concentrations at these areas. Owing to these excessive stress concentrations, the blocks possess a higher probability for breaking, potentially leading to a massive failure of an entire arrangement or assembly of blocks. Another drawback of the Kaneko et al. block is that the appendages do not stay together in an assembled fashion. This is due to the fact that the pillar-shaped members have a square cross-section which provides a limited area of frictional engagement with neighboring blocks. Yet another drawback derives from the regular arrangement of modules, whereby catastrophic failure to the entire protective structure can result from the failure of a relatively few armor blocks. Also, the regularly placed blocks produce an armor layer with very low porosity, providing little wave energy dissipation and therefore little contribution to reduction in wave energy from the protected area in the lee of the structure.

The Chevallier patent discloses a barrier block for protecting riverside structures and shorelines. The block comprises a cubic central core having top and bottom surfaces provided with anvil-shaped legs and opposed front and rear legs in the form of four-shaped truncated pyramids. A major drawback of the hydraulic stability characteristics of the Chevallier block is that the anvil-shaped legs are not slender and thus produce minimal unit-to-unit wedging which reduces interlocking stability. The blocks rely primarily on gravity forces from overlying units to enhance individual block stability and must therefore be placed on steep slopes to assure stability. However, steep-sloped structures have a tendency to fail catastrophically and have proven to have a high probability of failure and risk when used. Placed on slope, the Chevallier unit exhibits the characteristics of a low-porosity armor layer, which provides less reduction in wave energy than found in armor layer composed of more slender armor units. Further, the Chevallier blocks require exact placement in order to develop enhanced hydraulic stability.

Practical difficulties result in the manufacture, storage and transport of armor units. For example, some armor units have shapes which are not easily cast or formed. Some armor units do not allow for nested placement in yard areas or in shipping barges, and consequently are difficult to store and ship efficiently. Also, some structures are not repairable by simple addition of replacement armor units, but must be partially disassembled.

There is thus a need for a durable interlocking module capable of random placement resulting in a structure which has strong individual modules and which structure is stable. The module shape should have slender appendages to provide improved stability and wave energy dissipation over existing module shapes yet to be strong enough to prevent failure of any single armor unit. There is no need for a module which may be used to repair existing slopes. There is also a need for a module which may be manufactured at lower cost, and which further may be stored and shipped at reduced cost.

According to the present invention there is provided an armor unit for protecting coastal, river, lake and reservoir banks, shorelines and other structures from the damaging hydrodynamic forces of waves and water currents, the unit comprising:

- a central elongate member having a longitudinal axis; and,
- first and second identical outer elongate members connected with the central elongate member on opposite sides thereof, the first and second outer elongate members having coplanar central axes extending normal to the longitudinal axis of the central elongate member, the elongate members each having a cross-sectional area decreasing from an intermediate portion towards the opposite ends thereof, characterised in that each of the members has a regular octagonal cross-section and each outer member has a taper measured as the angle 8 between the longitudinal axis of the member and its outer surface in the range of about 10° to about 20°, whereby when a plurality of structures are interlocked to define a protective array, a high degree of wedging is afforded between the members and residual stability is provided in the array.

The present invention overcomes these and other drawbacks of the prior devices by providing an armor unit or erosion prevention module which is uniquely configured to produce a high degree of interlocking and which provides...
stability regardless of the steepness of the structure's slope. The module has slender appendages which provide both significantly improved hydraulic stability and wave energy dissipation over prior art systems. Internal stress levels are minimized by shortening the appendages by filleting all of the internal member intersections.

[0009] The present invention provides an armor unit or erosion prevention module as the fundamental component for protecting ocean, coastal, river, lake and reservoir banks, and other structure armor layers from the damaging hydrodynamic forces of waves and water currents.

[0010] In various embodiments, the modules have geometric characteristics including a separation aspect ratio, defined as the ratio of the separation distance between inner surfaces of the outer members to the overall length of the outer members in a range of about .45 and about .55; a depth aspect ratio, defined as the outer modular end length to the overall outer end length in a range of about 0.25 to 0.35.

[0011] According to a further embodiment of the invention, the elongate members are connected at central intermediate portions. The connections include chamfered surfaces, whereby stress between the members is reduced.

[0012] Another embodiment of the invention features internal reinforcing bars within the elongate members.

[0013] The invention also includes a structure for protecting coastal, river, lake and reservoir banks, shorelines and the like from the damaging hydrodynamic forces of waves and water currents, the structure comprising a plurality of the armour units defined above, as well as a form for the manufacture of such units.

[0014] Other objects and advantages of the invention will become apparent from a study of the following specification when viewed in the light of the accompanying drawings, in which:

Fig. 1 is a perspective view of one embodiment of an armor unit according to the invention;
Fig. 2 is a top plan view of the armor unit of Fig 1;
Fig. 3 is a front plan view of the armor unit of Fig. 1;
Fig. 4 is a perspective view of another embodiment of an armor unit;
Fig. 5 is a top plan view of the armor unit of Fig 4;
Fig. 6 is a front plan view of the armor unit of Fig. 4 partially cut away to illustrate internal reinforcing bars;
Figs. 7A and 7B are respective side sectional elevations of a breakwater structure and the revetment structure;
Fig. 8 is a graphic representation of percent damage versus stability coefficient for a variety of known structures, established during two dimensional physical modeling testing, compared with corresponding data for the structure according to the present invention;
Figs. 9A and 9B are fragmentary side elevations illustrating a chamfered and filleted transition between the members respectively;
Fig. 9C is an illustration of an unchamfered and unfilleted transition;
Fig. 10 is an illustration showing the packing density of armor units according to the present invention; and
Figs. 11A and 11B are fragmentary perspective illustrations of clam shell forms for concrete casting armor units in accordance with the present invention.

DESCRIPTION OF THE INVENTION

[0015] Referring first to Figs. 1-3, the armor unit or erosion prevention module 2 of the present invention comprises a central elongate member 4 having a longitudinal axis 6 and two outer elongate members 8 and 10 having longitudinal axes 12 and 14 respectively. The outer elongate members 8 and 10 are connected with the central elongate member 4 on opposite sides thereof. In the exemplary embodiment, the longitudinal axes 12 and 14 of the outer elongate members 8 and 10 extend parallel to each other and normal to the longitudinal axis of the central member 4. Preferably, the elongate members are connected at their central portions.

[0016] The three elongate members are substantially identical in shape and dimensions, and, in the preferred embodiment, have an octagonal cross-section.

[0017] As shown in Fig. 3, each of the elongate members is configured such that the cross-sectional area decreases from an intermediate portion 18 toward the opposite ends 20 and 22 thereof. The decreasing cross-sectional area is generally uniform, as shown. More particularly, the shape of each elongate member comprises an intermediate portion 18 having the bases of two frustum-shaped fluke sections 24 and 26 secured at opposite ends thereof. The armor units thus have an H shape when viewed from the end (e.g., Fig. 3). It should be understood that the armor units 2 may have various coplanar central axes 12 and 14. For example, the units may resemble an X in elevation. The central axes may also be curves derived from various conic sections, e.g., hyperbolic.

[0018] The connections between the central elongate member 4 and the outer elongate members 8 and 10 comprise chamfered surfaces 28 which reduce stress at the area of concentration. As shown in Figs. 9A and 9B in the present invention, chamfers or fillets 28 and 29 are placed at high-angle intersections of the members to reduce stress concentrations in these areas, thus further improving the structural integrity of the unit. An unchamfered or filleted device is shown in Fig. 9C for comparison. The internal high-angle intersections have been shown to have the highest stresses
in armor units of many shapes. Angular chamfers 28 would typically be easier to construct than circular fillets 29 but provide slightly less stress reduction. Tests have shown that chamfered sections, as specified for this module, provide 30% to 40% reduction in internal stresses over non-modified angled intersections while filleted sections provide 40% to 50% reduction in internal stresses over non-modified sections.

Figs. 4-6 illustrate another more slender embodiment of the invention comprising elongate members having reduced cross-sectional area with extended connections, or spacing, between the outer members and the central member.

Either embodiment of the present invention is adapted to be arranged with a multiplicity of other such modules to form a cohesive, interlocking armor array or barrier which resists hydrodynamic forces tending to erode navigation structures and shorelines and other structures. Ideally, stability is maintained in such an array or barrier even when individual modules are removed from the bottom by hydraulic action. The octagonal elongate members maintain a high degree of wedging with one another while spacing between the members and the chamfered surfaces offer excellent stability within an array. Assemblies formed from slender armor units (Figs. 4-6) tend to have greater stability than assemblies of stout modules (Figs. 1-3) due to better interlocking between elongate members.

Modules having varying aspect ratios (i.e., a degree of slenderness or stoutness) may be provided so that modules can accommodate a wider range of gradation of underlayer stone and optimization of stress versus layer stability. For example, aspect ratios may be defined in various ways to describe the geometrical dimensions of the erosion protection module according to the invention. Fig. 3 illustrates the exemplary dimensions referred to herein. The depth aspect ratio \( R_d \) may be defined as the ratio of the fluke end length \( A \), measured from the fluke end 25 to the surface 27 of the central member 4, to the fluke length \( C \). The separation aspect ratio \( R_s \) is the ratio of the widest separation distance \( B \) between the inner surfaces 29 of two adjacent fluke ends 25 to the fluke length \( C \) defined above. These two aspect ratios may be adjusted to provide the maximum wedging and interlocking among units without introducing failure-level stresses, when the units are placed randomly.

In accordance with the invention, the separation aspect ratio: \( R_s = B/C \) is generally in a range of about .45 and .55 and preferably about .47 and .48. Likewise, the depth aspect ratio: \( R_d = A/C \) is generally in a range of about .35 and about .25 and preferably about .32 and about .27 and more preferably about .32 and .30.

Each fluke 24 and 26 has a taper angle \( \theta \) measured as the angle between the longitudinal fluke axis 12 and 14 and the respective exterior surface 31 of the corresponding fluke 24 and 26. \( \theta \) varies generally in a range of about 10° and about 20°. The table below shows two exemplary embodiments.

<table>
<thead>
<tr>
<th>Example I</th>
<th>Example II</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta = 12^\circ )</td>
<td>( \theta = 20^\circ )</td>
</tr>
<tr>
<td>( R_s = 0.47 )</td>
<td>( R_s = 0.48 )</td>
</tr>
<tr>
<td>( R_d = 0.32 )</td>
<td>( R_d = 0.27 )</td>
</tr>
</tbody>
</table>

Although the cross-sectional shape of the members of the present invention can be various polygonal and conical shapes, the octagonal shape is thought to be the most efficient. Round or conical sections tend to produce less resistance to rocking. Fewer-sided sections, for instance square or hexagonal, have higher angled edges producing higher stresses at the edges resulting in increased spalling of the outer concrete surfaces. Sections with more than eight sides are more expensive to construct as form assembly and construction requires more labor to cut fabricate and attach the increased number of form panels.

Shape improvement is also provided by sufficiently tapering the member ends to permit wedging and interlocking of the member ends when individual units are placed in a random orientation within a single-layer matrix. Also, full symmetry of the member ends promotes wedging between units when units are placed randomly. This enhances the stability.

Although preferably made from concrete, the entire module may be formed of any suitable material or combination of materials such as composites, stone, and/or metal. The embodiments of the invention illustrated are strong enough not to require structural strengthening, although such strengthening may be included, if desired. As shown in Fig. 6, the module may include internal reinforcing bars 30, such as metal or fiberglass rebar, in the elongate members. The bars extend generally parallel to the axes 12 and 14 of the elongate members. If desired, a latticework of internal reinforcing bars may be provided. The bars can be either deformed rods or post-tensioned rods for extreme conditions.

Fig. 7A illustrates the cross-section of a jetty or breakwater 40 formed on the sea bottom 42 subjected to waves and currents 43. The breakwater 40 comprises a mound or core section 44 which has an upper surface covered with a so called underlayer 46 of stone or blocks or both, and a single over-lying layer of armor 48 comprising randomly placed armor units 2.
The present invention has been physically modeled up to a Hudson equation stability coefficient of 400 without showing zero measurable damage when tested in the laboratory using generally accepted coastal physical modeling practice. However, for purposes of comparison the 2D method characterizing three-dimensional testing is more complex and generally results in a lower stability coefficient, which more accurately characterizes the structure. However, for purposes of comparison the 2D method is believed to be appropriate.

Fig. 7B illustrates a revetment 50 in cross-section of an earth mound, an underlayer 56 and a single armor layer 58 of randomly placed modular armoring units 2. It should be understood that two dimensional (2D) testing is a well-recognized and preferred method for characterizing these structures. Three dimensional testing is more complex and generally results in a lower stability coefficient, which more accurately characterizes the structure. For the single layer, the volume of concrete and the number of units required are approximately half that of a conventional two-layer matrix.

The random orientation of armor units 2 in high-wave height applications is important because the precision necessary for reliable uniform placement is unattainable in deep, low-visibility coastal waters, and also in shallow but wavy environments. Also, the precision is generally not economically feasible on irregular underlayers composed of the randomly placed irregularly shaped stone, which are almost always used. In addition, most uniformly placed armor layers have little resistance to forces caused by back pressures which are due to excess pore pressure build-up in the structure underlayers and core. Uniformly placed armor layers composed of stout armor units often provide little wave energy dissipation and therefore offer less protection for objects in the lee of the structure than armor layers composed of slender units. Uniformly placed units are also seldom capable of self-healing whereas randomly placed units can heal themselves, as discussed below.

Another way to characterize the invention is that the shape of the module should be capable of exhibiting zero measurable damage when tested in the laboratory using generally accepted coastal physical modeling practice and subjected to wave heights of a magnitude corresponding to Hudson equation stability coefficients of at least 70. In comparison, tests conducted on a single-layer structure trunk section, using the armoring unit of the present invention indicate that the probability of damage is near zero for stability coefficients as high as 400. An increase in the stability coefficient by a factor of 2 decreases the stone weight by a factor of 2. Thus, it is clear that significant savings may be achieved by increasing the stability coefficient, as illustrated herein.

K_D is the stability coefficient, i.e., an empirical parameter used in the Hudson Equation and is typically around 10 for most prior art armor shapes. However, for purposes of comparison the 2D method is believed to be appropriate.
Physical model stability tests of the present invention have also shown the armor layer to be self healing for minor armor unit movements, which always occur during settlement of structures. The armor units move and nest together during settlement so as to achieve maximum interlocking and wedging, minimizing the distance between unit centroids. This occurs even if large movements of individual units are induced, such as dislodging or extraction of a unit from the slope, because the interlocking members will act to restrain the remaining units while the area renests. Other shapes that require uniformly placed slopes are typically not capable of exhibiting this self healing characteristic. This is because the stability of uniformly placed slopes is maximized by the unit-to-unit friction rather than the interlocking of member ends. Therefore, if one unit is dislodged there will be greatly reduced inter-unit frictional forces acting to restrain the remaining units.

The following is a comparison of various 2D design criteria which may be used to evaluate the stability and effectiveness of an armor unit of the invention with known systems.
<table>
<thead>
<tr>
<th>Invention CORE-LOC</th>
<th>Stone</th>
<th>Block</th>
<th>DOLOS</th>
<th>ACCROPODE</th>
<th>Tetrapod</th>
<th>Uniform Tribar</th>
<th>Random Tribar</th>
<th>HARO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope, cot(a)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.33</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>K₀</td>
<td>16</td>
<td>6</td>
<td>15.8</td>
<td>12</td>
<td>7</td>
<td>12</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>W (tons)</td>
<td>34.77</td>
<td>208.63</td>
<td>92.72</td>
<td>52.29</td>
<td>79.48</td>
<td>34.77</td>
<td>46.36</td>
<td>50.58</td>
</tr>
<tr>
<td>Unit Volume (cf)</td>
<td>486.32</td>
<td>2917.92</td>
<td>1296.85</td>
<td>393.36</td>
<td>731.31</td>
<td>1111.59</td>
<td>486.32</td>
<td>648.43</td>
</tr>
<tr>
<td>No. of Units per sq foot</td>
<td>0.0088</td>
<td>0.0062</td>
<td>0.0100</td>
<td>0.0161</td>
<td>0.0081</td>
<td>0.0097</td>
<td>0.0097</td>
<td>0.0125</td>
</tr>
<tr>
<td>Volume concrete (cf/sf)</td>
<td>4.28</td>
<td>18.01</td>
<td>12.96</td>
<td>5.94</td>
<td>5.90</td>
<td>10.77</td>
<td>4.71</td>
<td>8.12</td>
</tr>
<tr>
<td>Slope factor</td>
<td>1.00</td>
<td>1.24</td>
<td>1.00</td>
<td>1.24</td>
<td>0.92</td>
<td>1.00</td>
<td>1.24</td>
<td>1.24</td>
</tr>
<tr>
<td>Economics, Volume-Based</td>
<td>1.00</td>
<td>5.22</td>
<td>3.03</td>
<td>1.72</td>
<td>1.27</td>
<td>2.52</td>
<td>1.37</td>
<td>2.35</td>
</tr>
</tbody>
</table>
The Economic comparison of armor units from the Table is based on a design wave height of $H = 28$ feet and a unit weight density of $\gamma = 143$ pounds per cubic foot. The Economics, Volume-based row is the ratio of volume $V_I$ of the armor units of the invention to volume $V_o$ of other armor layer units for a given slope factor which must be considered:

\[
\text{Economics} = \frac{V_o}{V_I} \cdot \text{Slope factor}
\]

For example, an armor unit sold under the trademark ACCROPODE (corresponding to the armor unit shown in the Chevallier patent) having a volume 5.9, and a slope factor of .92 would cost approximately 27% more than the invention having a volume of 4.28 and a slope factor of 1. A Dolos layer, with a slope factor of 1.24, would cost 72% more than the invention. A block layer would be three times more expensive than the invention.

Dolos units are prone to breakage because of the slender central sections. The present invention has no slender central sections and is therefore not prone to such breakage. The shape of the armor unit 2 of the present invention allows the unit to be used in the repair of so-called Dolos slopes because of the octagonal member shape, similar tapers, and the similar aspect ratios. The separation and depth aspect ratios are both dimensioned such that the present invention interlocks well with the Dolos shape. The present invention can thus be intermixed with Dolos units or used to repair an entire section of a Dolos slope. The repair with modules according to the invention requires fewer new units than are required to replace the entire slope with a different type of unit. Moreover, a hybrid slope employing Dolos units and armor units of the invention provides improved stability over an all-Dolos slope.

The individual armor units of the present invention are also conveniently stackable, reducing the required casting yard and shipping space. One stacking scheme is shown in Fig. 10. Stacking is important to economic viability when armor units are to be barged long distances to remote sites or to sites where limited construction materials are available. Because of their unique configuration, the armor units of the invention can be efficiently stored in a casting yard. For example, the units can be tightly packed or stacked in multiple layers in a herring-bone configuration, as shown. Note the remarkably small center to center spacing of the invention. The packing density in terms of centroid to centroid spacing is minimal with the present invention and is typically about 100% of the largest diameter of the outer member for stacked units, and is in a range of about 120 and 140% for randomly placed units, which is less than known systems.

Fig. 11A is a fragmentary perspective view of a four piece clam shell form 60 for cast an armor unit 2 according to the present invention. The form 60 comprises four symmetrical quadrants 62, 64, 66 and 68 formed in hinged elongated halves 70 and 72 corresponding to the longitudinal portions and a split central section 73 corresponding to the central elongate member. Cross braces 74 secure the elongate sections 70 and 72 in side-by-side relationship. Supports 76 support the ends of the central elongate section 73. Hinges 80 and 82 hold the corresponding quadrants 62, 64, 66, 68 together respectively, as shown. The end portion 83 of the central portion is closed for containing concrete and the upper and lower ends of the lateral members are open for receiving concrete. It should be understood that the form 60 sits on the ground surface and contains the concrete therein. Port members 86 allow the release of entrained air and excess water. Alternatively, the arrangement of Fig. 11A may be modified as shown in Fig. 11B so that the entire unit 90 may be formed of respective upper and lower halves 92 and 94 secured together. The lower half 94 is supported by braces 96.

The forms may be constructed of any material but are commonly made of metal, wood, fiberglass or plastic, although large armor unit forms are most commonly made of welded sheet steel. The form must be efficiently built to minimize materials but maximize rigidity, even with repeated use.

While in accordance with the provisions of the patent statute and the preferred forms and embodiments have been illustrated and described, it will be apparent to those of ordinary skill in the art that various changes and modifications may be made without deviating from the inventive concepts as being defined in the appended claims.

Claims

1. An armour unit (2) for protecting coastal, river, lake and reservoir banks, shorelines and other structures from the damaging hydrodynamic forces of waves and water currents, the unit comprising:

   a central elongate member (4) having a longitudinal axis (6); and,
   first and second identical outer elongate members (8,10) connected with the central elongate member on opposite sides thereof, the first and second outer elongate members having coplanar central axes (12,14) extending normal to the longitudinal axis (6) of the central elongate member (4), the elongate members (4,8,10) each having a cross-sectional area decreasing from an intermediate portion towards the opposite ends thereof, characterised in that
each of the members (4,8,10) has a regular octagonal cross-section and each outer member (8,10) has a taper measured as the angle \( \theta \) between the longitudinal axis of the member and its outer surface in the range of about 10° to about 20°, whereby when a plurality of units are interlocked to define a protective array, a high degree of wedging is afforded between the members and residual stability is provided in the array.

2. An armour unit according to claim 1, wherein each of the elongate members (4,8,10) is configured as two frustums joined at their bases by an intermediate portion.

3. An armour unit according to claim 1, wherein the cross-sectional area of each member (4,8,10) decreases uniformly from the intermediate portion towards the opposite ends thereof.

4. An armour unit according to claim 1, wherein the central elongate member (4) and the outer elongate members (8,10) are connected via chamfered surfaces (28), whereby stress between the members is reduced.

5. An armour unit according to claim 4, wherein the chamfered surfaces (28) between the elongate members (4,8,10) are extended to connect the elongate members to the central elongate member, whereby greater structural stability within an array of the structures is achieved.

6. An armour unit according to claim 1, which has a depth aspect ratio (\( R_D \)) defined as the ratio of the length (A) of an outer member to the surface of the central member (4) to the length (C) of the outer member (8,10), wherein A/C is in a range of about 0.35 to about 0.25, preferably about 0.32 to about 0.27, and most preferably about 0.32 to about 0.30.

7. An armour unit according to claim 1, which has a separation aspect ratio (\( R_s \)) defined as the ratio of the widest separation distance (B) between inner surfaces of the outer members (8,10) and the length (C) of the outer member (8,10), wherein B/C is in a range of about 0.45 to about 0.55, and preferably about 0.47 to about 0.48.

8. An armour unit according to claim 1, wherein each outer member (8,10) has a taper angle in the range of about 12° to about 20°.

9. A structure for protecting coastal, river, lake and reservoir banks, shorelines and the like from the damaging hydrodynamic forces of waves and water currents, the structure comprising a plurality of armour units according to any of claims 1 to 9.

10. A structure unit according to claim 9, having a two dimensional stability coefficient of at least about 70, and preferably about 400.

11. A structure according to claim 10, wherein individual units are randomly placed such that the minimum spacing of adjacent members is within about 140% of the largest diameter of the outer member.

12. A structure unit according to claim 10, wherein the individual units (2) are stacked such that the minimum spacing of adjacent members (4,8,10) is within about 100% of the largest diameter of the outer member (8,10).

13. A structure according to any of claims 9 to 11, having a single layer of units (2).

14. A form (60) for casting an armour unit for protecting coastal, river, lake and reservoir banks, shorelines and other earthen and stone structures from the damaging hydrodynamic forces of waves and water currents, the form comprising:

   a hollow central elongate member (73) having a longitudinal axis; and, first and second outer hollow elongate members (62/68,64/66) connected with the central elongate member on opposite sides thereof, the first and second outer elongate members having coplanar longitudinal axes extending from and lying in a plane normal to the longitudinal axis of the central elongate member, the elongate members each having a tapered regular cross-section, the cross-sectional area of each member decreasing from an intermediate portion toward the opposite ends thereof characterised in that each of the members (73,62/68,64/66) has a regular octagonal cross-section and each outer hollow member has a taper measured as the angle \( \theta \) between the longitudinal axis of the member and its inner surface in the range of about 10° to about 20°.
15. Eine Bewehrungseinheit (2) zum Schützen von Küsten-, Fluß-, See- und Staubecken/Talsperrenufern, Stränden und anderen Strukturen vor den zerstörenden hydrodynamischen Kräften von Wellen und Wasserströmen, wobei die Einheit umfaßt:

ein zentrales längliches Teil (4), das eine Längsachse (6) aufweist, und

erste und zweite identische, äußere längliche Teile (8, 10), die mit dem zentralen länglichen Teil an gegenüberliegenden Seiten davon verbunden ist, wobei die ersten und zweiten äußeren länglichen Teile koplanare Mittelachsen (12, 14) haben, die sich normal zu der Längsachse (6) des zentralen länglichen Teils (4) erstrecken, wobei die länglichen Teile (4, 8, 10) jeweils eine Querschnittsfläche haben, die von einem Zwischenabschnitt in Richtung auf die gegenüberliegenden Enden davon abnimmt, dadurch gekennzeichnet, daß jedes der Teile (4, 8, 10) einen regelmäßigen oktagonalen Querschnitt hat und jedes äußere Teil (8, 10) eine Verjüngung, gemessen als der Winkel θ zwischen der Längsachse des Teils und seiner Außenfläche, in dem Bereich von etwa 10° bis etwa 20° aufweist, wodurch, wenn eine Mehrzahl Einheiten verriegelt ist, um eine Schutzanordnung festzulegen, ein hoher Verkeilungsgrad zwischen den Teilen gewährt und Eigenstabilität in der Anordnung geschaffen wird.

2. Eine Bewehrungseinheit nach Anspruch 1, bei der jedes der länglichen Teile (4, 8, 10) als zwei Stümpfe ausgebildet ist, die an ihren Basen durch einen Zwischenabschnitt verbunden sind.

3. Eine Bewehrungseinheit nach Anspruch 1, bei der die Querschnittsfläche jedes Teils (4, 8, 10) gleichförmig von dem Zwischenabschnitt in Richtung auf die gegenüberliegenden Enden davon abnimmt.

4. Eine Bewehrungseinheit nach Anspruch 1, bei der das zentrale längliche Teil (4) und die äußeren länglichen Teile (8, 10) über abgeschragte Flächen (28) verbunden sind, wodurch die Spannung zwischen den Teilen vermindert wird.

5. Eine Bewehrungseinheit nach Anspruch 4, bei der die abgeschragten Flächen (28) zwischen den länglichen Teilen (4, 8, 10) zum Verbinden der länglichen Teile mit dem zentralen länglichen Teil ausgedehnt sind, wodurch größere strukturelle Stabilität innerhalb einer Anordnung der Strukturen erreicht wird.

6. Eine Bewehrungseinheit nach Anspruch 1, die ein Tiefen-Erstreckungsverhältnis (R_D) aufweist, das definiert ist als das Verhältnis der Länge (des Abstands) (A) eines äußeren Teils bis zur Oberfläche des zentralen Teils (4) zu der Länge (C) des äußeren Teils (8, 10), wobei A/C in einem Bereich von etwa 0,35 bis etwa 0,25, bevorzugt etwa 0,32 bis etwa 0,27 und besonders bevorzugt etwa 0,32 bis 0,30 liegt.

7. Eine Bewehrungseinheit nach Anspruch 1, die ein Teilungs-Erstreckungsverhältnis (R_S) aufweist, das definiert ist als das Verhältnis des weitesten Teilungsabstands (B) zwischen Innenflächen der äußeren Teile (8, 10) und der Länge (C) des äußeren Teils (8, 10), wobei B/C in einem Bereich von etwa 0,45 bis etwa 0,55 und bevorzugt etwa 0,47 bis etwa 0,48 liegt.

8. Eine Bewehrungseinheit nach Anspruch 1, bei der jedes äußere Teil (8, 10) einen Verjüngungswinkel θ im Bereich von etwa 12° bis etwa 20° aufweist.


10. Ein Bauwerk nach Anspruch 9 mit einem zweidimensionalen Stabilitätskoeffizienten von mindestens etwa 70 und
11. Ein Bauwerk nach Anspruch 10, bei dem das einzelne Einheiten zufällig so angeordnet sind, daß der minimale Abstand benachbarter Teile innerhalb etwa 140 % des größten Durchmessers des äußeren Teils liegt.

12. Ein Bauwerk nach Anspruch 10, bei dem die einzelnen Einheiten (2) so geschichtet sind, daß der minimale Abstand benachbarter Teile (4, 8, 10) innerhalb von etwa 100 % des größten Durchmessers des äußeren Teils (8, 10) liegt.


14. Eine Form (60) zum Gießen einer Bewehrungseinheit zum Schützen von Küsten-, Fluß-, See- und Staubecken-/Talsperrenufern, Stränden und anderen Erd- und Steingefügen vor den zerstörenden hydrodynamischen Kräften von Wellen und Wasserströmern, wobei die Form umfaßt:

- ein hohles, zentrales längliches Teil (73) mit einer Längsachse und
- erste und zweite äußere hohle, längliche Teile (62/68, 64/66), die mit dem zentralen länglichen Teil an gegenüberliegenden Seiten davon verbunden sind, wobei die ersten und zweiten äußeren länglichen Teile koplaniare Längsachsen haben, die ausgehen von und liegen in einer Ebene, die normal zu der Längsachse des zentralen Teils liegt, wobei die länglichen Teile jeweils einen verjüngten regelmäßigen Querschnitt aufweisen, wobei die Querschnittsfläche jedes Teils auf einem Zwischenabschnitt in Richtung auf gegenüberliegende Enden davon abnimmt, dadurch gekennzeichnet, daß jedes der Teile (73, 62/68, 64/66) einen regelmäßigen oktagonalen Querschnitt und jedes äußere hohle Teil eine Verjüngung aufweist, gemessen als der Winkel $0$ zwischen der Längsachse des Teils und seiner Innenfläche, in dem Bereich von etwa $10^\circ$ bis etwa $20^\circ$ hat.

15. Eine Form nach Anspruch 14, bei der die Form entlang einer ersten Ebene, die die Längsachsen der äußeren Teile (62/68, 64/66) enthält, geteilt ist.

16. Eine Form nach Anspruch 15, bei der die Form entlang einer Ebene geteilt ist, die senkrecht zu der ersten Ebene steht und die Längsachse des zentralen Teils (73) enthält.

Revendications

1. Unité (2) d’armature destinée à protéger des rives côtières, de rivière, de lac et de retenues d’eau, des rivages et d’autres structures contre les forces hydrodynamiques nuisibles de vagues et de courants d’eau, l’unité comprenant:

- un élément allongé central (4) ayant un axe longitudinal (6) et des premier et second éléments allongés extérieurs identiques (8, 10) reliés à l’élément allongé central sur ses côtés opposés, les premier et second éléments allongés extérieurs ayant des axes centraux coplanaires (12, 14) s’étendant normalement à l’axe longitudinal (6) de l’élément allongé central (4), les éléments allongés (4, 8, 10) ayant chacun une superficie de section transversale qui va en diminuant d’une partie intermédiaire vers ses extrémités opposées, caractérisée en ce que chacun des éléments (4, 8, 10) a une section transversale octogonale régulière, et chaque élément extérieur (8, 10) présente une conicité, mesurée en tant qu’angle $0$, dans la plage d’environ $10^\circ$ à $20^\circ$, entre l’axe longitudinal de l’élément et sa surface extérieure, ce par quoi, lorsque plusieurs unités sont verrouillées mutuellement pour définir un groupement protecteur, on peut obtenir un degré élevé de coinçage entre les éléments et une stabilité résiduelle dans le groupement.

2. Unité d’armature selon la revendication 1, dans laquelle chacun des éléments allongés (4, 8, 10) est configuré comme deux cônes reliés au niveau de leurs bases par une partie intermédiaire.

3. Unité d’armature selon la revendication 1, dans laquelle la superficie de section transversale de chaque élément (4, 8, 10) diminue uniformément de la partie intermédiaire vers ses extrémités opposées.

4. Unité d’armature selon la revendication 1, dans laquelle l’élément allongé central (4) et les éléments allongés
extérieurs (8, 10) sont reliés via des surfaces chanfreinées (28), ce par quoi l'on obtient une réduction de contrainte entre les éléments.

5. Unité d’armature selon la revendication 4, dans laquelle les surfaces chanfreinées (28) qui se trouvent entre les éléments allongés (4, 8, 10) s’étendent pour relier les éléments allongés avec l’élément allongé central, ce par quoi l’on obtient une meilleure stabilité structurelle à l’intérieur d’un groupement des structures.

6. Unité d’armature selon la revendication 1, qui a un rapport d’aspect de profondeur (R_1) défini en tant que rapport de la longueur (A) d’un élément extérieur à la surface de l’élément central (4) à la longueur (C) de l’élément extérieur (8, 10), dans laquelle A/C se trouve dans une plage d’environ 0,35 à environ 0.25, de préférence d’environ 0.32 à environ 0.27, et de manière encore plus préférée d’environ 0.32 à environ 0.30.

7. Unité d’armature selon la revendication 1, qui a un rapport de distance de séparation (R_2) défini en tant que rapport de la distance de séparation la plus large (B) entre des surfaces intérieures des éléments extérieurs (8, 10) et la longueur (C) de l’élément extérieur (8, 10), dans laquelle B/C se trouve dans une plage d’environ 0.45 à environ 0.55 et, de préférence, d’environ 0.47 à environ 0.48.

8. Unité d’armature selon la revendication 1, dans laquelle chaque élément extérieur (8, 10) présente un angle de conicité γ qui se trouve dans la plage d’environ 12° à environ 20°.

9. Structure destinée à protéger des rives côtières, de rivière, de lac et de retenues d’eau, des rivages et analogues contre les forces hydrodynamiques nuisibles de vagues et de courants d’eau, la structure comprenant plusieurs unités d’armature selon l’une quelconque des revendications 1 à 9.

10. Unité de structure selon la revendication 9, ayant un coefficient de stabilité bidimensionnelle d’au moins environ 70 et, de préférence, d’environ 400.

11. Structure selon la revendication 10, dans laquelle des unités individuelles sont placées de manière aléatoire de sorte que l’espacement minimal entre éléments adjacents soit inférieur à environ 140% du diamètre le plus grand de l’élément extérieur.

12. Unité de structure selon la revendication 10, dans laquelle les unités individuelles (2) sont empilées de sorte que l’espacement minimal entre éléments adjacents (4, 8, 10) soit inférieur à environ 100% du diamètre le plus grand de l’élément extérieur (8, 10).

13. Structure selon l’une quelconque des revendications 9 à 11, comportant une couche unique d'unités (2).

14. Moule (60) pour couler une unité d’armature destinée à protéger des rives côtières, de rivière, de lac et de retenues d’eau, des rivages et d’autres structures terreuses ou rocheuses contre les forces hydrodynamiques nuisibles de vagues et de courants d’eau, le moule comprenant :

- un élément allongé central creux (73) ayant un axe longitudinal ; et,
- des premier et second éléments allongés extérieurs creux (62/68, 64/66) reliés à l’élément allongé central sur ses côtés opposés, les premier et second éléments allongés extérieurs ayant des axes longitudinaux coplanaires s’étendant normalement, et se trouvant dans un plan normal, à l’axe longitudinal de l’élément allongé central, les éléments allongés ayant chacun une section transversale régulière effilée, la superficie de section transversale de chaque élément allant en diminuant d’une partie intermédiaire vers ses extrémités opposées, caractérisé en ce que chacun des éléments (73, 62/68, 64/66) a une section transversale octogonale régulière, et en ce que chaque élément extérieur creux présente une conicité, mesurée en tant qu’angle γ, dans la plage d’environ 10° à 20°, entre l’axe longitudinal de l’élément et sa surface intérieure.

15. Moule selon la revendication 14, dans lequel le moule est ouvrant le long d’un premier plan incluant les axes longitudinaux des éléments extérieurs (62/68, 64/66).

16. Moule selon la revendication 15, dans lequel le moule est ouvrant le long d’un plan perpendiculaire au premier plan et incluant l’axe longitudinal de l’élément central (73).