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Description

The present invention relates to reinforced earth structures, specifically to reinforced earth structures having load bearing cladding.

Reinforced earth construction technology is well developed and established in the construction field. This technology involves reinforcing earth, which becomes a cohesive material of great strength and stability, by the association of granular soil and reinforcements. Through friction, tensile stresses are transferred to the reinforcements, improving the mechanical properties of the soil. A facing, usually of interlocking suitable panels, provides an aesthetically pleasing finish and serves as an anchor for the reinforcing elements. Such reinforced earth provides a coherent gravity mass that can be engineered for a variety of load bearing requirements. The reinforced earth mass has also been used for retaining walls and bridge abutments on highway projects, as well as other civil engineering requirements, such as sea walls, dams and bulk storage facilities. Israel Patent No. 21009 disclosed the characteristic methods of calculating and applying reinforced earth as a construction technique. Specifically a reinforced earth structure comprises a mass of particles normally extracted from the natural ground and reinforcing straps embedded in the mass, said reinforcing straps providing frictional contact with the grains or particles. These reinforcements ensure that the structure is stable. The free vertical surface of the reinforced structure is faced with cladding or skin for retaining the particles which are located in the vicinity of the said free surface and which are therefore not subject to the frictional retaining effect of the reinforcing straps. The above mentioned patent discloses cladding consisting of U-section elements in superimposed relation, having adjacent flanges of elements in contact with one another.

Israel Patent No. 35046 discloses cladding elements in the form of a plate or slab comprising means for fixing the cladding elements to the ends of the reinforcing straps, the slabs having edge portions which allow a relative displacement between adjacent slabs and a seal for preventing earth particles from passing between adjacent slabs.

Israel Patent No. 50515 discloses a specific type of reinforcing strap having traverse ribs extending over the full length of the strip to provide better friction with earth and improve the reinforcement for structures of reinforced earth. Today slabs of the type disclosed in Israel Patent 35046 are the most common cladding for reinforced earth structures. These slab claddings are usually arranged in an interlocking manner with the edges of one slab engaging those of the adjacent slab in tongue and groove arrangement. Reinforced earth can thus be prepared with a vertical end surface of 20 meters and more, having a cladding or facing of concrete slabs layered one upon the other to the very top of the structure, each concrete slab providing a barrier for lateral displacement of the ground adjacent to it, to which it is anchored by reinforcing straps.

In US-4618283 a method of constructing an archway or similar structure is described. The walls of the archway are made of mats formed of a fine mesh which are attached to similar mats which extend outwardly from the walls of the archway into the surrounding earth. With this method of construction it is the surrounding compacted earth which acts as the supporting structure for the roof of the archway with the mat walls of the archway functioning primarily to hold the earth in position. One method of constructing an archway described in this document involves the provision of a metal liner or the formation of a concrete face behind the mat walls of the archway. This is described as having the advantage of giving the interior of the archway a more finished appearance.

The concrete slab claddings have heretofore been used exclusively as a facing for reinforced structures. It was thought that the cladding is not capable of supporting vertical loads, since it is composed of discrete elements with flexible joints between them. All vertical loads associated with reinforced earth structures were applied on the earth at the back of the cladding or transferred to underlying strata by other means such as piles or columns.

The applicant has discovered that suitable cladding of reinforced earth structures can serve as load-supporting walls, capable of receiving vertical loads. The horizontal forces in the straps, which are anchored to the cladding elements are translated into vertical reactions which enable the discrete elements to accept substantial vertical forces with very small deflections well within tolerable limits.

Furthermore, it was discovered that cladding elements subject to vertical bearing loads were less prone to cave in when subjected to both internal and external blast forces. The vertical forces on the elements were translated into horizontal reactions, due to friction, which increased the resistance at the cladding elements to horizontal deflections.

It is the object of the present invention to provide vertical load bearing reinforced earth structures, said vertical loads being borne by the reinforced earth concrete slab claddings.

It is a further object of the invention to provide security structures using load-bearing concrete slab claddings to support a roof having a substantial load.

Yet another object of the invention is to provide a method of construction wherein concrete slab cladding of reinforced earth structures serve as load-bearing walls.

In accordance with this invention there is provided a structure comprising: a wall, a roof which applies a vertical force, and a reinforced earth fill structure in contact and coextensive with the wall, having a plurality of flexible reinforcing straps extending outwardly from the wall into the reinforced earth fill structure, characterised in that the wall comprises a cladding for the reinforced earth fill structure in the form of at least two load bearing tiers of interlocking concrete slabs disposed one on the other, with the vertical force exerted by the roof at the wall supported solely by the cladding and the reinforcing straps fixed to the concrete slabs, whereby when the wall is subjected to blast forces the interlocking concrete slabs provide a sufficient measure of flexibility to absorb the shock of the blast forces through displacement of the concrete slabs whilst maintaining adequate support for the roof.

In a further aspect the invention reside in a method of constructing a structure supporting a roof which applies a vertical force, the method comprising forming a wall; forming a reinforced earth fill structure in contact and coextensive with the wall, and providing a plurality of flexible reinforcing straps which extend outwardly from the wall into the reinforced earth fill structure characterised in that the wall comprises cladding formed by stacking concrete slabs one on the other with each of the concrete slabs interlocking with adjacent concrete slabs to form at least two load bearing tiers of slabs, the vertical force exerted by the roof at the wall being supported solely by the cladding and anchoring the cladding with the reinforcing straps fixed to the cladding, whereby when the wall is subject to blast forces the interlocking concrete slabs provide a sufficient measure of flexibility to absorb the shock of the blast forces through displacement of the concrete slabs whilst maintaining adequate support for the roof.

The applicant has discovered that suitable cladding of reinforced earth structures can serve not only as facing for anchorage of the straps to prevent lateral displacement of the adjacent earth, but also as vertical load supporting walls, although such walls are not vertically rigid, but rather comprise multiple tiers of concrete slabs disposed one on the other.

Furthermore, it was discovered that concrete roof structures supported by reinforced earth concrete slab cladding were less prone to cave in when subjected to both internal and external blast forces.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example only in the accompanying drawings, in which:

Figure 1 represents a top view of a preferred reinforced earth structure according to the invention;

Figure 2 is a cross-section of the structure in Figure 1 taken along line 1-1;

Figure 3 is a cross-section of the structure of Figure 1 taken along line 2-2;

Figure 4 illustrates in detail a load bearing wall of reinforced earth cladding;

Figure 5 shows a standard shape concrete slab element used for cladding reinforced earth as in Figure 4;

Figure 6 is an enlarged view of section A in Figure 5 illustrating means for anchoring reinforcing strips on the concrete slab; and

Figures 7a to 7f illustrate the displacement of concrete slab sections of the wall of Figure 4 after an explosion within the earth outside the structure.

Referring now to Figures 1-3, there are shown top and cross-sectional views respectively of a rectangular load bearing reinforced earth structure in accordance with the invention. The structure consists of three vertical load bearing walls 20, 21 and 22 and one open side 23. Each of the walls 20, 21 and 22 is comprised of three tiers 24, 25 and 26 of pre-cast concrete slab cladding anchored in position by reinforcing straps 27 buried in the earth 28. The slabs are interlocking one with the other (Figure 4) in both horizontal and vertical directions. A concrete roof 29 is cast in place and is supported solely by the walls 20, 21 and 22. The structure is covered with earth 30 which makes it undetectable from the air. The pre-cast concrete slabs used to make the load bearing wall may be of the conventional type, having a cross-shaped and interlocking configuration (Figure 4), and in the present example wall 20 comprises twelve slabs numbered 1-12 comprising several basic configurations, as is known in the art. Thus, for example, slab 4 has a basic shape for interlocking on four sides with adjacent slabs. Slabs 3 and 5 are respectively terminal upper and lower slabs with the upper and lower edge respectively smoothly finished.

Detailed construction of slab 4 is illustrated in Figure 5. The cross-sectional joints 31, 32, 33 and 34 have a tongue 35 for engaging an adjacent slab in a corresponding groove 36 in a tongue and groove arrangement. Anchors 37 are embedded in the concrete slab 4, as can better be seen in Figure 6. Flexible reinforcing straps 38 are fixed to the anchors 37 by means of bolts 39. Horizontal steel plate flanges 40 at the connection between the cladding element and the strap can optionally be introduced to further improve the interaction between the horizontal force exerted by the strap and the resistance to vertical forces applied on the cladding elements. Thus by using cladding having horizontal flanges, the vertical deflections under the static vertical loads as well as horizontal deformations of a structure subjected to blast loading will be further reduced, enabling construction of vertical load supporting walls without building a foundation.

As was discussed previously, the technology of reinforced earth structure using the reinforced earth to support loads is well-known and the concrete slab cladding for use in retaining walls of such structure has been detailed in Israel Patent No. 35046. No-one has previously considered or thought feasible the use of the concrete slab cladding wall itself as a vertical load bearing construction element. To demonstrate the advantage of this invention, an experiment was conducted wherein an explosive device was detonated in the earth outside of a reinforced earth roofed structure as shown in Figures 1-4 having the following dimensions: length 7.35 m, width 5.34 m and height 3 m, with the typical slab 4 illustrated in Figure 5 having the dimensions x = 1.335 m and y = 1.505 m. In the above structure at the location marked E (Figs. 1 and 4), a quantity of TNT to simulate a standard store containing 30 tons of TNT was detonated and the effect of the blast on the wall 20 of Figure 4 is shown in Figures 7a to 7f which illustrate cross-sections of the wall taken at a-a, b-b, c-c, d-d, e-e and f-f respectively. In general it can be said that the structure retained its integrity and the roof remained supported by the cladding walls, although individual cladding sections were displaced. Thus we see that the wall sections 11, 8 and 9 (Figs. 7a and 7b) which were closest to the source of the blast had the greatest displacement (m and n) 65.5 and 71.1 cm respectively from their original vertical position. Nevertheless, these sections did not totally collapse and remained interlocked with adjacent sections to provide adequate support for the roof 29 and prevent its collapse. As the distance from the blast source E increased (Figures 7c, d, e and f), the cladding displacement decreased, thus the distances o,p,q,r,s and t are 57.3, 38, 47.6, 28, 17.1 and 6.2 cm respectively. The blast caused the slabs to buckle but not to crumble, and the interlocking arrangement of the cladding provided a sufficient measure of flexibility to absorb the shock and merely displace the slabs, which remained anchored in the reinforced earth.

Such an explosion in a structure having the same dimensions but made with conventional concrete walls supporting a concrete roof would cause the walls to cave in and the roof to crash, making the structure unsuitable for security needs.

According to this invention, therefore, it is possible to rapidly construct heavy roofed structures at lower costs for ammunition storage bunkers and other security structures such as bomb shelters. Furthermore, because of the fact that these structures are able to withstand internal and external blasts better than conventional structures, ammunition depots made of such structures can be constructed at closer intervals one from the other since the debris and shock forces of internal explosion are spread over a much shorter distance

Similarly, the interior of these structures is better able to absorb the shocks of external explosions significantly reducing the ricocheting of debris therein. Thus bomb shelters made of such structures can safely be provided with stone tile flooring, which is not the case with conventionally constructed bomb shelters. Other applications of this invention, include the construction of bridge abutments with shorter spans, thus eliminating elaborate support platforms which are presently required for carrying loads on reinforced earth.

Claims

1. A structure comprising: a wall (20;21;22), a roof (29) which applies a vertical force, and a reinforced earth fill structure (28) in contact and coextensive with the wall, having a plurality of flexible reinforcing straps (27) extending outwardly from the wall into the reinforced earth fill structure (28), characterised in that the wall comprises a cladding for the reinforced earth fill structure (28) in the form of at least two load bearing tiers (24,25,26) of interlocking concrete slabs (1-12) disposed one on the other, with the vertical force exerted by the roof at the wall supported solely by the cladding, said reinforcing straps (27) being fixed to the concrete slabs (1-12), whereby when the wall (20;21;22) is subjected to blast forces the interlocking concrete slabs (1-12) provide a sufficient measure of flexibility to absorb the shock of the blast forces through displacement of the concrete slabs (1-12) whilst maintaining adequate support for the roof (29).

2. A structure as claimed in claim 1, comprising at least two spaced walls (20;21;22) supporting the roof thereon.

3. A structure as claimed in claim 2, wherein the roof (29) is a concrete roof.

4. A structure as claimed in claim 3, wherein the load (29) further includes earth fill (30) over the concrete roof.

5. A structure as claimed in any one of claims 1 to 4, wherein the concrete slabs (1-12) have horizontal flanges.

6. The structure as claimed in any one of claims 1 to 5 when used in a shelter.

7. The structure as claimed in any one of claims 1 to 5 when used in a depot for explosives.

8. The structure as claimed in any one of claims 1 to 5 when used in a bridge.

9. A method of constructing a structure supporting a roof (29) which applies a vertical force, the method comprising forming a wall (20;21;22); forming a reinforced earth fill structure (28) in contact and coextensive with the wall, and providing a plurality of flexible reinforcing straps (27) which extend outwardly from the wall into the reinforced earth fill structure (28) characterised in that the wall comprises cladding formed by stacking concrete slabs (1-12) one on the other with each of the concrete slabs (1-12) interlocking with adjacent concrete slabs (1-12) to form at least two load bearing tiers of slabs (1-20), the vertical force exerted by the roof at the wall being supported solely by the cladding and anchoring the cladding with the reinforcing straps (27) fixed to the cladding, whereby when the wall (20;21;22) is subject to blast forces the interlocking concrete slabs (1-12) provide a sufficient measure of flexibility to absorb the shock of the blast forces through displacement of the concrete slabs (1-12) whilst maintaining adequate support for the roof (29).

Patentansprüche

1. Bauwerk, das besteht aus: einer Wand (20;21;22), einem Dach (29), das eine vertikale Kraft ausübt, und einer verstärkten Erdfüllung (28) in Berührung mit und von gleicher Ausdehnung wie die Wand, mit einer Anzahl von flexiblen Verstärkungsbändern (27), die sich von der Wand nach außen in die verstärkte Erdfüllung (28) erstrecken, dadurch gekennzeichnet, daß die Wand aus einer Umhüllung für die verstärkte Erdfüllung (28) in Form von wenigstens zwei lasttragenden Lagen (24,25,26) aus ineinandergreifenden Betonplatten (1-12) besteht, die aufeinander angeordnet sind, wobei die vom Dach auf die Wand ausgeübte vertikale Kraft ausschließlich durch die Umhüllung getragen wird und die Verstärkungsbänder (27) an den Betonplatten (1-12) befestigt sind, wodurch, wenn die Wand (20;21;22) Explosionskräften unterworfen wird, die ineinandergreifenden Betonplatten (1-12) einen ausreichenden Grad an Flexibilität bieten, um den Stoß der Explosionskräfte durch Verschiebung der Betonplatten (1-12) zu absorbieren, während eine ausreichende Unterstützung für das Dach (29) aufrechterhalten wird.

2. Bauwerk nach Anspruch 1, mit wenigstens zwei im Abstand voneinander angeordneten Wänden (20;21;22), welche das daraufliegende Dach tragen.

3. Bauwerk nach Anspruch 2, bei welchem das Dach (29) ein Betondach ist.

4. Bauwerk nach Anspruch 3, bei welchem die Last (29) ferner eine Erdfüllung (30) über dem Betondach umfaßt.

5. Bauwerk nach einem der Ansprüche 1 bis 4, bei welchem die Betonplatten (1-12) horizontale Flansche aufweisen.

6. Bauwerk nach einem der Ansprüche 1 bis 5, das in einem Bunker verwendet wird.

7. Bauwerk nach einem der Ansprüche 1 bis 5, das in einem Sprengstofflager verwendet wird.

8. Bauwerk nach einem der Ansprüche 1 bis 5, das in einer Brücke verwendet wird.

9. Verfahren zum Aufrichten eines Bauwerks, das ein eine vertikale Kraft ausübendes Dach (29) trägt, wobei das Verfahren umfaßt: Ausbilden einer Wand (20;21;22); Ausbilden einer verstärkten Erdfüllung (28) in Berührung mit und von gleicher Ausdehnung wie die Wand, sowie Anbringen einer Anzahl von flexiblen Verstärkungsbändern (27), die sich von der Wand nach außen in die verstärkte Erdfüllung (28) erstrecken, dadurch gekennzeichnet, daß die Wand aus einer Umhüllung besteht, die durch Übereinanderstapeln von Betonplatten (1-12) gebildet ist, wobei jede Betonplatte (1-12) mit benachbarten Betonplatten (1-12) in Eingriff steht, um wenigstens zwei lasttragende Lagen von Platten (1-12) zu bilden, die vom Dach auf die Wand ausgeübte vertikale Kraft lediglich von der Umhüllung getragen wird, und die Umhüllung mit den an der Umhüllung befestigten Verstärkungsbändern (27) verankert wird, wodurch, wenn die Wand (20;21;22) Explosionskräften ausgesetzt wird, die ineinandergreifenden Betonplatten (1-12) einen ausreichenden Grad an Flexibilität erzeugen, um den

stoß der Explosionskräfte durch Verschiebung der Betonplatten (1-12) zu absorbieren, während eine ausreichende Unterstützung des Daches (29) aufrechterhalten bleibt.

Revendications

1. Construction comprenant : un mur (20; 21; 22), un toit (29) qui applique une force verticale, et une structure de terre armée (28) en contact avec le mur et dans la même extension, comportant une pluralité de plaques de renfort flexibles (27) s'étendant vers l'extérieur depuis le mur dans la structure de terre armée (28), caractérisée en ce que le mur comprend un habillage pour la structure de terre armée (28) sous la forme d'au moins deux étages porteurs (24, 25, 26) de dalles de béton à emboîtement (1-12) disposées les unes sur les autres, avec la force verticale exercée par le toit au mur supportée uniquement par l'habillage, lesdites plaques de renfort étant fixées au dalles de béton (1-12), de sorte que lorsque le mur (20; 21; 22) est soumis à des forces d'explosion les dalles de béton à emboîtement (1-12) procurent un degré suffisant de flexibilité pour absorber le choc des forces d'explosion par déplacement des dalles de béton (1-12) tout en demeurant un support adéquat pour le toit (29).

2. Construction selon la revendication 1, comprenant au moins deux murs espacés (20; 21; 22) supportant le toit.

3. Construction selon la revendication 2, dans laquelle le toit (29) est un toit de béton.

4. Construction selon la revendication 3, dans laquelle le toit de béton (29) comprend en outre de la terre (30) sur lui.

5. Construction selon l'une quelconque des revendications 1 à 4, dans laquelle les dalles de béton (1-12) comportent des rebords horizontaux.

6. Construction selon l'une quelconque des revendications 1 à 5 utilisée dans un abri contre les bombes.

7. Construction selon l'une quelconque des revendications 1 à 5 utilisée dans un dépôt d'explosifs.

8. Construction selon l'une quelconque des revendications 1 à 5 utilisée dans un pont.

9. Procédé de réalisation d'une construction supportant un toit (29) qui applique une force verticale, le procédé comprenant les phases consistant à former un mur (20; 21; 22), former une structure de terre armée (28) en contact avec le mur et dans la même extension, et disposer une pluralité de plaques de renfort flexibles (27) qui s'étendent vers l'extérieur depuis le mur dans la structure de terre armée (28), caractérisé en ce que le mur comprend un habillage formé en empilant des dalles de béton (1-12) les unes sur les autres avec chacune des dalles de béton (1-12) s'emboîtant avec les dalles de béton adjacentes (1-12) pour former au moins deux étages porteurs de dalles (1-12), la force verticale exercée par le toit au mur étant supportée uniquement par l'habillage et l'habillage étant ancré avec les plaques de renfort fixées à l'habillage, de sorte que lorsque le mur (20; 21; 22) est soumis à des forces d'explosion les dalles de béton à emboîtement (1-12) procurent un degré suffisant de flexibilité pour absorber le choc des forces d'explosion par déplacement des dalles de béton (1-12) tout en demeurant un support adéquat pour le toit (29).

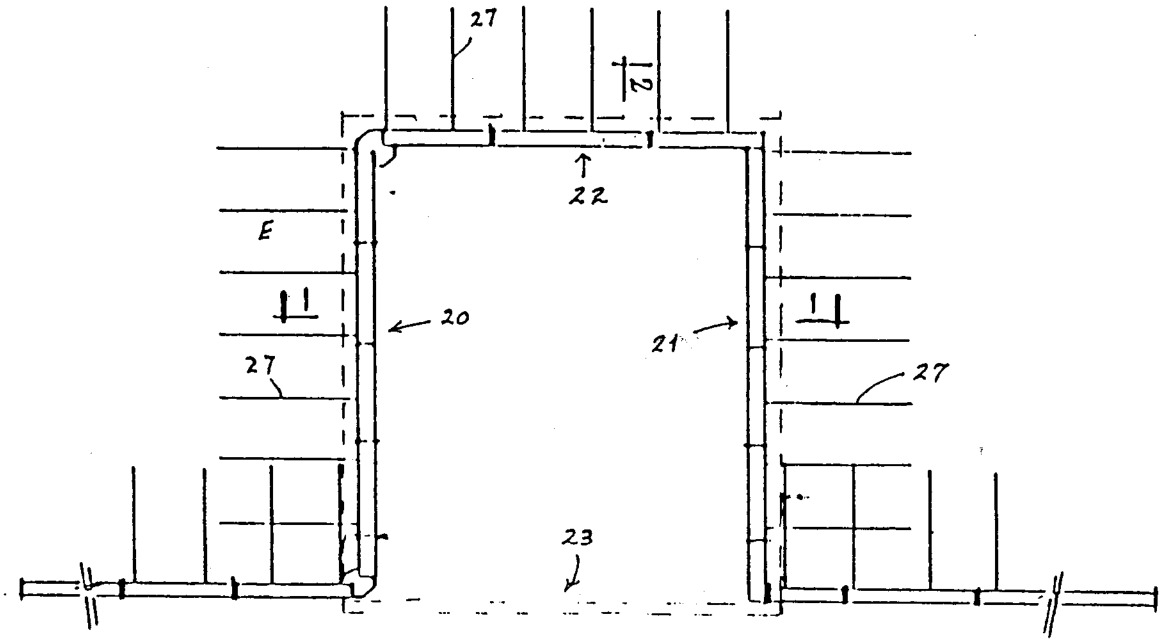


Fig. 1

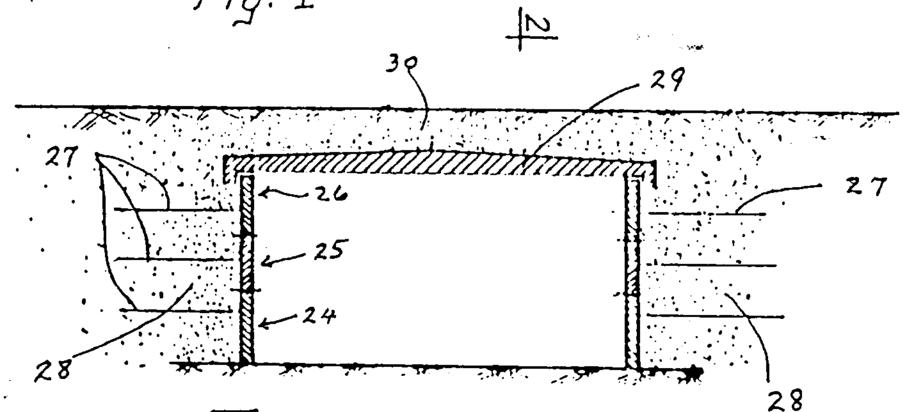


Fig. 2

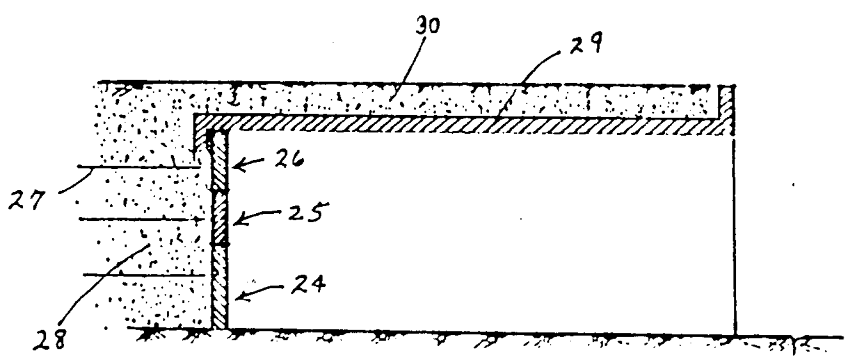


Fig. 3

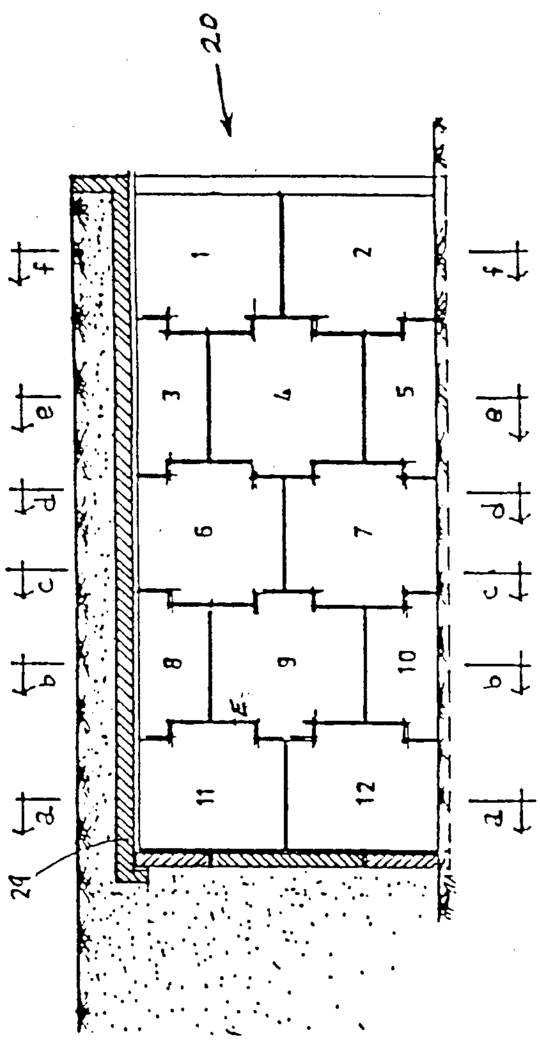
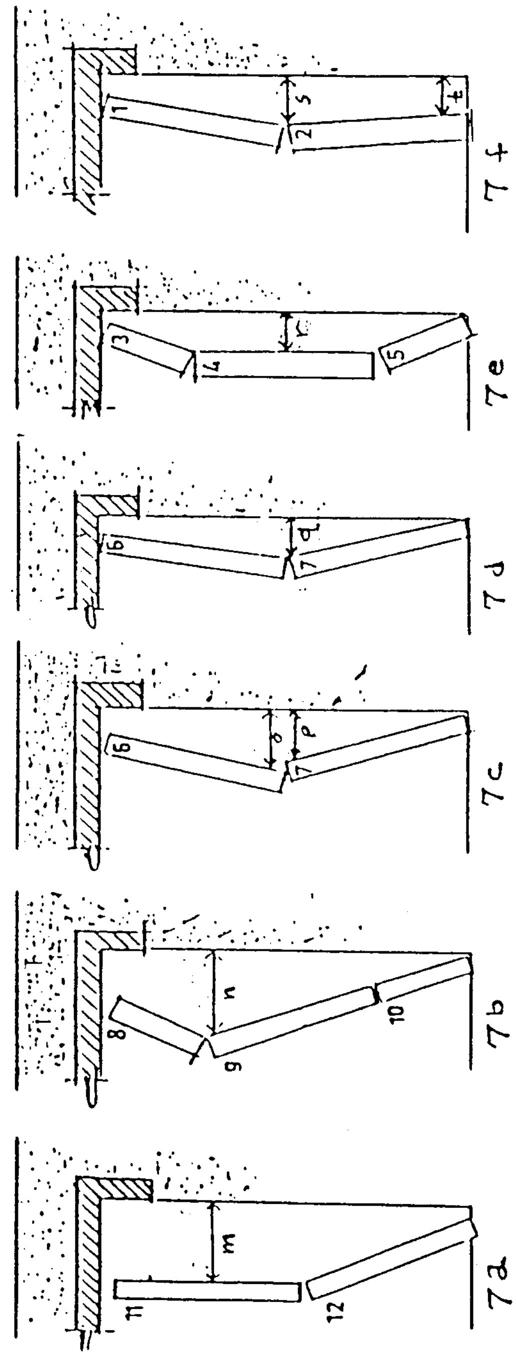


Fig. 4



Figs. 7a-f

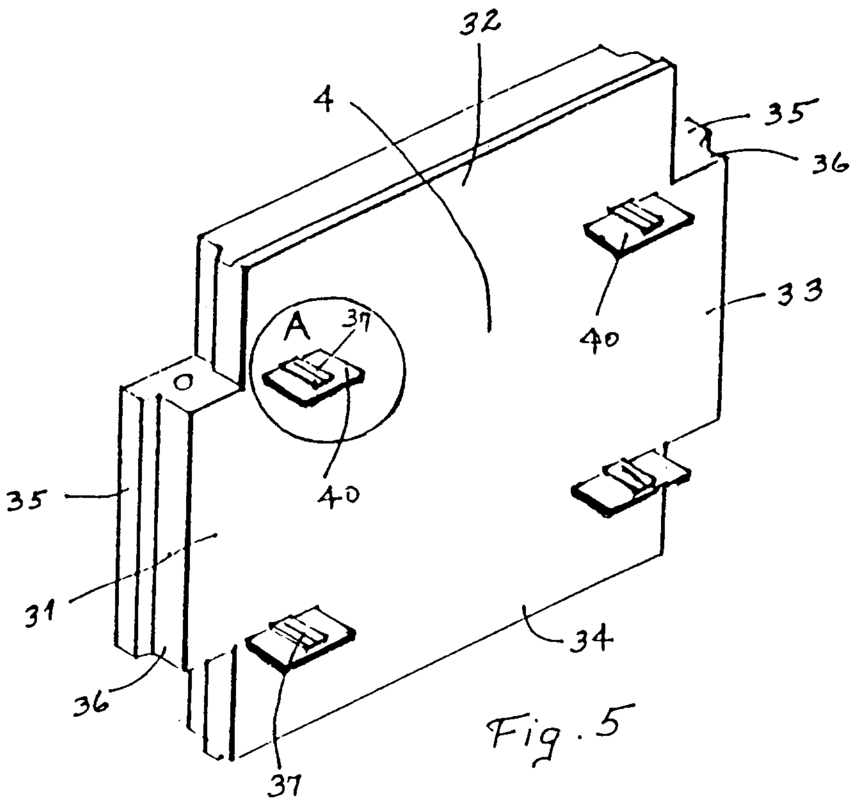


Fig. 5

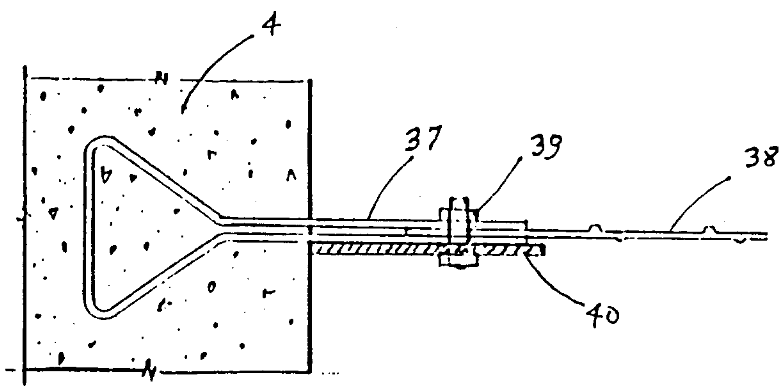


Fig. 6