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GB 2274666 A GB 2269838 A GB 2196681 A
GB 1180689 A WO 95/00711 A1 WO 88/06220 A1
US 4867377 A

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UK CL (Edition O) **A1B B5 , E1C C15 , E1D DDP DF117 DF119 DF123 DF193 , E1G G60N G65**
INT CL^6 **E01C , E02D , E04B**

(54) Foundations for poor soils

(57) A buoyant foundation for poor soils comprises a base layer formed from individual elements of a foamed synthetic plastics material and an upper layer 30 of aggregate or settable cementitious material such as concrete. The upper surface of the upper layer 30 is substantially horizontal surface for supporting an applied structure. The elements 20 transmit the load of the applied structure directly to the soil of a prepared site. Preferably, the synthetic plastics material of the elements 20 is polyurethane or polystyrene. The combined weight of the foundation, the applied structure and any dynamic loads gives an overall displacement weight which is no greater than the weight of the displaced soil material (water and soil combined).

Neutral buoyancy stormwater drains and methods of forming buoyant foundations are also disclosed.

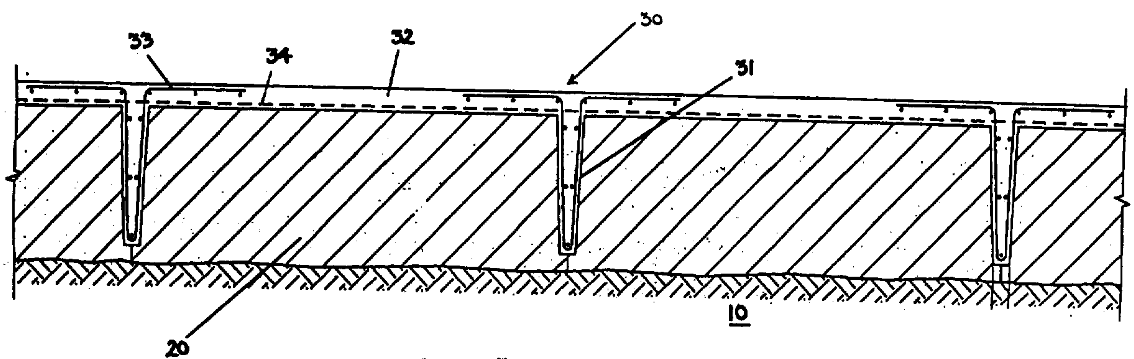

FIGURE 3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

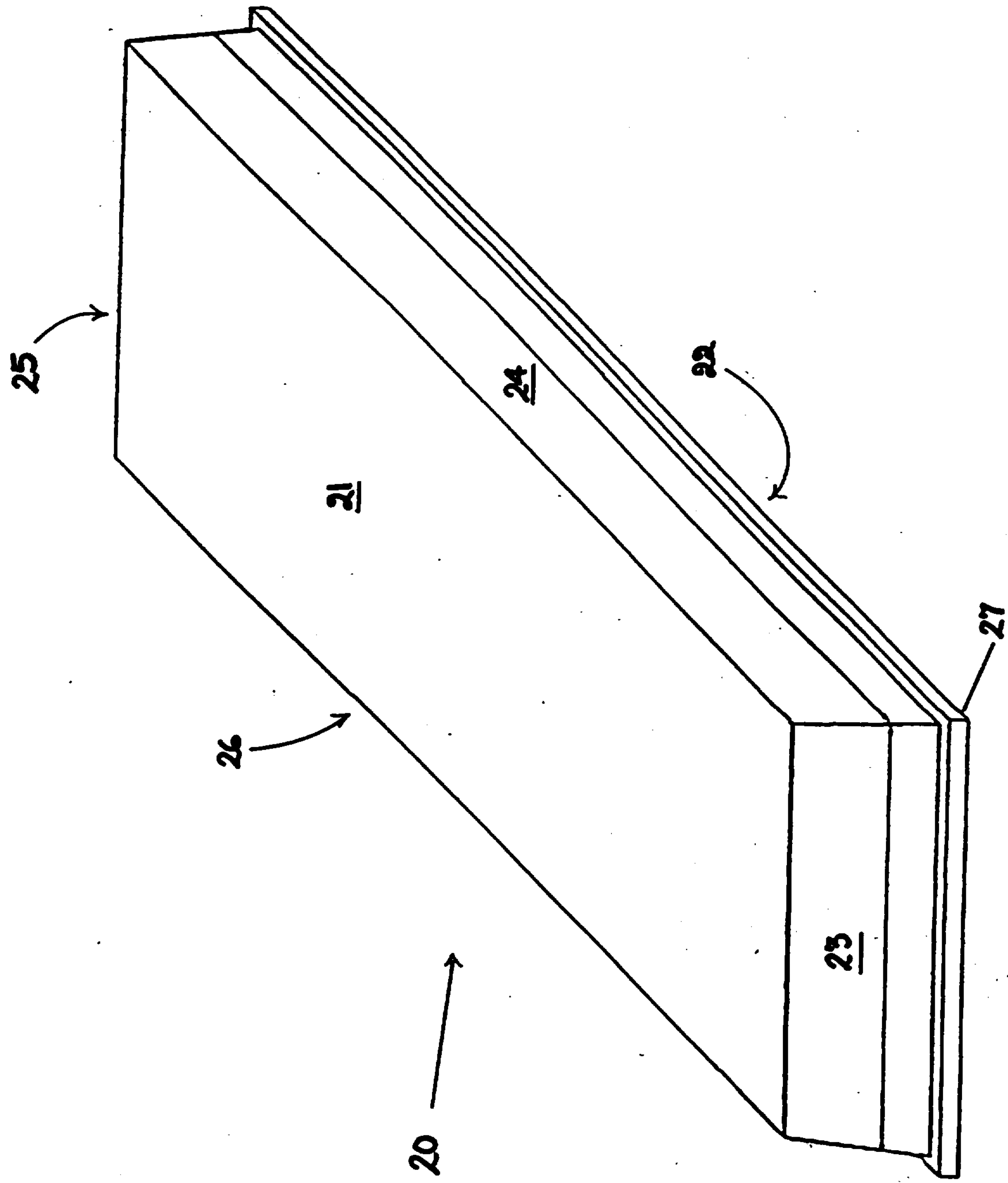

Figure 1

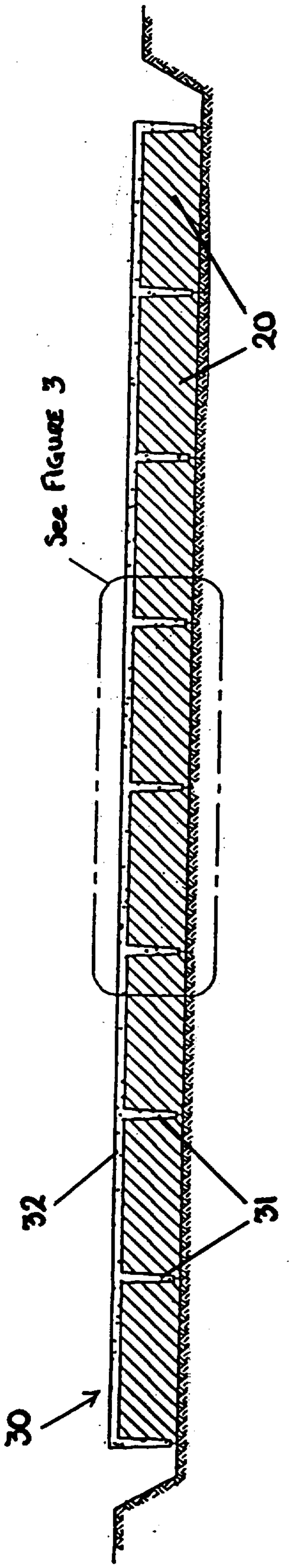

FIGURE 2

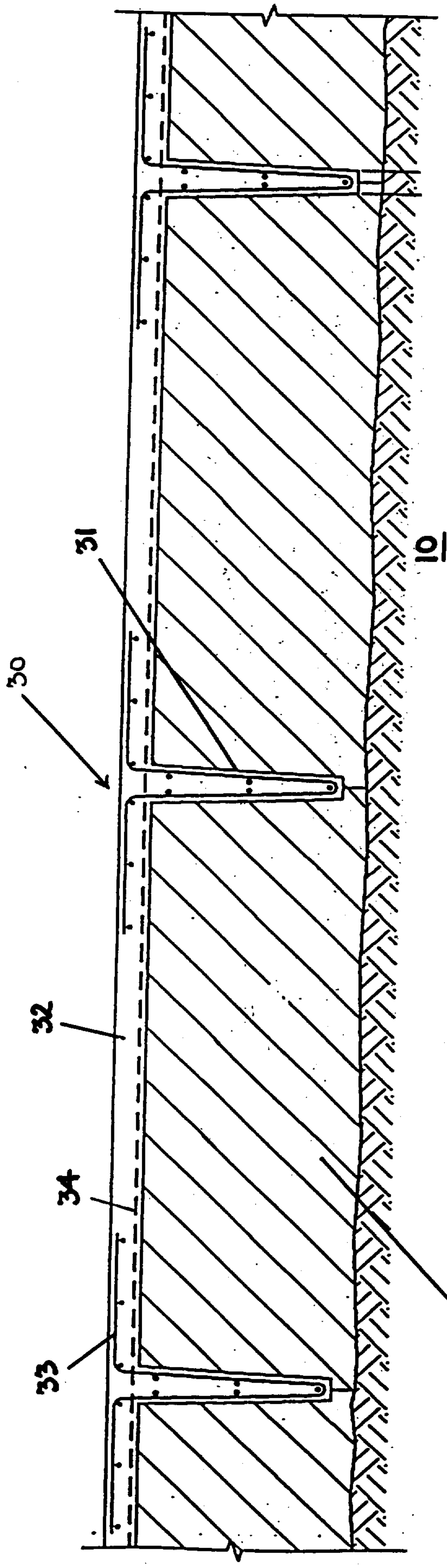

FIGURE 3

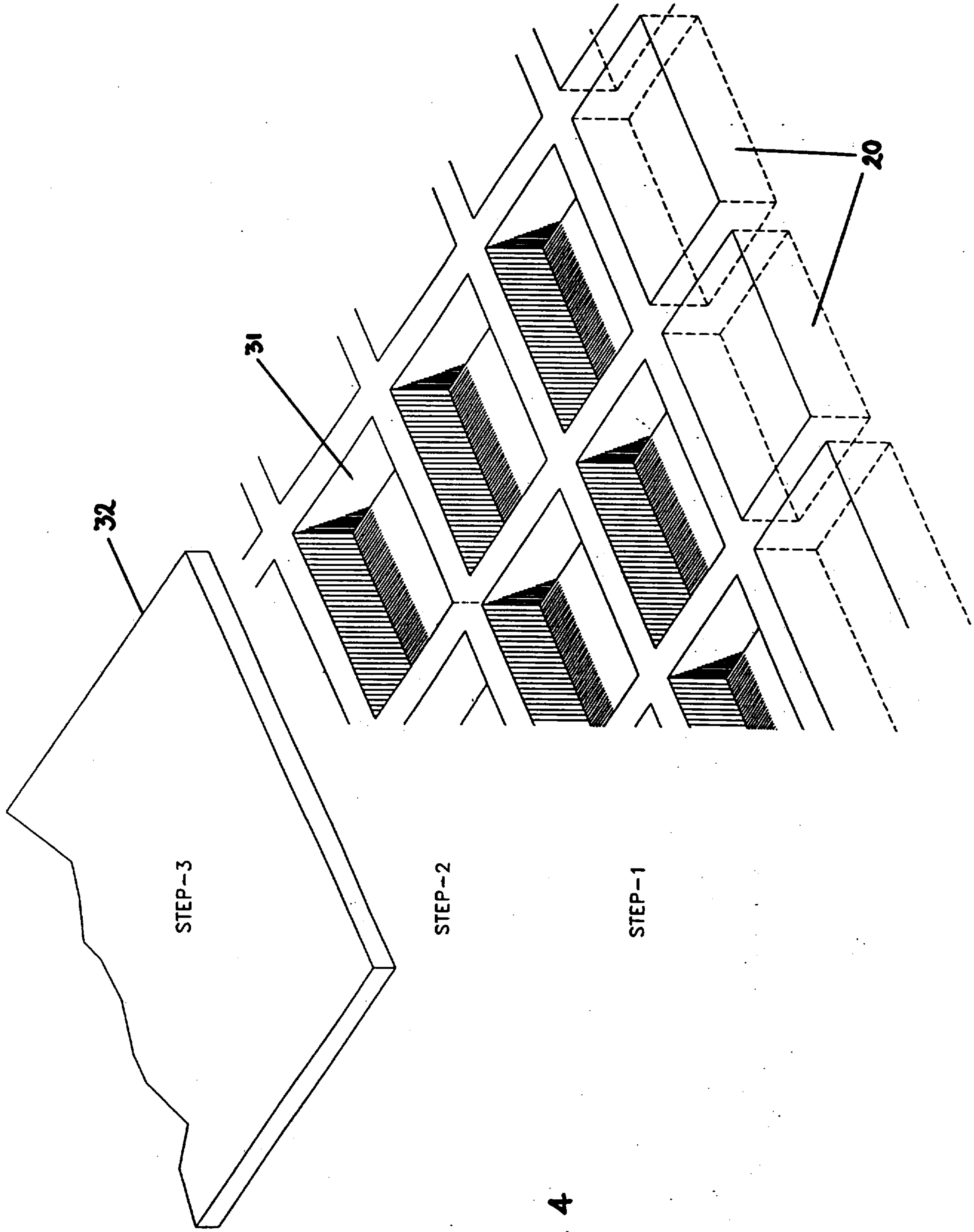

FIGURE 4

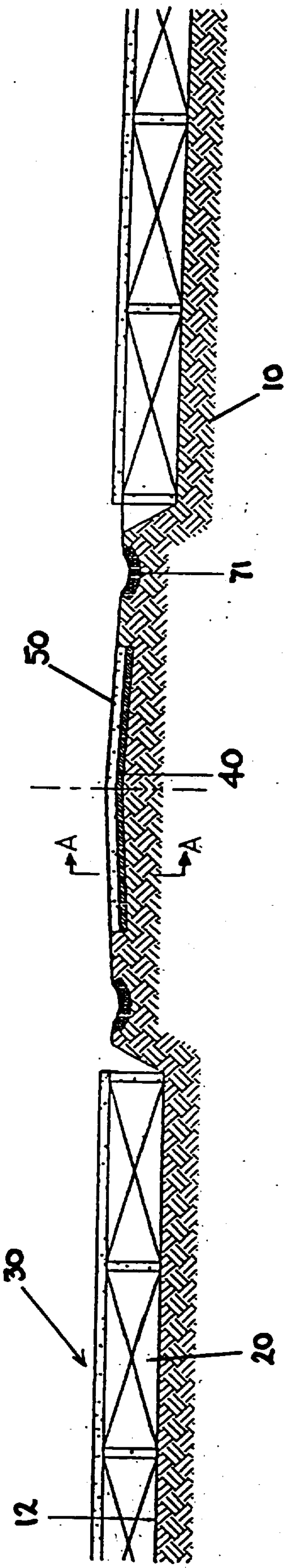

FIGURE 5

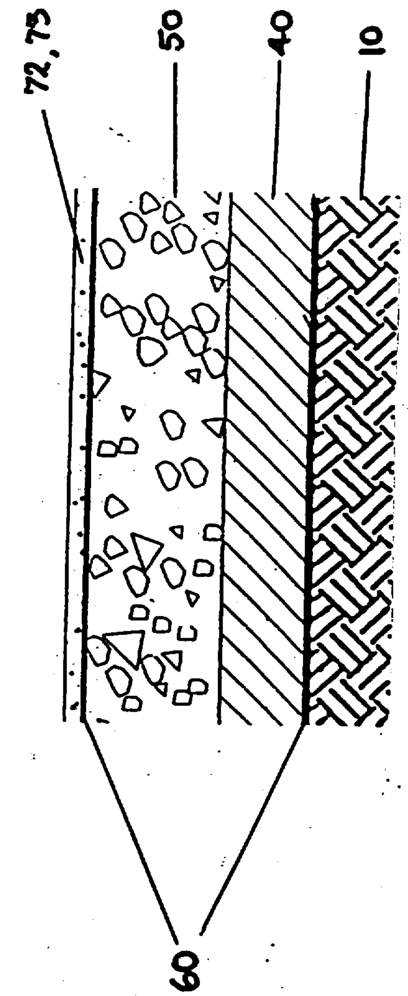

FIGURE 6

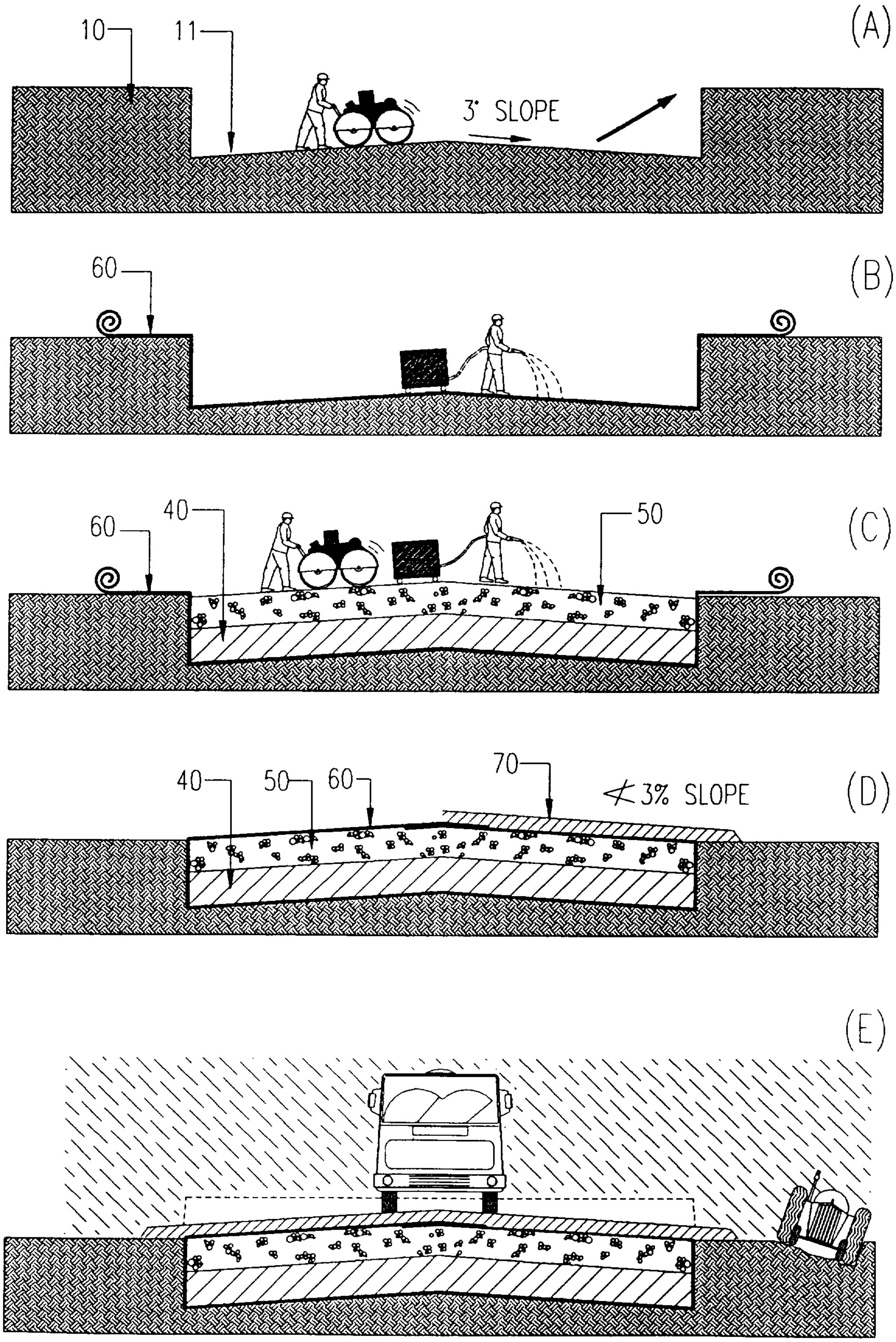

FIGURE 7

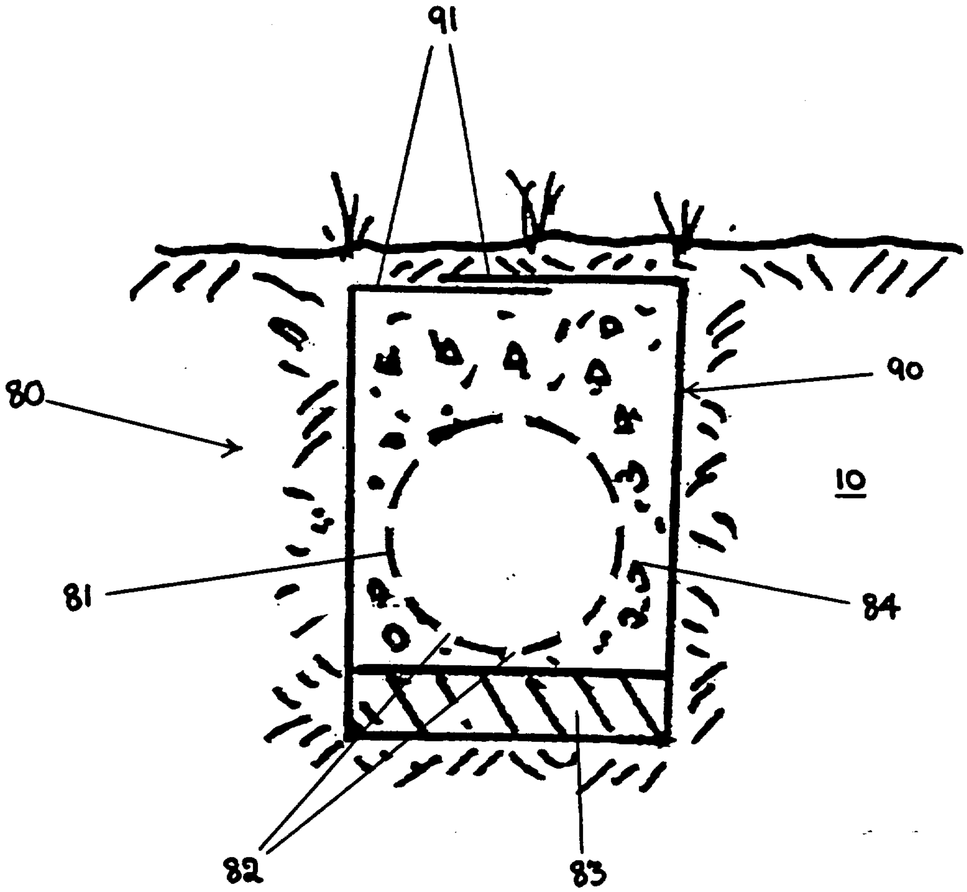

FIGURE 8

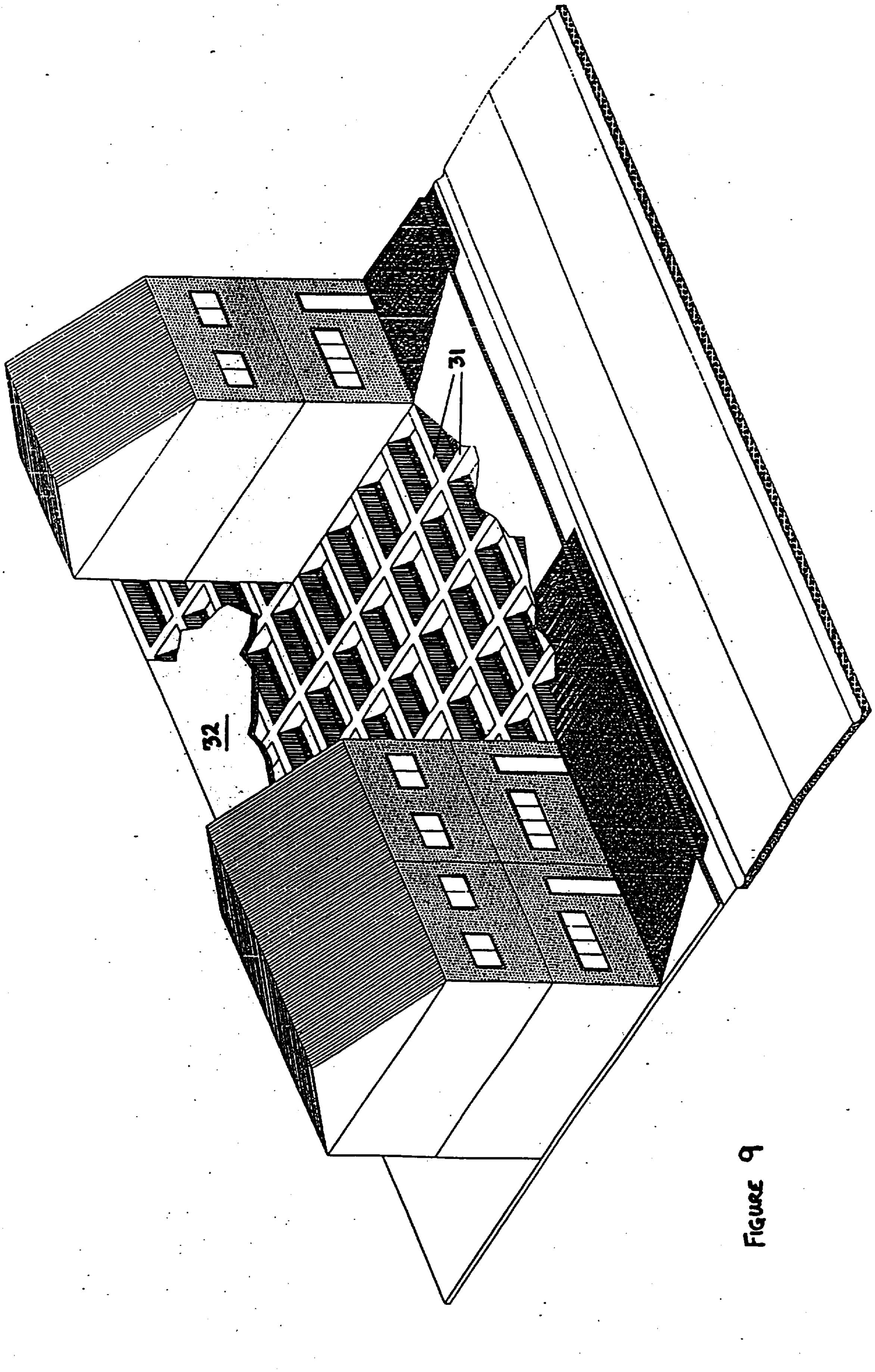

FIGURE 9

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BUOYANT FOUNDATIONS FOR BAD SOILS

The present invention relates to foundations and, in particular, to a buoyant foundation suitable for supporting structures on bad soils having low bearing capacity such as marshy or swampy land.

Foundation systems for bad soils are known which are capable of providing the necessary degree of support for low-rise buildings of up to about three floors in height, roads, railway track beds, airport runways or the like. Such systems have found use on soils comprising active clays which may be prone to heaving or settling as a result of swelling or shrinkage due to variation in moisture content. These systems are also suitable for sandy soils which are prone to settling due to consolidation.

An example of a known foundation system for bad soils is described in United States Patent No. 5,189,855. This system comprises a foundation raft formed from a pair of vertically spaced, substantially horizontal foundation slabs of set cementitious material. The upper and lower slabs are spaced apart by a plurality of upwardly-extending webs. The lower slab has a lower surface which is adapted to rest directly on the underlying soil and the upper slab has an upper surface which is adapted to support a building or similar structure at least in part on portions of the upper slab which have no underlying web. Each of the upper and lower slabs and the webs are reinforced in conventional manner.

The webs may be arranged so that they define a plurality of closed cells between the upper and lower slabs.

In constructing a foundation raft of this type, the first step is the casting of the lower slab of settable cementitious material on the prepared soil surface. In one construction variation, pre-cast webs are arranged in a spaced array on the settable cementitious material forming the lower slab before it has set. Hence, during setting, the webs become integral and are made fast with the lower slab. In an alternative variant of this construction, the webs may be cast *in situ* on the lower slab using suitable formwork or shuttering. This alternative method also achieves the desired effect of integration between the lower slab and the upstanding webs.

The spaces between the webs may then be filled with sand or may have formers or shuttering placed upon them for the purpose of providing a surface on which the upper slab is cast. The upper edges of the webs project above the forming surface so that they are cast into and embedded in the upper slab when it is set.

In this type of construction, the backfilling and/or shuttering forms an integral part of the completed foundation and adds to the overall mass of the structure.

An arrangement of this type of is sometimes referred to as a "hull" construction. It relies on the creation of a cellular structure for buoyancy, each cell being closed on six faces to create a buoyant raft.

The disadvantage of such "hull" constructions is that the settable cementitious material has to be waterproofed, either internally inside each cell, or externally in order to prevent ingress of water through microcracks which may develop. This additional step can prove very costly. Even when it is done, it is virtually impossible to ensure that the foundation raft remains impervious to water over an extended period of time.

Another method of forming a foundation for bad soils is the so-called "encapsulation" method, in which the foundation material is encapsulated in a geotextile membrane such as ICI's "Terram" (Trade Mark). This technique has been most widely used in the construction of permanent road beds, the object of encapsulation being to provide an effective separator between the compacted sub-base of the road and the soil or sub-grade upon which it is constructed.

Road design for steady dry or moderately wet conditions is not especially problematic. The encapsulation method is found to be particularly effective in regions subject to severe, and often rapid, climatic variations, for example where it is desired to construct a permanent road on a water-sensitive soil subject to intermittent but heavy rainfall.

Unfortunately, there is no known technique which is capable of providing a stable foundation on soils which are permanently saturated, such as marshy or swampy regions.

It is therefore an object of the present invention to provide an improved foundation system capable of supporting low-rise buildings, roads, railway track beds, airport runways or the like on poor soils. It is a further object of the invention to provide a foundation system which remains impervious to water even after prolonged exposure over many years. It is yet another object of the invention to provide a method of forming such a foundation on poor soils.

In a first aspect, the invention is a buoyant foundation for poor soils comprising:

a base layer formed of individual elements of a foamed synthetic plastics material, and

an upper layer of aggregate or settable cementitious material provided with a substantially horizontal surface for supporting an applied structure;

wherein said elements transmit the load of said applied structure directly to the soil of a prepared site in use.

Preferably, the combined weight of the foundation, the applied structure and any dynamic loads gives an overall displacement weight which is no greater than the weight of the displaced soil material (water and soil combined). This is an important consideration in deciding the depth of foamed synthetic plastics material required and the overall depth of the foundation. These depths are determined by the amount of free board desired, the specific weight of the material displaced, and the total mass of the whole superstructure and foundation raft, i.e. all live loads.

Conveniently, the foamed synthetic plastics material used for the individual elements in the base layer is polyurethane. Other light weight foamed polymers may also be used, such as expanded polystyrene.

The elements may be blocks having plain faces, or they may be provided with surface formations which aid keying with the material of the upper layer. The sides of such blocks may be slightly tapered so that the top surface is smaller than the bottom or ground-engaging surface. This means that the bases of adjacent blocks can be butted up against one another, forming a substantially continuous ground-engaging surface whilst leaving gaps between the sides for receipt of crushed aggregate or settable cementitious material. In an alternative embodiment, the individual elements may be provided with an integral flange formation on the base thereof which is abutted against the flange formation of an adjacent element to create a gap between facing side walls of neighbouring elements. Alternatively, the elements may have tapered side surfaces in addition to flange formations on their bases.

Preferably, the settable cementitious material is concrete, which may be reinforced in conventional manner. In those arrangements in which there are gaps between adjacent synthetic plastics elements, the ribbed structure obtained by the use of concrete or similar material as a matrix infill gives the necessary resistance to the foundation to accommodate any stresses induced by the applied structure.

The arrangement of the present invention achieves the two principal requirements for an effective foundation for marshy or swampy ground, namely buoyancy and effective transfer of loads to the ground. The main advantage derived from this type of construction is that soils which were hitherto regarded as unsuitable for construction, because of low bearing capacity and deep layers of peat and poor soils, can now be put to full use.

The difference between the buoyant foundation of the present invention and other forms of cellular construction is that the foamed synthetic plastics material is in direct contact with the ground and is therefore able to transfer loads directly to the ground. It should therefore be regarded as the principal element of the foundation material itself. The aggregate layer or settable cementitious material forming the upper portion of the foundation is entirely supported by the plastics material beneath it. This is in contrast to other forms of cellular foundations in which the top slab is suspended between webs, yet has to carry the full weight of a superstructure across unsupported spans.

The problem of water ingress through microcracks does not arise in the present invention because the foamed synthetic plastics material maintains its buoyancy regardless of whether or not the matrix material is waterproof.

In another variant of the invention, the base layer and upper layer are enclosed in a geotextile membrane which serves to hold all the materials together in a capsule.

In such an arrangement, the geotextile membrane generally acts as a restraint to resist excessive deformations and to provide the necessary degree of structural integrity to the capsule. Even though the base layer sits on a layer of geotextile material, the transfer of loads into the soil is occurs *via* the lower surfaces of the foamed synthetic plastics elements. The contribution of the geotextile membrane to this load transfer is negligible.

A roadbed of conventional form can then be constructed on the top surface of the geotextile membrane which surrounds the buoyant foundation. The objective of the buoyant foundation is to establish an equilibrium between the external quasi-hydrostatic forces exerted by the underlying soil and the weight of the roadbed, so that the roadbed effectively "floats" on the soil. This is particularly desirable for the saturated soils found in marshy or swampy areas.

In a second aspect, the invention is a method of forming a buoyant foundation for bad soils, the method comprising the steps of:

(a) excavating soil from a predetermined area and optionally consolidating the exposed excavated area;

(b) placing a plurality of individual elements of a foamed synthetic plastics material in a predetermined pattern on said exposed excavated area;

(c) forming an upper layer of aggregate or settable cementitious material on said elements, and

(d) providing a substantially horizontal surface for supporting an applied structure.

Preferably, the foamed synthetic plastics material used for the individual elements in the base layer is polyurethane, although other light weight foamed polymers such as expanded polystyrene may also be used. The settable cementitious material is preferably concrete.

During steps (c) and (d), steel or similar reinforcements may be incorporated in the structure for strengthening purposes. In some circumstances, it may be convenient to combine steps (c) and (d) in a single step for forming a matrix of aggregate or settable cementitious material which surrounds the synthetic plastics elements on five sides.

In an especially preferred form of the invention, which is particularly well suited to the construction of roads on bad soils, the above method includes the additional feature of encapsulating the base and upper layers in a geotextile membrane. This may be done in two additional stages interposed between the steps (a) to (d) outlined above.

In the first additional stage, which is carried out between steps (a) and (b), an over-sized layer of geotextile material is placed on the ground in such a manner that the excess geotextile material is spread over the unprepared ground beyond the bounds of the excavated area. In the second additional stage, which is carried out after execution of steps (b) to (d), the excess geotextile material is wrapped around the sub-assembly comprising the synthetic plastics elements and the upper layer to form an encapsulated foundation.

The buoyant foundation thus formed may then receive conventional base and wearing courses for the construction of a road. The foundation remains resistant to water even if the surrounding water table rises to ground level and the surface of the road becomes flooded.

In another variant of this technique, the present invention may be applied to the construction a neutral buoyancy stormwater drain for bad soils. The principle involved here is to form an encapsulated drainage module which is in a neutral state of flotation relative to the surroundings. A stormwater pipe is provided in the encapsulated drainage module and is perforated so that it is prevented from floating. The perforations also allow ingress of water from the outside, through an encapsulating layer of filter cloth, usually a geotextile material. A combination of pieces of foamed synthetic plastics material and crushed stone or similar aggregate material is also enclosed within the capsule to give the drainage element zero buoyancy or near-zero buoyancy, depending on the water level in the surrounding soil.

The invention will now be described in more detail, by way of example only, with reference to the drawings, in which:

Figure 1 is a perspective view of one embodiment of synthetic foamed plastics block for use in a buoyant foundation in accordance with the present invention;

Figure 2 is a cross-sectional view through a buoyant foundation raft constructed in accordance with the present invention;

Figure 3 is an enlarged view of a portion of Figure 2;

Figure 4 is a schematic diagram showing the sequence of steps undertaken in constructing a buoyant foundation in accordance with the present invention;

Figure 5 is a cross-sectional view through a buoyant foundation raft for forming a roadbed in accordance with the present invention;

Figure 6 is an enlarged cross-sectional view on line AA of Figure 5;

Figure 7 is a schematic diagram showing the sequence of steps undertaken in constructing a buoyant foundation for a roadbed in accordance with the present invention;

Figure 8 is a cross-sectional view through a substantially neutral buoyancy stormwater drain in accordance with the present invention, and

Figure 9 is a partially cut-away perspective view showing houses positioned on a buoyant foundation constructed in accordance with the present invention.

Referring now to Figure 1, there is shown a typical block 20 of foamed synthetic plastics material such as might be used in the present invention. The illustrated block is formed from polyurethane, though any light weight foamed synthetic plastics material such as expanded polystyrene would be equally applicable. The block 20 is essentially cuboid in shape, having an upper surface 21, a ground-engaging surface 22 (not visible in this view) and side surfaces 23 - 26. Although not drawn to scale, typical dimensions for such a block would be 3045 mm in length, 2000 mm in width and 670 mm in height. It will be understood by persons skilled in the art that block sizes can be varied such that a number of blocks may be combined to give an assembly of the required dimensions.

Block 20 has an integral flange formation 27 on its base forming part of the ground-engaging surface 22. The side surfaces 22 - 26 are slightly tapered so that the upper surface 21 is smaller than the ground-engaging surface 22.

As best seen with reference to Figures 2 and 3, when the flange formations 27 of adjacent blocks 20 are abutted against each other, channels 28 are formed between the blocks into which settable cementitious material 30 is poured during construction of the foundation.

If the buoyant foundation is constructed *in situ*, the ground 10 is first excavated to form a pit 11 as shown in Figure 2. Preferably, the excavation is carried out when the water table is at a low level. The assembly shown in Figure 2 comprises a foundation raft which is eight blocks in width having an overall covering of a settable cementitious material such as concrete.

In Figure 3, an enlarged sectional view is provided of a portion of the foundation raft shown in Figure 2. In this Figure, it is possible to see that the substantially vertical webs 31 of concrete have steel reinforcements 33 embedded therein. Also, the substantially horizontal concrete slab 32 which forms the surface for receiving a supported superstructure, has an embedded steel mesh reinforcement 34. Assuming that the thickness of the slab 32 is 100 mm, the overall height of the foundation raft is 770 mm.

Figure 4 shows the typical sequence of steps which is followed during the construction of a buoyant foundation in accordance with the invention. In step 1, the foamed polyurethane blocks 20 are positioned on the ground 10 in an arrangement which corresponds to the intended shape of the foundation. In step 2, the steel reinforcements 33 are placed between adjacent blocks 20 and then concrete is poured into the gaps 28 to form the substantially vertical webs 31. In that part of Figure 4 which illustrates step 2, the blocks 20 have been omitted for clarity. In step 3, a steel mesh reinforcement 34 is placed over the sub-assembly formed in step 2 and concrete is poured to a depth of 100 mm to form horizontal slab 32.

Turning now to Figure 5, here there is shown a cross-sectional view through a roadbed constructed using a buoyant foundation in accordance with the present invention. On either side of the road 70 there is formed a dish drain 71, and outboard of the drains 71 there are foundation rafts of the type described above in relation to Figures 1 to 4. These foundation rafts need not be described in detail again here.

Figure 6 is an enlarged cross-sectional view on line AA of Figure 5. Here, it can be clearly seen that the ground-engaging element is a sheet of geotextile material 60, such as ICI's "Terram". Polyurethane slabs 40 are placed on top of the geotextile sheet 60 to form the load-transferring base layer, and crushed aggregate material 50 is applied over the top of the polyurethane slabs 40. In this cross-sectional view, a second layer of geotextile material 60 is shown overlying the aggregate layer 50. In fact this is a continuation of the bottom-most sheet of geotextile material, wrapped around the entire polyurethane/aggregate sub-assembly. The way in which such "encapsulation" is carried out will be described in more detail below.

Figure 7 shows the sequence of steps for constructing a buoyant foundation for a roadbed in accordance with the present invention. In the first step, the soil is excavated from a predetermined area which is to form a trench for the base of the proposed road. To the extent that it is possible, the soil in the bottom of the excavated trench is consolidated.

In the next step, shown in view (B), a layer of geotextile material is laid over the bottom of the excavated trench and over the surrounding area. The excess geotextile material is intended to be wrapped over the other elements of the foundation after they have been inserted into the trench, so a generous excess is required, roughly equivalent to double the width of the excavated trench. The geotextile material is then over-sprayed with bitumen to develop bonding between all loose elements and overlaps of the geotextile.

As shown in view (C), polyurethane slabs 40 are positioned in the bottom of the trench, on top of the layer of geotextile material 60. Following this, crushed aggregate material 50 is added on top of the polyurethane slabs 40.

After consolidation of the aggregate layer 50, the surface is again over-sprayed with bitumen and then the excess geotextile material is wrapped over the top of the aggregate layer to form a capsule. The contained material is typically made up of about one third polyurethane slabs and two thirds crushed aggregate. Although not clearly shown in Figure 7, the geotextile material encapsulating the road foundation material is preferably laid in two directions: transversely to the road axis and longitudinally parallel to the road axis.

The purpose of this is to develop tensile resistance in both directions. In addition, by spraying all the layers of geotextile material and overlaps with bitumen, bonding is promoted between the various components of the foundation and a reasonably waterproof environment is created which maintains a fairly constant moisture content within the encapsulated material.

The exposed surface of the overturned geotextile layer 60 then forms the surface on which conventional base and wearing layers are applied for formation of a road, as shown in view (D).

During prolonged spells of wet weather, when the water table is at its highest level, the road foundation retains its structural integrity whilst surrounding land is incapable of supporting loads (view (E)).

In Figure 8 there is shown yet another practical application of the present invention. This view is a cross-sectional view through a stormwater drain adapted to have substantially neutral buoyancy in relation to its surroundings.

A stormwater drain generally designated by the reference numeral 80 comprises a capsule 90 formed from a sheet or sheets of a geotextile material 91, such as ICI's "Terram". Inside the capsule 90, a length of pipe 81 is surrounded by crushed stone 84 and is supported on a bed of a foamed synthetic plastics material such as polyurethane foam slab 83. The pipe 81 is provided with a plurality of perforations 82 around its periphery. The perforations 82 allow ingress of water from the outside, through the encapsulating layer of geotextile material 91 and prevent the drain from floating.

The combination of pieces of foamed synthetic plastics material 83 and crushed stone 84 or similar aggregate material give the stormwater drain 80 zero buoyancy or near-zero buoyancy, depending on the water level in the surrounding soil 10.

Figure 9 is a partially cut-away perspective showing a buoyant foundation constructed in accordance with the present invention supporting a development of low-rise housing. As in step 2 of Figure 4, the polyurethane blocks 20 have been omitted from Figure 9 for clarity.

Although the invention has been described with reference to particular and preferred embodiments thereof, it will be understood by persons skilled in the art that other variants are possible without departing from the scope of the claims which follow.

CLAIMS

1. A buoyant foundation for poor soils comprising:

a base layer formed of individual elements of a foamed synthetic plastics material, and

an upper layer of aggregate or settable cementitious material provided with a substantially horizontal surface for supporting an applied structure;

wherein said elements transmit the load of said applied structure directly to the soil of a prepared site in use.

2. A buoyant foundation as claimed in claim 1 wherein the combined weight of the foundation, the applied structure and any dynamic loads gives an overall displacement weight which is no greater than the weight of the displaced soil material (water and soil combined).

3. A buoyant foundation as claimed in claim 1 or claim 2 wherein the foamed synthetic plastics material used for the individual elements in the base layer is a light weight foamed polymer selected from the group consisting of polyurethane and polystyrene.

4. A buoyant foundation as claimed in any preceding claim wherein the settable cementitious material is concrete.

5. A buoyant foundation as claimed in any preceding claim wherein the foamed synthetic plastics elements are blocks having surface formations to aid keying with the material of the upper layer.

6. A buoyant foundation as claimed in any preceding claim wherein the foamed synthetic plastics elements have tapered sides so that the top surface is smaller than the bottom or ground-engaging surface.

7. A buoyant foundation as claimed in any preceding claim wherein the foamed synthetic plastics elements have an integral flange formation on the base thereof which is adapted to be abutted against the flange formation of an adjacent element to create a gap between facing side walls of neighbouring elements.

8. A buoyant foundation as claimed in any preceding claim wherein the base layer and upper layer are enclosed in a geotextile membrane.

9. A buoyant foundation as claimed in claim 8 wherein the upper surface of the geotextile membrane capsule is provided with conventional base courses and wearing layers for a road.

10. A method of forming a buoyant foundation for poor soils, the method comprising the steps of:

(a) excavating soil from a predetermined area and optionally consolidating the exposed excavated area;

(b) placing a plurality of individual elements of a foamed synthetic plastics material in a predetermined pattern on said exposed excavated area;

(c) forming an upper layer of aggregate or settable cementitious material on said elements, and

(d) providing a substantially horizontal surface for supporting an applied structure.

11. A method as claimed in claim 10 wherein the foamed synthetic plastics material used for the individual elements in the base layer is a light weight foamed polymer selected from the group consisting of polyurethane and polystyrene.

12. A method as claimed in claim 10 or claim 11 wherein the settable cementitious material is concrete.

13. A method as claimed in any one of claims 10 to 12 wherein steel or similar reinforcement is incorporated in the structure during steps (c) and (d) for strengthening purposes.

14. A method as claimed in any one of claims 10 to 13 wherein steps (c) and (d) are combined in a single step for forming a matrix of aggregate or settable cementitious material which surrounds the synthetic plastics elements on five sides.

15. A method as claimed in any one of claims 10 to 14 further comprising encapsulating the base and upper layers in a geotextile membrane.

16. A method as claimed in claim 15 wherein said encapsulation in a geotextile membrane is carried out in two additional stages interposed between the steps (a) to (d), the first additional stage being carried out between steps (a) and (b) and comprising:

(i) placing an over-sized layer of geotextile material on the ground in such a manner that the excess geotextile material is spread over the unprepared ground beyond the bounds of the excavated area;

the second additional stage being carried out after execution of steps (b) to (d) and comprising:

(ii) wrapping the excess geotextile material around the sub-assembly consisting of the synthetic plastics elements and the upper layer to form an encapsulated foundation.

17. A method as claimed in claim 15 or claim 16 wherein the geotextile material is over-sprayed with bitumen.

18. A substantially neutral buoyancy stormwater drain comprising a capsule formed from a sheet or sheets of a geotextile material, said capsule enclosing a length of pipe surrounded by crushed aggregate supported on a bed of a foamed synthetic plastics material, wherein the pipe is provided with a plurality of perforations around its periphery which serve to admit water from the surroundings in order to prevent the drain from floating.

19. A buoyant foundation for poor soils substantially as described herein with reference to Figures 1 to 5 and Figure 9 of the drawings.

20. A method of forming a buoyant foundation for poor soils substantially as described herein with reference to Figures 5 to 7 of the drawings.

21. A substantially neutral buoyancy stormwater drain substantially as described herein with reference to Figure 8 of the drawings.

The Patent Office

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Application No: GB 9520740.3
Claims searched: 1-17,19,20

Examiner: Dave Lovell
Date of search: 7 August 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1D (DDP, DF117, DF119, DF123, DF193) E1C (C15) A1B (B5) E1G (G60N, G65)

Int Cl (Ed.6): E01C E02D E04B

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2274666 A	Roxbury Ltd	1,3,4,10-14
X	GB 2269838 A	Obermeister	"
X	GB 2196681 A	Ashley	"
A	GB 1180689	Shell	
X	WO 95/00711 A1	Aaltonen	1,3,4,10-14
X	WO 88/06220 A1	Dow Kakoh K K	1,3,4,10-14
X	US 4867377	Ingestrom	1,3,4,10-14

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.