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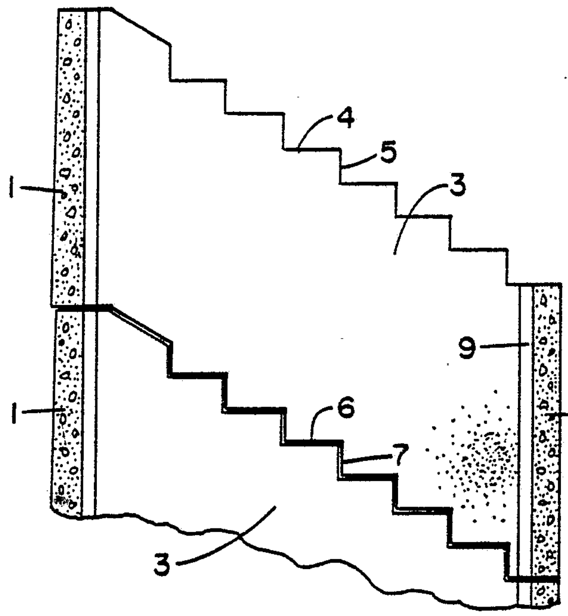

(57) Abstract

A prefabricated concrete module (11) and a composite wall structure comprised of an assembly of modules, where the module comprises a generally rectangular front and rear panel (1, 2), joined by at least one generally trapezodial partition means (3). A cellular wall structure is formed by stacking the modules and aligning the partition means (3) on top of each other, thereby forming bins which contain loose material contributing to the weight of the structure. Provisions can be made for slabs (49) which span longitudinally across partition means to be positioned upon or between partition means of vertically contiguous modules. These slabs (49), which capture an additional amount of loose material, can also, where desired, transfer lateral forces between superposed partition means.

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STRUCTURAL MODULE FOR RETAINING WALLS AND THE LIKE

Background of the Invention

This invention relates generally to specially configured prefabricated cellular modules for employment in the construction of gravity retaining walls.

The structural modules of the present invention are intended to be used in combination with other similar modules arranged in horizontal rows and, according to the height required of the structure, in additional superposed horizontal rows of modules each properly proportioned to provide adequate stability to the assembled structure.

An object of the present invention is to provide an improvement over other prefabricated modules presently used for wall structures of this type, since the modules described in this invention are configured in such a manner as to conform more efficiently to the locations, directions and patterns of stresses induced in the wall assembly by the fill material within and by the external loads acting upon the wall.

Summary of the Invention

In order to accomplish the objective of the present invention, the precast structural module is configured as follows: a front panel is provided which typically is of generally rectangular configuration when viewed in front elevation. A rear panel is located with its longitudinal axis parallel to that of said front panel, and one or a plurality of partition means connect said front panel with said rear panel. When said modules are placed in lateral contiguity, the front panels and rear panels form two opposite longitudinal sides of a cellular chamber, with each partition means serving to connect the front panel with the rear panel, and further serving to transversely divide the chamber into smaller individual cells.

The partition means are of a pronounced generally trapezoidal shape when viewed along a horizontal line parallel with the longitudinal axis of the front panel. (For the purpose of this application, the term "trapezoidal" includes a parallelogram.) This trapezoidal shape is such that, when the module is placed in its final erected position within the assembled wall structure, the upper edge of the rear panel of a module is situated at an elevation considerably below a plane extending from the upper edge of the front panel at right angles thereto, and the principal axes of the partition means extend in a downward direction. This invention provides a substantial improvement over existing cellular modules, since this arrangement of the modules' elements beneficially lowers the centers of gravity of both the overturning forces and the restraining forces with respect to the pivot points of superposed modules.

Description of the Drawings

Figs. 1 and 2 are perspective views of advantageous forms of structural modules incorporating features of the invention.

Figs. 3 and 4 are cross sectional and top plan views respectively illustrating a module of the general type shown in Fig,1, with parallel front and rear panels.

Figs. 5 and 6 are fragmentary cross sectional and plan views, similar to Figs. 3 and 4, illustrating a modification in which the rear panel is tilted at an acute angle to the front panel.

Fig. 7 is a fragmentary perspective view of an assembled retaining wall or the like utilizing structural modules according to the invention, as viewed from the back.

Fig. 8 is a perspective view of a base module of a type which may be used in connection with a wall assembly such as that of Fig. 7.

Fig. 9 is a cross sectional view of a preferred form of base module according to the invention having an extended toe flange for increased resistance to overturning.

Fig. 10 illustrates a modified form of structural module, having a notched-out area for reception of a horizontal, earth-retaining slab.

Figs. 11 and 12 are cross sectional views illustrating different advantageous construction techniques utilizing the structural modules of the invention.

Fig. 13 is a diagrammatic illustration of a structural wall utilizing the modules of the invention, for force analysis purposes.

Fig. 14 and 15 are cross sectional views taken on lines 14-14 and 15-15 of Fig. 16 illustrating advantageous forms of construction for the tops of retaining walls or the like.

Fig. 16 is a composite cross sectional view illustrating the construction features of Figs. 14,15.

Fig. 17 is a fragmentary cross sectional view illustrating another form of top structure for a retaining wall or the like.

Fig. 18 is a cross sectional view generally on line 18-18 of Fig.19.

Fig. 19 is a top plan view of an arrangement for joining so-called half modules to adjacent structural modules by means of an intermediate connecting panel.

Fig. 20 is a perspective view of a modified form of half module having an integral stabilizing slab.

Fig. 21 is a front elevational view of a retaining wall or the like constructed with structural modules according to the invention.

Fig. 22 is a cross sectional view taken on line 22-22 of Fig. 23.

Fig. 23 is a top plan view of a structural module according to the invention which is cast in individual components and assembled before installation.

Fig. 24 is an enlarged fragmentary cross sectional view taken on line 24-24 of Fig. 22.

Figs. 25 and 26, together, constitute a cross sectional view of a further modified form of retaining wall assembly utilizing an advantageous form of interlocking means between vertically adjacent modules.

Fig. 27 is a perspective view of an advantageous form of drop-in panel, which may be used at the back of the assembly or, more typically, as an intermediate vertical panel.

Fig. 28-30 illustrate various views of an arrangement for mounting of the drop-in panel in an assembly of modules.

Figs. 31 and 32 are fragmentary views in vertical cross section illustrating advantageous arrangements for keying together vertically adjacent structural modules for resistance to shear.

Fig. 33 is a side elevation of an advantageous form of structural module, in which the front and rear panels are generally at the same height, joined by partition elements stepped to provide a plurality of forward facing abutment elements for improved resistance to shear.

Fig. 34 is a fragmentary cross sectional detail, illustrating an advantageous form of connector for joining a connecting panel to adjacent structural modules.

Fig. 35 is a perspective view illustrating a further modified form of the invention.

Fig. 36 is a cross sectional view of a retaining wall or the like of the general type shown in Fig. 35.

Figs. 37 and 38 are enlarged, fragmentary cross sectional views, illustrating details of through retaining/supporting element incorporated in the assembly of Fig. 36.

Figs. 39, 40 are perspective views of special configurations of base modules, for use in wall assemblies such as shown in Figs. 35, 36.

Figs. 41 and 42 are cross sectional and top plan views respectively of a modified structural module configuration providing for aligned pairs of mortise notches between vertically adjacent modules, for the reception of keying elements.

Figs. 43 and 44 are cross sectional and top plan views respecively, similar to Figs. 41, 42, where the module is provided with an inclined rear panel.

Fig. 45 is an end elevational view of a retaining wall or the like constructed of various modified forms of structural modules having advantageous load bearing characteristics.

Preferred Embodiments

This invention relates generally to specially configured prefabricated structural modules for employment in the construction of non-massive gravity retaining walls. More particularly this invention relates solely to that class of wall wherein the structural elements of the module form interior cavities or cells in which granular material is deposited. This enclosed granular material, through the action of friction against the generally upright walls of the cells, adds its own weight to that of the structural parts to form a more effective assembly. This invention specifically does not relate to walls which are anchored or tied back by tension members. It also does not relate to walls constructed by embedding cantilevered piles or other cantilevered flexural members into the underlying strata of soil.

In a wall where modules are stacked vertically, each module beginning with the topmost module is acted upon by its respective overturning and resisting forces and subsequently transmits those forces to the contiguous module(s) below according to the details of the transfer mechanism provided in the design. Such mechanisms have heretofore consisted of commonly used interlocking means, such as mortise and tenon keys on connecting arms or depended lips on the lower surfaces of the face panels. The use of mortise and tenon keys in the partition means results in very heavy bending stresses in the partition means as well as high local shearing stresses in the keys. The use of depending lips in the face panels results in excessively high shearing stresses and bending in the weaker direction of the panel.

The present invention, although not restricted to the use of any particular material of construction, utilizes most effectively and economically the very efficient natural compressive strength of concrete.

To affect this natural ability of concrete to transmit stresses compressively, one principle of this invention prescribes a variation of configurations of the contact surfaces of vertically contiguous partition means, each embodiment utilizing the advantages of a generally sloped orientation of the contact surfaces of the partition means. In its simplest form, the contact surface consists of a straight inclined plane oriented in such a way that the total resultant forces, overturning and resisting, exerted by the upper module upon the lower module, occur at such an angle that ordinary frictional forces between the surfaces in contact more than compensate for any component of the resultant force which may occur in a direction parallel to said contact surfaces. Another form of this invention utilizes a more positive engagement of contact surfaces wherein alternate surfaces are angled with respect to each other, presenting surfaces normal to any resulting components of loading.

Figures 1, 3, 7, 35 and 43 illustrate some of the more preferred embodiments of a module with trapezoidal partition means. The modules comprise front and rear panels, and trapezoidal partition elements, which connect the front and rear panels, and form cellular chambers to contain granular fill material. Figure 1 is a perspective view of the module 11 with a front panel 1, a rear panel 2, and generally trapezoidal partition elements 3. Usually, but not necessarily, there are two spaced partition elements 3, panel-like in form. At the intersection of the panels with the partition elements are fillets 9 which are placed according to usual practice.

Figures 1 and 3 clearly show views of one of many sawtooth patterns made according to the invention. A plurality of surfaces 4 and 5 form the upper sawtooth edge and a plurality of surfaces 6 and 7 form the lower matching sawtooth edge. In one form of the invention, surfaces 4 and 6 do not come in contact with each other, and the component, parallel to the plane of the front panel, of the resultant of all forces acting upon the module, is carried by the front and rear panels and transmitted to the front and rear panels of the lower module at the panels' respective contact surfaces. The component, perpendicular to the plane of the front panel, of the resultant of all forces acting upon the superposed module is transmitted from contact surface 7 to contact surface 5 of the supporting module and is carried by the partition means 3 of the supporting module. In a preferred form of the invention, all surfaces 6 and 7 come in contact with their respective matching surfaces 4 and 5 and each surface bears a proportionate amount of the component, perpendicular to the contact surface, of the resultant of all forces acting upon the module. In a further preferred form of the invention, the modules are constructed to dimensions which prevent the transmission of major forces from one face panel (i.e. front or rear panels 1, 2 or 1, 10) to another. This feature minimizes the occurrence of cracking in said panels.

Figure 7 shows a perspective view of an assembly of modules arranged laterally in horizontal rows with additional horizontal rows of modules superposed above. The assembly as seen in Figure 7 is of a wall structure viewed from the rear. The assembly of front panels 1 form the exterior face of the wall structure. The rear panels 2 are shown at an acute angle with respect to the plane of the front panels. With the exception of the base module, each superposed module is shown with its partition means of lesser width than the partition means of the module upon which it is supported. This method of stacking is also shown in cross-sectional view in Figure 11 and represents the conventional method of stacking when constructing a modular gravity retaining wall.

Figures 25,26 and 35 through 45 also illustrate modules and assemblies of modules which utilize the principles set forth in the invention. The trapezoidal partition means, as shown in Figures 35, 43 and 44, are represented in their simplest form, inclined bearing surfaces. In Figure 35 an assembly of modules 61 is shown. Module 61 comprises a front panel 1, and a non-parallel rear panel 2 connected by a plurality of trapezoidal partition elements 63. As set forth in the teachings of the invention, the longitudinal (principal) axes of the partition means 63 are inclined at an acute angle from the plane of the front panel such that the upper contact surface 64 and the lower contact surface 65 are disposed at an angle which is substantially normal to the line of action of the resultant force representing all loads being transferred from superposed module to supporting module. Specifically, the principal axes of the partition elements extend downward and rearward at an angle of between 20 and 82 degrees from the plane of the front panel 1, such that the upper edge of the rear panel 2 lies substantially below a plane extending from the upper edge of the front panel, and at right angles thereto. As represented in Figures 35, 36, and 39 through 44, the superposed module is held in place during erection of the assembly by a surface 66 perpendicular to the front panel in the zone of the intersection of the partition elements 63 with the front panel 1. As soon as a course of modules is loaded with fill material inside its cells and a commensurate quantity of retained material, the resultant loading is substantially normal (within the angle of friction between surfaces 64 and 65) to the resultant load being transferred from module to module.

Figures 41 and 42 show a module 61 with a vertical rear panel 10 and with mortises 56 provided in the upper and lower edges of the partition elements 63A. These mortises are dimensioned to accept a keying block 57 or slab 58 similar to those illustrated in Figures 31, and 32. Key 57 is shown in Figure 41 but a slab 58 may be used with equal facility. The purpose of the key is to secure the position of the blocks during assembly and until the lateral force from the retained material is allowed to act.

Figure 21 shows a front elevation of a wall assembly using modules 11 and cantilevered panels 17 (shown in cross section view in Fig. 14). The modules are arranged to stagger the vertical joints so that each superposed module, where possible, is supported by two different modules in the course below it. To accomplish this preferred interlocking pattern, the partition means are spaced apart at virtually twice the distance from the partition means to the lateral edge of the front panel 1 of modules 11. The center lines 35 of a few adjacent partition means are shown. As can be seen, this spacing allows all the partition means to occur in continuous planes from top to base as required in the invention, and also allows the lateral edges of the front panels essentially to touch.

In the analysis of a modular retaining wall for stability against overturning, it is necessary to investigate the stability of the structure above each possible pivot point. It is readily apparent from Figure 11 that the inclined trapezoidal shape of the partition means and lowered position of the rear panel results in several advantages. It substantially lowers the center of gravity of each of the stacked modules and likewise lowers the center of gravity of the granular material enclosed within each of the cells of the modules. In that part of a wall in which the rear face is stepped, toward the front face as the courses progress upward, the trapezoidal shape of the partition means also lowers the center of gravity of the retained material trapped above the protruding rear portion of the modules. The inclined trapezoidal shape of the partition elements and the lowered position of the rear panel has another important effect on the behavior of the modular wall. In the analysis of the complete wall, when investigating the tendency of the bottommost module course to overturn about the toe, or to slide along the base, the lowered position of the rear panel has no effect, either beneficial or detrimental. However, when analyzing the stability of the individual courses above the bottom course, the advantages of the new design are substantial. Referring to Figure 13, if we perform an overturning analysis about point 39, the pivot point of a typical module 11C, which lies in an arbitrarily chosen upper course of the wall, the improvements become evident. The resultant of those forces causing overturning, as well as the resultant of those forces affecting resistance to overturning, are substantially lowered in elevation. Although the overall magnitude of the overturning force on any one of the superposed modules is increased, nevertheless the moment is reduced. At the same time, both the magnitude and effectiveness of the beneficial resisting forces are increased.

To illustrate in more detail the effect of a lowered rear panel on the behavior of the force tending to cause overturning, refer to Figure 13. In the analysis of a conventional wall built according to the present state of the art, the rear panel 45 is, within the tolerances of usual wall batters and construction accuracies, at the same elevation as the front panel. This condition is illustrated by the dashed lines in Figure 13. Taking the summation of moments about pivot point 39, the lateral overturning force 41 caused by the retained material above the heel 40 acts at an elevation approximately one-third the distance from the elevation of tha heel 40 to the surface 44 of retained material. In contrast, in the analysis of the wall built according to the teachings of the present invention shown by solid lines in Figure 13, when we take the summation of moments about the same pivot point 39, the lateral overturning force now consists of the combined effects of the same overturning force 41, plus the overturning force 43 due to the additional volume of retained material between point 40 and the new heel 42. The additional force 43, although increasing the total horizontal force against the wall, actually has a stabilizing effect since its line of action lies below the elevation of the pivot point 39. Thus the total effective overturning moment is in fact reduced, and the size and weight of the wall structure including module 11C and those modules above it may be reduced in size, thereby affecting a more economical construction.

In the analysis of overturning conditions for the entire wall, it is necessary to evaluate moments about the base at pivot point 47 (representing the pivot point location in a standard wall, see Fig. 11). Since the heel 46 of the entire wall is at the same elevation as pivot point 47, there is no benefit from the trapezoidal partition means, and the overturning condition is the same for the standard wall and for the wall according to the invention. When the base module is fabricated with its lower edge extended forward from the face, forming the pivot point at 48 (see Figs. 9, 11), overturning moments are reduced, and resisting moments are increased.

As shown in Figures 7 and 35, the base modules 13A and 62 are forms of the new modules with the bottom portions of their partition means truncated to conform to the plane of the subgrade. Each base module is of smaller width than the module directly superposed on it, because in a typical case the heel of the wall is the bottom edge of the rear panel of the module resting on the base unit and is substantially at the elevation of the base module's subgrade. Figure 8 shows a solid base unit 15 used for small variations of the subgrade elevation.

In Figure 2, the rear panel 8 is shown in a special configuration more suitable for a base module, where its plane is perpendicular to the plane of the partition means 3A and approximately perpendicular to the plane of the front panel 1. The rear panel 8, as shown, positively captures the force from the weight of the fill above it.

The rear panel of any module may be either substantially perpendicular to the front panel, as in Figure

2, substantially parallel with the front panel, as in Figures 3 and 4, or inclined at an acute angle with respect to the plane of the front panel, depending upon the particular purpose to which it is to be applied. When a smaller module is to be used below a larger module at the base of the wall, a rear panel 8 which is substantially perpendicular to the front panel 1 of the module is especially beneficial. When it is desired to use the rear panels to assist in transferring weight between modules, such as in a bridge abutment, it is preferred that the rear panels 10 be parallel with the front panel 1 (Fig. 3) so the rear panels can be readily aligned. When it is desired to increase the forces resisting overturning it is beneficial to tilt the rear panel 2 at an acute angle with the front panel 1, with its upper edge farther away from the front panel, as illustrated in Figures 5 and 6, so as to increase the amount of fill captured, and to reduce simultaneously the lateral pressure exerted by the retained material behind the module.

Figures 5 and 6 show in side view and plan view the rear panel 2 tilted in a manner which increases the force it receives from the bin-action effect of the fill within the cells of the module while at the same time reducing the lateral force it receives from the retained material. For the tilting to be worthwhile, the rear panel 2 should be at least about 8 degrees with respect to the front panel.

When the rear panel of a module is located sufficiently forward of the rear panels of modules below so that the tilting of the rear panel has no effect on the magnitude or direction of the overturning force exerted by the retained material against the entire wall structure, then it is appropriate to tilt the panel forward so as to cause the direction of the force exerted by the retained material against the rear panel of this module to be located at a more vertical angle and to be greater in magnitude. These forces can be translated into improved resisting moments for the overall wall structure. Further, the forward tilting of the rear panel of a module superposed above a module of a longer partition means improves the bin-action at the rear of the larger module below.

Figure 12 and 36 illustrate assemblies of modules according to the invention arranged in more beneficial sequences of sizes from smaller to larger to smaller as the courses progress upwardly. In this type of stacking, the rear panel 2A of module 11A, which extends farthest away from the front panels is located a substantial distance above the elevation of the base modules 14, 62. The rear panels 2A act to protect each of the rear panels beneath them from the full effects of the retained material. The overall effect is to reduce substantially the amount of material used to construct the wall, and to require substantially less material (e.g. earth) to be removed prior to construction.

These patterns also illustrate the facility with which different sizes of modules fit one above the other in any sequence without special fabrication. This greatly simplifies the number of different shape variations which must be fabricated or carried in inventory.

Figures 11 and 12 show the location of an auxiliary feature which is detailed in Figure 10. This is a prefabricated slab or plank 49 which can be placed between contact surfaces 4 and 6 of superposed partition means. The partition means will behave the same as it would without the space, but an additional beneficial action is obtained. The slabs 49, extending into the fill material contained in the cells of the modules, form shelf-like members which engage the weight of fill material above in a more positive manner than does the bin-action against vertically extending panels and partitions.

Figures 37 and 38 show special closure slabs which may be incorporated in a wall assembly constructed of modules similar to module 61. On the top surface of a module which does not support a larger module, the exposed top of the cells containing fill material may be, if desired, covered by a closure slab 67, as shown in Figures 36 and 37. If a smaller module is superposed, the additional width exposed may be covered by adding one or a plurality of closure slabs 68.

In some cases it may be desirable to use a closure slab 69, shown in Figure 38 to close the open space at the bottom of a module which overhangs its supporting module.

Figures 25 and 26 show an assembly of wall modules 71 which are keyed in a manner which provides additional benefits. Each module 71 has the rearmost portion of its partition means displaced upwardly to form a pair of interlocking surfaces when the module is placed in vertical contiguity with a similar module 71. Interlocking surface 74 is on the top of each partition means 77, and interlocking surface 75 is on the bottom of each partition means 77 except the partition means of the smallest module, which is too small to contain surface 75. The interlocking surfaces 74 for the top edge all occur at the same distance from the front panel 1 for each size module 71, except the smallest. Likewise the interlocking surfaces 75 on the bottom edge all occur at the same distance from the front panel 1 for each size module 71, except the smallest. The interlocking surfaces 74 and 75 could be placed at the same distance from the front panel 1 allowing them to mate directly, but in the assembly illustrated in Figures 25 and 26, surface 75 is placed a substantial distance forward (toward front panel 1) of surface 74. This separation of the mating surfaces allows the placement of a slab 76 which spans between adjacent partition means, and which produces substantial benefits to the wall structure. The slabs 76 impart additional overturning resistance to the wall. Furthermore, when slabs 76 occur behind a superposed module they direct the overturning force in a more downward direction which is beneficial in effect.

When slabs 76 occur within the cells of a wall assembly they very efficiently engage the forces present in the fill material and transfer these forces to the partition means upon which they are supported. Figure 26 shows how top unit 23, shown also in Figure 17, may be used effectively in combination with modules 71.

In certain large modules, it may be desirable to include one or more dividing intermediate panels behind the front panel to improve the ability of the cellular structure to capture the weight of the fill material. Such panels may be either parallel to or inclined with respect to the front panel and may be either cast integrally with the modules or of drop-in design. An improved form of drop-in panel 51 is shown in Figs. 27, 28 and 30. This panel is provided with tapered bearing surfaces 52 which rest on matching tapered bearing surfaces 53, in Figs. 28, 29, and 30, located in notched brackets 54 on the sides of the partition means 3 of selected modules.

It is often necessary in the construction of a wall to provide continuous vertical joints at certain locations. Such a joint 60 is shown in Figure 21. Because of the pattern where each module overhangs half of a module immediately below it, it is necessary to provide half-modules 12 adjacent to the joint in alternating courses as indicated.

Figure 20 shows a half-module 12. In walls where the partition means supports the vertical component of the forces, a lateral stabilizing mechanism is provided, since the half-module possesses only one partition means. One such mechanism is shown in Figure 20. A slab 30 dimensioned to bear on a contact surface 4 is cantilevered from the half-module's partition means 3. A gusset panel 31 is provided for rigidity and strength. When slab 30 is locked between the partition means of a laterally adjacent pair of vertically contiguous modules, half-module 12 is laterally stabilized against rotation.

An alternate method of lateral stabilization is illustrated in Figures 18, 19 and 34 where a lateral diaphragm 27, vertically disposed, is provided to span between the partition means of the half-module to the nearest partition means of the adjacent module.

In Figures 14, 15 and 16 there are shown two methods of constructing the tops of walls. The top-most front panel shown is a cantilevered panel 17 or 18 with offset arms 20 set vertically behind the front panel 1 of a module. The vertical load from the panel is transmitted to the top of the front panel 1 by bottom surface 19 of the offset shoulder. Horizontal loads against the top portion of the cantilevered panel are resisted by cantilever action of the T-beam formed by the panel and the partition element, with the restraining thrust supplied by thrust blocks. Two forms of thrust blocks 16 and 21 are shown.

Figure 16 is a cross-sectional view looking forward at the rear faces of the cantilevered panel and of the front panel. The left portion of Figure 16 shows the construction as in Figure 14, while the right portion of Figure 16 shows the construction as in Figure 15.

Figure 17 illustrates a top unit 23 in the form of a V-shaped cantilever. This unit also may be used in lieu of a top module, as shown in Figures 11, 12 and 26, or it may be used as shown in Figure 17 where it is indicated as a parapet with an integral traffic barrier. Whenever it is desired to provide additional stability to unit 23, the slab 24 may be extended as indicated by 25. Since extending slab 24 causes the edge to descend deeper into the fill as well as rearward, it can be seen that the V-shape of unit 23 is more effective than an L-shaped unit, one whose rearward extending slab is substantially perpendicular to the front panel. The V-shaped unit also allows more space for underground structures such as utility structures.

Figure 45 illustrates several keying mechanisms which may be used to secure a superposed module. Joint 73A is secured by depending keys in the front and rear panels which mate with keyways in the top of the front panel and in the tops of the generally trapesoidal partition means of the lower module. Joint 73B is secured by a wedge-shaped protrusion and matching recess. Joint 73C is secured by one or a plurality of key locks 57, see Fig. 32 (may be a shelf-like member 58, see

Fig. 31) which fit in recesses (such as mortises) placed in contraposition in the contact surfaces of vertically contiguous modules. Joint 73D and 73E are secured by standard mortise and tenon keys. In joint 73D the tenons extend upward while in 73E the tenons extend downward into their mating mortises. Joints 73F are planer contact surfaces which are secured during erection by a reversal in the direction of inclination of the contact surfaces in the zone of the intersection of the partition means with the front panel. This reversal of the incline of the surfaces at the face of the wall (downward toward the front) would provide the additional benefit of decreasing the quantity of water likely to seep through the joint from the exterior surface of the wall. Figure 45 is intended only as a composite drawing of representative means to secure the modules.

Figures 22 through 24 show a module 88, substantially the same as module 11 or 71, wherein each element of the module, front panel 81, rear panel 82, and partition means 83, is fabricated separately and subsequently assembled using a plurality of fastening means which, in the example illustrated, are interengaging threaded elements. In the example shown a mortise and tenon shear transfer interlock is designed to transfer shear in two planes. One method of stiffening the assembled module against warping is shown in Figures 22 and 23 wherein a slab 89 is placed between the partition means during assembly of the module. An alternative method of stiffening is to attach gussets at the intersections of the partition means 83 with front panel 81 and rear panel 82.

Modules, whose partition means carry the principal wall loads and which transfer these loads directly to partition means upon which they bear, are more readily constructed of separately cast elements because the stresses required to be transferred at the connecting joints are minimal and the joint is therefore simpler and more economical.

Figure 33 shows a further embodiment of the invention where the partition means 3 is predominantly trapezoidal, with its upper and lower surfaces arranged in a sawtooth pattern, but the rear panel 10 is approximately at the same level as the front panel 1. Its contact surfaces 5 and 7 are positioned to engage mutually with similar modules above and below. Surfaces 4A and 6A may be located to bear against matching surfaces of similar modules above and below, or they may be located, so as to avoid contact with each other when it is desired that the vertical load be transferred from front panel to front panel and from rear panel to rear panel. Any module constructed according to the detail shown is able to interlock with, above or below, any other module of the same or larger front-to-rear width. This ability will markedly decrease the variations in models and significantly reduce inventory requirements for stock piling and adjustments to molds during manufacture compared with ordinary mortise and tenon interlocked modules in use. Since the resultant force acting upon a module is always directed toward the front panel, it is not necessary to have two-way interlocking keys. This condition of a one-direction lateral loading allows the use of the sawtooth pattern shown in Figure 33 and also the pattern shown in Figures 1 through 9, etc. The uses of these and similar patterns results in improved bearing and shear behavior because significantly more area for bearing and shear resistance can be furnished, when compared with existing mortise and tenon, depending lip, or tongue and groove interlocks for wall modules.

It should be understood, of course, that the specific forms of the invention herein illustrated and described are intended to be representative only, as many modifications thereof may be made without departing from the clear teachings of the disclosure. Accordingly, reference should be made to the following appended claims in determining the full scope of the invention.

We Claim:

(1) A prefabricated structural module which, when placed in vertical and horizontal relationship with appropriately proportioned like modules, is used in constructing retaining walls, sea walls, and the like, said module comprising (a) a front panel, (b) a rear panel, and (c) at least one partition means connecting said front panel and said rear panel, (d) said partition means, and said front ad er panels rigidly interconnected in a geometrical relationship such that the uper edge of said rear panel, in its erected position in a wall, is situated at an elevation substantially below a plane extending from the upper edge of said front panel at right angles to the plane of said front panel.

(2) A prefabricated structural module as set forth in claim 1, wherein said rear panel is positioned in a plane set at an acute angle with the plane of said front panel.

(3) A prefabricated structural module as set forth in claim 1, wherein said partition means are of sufficient vertical dimension, in relation to the vertical dimensions of said front and rear panels, that, when assembled with like modules to form a wall, the lower surface areas of said

partition means rest in direct contact with, and are supported by the upper surface areas of the partition means of the module immediately beneath it.

(4) A prefabricated structural module as set forth in claim 1, wherein (a) said partition means comprise spaced apart left and right partition panels, (b) said partition panels being spaced apart at such a distance that the modules can be stacked in staggered bond with the left partition panel of each module resting directly upon the right partition panel of a module in the course immediately beneath it, and the right partition panel of each upper module resting directly upon the left partition panel of a module in the course immediately beneath it, such that all partition panels may be aligned in a stack which is continuous from the base module to the top module without interruption.

(5) A prefabricated structural module as set forth in claim 1, wherein (a) said partition means comprise one or more partition panels, (b) said partition panels having upper and lower surface contours of irregular shape, whereby said back-to-front shear forces between vertically adjacent modules are resisted by said partition panels.

(6) A prefabricated structural module as set forth in claim 5, wherein said surface contours are generally of saw tooth configuration.

(7) A prefabricated structural module as set forth in claim 5, wherein said surface contours comprise mutually interengaging mortise and tenon means.

(8) A prefabricated structural module as set forth in claim 5, wherein (a) said surface contours comprise mutually facing notched-out areas of said partition elements, and (b) independent locking elements are provided for engaging the notched-out areas of partition elements of vertically adjacent modules.

(9) A prefabricated structural module as set forth in claim 1, wherein a plane defined by the upper edges of said front and rear panels lies at an angle of from 20 to 82 degrees to the plane of the front panel.

(10) A prefabricated structural module as set forth in claim 9, wherein said back panel lies at an angle to said front panel of at least about 80 degrees.

(11) A prefabrixated structural module as set forth in claim 1, wherein (a) said partition means comprises laterally spaced partition elements, (b) the height and geometry of said partition elements being such in relation to the height and geometry of the front and rear panels that, in a vertical stack of modules, the loads borne by superposed modules are supported by said partition elements.

(12) A prefabricated structural module as set forth in claim 1, wherein said partition elements have complementary non-linear upper and lower surface configurations whereby, when said modules are stacked vertically to form a wall or the like, vertically adjacent modules are keyed together to resist forces in shear.

(13) A prefabricated structural module as set forth in claim 1, wherein a plurality of said prefabricated structural modules are superimposed one upon the other in a vertical arrangement such that the module which extends rearward the farthest into the retained material lies at or very near the bottommost elevation at the heel of the wall, and each succeeding module superposed above is dimensioned so that it extends either the same distance rearward into the embankment or a lesser distance.

(14) A prefabricated structural module as set forth in claim 1, wherein an assembly of said prefabricated structural modules are superimposed one upon the other in a vertical arrangement such that the module which extends rearward the farthest into the retained material lies a considerable distance above the bottommost elevation at the heel of the wall, and each succeeding module superposed above is dimensioned so that it extends either the same distance rearward into the retained material or a lesser distance, and those modules below said farthest rearward extending module are of progressively smaller dimensions as they approach the bottommost module at the base of the wall.

AMENDED CLAIMS
[received by the International Bureau on 10 June 1985 (10.06.85); original claims 1-14 replaced by amended claims 1-21 (5 pages)]

1. A prefabricated cellular module which, when placed in vertical and horizontal relationship with appropriately proportioned like modules, is used in constructing retaining walls, sea walls, and the like, said module comprising (a) a front panel, (b) a rear panel, (c) at least one vertically oriented partition means connecting said front panel and said rear panel, wherein, for a substantial length of said partition means the thickness of said partition means is substantially less than the overall width of the module, thereby creating at least one cellular chamber with vertical through-opening(s), and (d) said partition means, and said front panel and said rear panel being rigidly interconnected in a geometrical relationship such that, when the module is in its erected position in a wall structure, the uppermost and lowermost surfaces of said partition means are each disposed downwardly from said front panel at an angle, as measure from a line perpendicular to the plane of the front of said wall structure, so that the bottom edge of said rear panel is situated at an elevation substantially below a line extending from the lower edge of said front panel perpendicular to the plane of said wall structure.

2. A prefabricated cellular module as set forth in claim 1, wherein said rear panel is positioned in a plane set at an angle with the plane of said front panel.

3. A prefabricated cellular module as set forth in claim 1, wherein (a) said partition means comprise spaced apart left and right partition elements, (b) said partition elements being spaced apart at such a distance that the modules can be stacked in a pattern which allows the front panel of a superposed module to overhang the front panels of two modules in the course immediately beneath it, with the left partition element of said superposed module vertically aligned with the right partition element of a module in the lower course, and the right partition element of said superposed module vertically aligned with the left partition element of another module in the lower course, such that said partition elements are aligned in a stack.

4. A prefabricated cellular module as set forth in claim 1,

wherein (a) said partition means comprise one or more partition elements, (b) said partition elements having upper and lower surface contours of irregular shape, whereby back-to-front shear forces between vertically adjacent modules are resisted by said partition elements.

5. A prefabricated cellular module as set forth in claim 4, wherein said upper and lower surface contours comprise a plurality of stepped surfaces of a generally saw tooth configuration.

6. A prefabricated cellular module as set forth in claim 4, wherein said surface contours comprise mutually interengaging mortise and tenon means.

7. A prefabricated cellular module as set forth in claim 4, wherein (a) said surface contours comprise mutually facing notched-out areas of said partition elements, and (b) independent locking elements are provided for engaging the notched-out areas of partition elements of vertically adjacent modules.

8. A prefabricated cellular module as set forth in claim 7, wherein said independent locking element(s) and said mutually facing notched-out areas are configured in such a manner that either vertical movement and/or pivoting of the superposed module with respect to the supporting module(s) is accommodated by said independent locking element(s).

9. A prefabricated cellular module as set forth in claim 7, wherein said mutually facing notched-out areas and said independent locking elements are so configured, that said surface contours and said independent locking elements are capable of transmitting lateral forces in one direction only.

10. An assembly according to claim 7, wherein said locking elements comprise slab-like members, portions of said slab-like members extending laterally from said partition means and providing surfaces, capable

of engaging some of the fill material within said cellular chamber(s) of said module(s).

11. A prefabricated cellular module as set forth in claim 1, wherein upper and lower planes defined respectively by the upper and lower edges of said front and rear panels lie at angles of from 20 to 82 degrees to the plane of the front face of said wall structure.

12. A prefabricated cellular module as set forth in claim 11, wherein said uppermost and lowermost surfaces of said partition means are substantially parallel to each other.

13. A prefabricated cellular module as set forth in claim 1, wherein said rear panel lies at an angle to said front panel of at least about 80 degrees.

14. A prefabricated cellular module as set forth in claim 1, wherein (a) said partition means comprise laterally spaced partition elements, (b) the height and geometry of said partition elements being such in relation to the height and geometry of the front and rear panels that, in a vertical stack of modules, the loads being borne by superposed modules are supported by said partition elements of lower modules.

15. A prefabricated cellular module as set forth in claim 1, wherein said partition means have complementary non-linear upper and lower surface configurations whereby, when said modules are stacked vertically to form a wall or the like, vertically adjacent modules are keyed together to resist lateral forces.

16. A prefabricated cellular module as set forth in claim 1, wherein a plurality of said prefabricated cellular modules are superposed one upon the other in a vertical arrangement such that the module which extends rearward the farthest into the retained material lies at or very near the bottommost elevation at the heel of the wall, and each succeeding module superposed above is dimensioned so that it extends either the same distance rearward into the embankment or a lesser distance.

17. A prefabricated cellular module as set forth in claim 1, wherein an assembly of said prefabricated structural modules are superposed one upon the other in a vertical arrangement such that the farthest rearward extending module, the module which extends rearward the farthest into the retained material, lies a considerable distance above the bottommost elevation at the heel of the wall, and each succeeding module superposed above said farthest rearward extending module is dimensioned so that it extends either the same distance rearward into the retained material or a lesser distance, and those modules below said farthest rearward extending module are of progressively smaller dimensions as they approach the bottommost module at the base of the wall.

18. A wall structure comprising an assembly of prefabricated cellular module(s) as set forth in claim 1, further including a base module comprising a front panel, and partition means whose uppermost surface is disposed downwardly from said front panel at an angle of between 8 degrees and 70 degrees as measured from a line perpendicular to the plane of the front surface of said wall structure, wherein said base module supports a portion of the superposed wall structure.

19. A wall structure as set forth in claim 18, wherein said front panel of said base module includes a base which extends forward from the plane of the assembled wall structure's front surface to form an extended toe.

20. A wall structure comprising an assembly of prefabricated cellular modules as set forth in claim 18, further including a top unit comprising (a) a front panel rigidly connected to (b) one or more projecting arms which extend downward along the rear surface of the front panel of the supporting module, (c) a means for transmitting vertical and lateral forces from said top unit to the supporting module, and (d) a means for laterally restraining the lower end of said projecting arms against the rear surface of the module's front panel in a manner which prevents rotation of said top unit.

21. A wall structure comprising an assembly of prefabricated

cellular modules as set forth in claim 18, further including a top unit comprising (a) a front panel rigidly connected to (b) one or more projecting arms which extend rearward at an angle of between 8 degrees and 70 degrees as measured from a line perpendicular to the plane of the front surface of said wall structure, (c) a means for transmitting vertical and lateral forces from said top unit to the cellular module or the base module upon which it is superposed.

STATEMENT UNDER ARTICLE 19

New claims 1-21, substituted hereby for original claims 1-14, are intended to improve the terminology and definition of the claimed invention, taking into consideration the prior art referred to in the International Search Report.

In particular, independent claim 1 has been drafted to call for vertically oriented partition means creating at least one cellular chamber with vertical through-opening(s), with the upper and lower surfaces of the partition means disposed at a downward angle from the front panel, as measured from a line perpendicular to the plane of the front of the wall structure, such that the bottom edge of the rear panel of the module is situated at an elevation substantially below a line extending from the lower edge of the front panel perpendicular to the plane of the wall structure.

This structure, which is of course present in all of the dependent claims, is believed to be both unique and uniquely advantageous.

FIG. 1

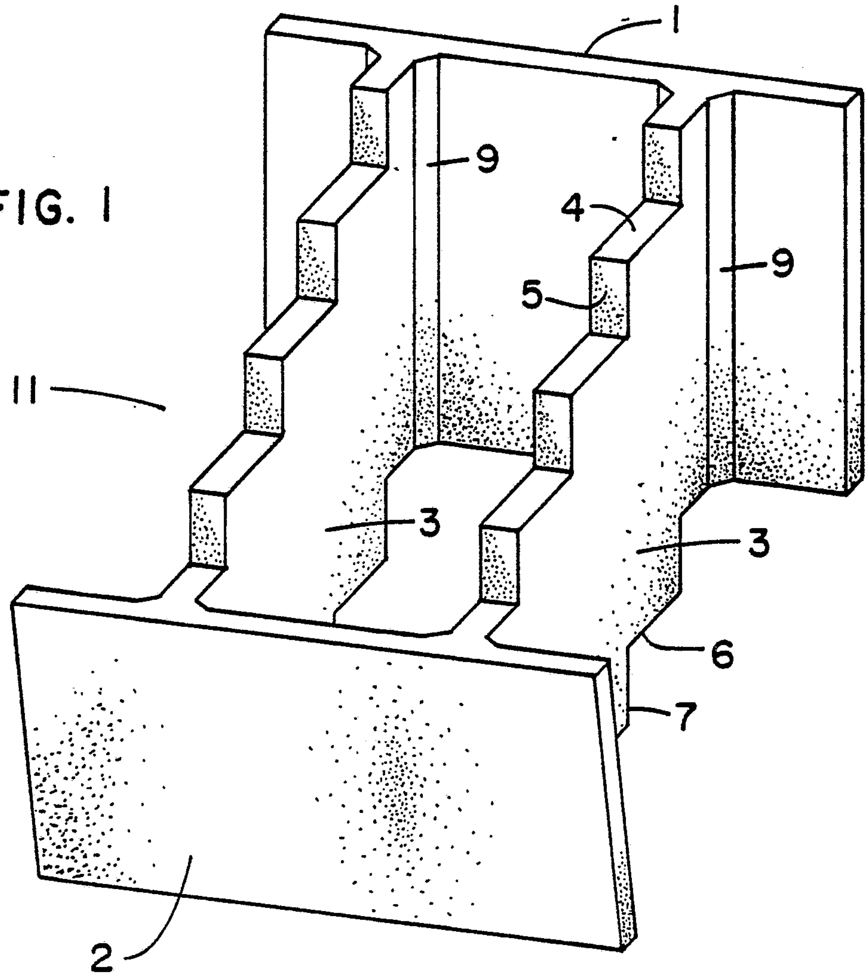
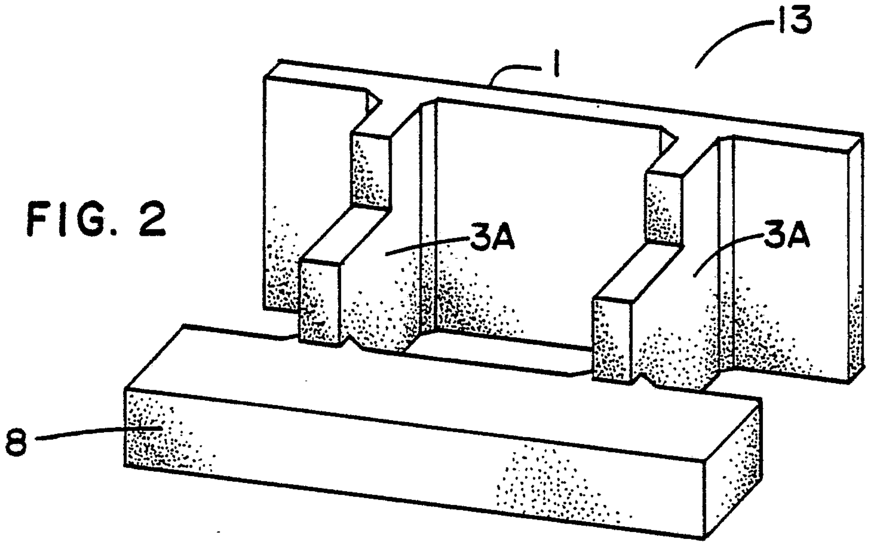


FIG. 2



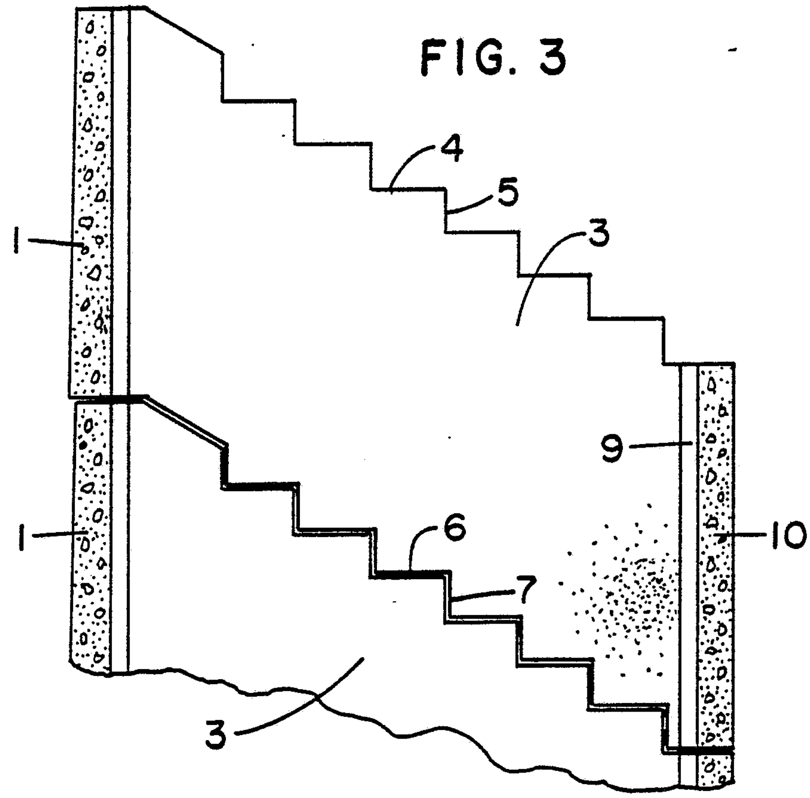


FIG. 3

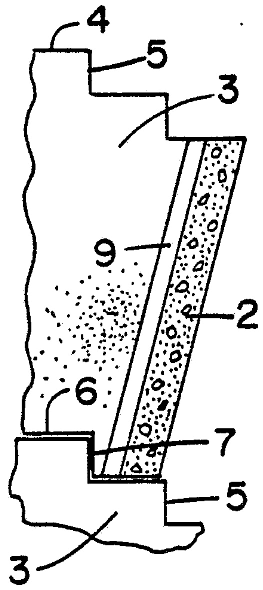


FIG. 5

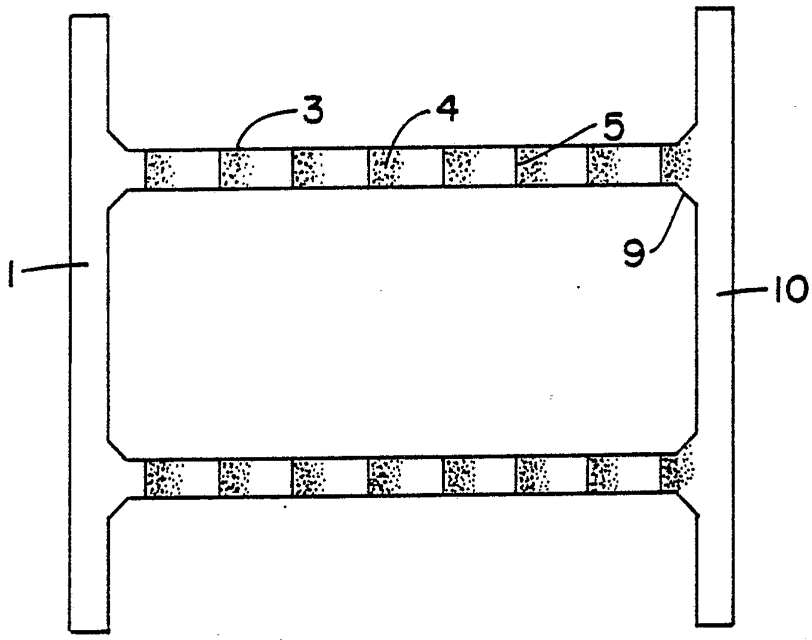


FIG. 4

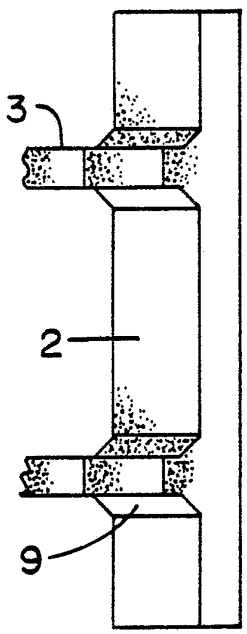


FIG. 6

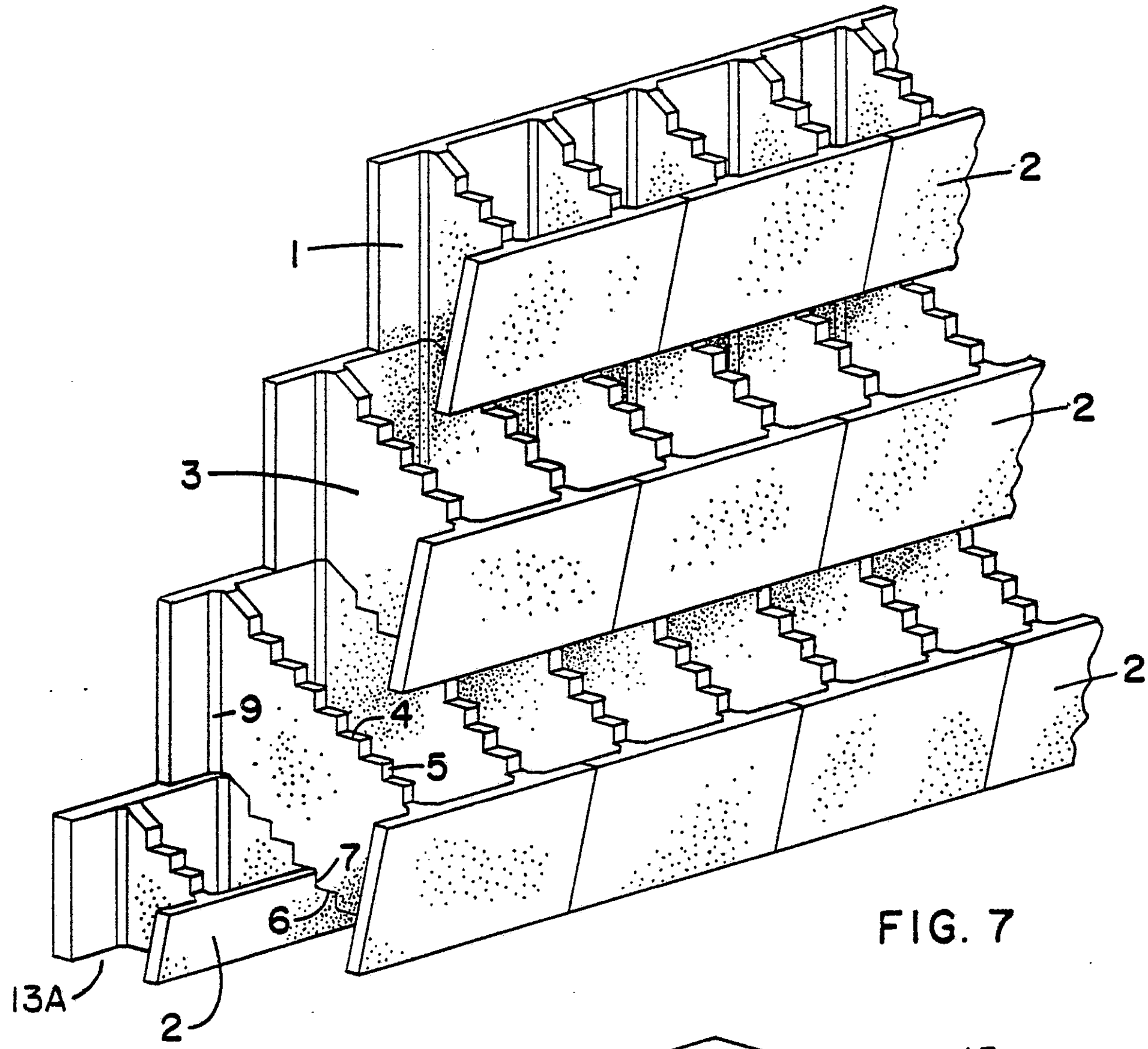


FIG. 7

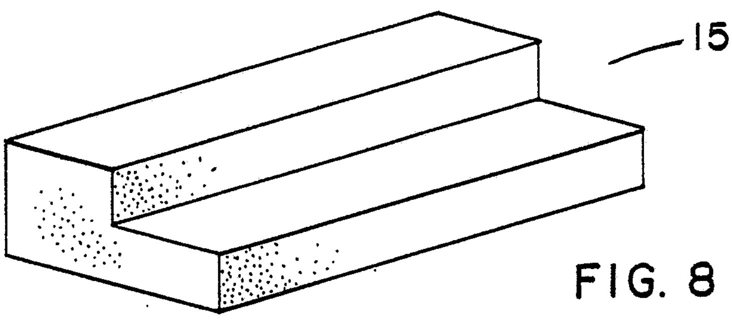


FIG. 8

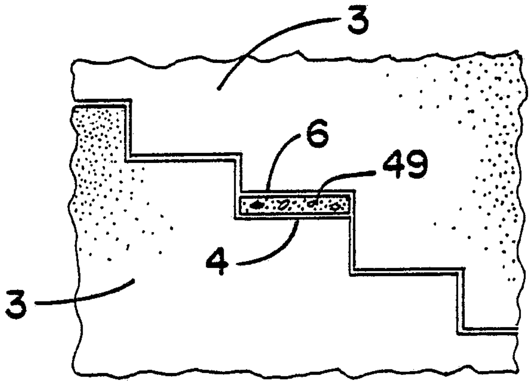


FIG. 10

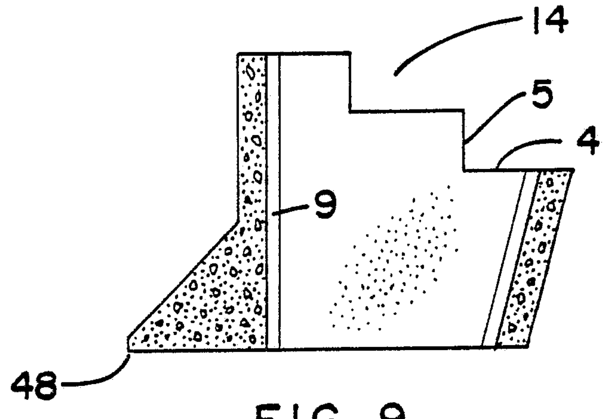


FIG. 9

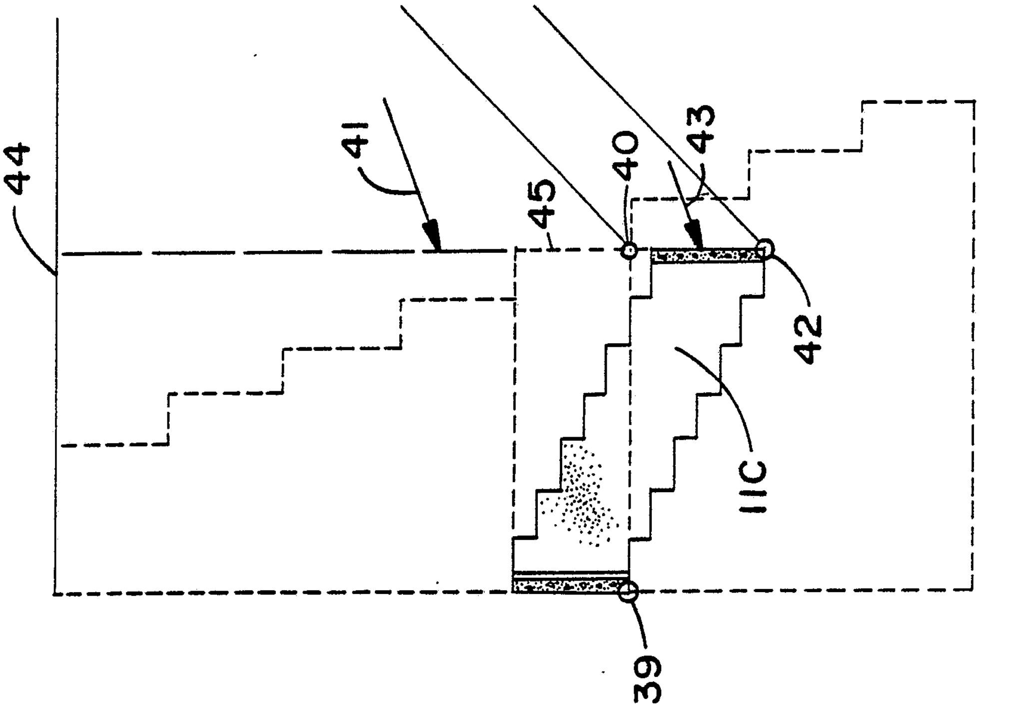


FIG. 13

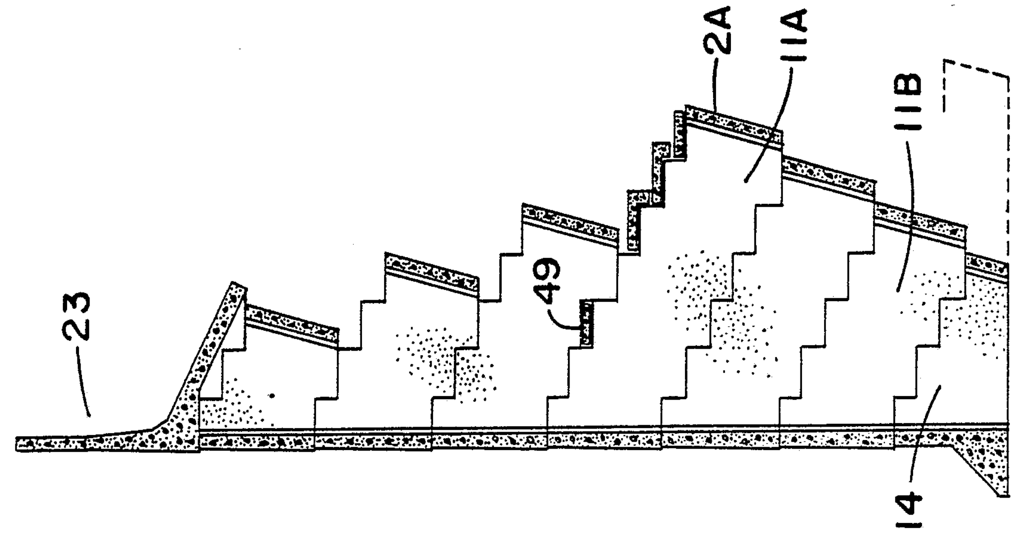


FIG. 12

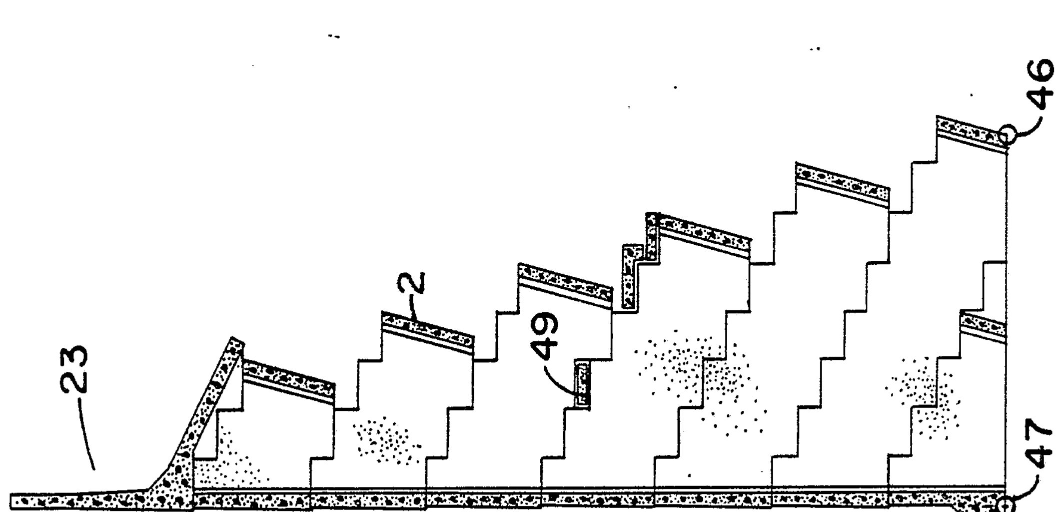


FIG. 11

SUBSTITUTE SHEET

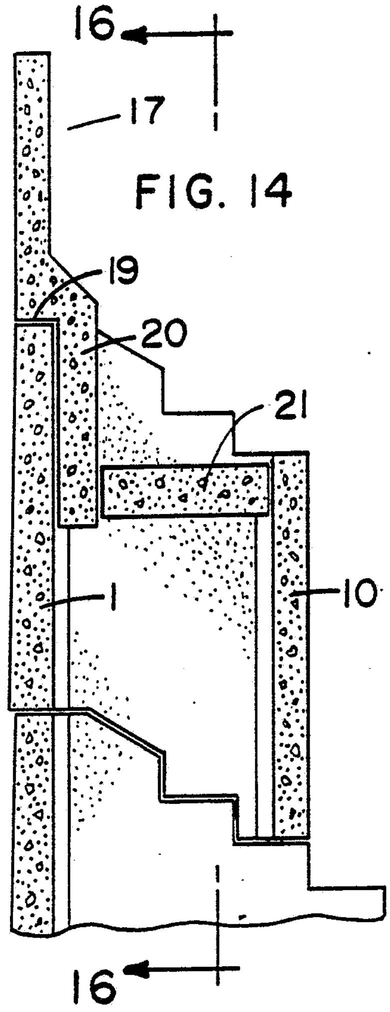


FIG. 14

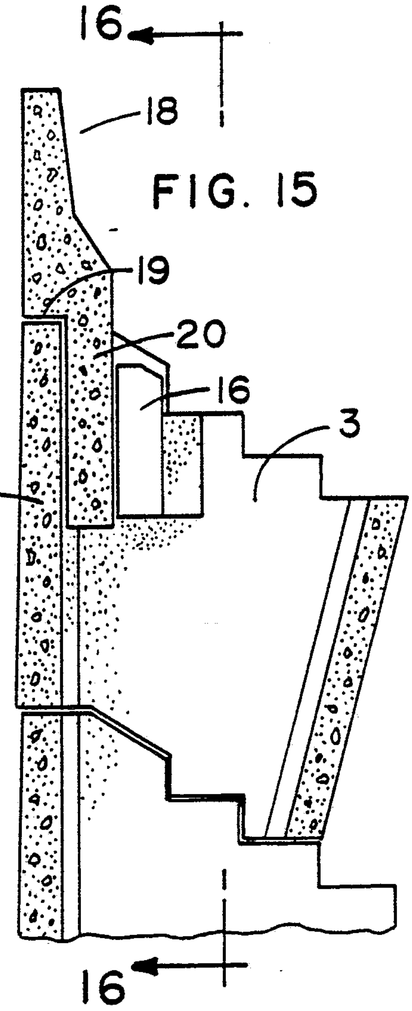


FIG. 15

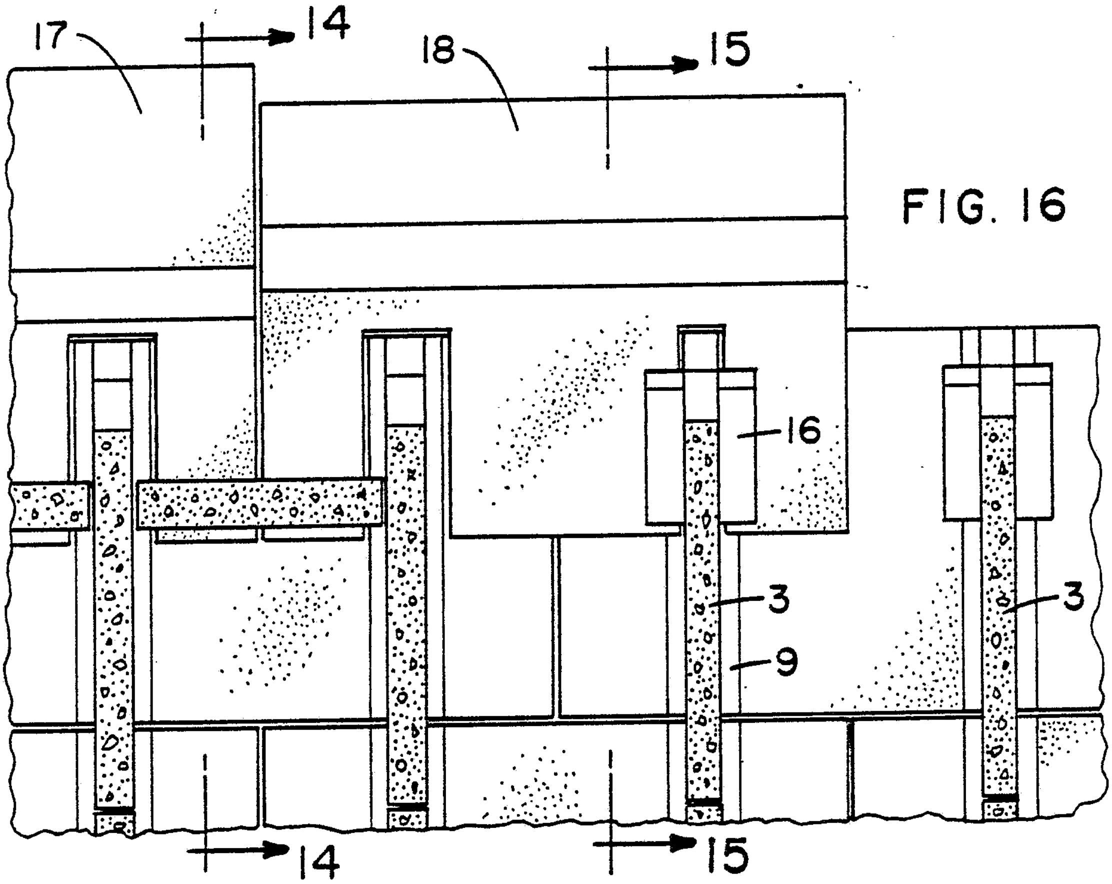


FIG. 16

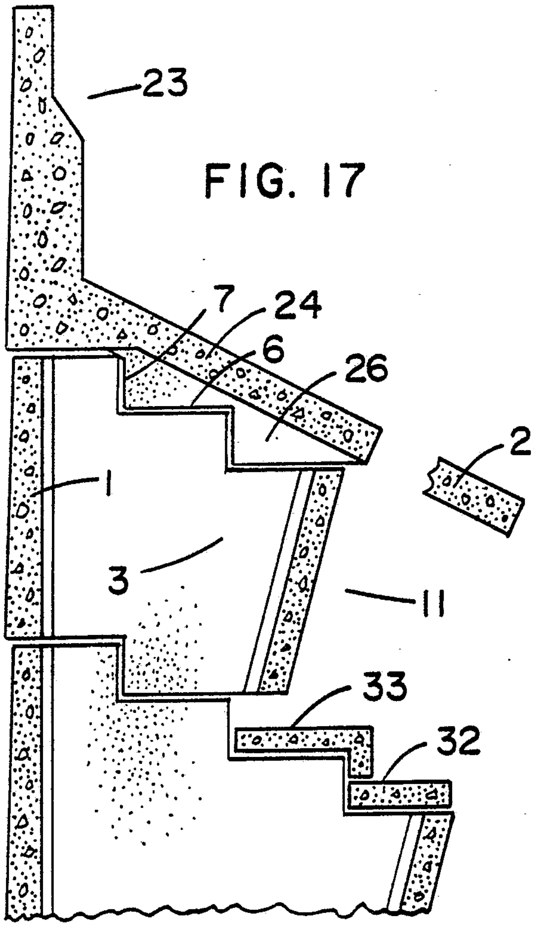


FIG. 17

FIG. 34

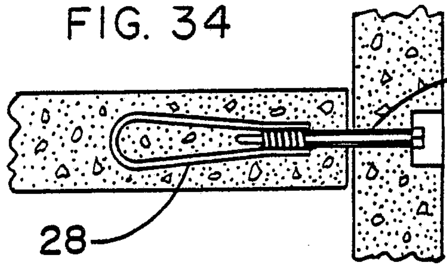


FIG. 18

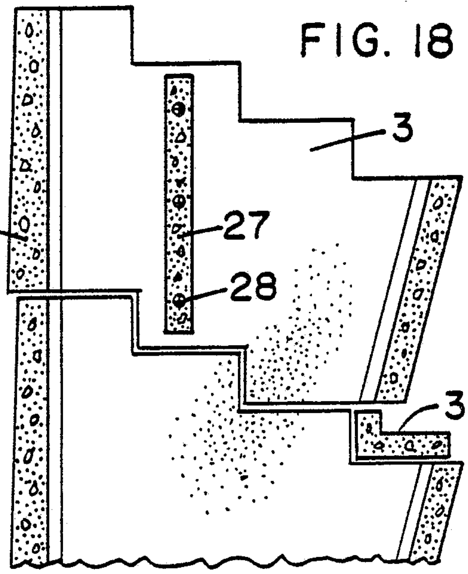
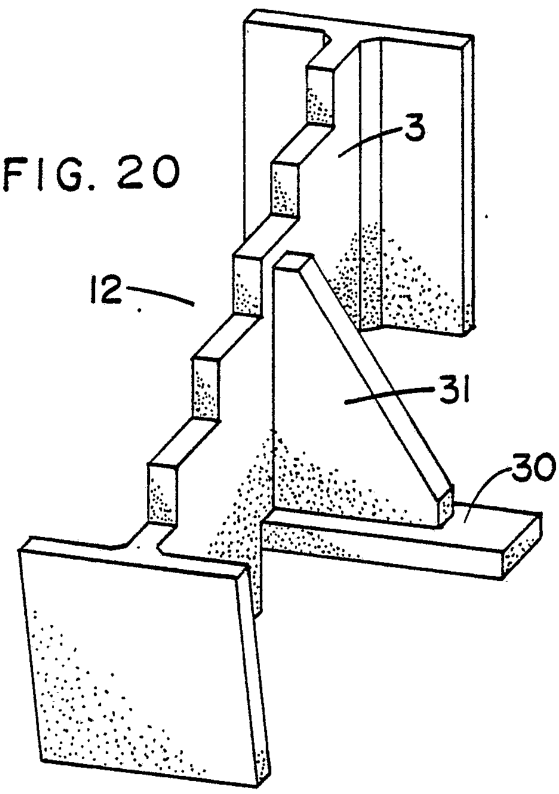
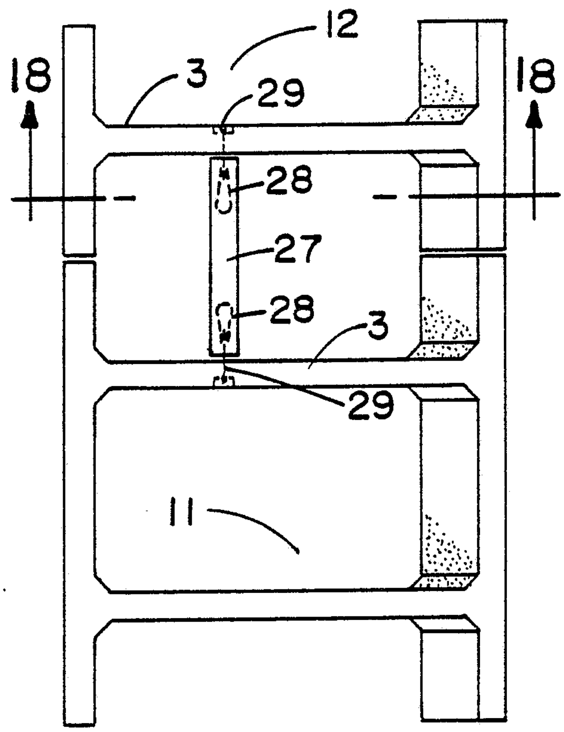


FIG. 20





SUBSTITUTE SHEET

FIG. 19

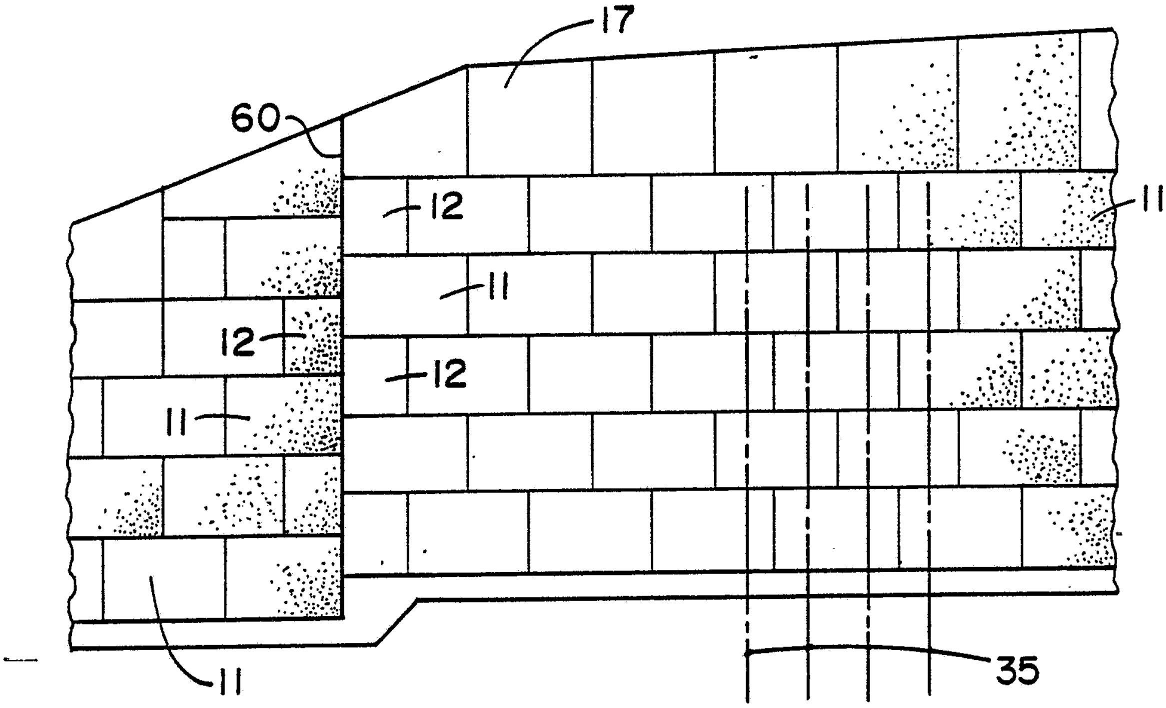
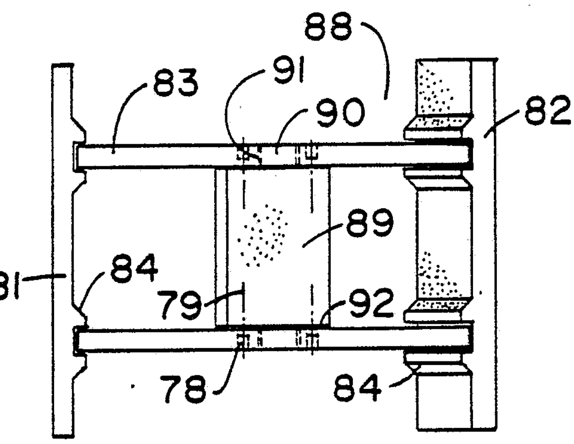


FIG. 21

FIG. 23



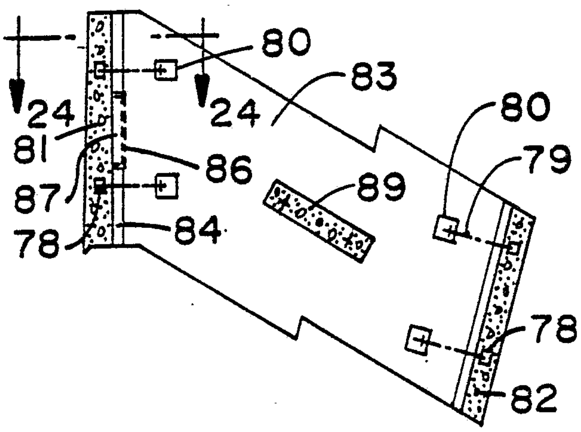


FIG. 22

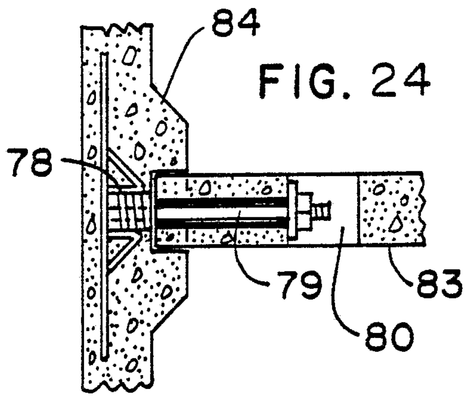


FIG. 24

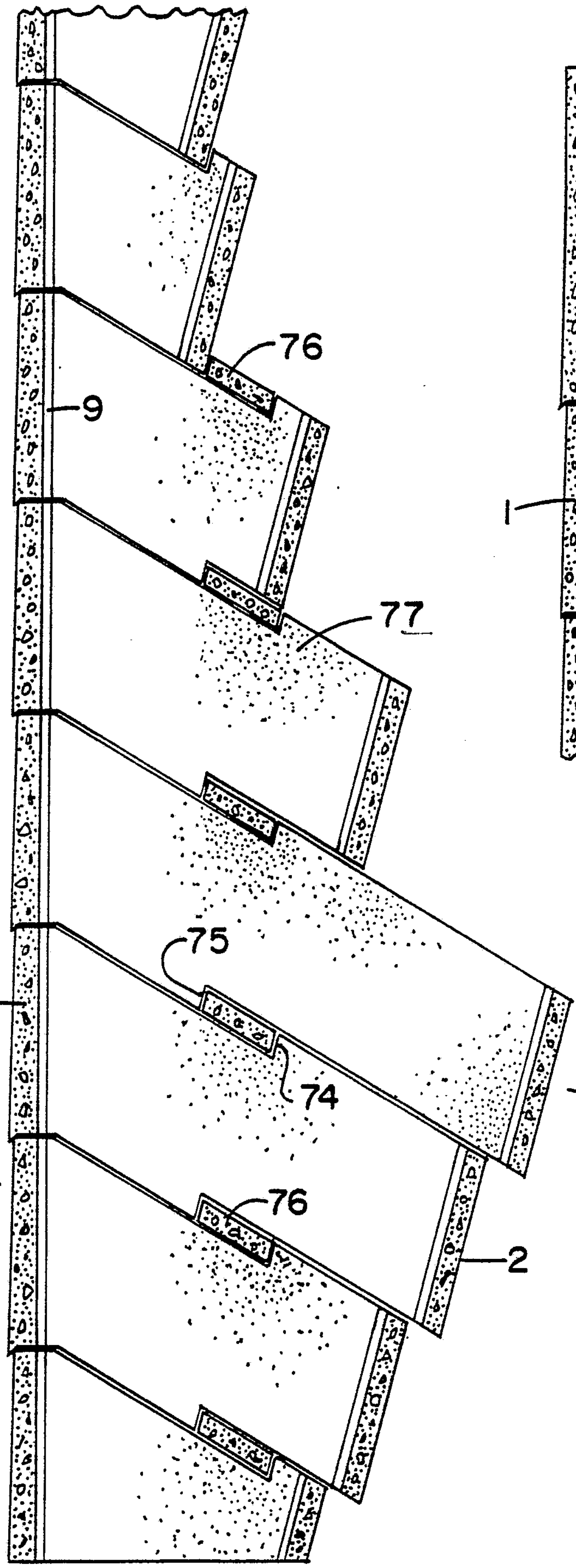


FIG. 25

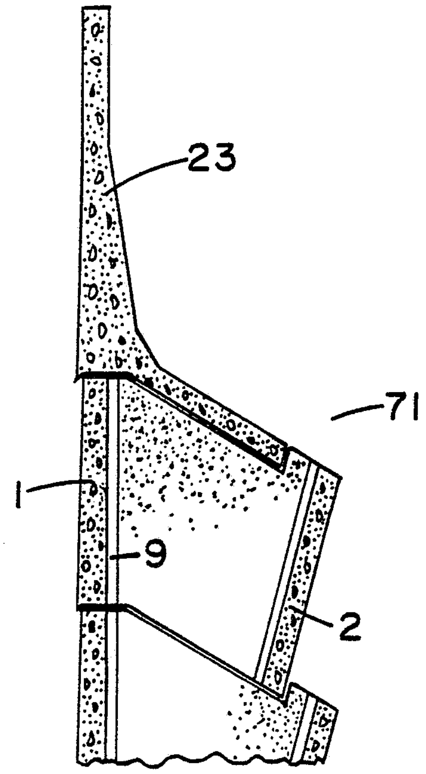


FIG. 26

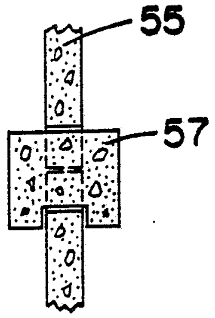


FIG. 32

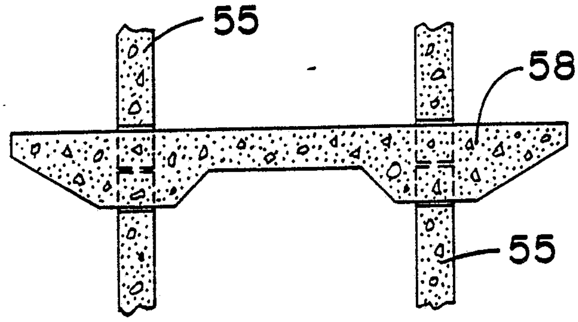


FIG. 31

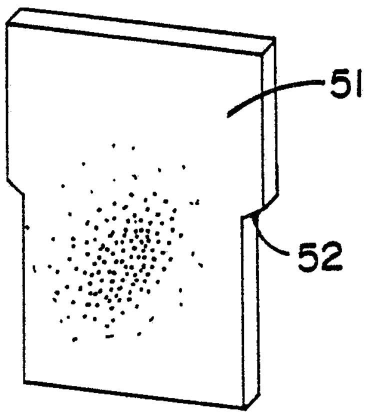


FIG. 27

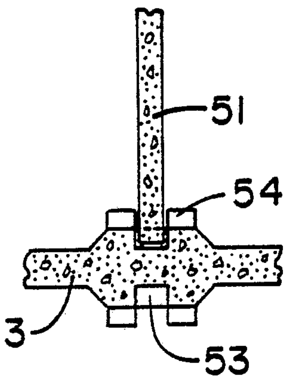


FIG. 28

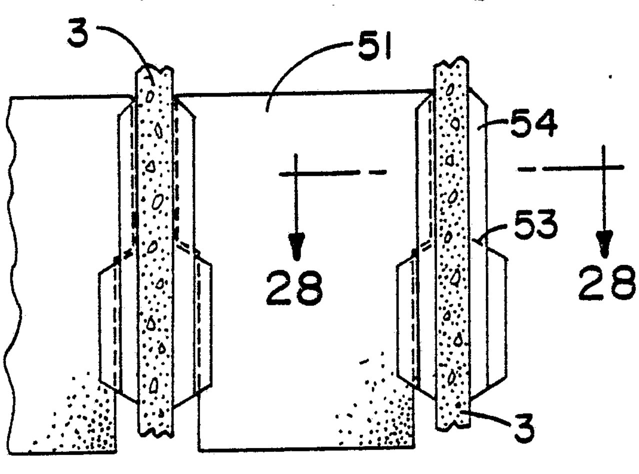


FIG. 30

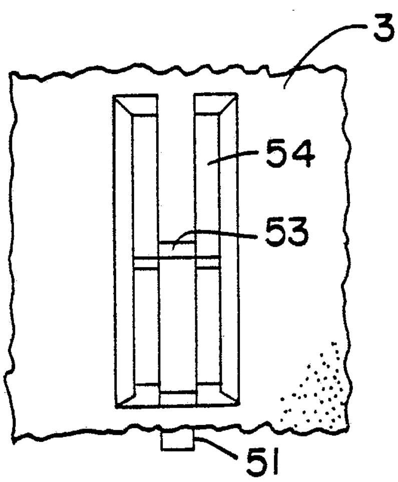


FIG. 29

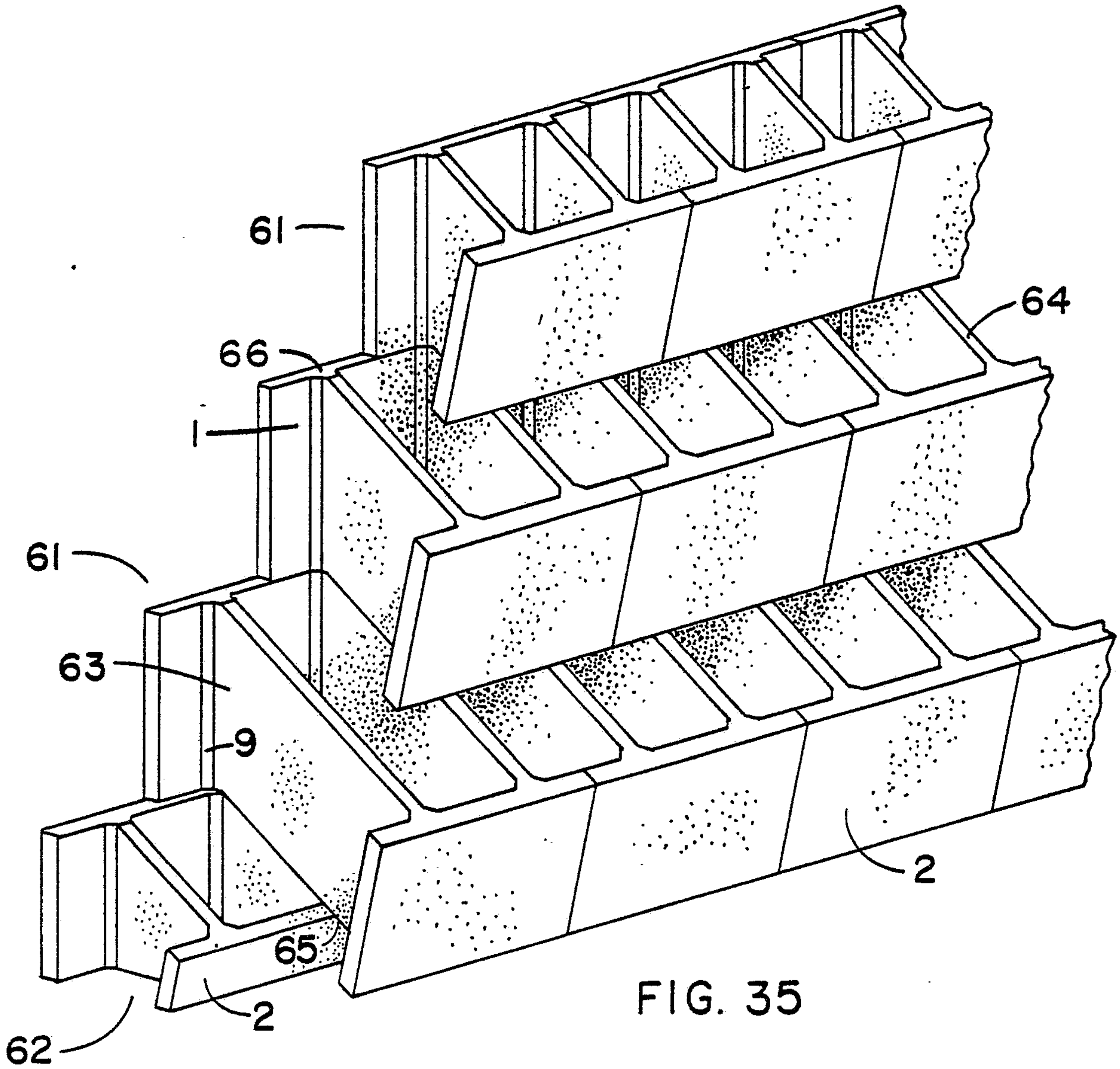


FIG. 35

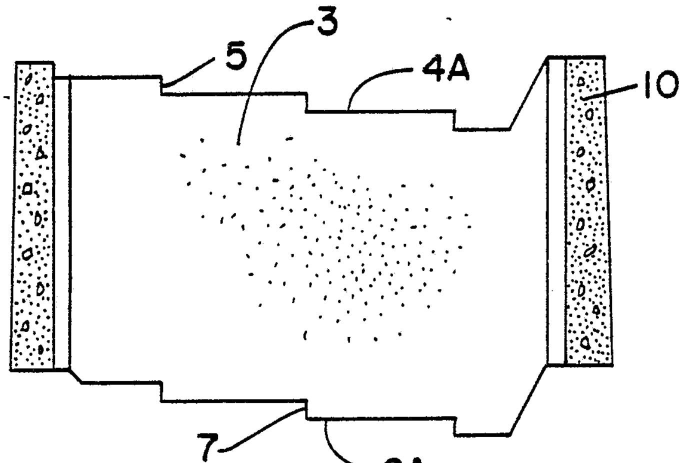


FIG. 33

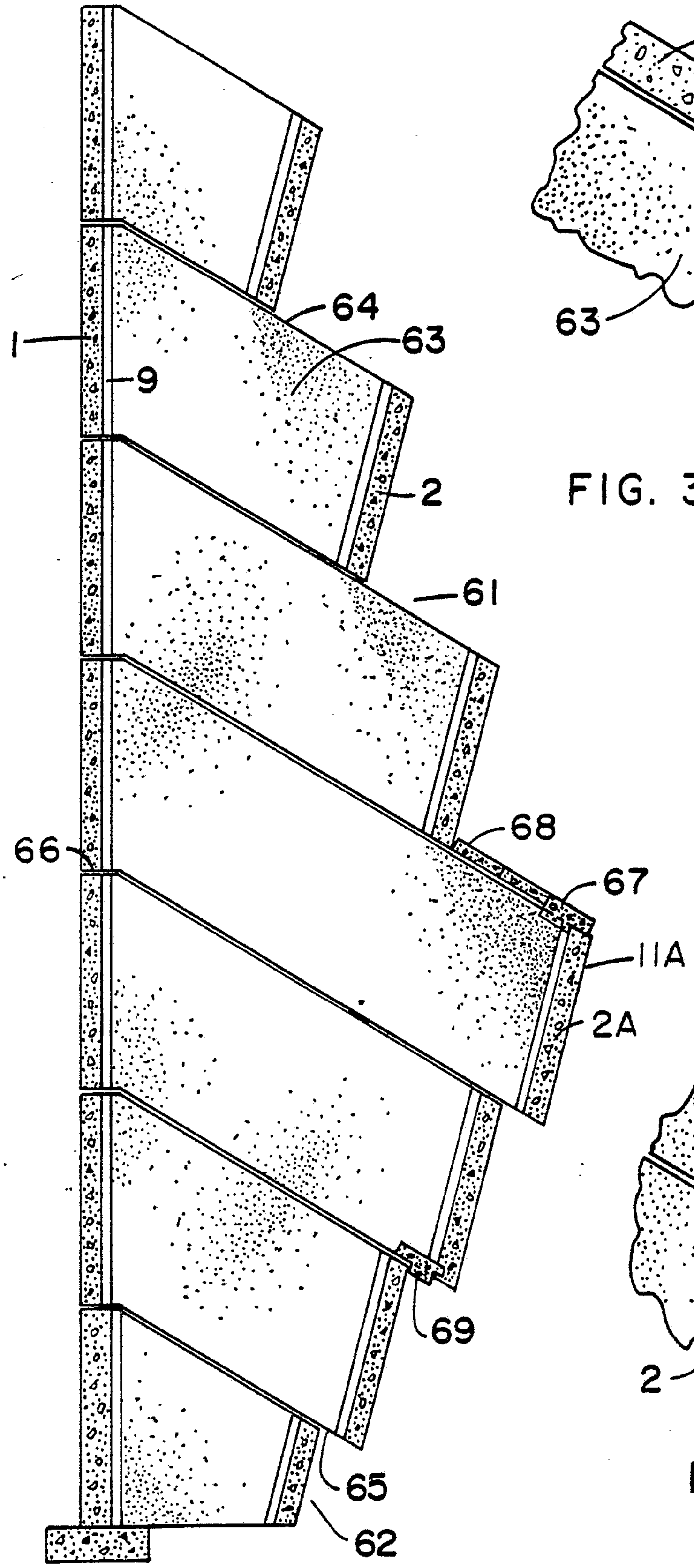


FIG. 36

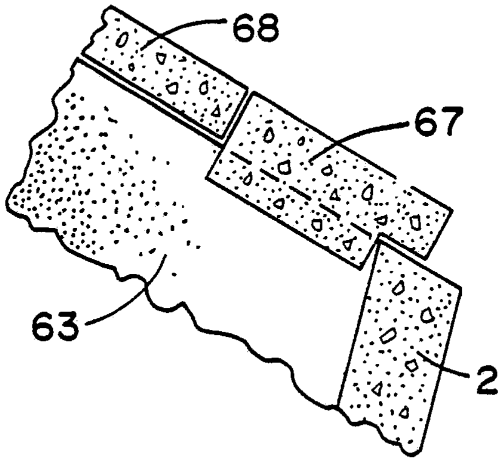


FIG. 37

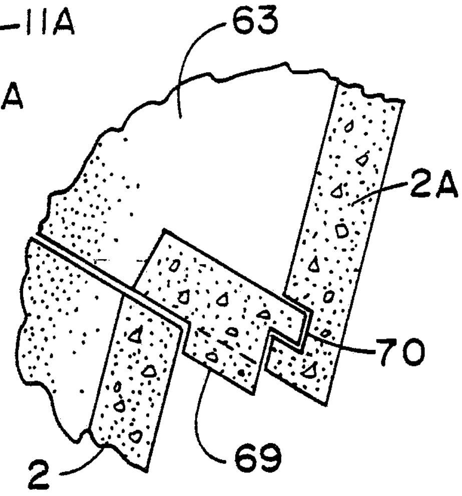


FIG. 38

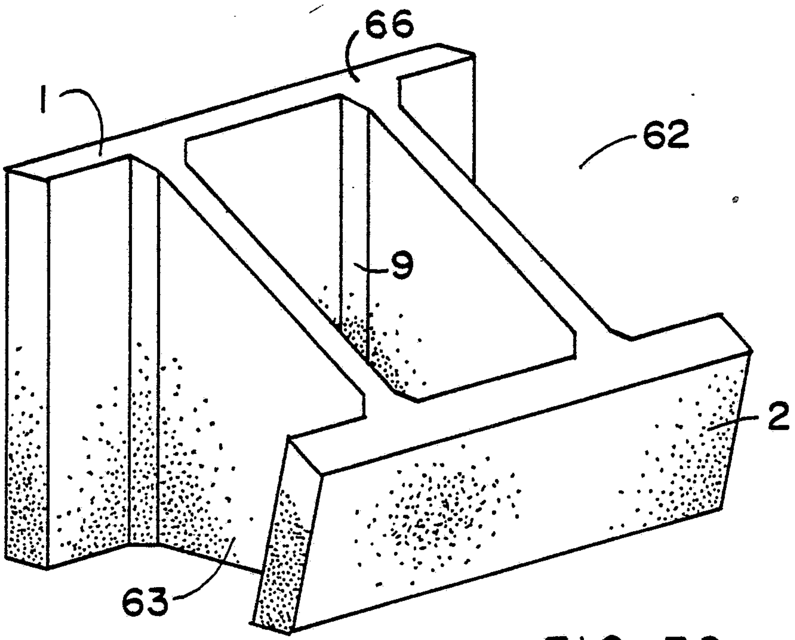


FIG. 39

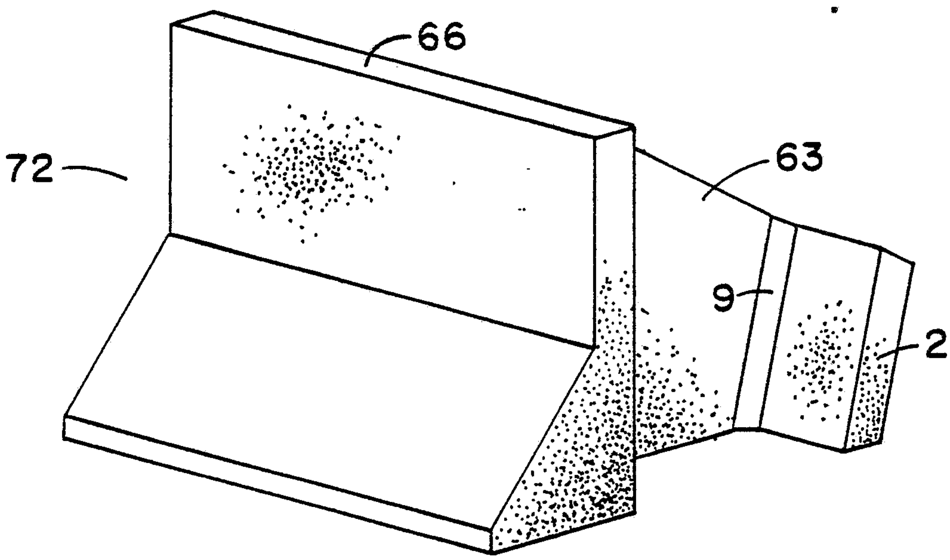


FIG. 40

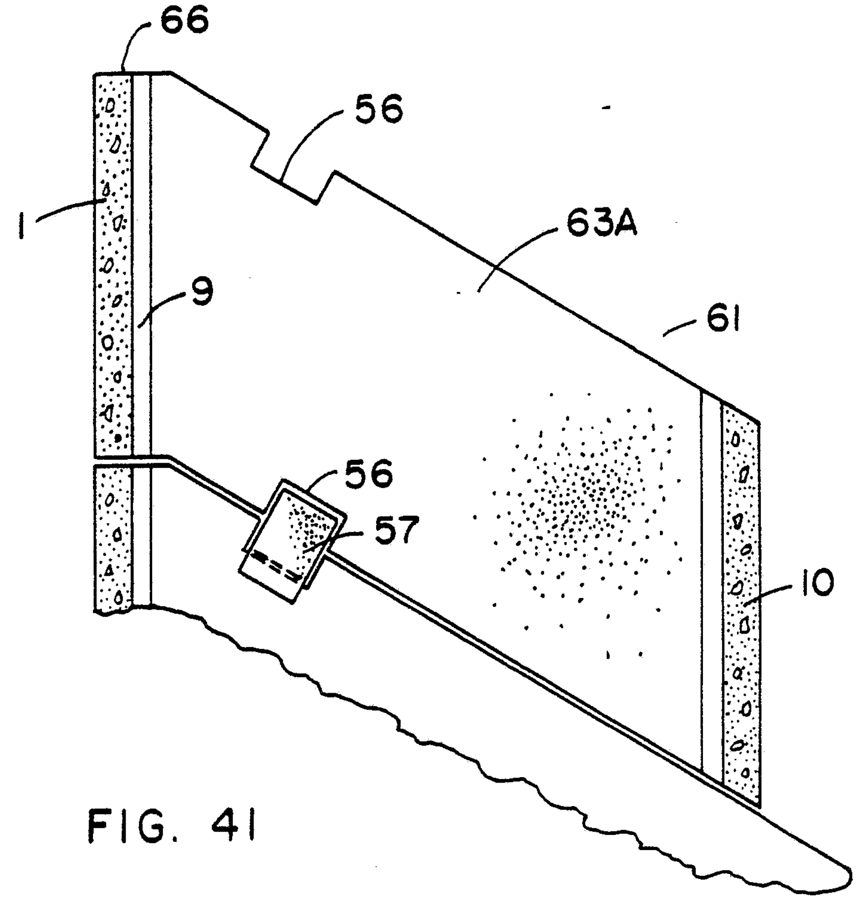


FIG. 41

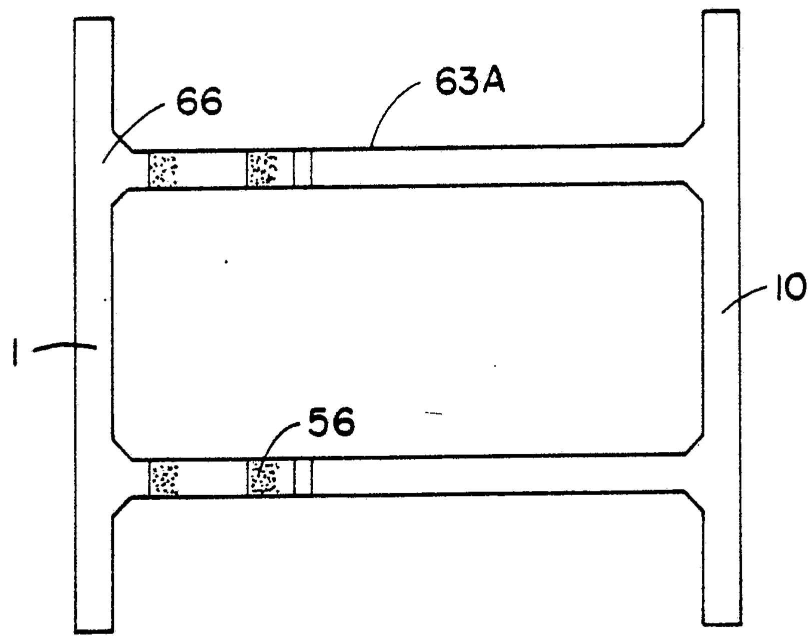


FIG. 42

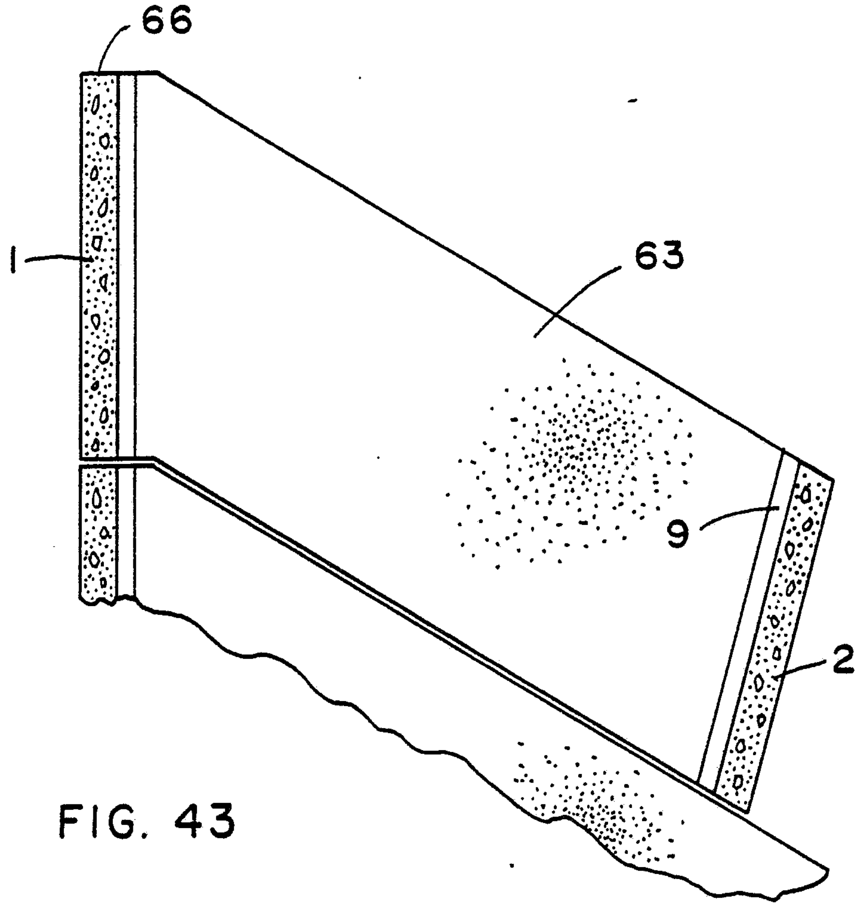


FIG. 43

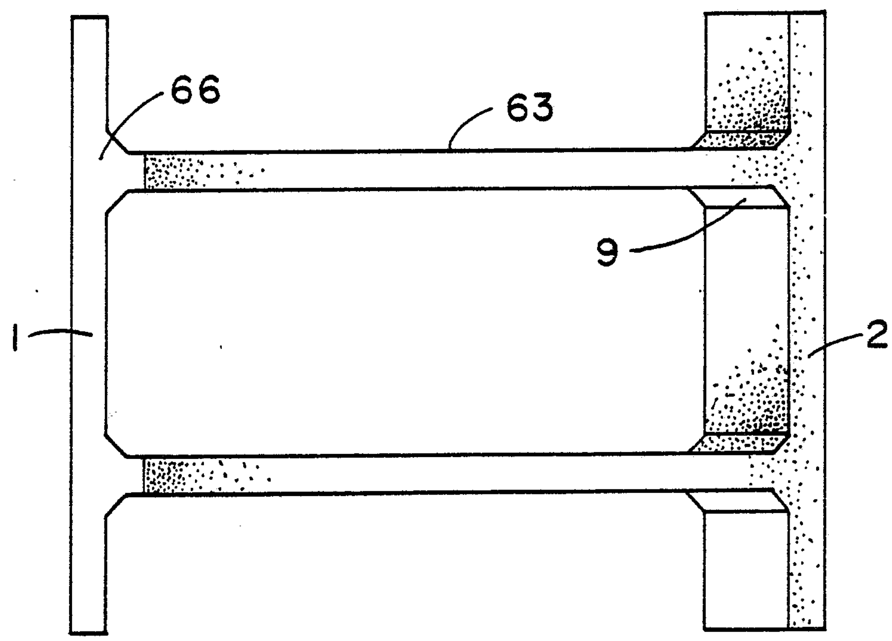


FIG. 44

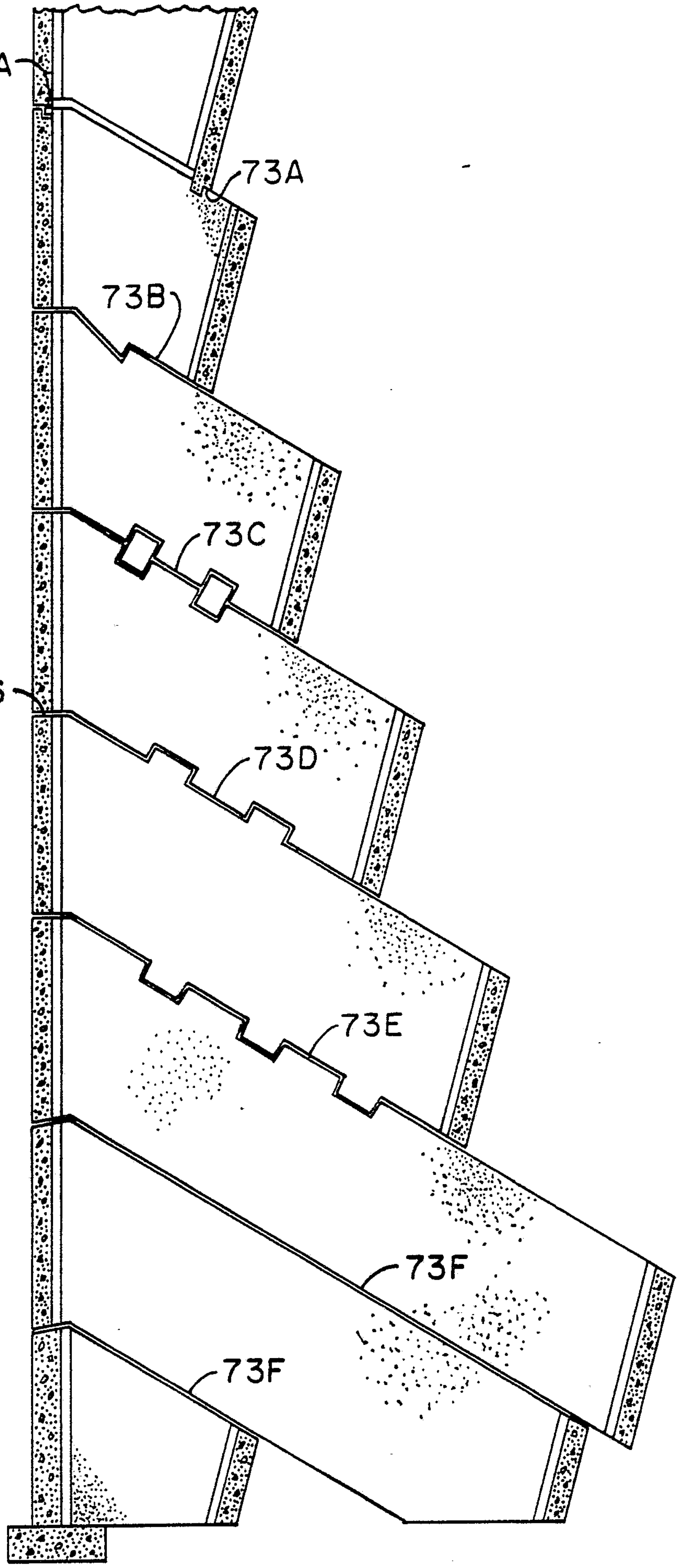


FIG. 45

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 85/00190

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

Int. Cl. E02B 3/04 E02D 29/02
US Cl. 52/596

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
US	52/561-572, 589-594, 596, 603-605 405/284-286

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	SU, A, 256,647, published 04 November 1969 Darevaku	1,2,9,10
Y	US, A, 2,880,538, published 07 April 1959 Pickersgill	3-6,11,12
Y	US, A, 4,074,538, published 21 February 1979 Janus	7,8
Y	US, A, 3,953,979, published 04 May 1976 Kurose	13
A	FR, A, 2,268,116, published 14 November 1975 Chanet	1-14
A	US, A, 3,269,125, published 30 August 1966 Moore	1-14
A	JP, A, 55-78724, published 13 June 1980 Shimonohava	1-14
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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
28 February 1985	07 MAR 1985
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	J. Karl Bell J. K. Bell

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