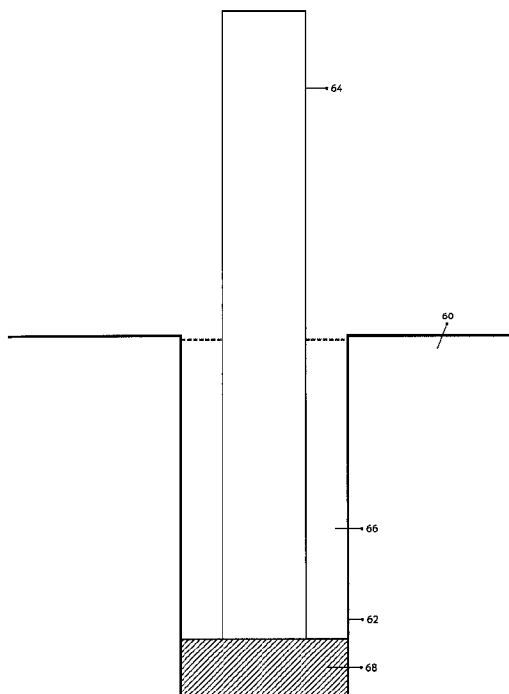




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(54) Title: POLYURETHANE FOAM IN FOUNDATION FOOTINGS FOR LOAD-BEARING STRUCTURES



(57) Abrégé/Abstract:

Foundation footing system for a load-bearing structure comprising a hole in the ground and a post in the hole extending above the hole. A gap present between the sides of the post and the sides of the hole contains a cured, hydrophobic, closed-cell, polyurethane foam to firmly hold the post in place and protect the post from moisture. Alternatively, a foundation footing system for a load-bearing structure comprising a hole in the ground filled with a cured, hydrophobic, closed-cell, polyurethane foam and a post placed on and connected to the top of the foam.



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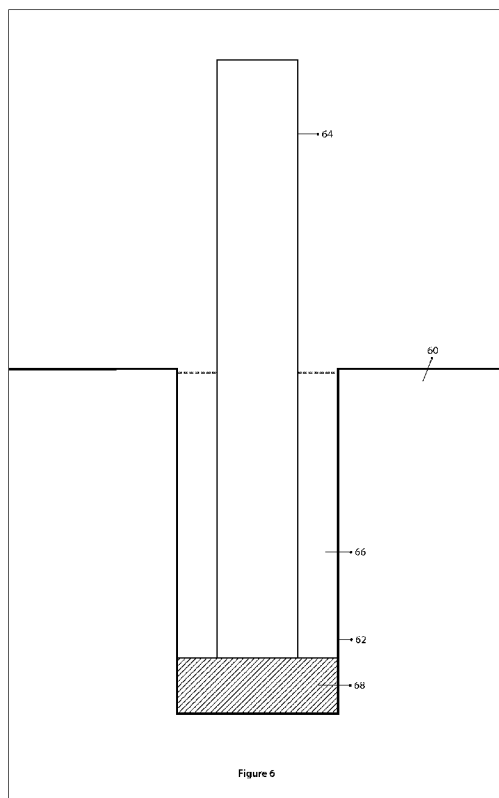
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(54) **Title:** POLYURETHANE FOAM IN FOUNDATION FOOTINGS FOR LOAD-BEARING STRUCTURES



(57) **Abstract:** Foundation footing system for a load-bearing structure comprising a hole in the ground and a post in the hole extending above the hole. A gap present between the sides of the post and the sides of the hole contains a cured, hydrophobic, closed-cell, polyurethane foam to firmly hold the post in place and protect the post from moisture. Alternatively, a foundation footing system for a load-bearing structure comprising a hole in the ground filled with a cured, hydrophobic, closed-cell, polyurethane foam and a post placed on and connected to the top of the foam.

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POLYURETHANE FOAM IN FOUNDATION FOOTINGS FOR LOAD-BEARING STRUCTURES

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application Serial No. 61/928,453 filed January 17, 2014.

FIELD OF THE INVENTION

[0002] The invention relates to polyurethane foam compositions in raised foundation footings for load-bearing structures and methods of making foundation footings using polyurethane foams.

BACKGROUND OF THE INVENTION

[0003] A firm foundation is essential to good performance of buildings and other load-bearing structures. The foundation includes properly installed footings of adequate size to support a structure and prevent excessive settling. Foundation systems are classified as shallow and deep foundations, depending on the depth of the load-transfer member below the super-structure and the type of transfer load mechanism. The required foundation system depends on several factors or conditions such as the strength and

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compressibility of the site soils, the proposed loading conditions, and the project performance criteria (i.e. total settlement and differential settlement limitations.)

[0004] In construction sites where settlement is not a problem, shallow foundations provide the most economical systems. Shallow foundations are typically placed from ground level to 3 meters below ground level or below the frost line. Shallow foundation construction is typically utilized for most residential and light commercial raised floor building sites. Figure 1, building structure 10 is built on shallow foundation 12. The shallow foundation may be of any suitable shape such as the inverted "T" shape shown. This shape allows more stability.

[0005] Where poor soil conditions are found, deep foundations may be needed to provide the required load-bearing capacity and to limit settlement. In Figure 1, building structure 14 is built on a deep foundation 16. Examples of deep foundation systems include driven piles (i.e. pressure-treated timber piles, concrete, or steel), drilled shafts, or micro piles.

[0006] Foundation specifications, including footing requirements, are covered in various building codes, and sized in accordance with the building capacity of the soil and the weight of the building. In areas subject to seasonal frost, the bottom of the footing must be placed below the frost line to prevent damage to the footing and structure due to frost heave.

[0007] A raised foundation is a foundation which is raised above the plane of the surrounding earth. The main floor of a home or business is built on this foundation. A post and pier

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foundation system is one example of a raised system. Poured concrete footings are often used in raised foundations. In one example, a wood, metal, plastic, or composite post is set in the ground with concrete and bears the weight of the structure on it. The post is below grade.

[0008] In another example, a concrete pier extends from the footing base to above grade. There are several variations of this footing type. Figure 2 and Figure 3 depict concrete footings that extend below the frost line to above the ground. Both footings have a wood post 20, typically a 6" x 6" post, attached above ground to the concrete pier. For example, in Figure 2, an anchor bolt 22 is used to connect the post to a concrete footing 24. A gravel base 26 may be used at the bottom of the concrete footing to prevent frost heave. In Figure 3, a concrete footing 30 is poured in fiber tube 32, a metal post anchor 34 is placed in the concrete, and then the concrete is allowed to set. The above ground portion of the fiber tube is removed after the concrete is set. The metal post anchor 34 connects the post 20 to the concrete footing 24. Such concrete footings typically extend six inches below the frost line 36 and rest on undisturbed soil 38. The top of the footing is typically at least 6" above grade.

[0009] Wood posts are usually attached to the top of the concrete footing above ground. Untreated wood posts will quickly rot if placed below ground due to the presence of water and oxygen which results in fungal attack, for example. Likewise, untreated metal posts placed below ground will rust. Pressure treated wood is available for use in ground contact applications, some having warranties as long as 75 years, however they

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are expensive and further may contaminate the ground. Galvanized metals are used for underground applications. Because such foundations rely on anchors, the structure can be compromised if the anchor bolt becomes loose or breaks.

[0010] Concrete has many drawbacks. For instance, concrete takes time to cure, is heavy, porous, and brittle, has high labor costs, has a high carbon footprint, needs large quantities of water, and cannot be poured below 5°C. It is desirable to provide an alternative to concrete footing systems.

BRIEF SUMMARY OF THE INVENTION

[0011] The present invention is based on three types of polyurethane footings as herein described. In the first type, as exemplified in Figures 5 and 6, the post is placed at the bottom of the hole. In the second type, as exemplified in Figures 7 and 8, the post is placed on top of the foam, above grade. In the third type of footing, the post is placed inside the foam footing as in Figure 10.

[0012] In a first embodiment, foundation footing system for a load-bearing structure comprises a hole in a ground, the hole having a bottom and sides, and a post placed on the bottom of the hole and generally centered within the hole, wherein the post extends above the hole, wherein the width of the hole is wider than a width of the post thus forming a gap between sides of the post and the sides of the hole; the foundation further comprising a cured, closed-cell, polyurethane foam surrounding the post, wherein the polyurethane foam fills the gap between the post and sides of the hole, the polyurethane foam

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comprising a cured mixture of a polyurethane composition comprising polyisocyanate and at least one active hydrogen containing compound. The foundation footing system comprises the post and foam.

[0013] In another embodiment, method of making a foundation footing system for a load-bearing structure comprises, a) forming a hole in a ground, the hole having a bottom and sides; b) placing a post onto the bottom of the hole such that the post is generally centered within the hole and a gap is formed between sides of the post and the sides of the hole; and c) adding a polyurethane composition into the gap, allowing the polyurethane composition to react and form a foam, thereby filling in the gap, and then to cure to form a cured, closed-cell, polyurethane foam, the polyurethane foam mixture comprising polyisocyanate and at least one active hydrogen containing compound.

[0014] In a further embodiment, foundation footing system for a load-bearing structure comprises a hole in a ground, the hole having a top, bottom, and sides; the foundation further comprising cured, polyurethane foam, wherein the foam fills the hole and extends above the top of the hole to form a foundation footing, the polyurethane foam comprising a cured mixture of a polyurethane composition comprising isocyanate, and at least one active hydrogen containing compound; and further comprising a post placed on and attached to the top of the foam and generally centered on the foam. The foundation footing system comprises the post and foam.

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[0015] In a further embodiment, method of making a foundation footing system for a load-bearing structure comprises a) forming a hole in a ground, the hole having a top, bottom, and sides; b) placing a polyurethane composition into the hole, allowing the polyurethane composition to react and form a foam, filling in the hole and rising above the hole, and then to cure to form a cured, polyurethane foam footing, the polyurethane foam mixture comprising a polyurethane composition comprising isocyanate, and at least one active hydrogen compound; and further comprising attaching a post to the top of, and generally centered on, the foam.

[0016] In preferred embodiments of the above, the foam is a hydrophobic, closed-cell foam that contains at least one water-immiscible component.

[0017] These and other aspects of the invention are apparent from the following Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Figure 1 illustrates examples of shallow and deep building foundations.

[0019] Figure 2 illustrates an example of a prior art concrete footing.

[0020] Figure 3 illustrates another example of a prior art concrete footing.

[0021] Figure 4 illustrates an example of a foam and post footing in accordance with aspects of the present invention.

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- [0022] Figure 5 illustrates an example of a foam and post footing in accordance with aspects of the present invention.
- [0023] Figure 6 illustrates another example of a foam and post footing in accordance with aspects of the present invention.
- [0024] Figure 7 illustrates an example of a foam footing having a post attached to the top of the foam footing in accordance with aspects of the present invention.
- [0025] Figure 8 illustrates another example of a foam footing having a post attached to the top of the foam footing in accordance with aspects of the present invention.
- [0026] Figures 9a-9c illustrate concrete anchoring systems that can be used with aspects of the present invention.
- [0027] Figure 10 illustrates an anchoring system where the post is imbedded in the foam.
- [0028] Figure 11 illustrates the use of foam in prefabricated and pre-molded footing forms in accordance with aspects of the invention.
- [0029] Figure 12 illustrates a space between the footing pad on top of the foam footing and the edge of the foam in accordance with an aspect of the invention.
- [0030] Figures 4-12 should be understood as illustrative of various aspects of the invention, relating to the compositions, systems, and methods described herein and/or the principles involved. Some features depicted have been enlarged or distorted relative to

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others, in order to facilitate explanation and understanding. Figures 4-12 do not limit the scope of the invention as set forth in the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Type A, unconfined soil, has a compressive strength from about 21 psi to 83 psi. It can support a load of at least 3000 lb./ft² and as high as 12,000 lb./ft². It was discovered that polyurethane foam with similar compressive strength, can have similar load-bearing capacity. This allows for improvements over conventional concrete-based raised foundation systems and footings such as shown in Figures 2 and 3. The present invention is therefore directed to the use of polyurethane as footers in foundation systems.

[0032] It was further discovered that polyurethane provides improved results over conventional concrete footings. (a) Concrete takes time to cure, for example, standard concrete takes up to 28 days to cure. Polyurethane foam cures in less than five minutes and reaches full strength in 30 minutes. (b) Labor costs are much higher for constructing foundations with concrete than with polyurethane. (c) Concrete is very heavy; thus transportation and handling costs are very high. In addition, the carbon footprint with concrete is very high. Polyurethane foam is much lighter than concrete and hence cheaper to transport. One pound of polyurethane foam replaces about 100 pounds of concrete. (d) Concrete needs large quantities of water. Polyurethane foam does not need water and can be easily used in isolated areas. (e) Concrete is porous and allows water to travel through

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it. Polyurethane foam can be made impervious to water and will protect the post from rotting or rusting. It also blocks chemicals used to treat the wood from contaminating the soil. (f) Concrete cannot be poured below 5°C. For every 10°C reduction in concrete temperature, the time of setting of the concrete doubles, thus increasing the amount of time that the concrete is vulnerable to damage due to freezing. Polyurethane foam can be poured below freezing, as long as the foam components are maintained at about 20 to 25°C prior to mixing. (g) Concrete is very brittle and, without reinforcement, breaks easily. The polyurethane foam utilized in the present invention is not brittle, does not stress the post, and will not break easily.

[0033] The present invention is directed to post and pier foundation footings that allow for wood, metal, plastic, and composite posts to be used both above ground and below ground for load-bearing structures without a concern of rotting, rusting, or deterioration. In one aspect, the foundation footings utilize posts, such as load-bearing wood and metal posts, as well as water-immiscible and hydrophobic, closed-cell, polyurethane foam surrounding the posts. The closed-cell polyurethane foam bonds to a wood post, preventing moisture from reaching the wood and thus preventing fungal attack. The closed-cell polyurethane foam also bonds to a metal post preventing moisture from reaching the metal and thus preventing rust. The closed-cell polyurethane foam may also be bonded to a plastic post to prevent moisture from reaching the plastic, preventing deterioration or weakening of the plastic.

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- [0034] The present invention further allows for posts to be used both above and below ground for load-bearing structures without a concern of the post moving or shifting. That is, the polyurethane foam of the present invention will provide full support for a post for a load-bearing structure.
- [0035] A load-bearing foundation is one that supports more than its own weight. It transmits force generally from a higher level to a lower level.
- [0036] The term post includes any suitable support structure, pole, pier, and the like, to create a proper foundation for a load-bearing structure. The post may be wood, metal, plastic, composite material, or any other material capable of supporting the load. The post may be any suitable geometric shape such as round or square. Typical woods used for support posts are pine and fir. Typical metals used for support posts are aluminum and galvanized steel. Typical plastics used for support posts are PVC and ABS. An example of a composite post is fiberglass or carbon fibers with polyester or epoxy resin as a binder.
- [0037] One aspect of the invention is shown in Figure 4. A post hole 42 is made in the ground (aka earth) 40 to a suitable depth depending on the required foundation specifications. The hole may be made with any suitable device including, but not limited to, an auger. As shown in Figure 1, the depth will depend on whether a shallow or a deep foundation is required and depends on the weight of the structure and type of ground. Generally holes are round, but other shape holes may be used if desired such as square holes.

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[0038] The sides of the hole may be scarified to increase the friction between the soil and the footing. As the foam rises it will follow the shape of the scarified walls and go into all the grooves. This will increase the contact area and increase the friction between the soil and the foam. This also pushes the foam against the soil, compacting the soil, and increasing the compressive strength of the soil contacting the foam.

[0039] A concrete footing pad can also be placed at the bottom of the hole and below the post. Larger diameter pads are used for weaker soils to increase the load-bearing capacity. This is shown in Table 1.

Table 1

Minimum Width of Concrete or Masonry Footings (inches)						
	Load-Bearing Value of Soil (psf)					
	1,500	2,000	2,500	3,000	3,500	4,000
Conventional Wood Frame Construction						
1-story	16	12	10	8	7	6
2-story	19	15	12	10	8	7
3-story	22	17	14	11	10	9
4-Inch Brick Veneer Over Wood Frame or 8-Inch Hollow Concrete Masonry						
1-story	19	15	12	10	8	7
2-story	25	19	15	13	11	10
3-story	31	23	19	16	13	12
8-Inch Solid or Fully Grouted Masonry						

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1-story	22	17	13	11	10	9
2-story	31	23	19	16	13	12
3-story	40	30	24	20	17	15

[0040] Usually precast concrete, at least four inches thick with a 28 day compressive strength greater than 1200 psi, or poured-in-place concrete at least six inches thick with a compressive strength of at least 3000 psi after 28 days, is used. For heavy loads, pads over twelve inches thick may be required. ABS footing pads and other pads that are listed for the required load capacity can also be used.

[0041] A post 44 is placed onto the bottom of the hole, either directly, or on a footing pad placed on the bottom of the hole, and generally centered within the hole 42. The post being generally centered means that the post is placed roughly in the middle of the hole; but the post may be slightly off center with the hole so long as the foundation structure is not compromised. Moreover, the shape of the hole and the shape of the post may not correspond to provide the same distance between all sides of the post and all sides of the hole. For instance, a square post may be used in a round hole.

[0042] A footing pad has a very high compressive strength (greater than 1000 psi). It will not distort when there are high loads on the post. This ensures that the load is evenly distributed over the entire surface of the footing pad and the soil.

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[0043] A polyurethane composition is mixed, and immediately poured into the hole around the post. The foam will rise and generally will be tack-free in 1 to 20 minutes, more typically 2 to 10 minutes, or 4 to 6 minutes at 25°C. It will be fully cured in 25 to 180 minutes, generally approximately 60 minutes. At this point a load can be placed on the post. The foam components can be mixed in environments from about 30°C to temperatures well below freezing. The components of the foam just prior to mixing can be at any suitable temperature, but preferably between 20 and 25°C. Typically component temperatures should be at least 15°C prior to mixing. At lower temperatures, the foam will cure slower and will have a higher foam density than when cured at higher temperatures. At higher temperatures the foam will cure faster and will be tack-free in a shorter time but the cured density of the foam may be much lower than required for the application. A lower foam density will make the foam weaker. The air temperature can be hot or cold, but soil temperature in the hole typically should not be above 30°C. The foam generates a considerable amount of heat as it cures. This exotherm allows it to cure quickly at low temperatures. For example, the foam when cured at 25°C may have a foam density of 0.080 gm/cc and a compressive strength of 100 psi. When cured at 15°C, the foam density will be 0.100 gm/cc with a compressive strength of 150 psi. When cured at higher temperatures, such as 35°C, the foam density will be around 0.050 gm/cc, with a compressive strength around 70 psi.

[0044] Any premeasured portable mixing/dispensing system can be used to mix and dispense small quantities of the foam. For large holes or for filling many holes, a meter/mix

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dispenser can be used. In this equipment, the two components can be dispensed and mixed from 5 gallon pails, 55 gallon drums, or bulk dispensers. The two components can be mixed with a dynamic or static mixer. This equipment is well known by those familiar with the art.

[0045] Turning again to Figure 4, the polyurethane components react and foam 46 rises up, typically to above the ground surface, and completely surrounds the post 44. After curing, the foam firmly anchors the post in the ground. Any excess foam that rises above ground level may be cut off, if desired. The polyurethane foam allows the post to be placed directly in the hole, below the frost line. The foam holds the post firmly in an upright position and prevents moisture from contacting the post. Unlike concrete, the foam does not stress the post. The foam bonds to the post. The foam adapts to the changing climatic conditions and efficiently transfers the load from the foundation to the soil. A building floor 48 may be built on the post 44.

[0046] Figures 5 and 6 show two aspects of using a post below ground. In Figure 5, post hole 52 is made in the ground 50. A post 54 is placed onto the bottom of the hole and generally centered within the hole 52. Polyurethane components are combined and poured into the hole. The polyurethane components react and foam 56 rises up. In Figure 6, post hole 62 is made in the ground 60. A footing pad 68 is placed at the bottom of the hole. A post 64 is placed onto pad 68 at the bottom of the hole and generally centered within the hole 62. Polyurethane components are combined and poured into the hole. The polyurethane components react and foam 66 rises up. As

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discussed above, pads may be made of any suitable material and would typically be concrete or a polymer, such as ABS.

[0047] As shown in Figure 7 and Figure 8, the polyurethane foam can also be used to completely fill the hole and rise above the hole. The post can then be placed on top of the foam and anchored to it. The foam is the foundation footing.

[0048] In Figure 7, a post hole 72 is made in the ground 70 to a suitable depth depending on the required foundation specifications. Polyurethane components are combined and poured into the hole. The polyurethane components react and foam 76 rises up, typically from one to three feet above ground. A round cardboard forming tube, the same diameter as the hole, such as a Sonotube, can be used to shape the foam when it rises above ground. When the foam has cured, it can be cut level to the ground or up to three feet above the ground. It is usually cut above the ground to prevent the post from degrading by contacting the wet soil.

[0049] A footing pad 73 can be placed on top of the tube so that the foam presses up against the pad as it rises. The foam must bond to the pad as it cures. The pad helps to distribute the load on the post over the surface of the foam that is under the pad. The floor of a structure can be built on top of the post 74. When the post is on top of the footing pad, the compressive strength of the foam and the adhesions of the foam to the soil are important factors in the load-bearing capacity of the footing.

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- [0050] Post 74 may be attached to the foam footing or the plate on top of the foam footing in any suitable manner. For example, brackets or adhesives may be used to attach the post.
- [0051] Similarly in Figure 8, a post hole 82 is made in the ground 80 to a suitable depth. A footing pad 88 is placed at the bottom of the hole. Polyurethane components are combined and poured into the hole. The polyurethane components react and foam 86 rises up as discussed above. A flat footing pad 83, as discussed above may be used so that the foam cures flat and the pad is bonded to it. Post 84 is then attached to the pad as discussed above.
- [0052] Many of the anchoring systems used with concrete footings also can be used with foam footings. Figures 9a – 9c illustrate examples of concrete anchoring systems that can be used with foam footings. The bottom of such systems may either be embedded into the foam (Figure 9a) and/or attached to the foam or a footing pad via fasteners such as screws or bolts (Figures 9b and 9c.). Adhesives can also be used.
- [0053] Figure 10 shows an anchoring system where the post 104 is imbedded in the foam 106. A hole 102 is dug in soil 100. A footing pad 103 is attached to the bottom of the post 104. Foam 104 fills the hole 102 to the desired level. The footing pad 103 and post 104 are placed on top of the foam and leveled. Additional foam is poured on top of the footing pad and surrounding the post and then the foam is allowed to cure.

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- [0054] Figure 11 depicts the use of a prefabricated footing form. A hole is dug in soil 110. A prefabricated footing form 117, for example, a prefabricated box, such as a wood box attached to a cardboard construction tube or a pre-molded footing form, is placed in the hole and soil is back filled outside the footing form. The footing form 117 extends above the ground level 118. The post 114 is placed within the footing form 117. Foam 116 fills the interior of the footing form and surrounds the pole.
- [0055] Figure 12 depicts a post 124 placed in soil 120 utilizing a foam footing 126 and a footing pad 123. The space between the footing pad 123 on top of the foam footing 126 and the edge of the foam footing should be small so the load on the post will be distributed over the largest area possible. That is, in Figure 12, the radius of footing pad 123 is only slightly smaller than the radius of the foam footing 126.
- [0056] The post with the footing pad attached to its bottom can be placed at the bottom of the hole or at the top or it can be placed anywhere in between. It is preferable to place it closer to the top of the hole to make leveling of the foam easier.
- [0057] When prefabricated footing forms are used, the post can be placed above ground or below ground as described above. The foam footings can also be cured inside of the prefabricated footing form during the manufacture of the footing form or at the construction site.
- [0058] Deep foundations are greater than 3 meters below ground level. In deep foundations driving piles have a higher load-bearing capacity than drilling shafts. Driving the piles

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compress the surrounding soil, causing greater friction against the soil next to the pile. Injecting the polyurethane composition between the drilling shaft and the soil will increase the friction and the load-bearing capacity of the pile.

[0059] Depending on the load, the soil and the compressive strength of the foam, a footing pad may need to be placed under the foam footing. When the post is at the bottom of the hole, a concrete footing pad can be used. When the post is not touching the soil at the bottom of the hole, the post should be attached to a treated wood, ABS, or any other type of footing pad that will not substantially increase the load on the foam.

[0060] The method to determine the proper size and load-bearing capacity required for footings is the same for foam, concrete, or any other load-bearing footing material. First it must be established how much total weight each footing will support. The type of soil that will be under the footing and the load-bearing capacity of this soil must be determined. As discussed above, the compressive strength of the foam must also be considered. For higher loads or weaker soils, larger footings are required. There are standard tables available to help determine the size and design of footing (see Table 1 above). An engineer may be required to calculate the footing requirements for higher loads or in areas where the load-bearing capacity of the soil is less than 1500 lb/ft². Determining the requirements of the footing can easily be obtained by those skilled in the art. The footing transmits the load into the soil. The lower the bearing capacity of the soil, the wider the footing needs to be.

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[0061] Table 2 illustrates a sample load footing size chart utilizing polyurethane foam.

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Table 2

SOIL TYPE	Gravel	Sand	Clay
Compressive Strength of Soil (lb/ft ²)	3000	2000	1500
Circular Footing Size (inches) (Nominal 4"x4" Post in Fast 2K Load)	Maximum Allowable	Load/Footing (lbs.)	
6"	600	400	300
8"	1000	700	500
10"	1600	1100	800
12"	2300	1500	1100
13"	2700	1800	1300
14"	3200	2100	1600
15"	3600	2400	1800
16"	4100	2700	2000
17"	4700	3100	2300
18"	5300	3500	2600
19"	5900	3900	2900
20"	6500	4300	3200
21"	7200	4800	3600

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22"	7900	5200	3900
23"	8600	5700	4300
24"	9400	6200	4700

(A nominal 4" x 4" post is actually a 3 ½ "x 3 ½" post)

[0062] Structures that weigh little and only put a light load on the soil only require small footings. For example, a small pergolas or arbor that weights 400 lbs will have a 100 lb load per footing. A 6" footing on the weakest soil can hold up to 300 lbs and would be adequate for this type of project.

[0063] One can look up the recommended footing size, based on the size and type of house and the bearing capacity of the soil. As can be seen, heavy houses on weak soil may need footings 2 feet wide or more. But the lightest buildings on the strongest soil may only require footings as narrow as 7 or 8 inches.

[0064] It is very important that the foam used for this application, in wet or damp soil is water-repellant and hydrophobic. "Water-repellant" refers to the mixed isocyanate and polyols composition in the liquid state and while it is curing. "Hydrophobic" refers to the polyurethane foam when it is cured.

[0065] The hole to be filled with the polyurethane foam may contain ground water or runoff water. Standard polyurethane foam will absorb and react with this soil water. This will

produce a footing having low density and low strength. The foam density and strength must be closely controlled. The present invention utilizes special polyurethane foam forming compositions which are resistant to the undesired side reaction with ground water. Foams that are not water-repellant can be used when the soil is not wet and the hole to be filled does not contain ground water or runoff water. They can also be used to make prefabricated footings.

[0066] U.S. 3,564,859 first introduced the concept of adding a non-volatile water-immiscible material to polyurethane components so that the properties of the resultant product are not affected excessively in the presence of groundwater. U.S. 4,966,497 improved on the above by removing halogenated hydrocarbon blowing agents from the formulation. It was discovered for the present application that adding a hydrophobic surfactant to the formulation provides the desired properties for the polyurethane foam used for footers.

[0067] WATER-REPELLENCY

[0068] The composition of the present invention utilizes conventional materials such as polyisocyanate and active hydrogen containing compounds, but for wet or damp conditions, also includes water-immiscible components. The water-immiscible components provide the water-repellency of the polyurethane foam composition in the liquid state, while it is curing. The water-immiscible components can be any of a large number of materials or mixtures of materials. Preferably the water-immiscible

component is a liquid having a low vapor pressure which is substantially non-reactive under the usual conditions of foam formation with either the active hydrogen or the isocyanate components used to form the polyurethane compositions. Materials which react with either or both of the polyurethane components may comprise part or most of the water-immiscible component.

[0069] "Water-immiscible" means that the solubility in water at about 70°F is less than about 5 grams per 100 grams and preferably less than about 1 gram per 100 grams of water. In a preferred embodiment, the water-immiscible component has no measurable solubility in water. Among the water-immiscible components are those described in U.S. 3,968,657, hereby incorporated by reference in its entirety. Among the water-immiscible components having a low vapor pressure are the higher alkanes (C₈ and above), crude oil, petroleum oils and higher petroleum fractions of all kinds (both pure and crude), asphalts, tars, petroleum refining bottom or residues. Components that are comprised primarily of aromatic or aliphatic hydrocarbons are water-immiscible. Also included are materials such as coal tar pitch, wood tar pitch, tall oil, tall oil derivatives, vegetable oil, vegetable oil derivatives, and waxes. Solid materials that are water-insoluble and that can be dissolved in a water-immiscible liquid. Halogenated hydrocarbons and halogen derivatives can also be used.

[0070] Water-immiscible solvents can also be used. Suitable water-immiscible solvents include blowing agents such as HCFC's, pentane, and hexane as well as high boiling

solvents such as high flash aromatic naptha in amounts up to about 15% by weight of the total composition.

[0071] Sufficient compatible water-immiscible components should be present to inhibit the reaction with water. Excessive water-immiscible components or incompatible water-immiscible components may result in unacceptable deterioration of the physical characteristics of the final foam and should be avoided. The desired polyurethane foam can be obtained from compositions containing 10% - 80% by weight of the water-immiscible components. Preferably, the amount of water-immiscible components is in the range of 30% to 60% by weight of the polyurethane foam forming compositions.

[0072] HYDROPHOBICITY

[0073] It is preferred that the cured foam is closed-cell. Water should not be able to pass through the foam. This is particularly important when the post is in-ground and surrounded by the foam.

[0074] Surfactants help to control the precise timing and the size of the foam cells. Within each foam formulation, a minimum level of surfactant is needed to produce commercially acceptable foam. In the absence of a surfactant, a foaming system will normally experience catastrophic coalescence and exhibit an event known as boiling. With the addition of a small amount of surfactant, stable yet imperfect foams can be produced; and, with increasing surfactant concentration, a foam system will show improved stability and cell-size control.

[0075] Most cured, rigid polyurethane foams contain closed cells. Higher density rigid foams have thicker cell walls and thus have a higher percentage of closed cells than lower density rigid foams. The inclusion of a hydrophobic surfactant improves the uniformity and size of the cell structure. It also increases the closed cell content; thus, increasing the hydrophobicity of the foam. It is important that lower density foams that require hydrophobicity have a sufficient concentration of closed cells to make them hydrophobic. Foams suitable for use in some footing applications have foam densities as low as 0.035gm/cc and a compressive strength as low as 10 psi although generally at least 30 psi. Foams with densities higher than 0.10 gm/cc and compressive strengths higher than 100 psi can be used, but may be cost prohibitive in many applications. Preferred foam densities are higher than about 4 lb/ft³. Preferred compressive strengths are higher than about 50 psi, 80 psi, and in some instances are preferably 100 psi. There is no preferred upper limit for both the foam density and the compressive strength. However, the cost will increase as the foam density increases. Foams can be formulated with specific properties, such as compressive strength and foam density for specific applications.

[0076] SURFACTANTS

[0077] The foams of the invention are prepared using a surfactant, particularly a hydrophobicity inducing surfactant. Typically, hydrophobicity inducing surfactants are polysiloxane-polyalkylene oxide copolymers, usually the non-hydrolyzable polysiloxane-polyalkylene oxide copolymer type. The polyoxyalkylene (or polyol) end

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of the surfactant is responsible for the emulsification effect. The silicone end of the molecule lowers the bulk surface tension. When a hydrolyzable surfactant, which contains Si-O linkages between the silicon and polyether groups, is contacted with water, the molecule breaks apart to form siloxane and glycol molecules. When this occurs, the individual molecules no longer exhibit the proper surfactant effects. Non-hydrolyzable type surfactants, which contain a water stable Si-C bond between the silicon and polyether chain, are thus preferred.

[0078] Hydrophobicity inducing surfactants include: Goldschmidt Chemical Corp. of Hopewell, Va. products sold as B8110, B8229, B8232, B8240, B8870, B8418, B8462; Organo Silicons of Greenwich, Conn. products sold as L6164, L600 and L626; and Air Products and Chemicals, Inc. products sold as DC5604 and DC5598. Preferred surfactants are B8870, B8110, B8240, B8418, B8462, L626, L6164, DC5604 and DC5598. B8870 and B8418 from Goldschmidt Chemical Corp. are more preferred; B8418 is most preferred.

[0079] Non-hydrophobic inducing surfactants, such as Dow Corning DC190 and DC 193 can be used in dry, above ground and prefabricated applications.

[0080] The surfactant is used in the range of 0.1-5% of the total formulation. Generally, lower density foams require more surfactant than higher density foams

[0081] ISOCYANATES

[0082] In principle, a wide range of isocyanates may be used to prepare polyurethane foams of the invention such as, for example, toluene diisocyanate (TDI), diphenylmethane diisocyanate, polymethylenepolyphenylene polyisocyanate, hexamethylene diisocyanate (HMDI), 1, 5-naphthylene diisocyanate, xylylene diisocyanate, hydrogenated polymethylenepolyphenylene polyisocyanate, and mixtures thereof. Isocyanate prepolymers can also be used. Polymeric MDI is the preferred isocyanate used in this invention.

[0083] POLYOLS

[0084] Polyols useful in the preparation of the polyurethane foams used in this invention can be either one or a combination of polyether, polyester polyols, or polyalkyldiene polyols, or derived from reaction of excess of such polyols, alone or in combination with isocyanate function compounds. The polyols can be diols, triols, tetrols or polyols with higher functionality. They can be used alone or in combination. Representative examples of useful polyols include polyoxypropylene polyol, polyalkylene polyol, and polypropylene glycols. They can be amine polyols, sucrose polyols, glycerol polyols, sorbitol polyols, or combinations. The polyols used can be aliphatic or aromatic.

[0085] Most commercially available polyols have a polyether or polyester backbone. They are usually hydrophilic and soluble in water. Water-immiscible and hydrophobic polyols available include those with hydrocarbon and polybutadiene backbones. Bio based, water-immiscible, polyols are also available.

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[0086] CATALYSTS

[0087] Tertiary amines and organo-tin compounds are preferably used as catalysts. The particular tertiary amine and organo-tin catalyst used in obtaining the hydrophobic polyurethane foams of the present invention is not critical, and any combination of components readily known to those skilled in the art may be used. Examples of suitable tertiary amines include triethylenediamine, triethylamine, N-methylmorpholine, N-ethylmorpholine and N,N,N'-tetramethylbutanediamine. Suitable organo-tin catalysts include stannous octoate and dibutyltin dilaurate.

[0088] Up to about 5% by weight of a catalyst can be used based on the total reaction material weight. Preferably the catalyst should range from 0.01 to about 1.0% by weight. Tertiary amine and organo-tin compounds are preferred.

[0089] BLOWING AGENTS

[0090] Examples of blowing agents that can be used in the present invention include water, low boiling alkanes such as butane and pentane, acetone and liquid carbon dioxide. Halogenated blowing agents (HCFC's) can also be used, even though they are not preferred. Water is the preferred blowing agent in this invention. Blowing agents are used between 1 and 20% by weight and more preferably between 1 and 15% based on the total weight of the formulation.

[0091] ADDITIONAL COMPONENTS

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- [0092] Additional components that may be used in the present polyurethane foams include, for example, crosslinking agents; fillers, such as carbon black and calcium carbonate; coloring dyes, antioxidants, fungicides, pesticides and anti-bacterial additives, flow agents, viscosity modifiers, foam control agents, plasticizing agents, moisture scavengers, adhesion promoters, temperature stabilizers, and ultraviolet radiation stabilizers.
- [0093] Flame retardants may also be added to render the foamed product flame retardant. Suitable flame retardants include tris(chloroethyl) phosphate, tris(2-chloroethyl) phosphate, tris(dichloropropyl) phosphate, chlorinated paraffins, tris(chloropropyl) phosphate, phosphorus-containing polyols, and brominated aromatic compounds such as pentabromodiphenyl oxide and other brominated polyols.
- [0094] The polyurethane composition has a low viscosity, typically 500 to 5000 cps when measured with a Brookfield Viscometer at 25°C temperature. The low viscosity, in part, allows the composition to be easily poured into the hole. The composition can be made water-repellant and hydrophobic to prevent external moisture from becoming part of the foam structure and reducing the compressive strength. The polyurethane will start to foam as soon as the two components are mixed together.
- [0095] The polyurethane composition is added to the hole, reacts, and foams up. It is noted that some of the reaction may begin prior to adding to the hole. For in-ground applications, it is preferred that the resulting polyurethane foam is water-repellant

hydrophobic and closed-cell, to prevent water or other liquids from passing through the foam to rot wood or corrode metal. The resulting polyurethane foam then preferably cures to touch in about 3 to 4 minutes after mixing and is fully cured in less than 2 hours after mixing. By changing the catalyst concentration, the gel time and tack-free time of the foam can be made faster or slower, depending on the working time required for a particular application. The gel time can be as long as 20 minutes and as fast as 30 seconds.

[0096] The polyurethane foam has good adhesion to wood, metal, plastics and composite materials, soil, clay, gravel and rocks. This is evident from the results listed in Table 2 below.

[0097] The polyurethane foam also provides an abrasive surface to increase friction against soil. This helps prevents movement of the footing through the soil.

[0098] The compressive strength is also important to prevent damage to the foam as a greater load is placed on the footing and it moves through the soil. The compressive strength of the foam is usually between 30 psi and 300 psi for most applications. However, it may be higher, depending on the footing requirements. A particular aspect utilizes foam that provides a compressive strength of 100 psi.

[0099] The foamable compositions utilized in the present invention can vary with the requirements mentioned above. The following are representative of water-repellant, hydrophobic closed cell foams. All parts are by weight.

[00100] Aspects of the invention include compositions and methods as follows:

[00101] Aspect 1: A foundation footing system for a load-bearing structure comprising a hole in a ground, the hole having a bottom and sides, and a post positioned in the hole and generally centered within the hole, wherein the post extends above the hole, wherein the width of the hole is wider than a width of the post thus forming a gap between sides of the post and the sides of the hole; the foundation further comprising a cured, closed-cell, polyurethane foam surrounding the post, wherein the polyurethane foam fills the gap between the post and sides of the hole, the polyurethane foam comprising a cured mixture of a polyurethane composition comprising polyisocyanate and at least one active hydrogen containing compound wherein the cured polyurethane foam has a compressive strength of greater than 10 psi, greater than 30, greater than 50, greater than 80, or 100 psi.

[00102] Aspect 2: A foundation footing system for a load-bearing structure comprising a hole in a ground, the hole having a top, bottom, and sides; the foundation further comprising cured, polyurethane foam, wherein the foam fills the hole and extends above the top of the hole to form a foundation footing, the polyurethane foam comprising a cured mixture of a polyurethane composition comprising isocyanate, and at least one active hydrogen containing compound; and further comprising a post placed on and attached to the top of the foam and generally centered on the foam, or wherein at least a portion of the post is embedded within the foam wherein the cured polyurethane foam has a

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compressive strength of greater than 10 psi, greater than 30, greater than 50, greater than 80, or 100 psi.

[00103] Aspect 3: The foundation footing system of aspect 1 or aspect 2 comprising at least two holes and at least two posts, wherein the posts have the same or different diameters, and each hole has a diameter accommodating the diameter of the respective post and requisite gap.

[00104] Aspect 4: The foundation footing system of aspects 1-3 wherein the cured polyurethane foam is prepared from mixing a polyurethane composition, pouring the composition into the hole, and allowing the composition to foam, wherein the polyurethane foam cures to touch in about 1 to 10 minutes after mixing the composition.

[00105] Aspect 5: The foundation footing system of any of aspects 1-4 further comprising a footing pad underneath the post positioned in the hole and/or the post is positioned at the bottom of the hole.

[00106] Aspect 6: The foundation footing system of any of aspects 1-5 wherein the polyurethane composition is hydrophobic.

[00107] Aspect 7: The foundation footing system of any of aspects 1-6 wherein the polyurethane foam further comprises at least one water-immiscible component in an amount from 10% to 80% by weight or 30% to 60% by weight of the total composition.

- [00108] Aspect 8: The foundation footing system of any of aspects 1-7 wherein the composition further comprises a hydrophobicity inducing surfactant in an amount from 0.1% to 5% by weight of the total composition, wherein the surfactant may be selected from polysiloxane-polyalkylene oxide copolymers.
- [00109] Aspect 9: A method of making a foundation footing system for a load-bearing structure comprising a) forming a hole in a ground, the hole having a bottom and sides; b) placing a post in the hole such that the post is generally centered within the hole and a gap is formed between sides of the post and the sides of the hole; and c) adding a polyurethane composition into the gap, allowing the polyurethane composition to react and form a foam, thereby filling in the gap, and then to cure to form a cured, closed-cell, polyurethane foam, the polyurethane foam mixture comprising polyisocyanate and at least one active hydrogen containing compound wherein the cured polyurethane foam has a compressive strength of greater than 10 psi, greater than 30, greater than 50, greater than 80, or 100 psi.
- [00110] Aspect 10: A method of making a foundation footing system for a load-bearing structure comprising a) forming a hole in a ground, the hole having a top, bottom, and sides; b) placing a polyurethane composition into the hole, allowing the polyurethane composition to react and form a foam, filling in the hole and rising above the hole, and then to cure to form a cured, polyurethane foam footing, the polyurethane foam mixture comprising a polyurethane composition comprising isocyanate, and at least one active hydrogen compound; and further comprising attaching a post to the top of, and

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generally centered on, the foam, or embedding a pole within the foam wherein the cured polyurethane foam has a compressive strength of greater than 10 psi, greater than 30, greater than 50, greater than 80, or 100 psi.

[00111] Aspect 11: The method of aspect 9 or aspect 10 further comprising forming at least two holes and placing a post in each of the holes, wherein the posts have the same or different diameters, and each hole has a diameter accommodating the diameter of the respective post and requisite gap; and erecting a load-bearing structure on the foundation footing system.

[00112] Aspects 9-11 may likewise have the features of any or all of the features of aspects 3-7 above.

[00113] **Example 1**

Component 1

4,4' diphenylmethane diisocyanate	100%
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Component 2

Sucrose Based Polyether Polyol	60.8%
Petroleum Hydrocarbon	30%
High Flash Naptha Solvent	5%
Hydrophobic Silicone Surfactant	2%
Catalyst	0.2%
Water	2%

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The mixed viscosity is 1100 cps. This composition has a cured foam density of 0.10 gm/cc and a compressive strength of 100 psi.

[00114] Example 2

Component 1

4,4' diphenylmethane diisocyanate	100%
-----------------------------------	------

Component 2

Sorbitol Polyol	47.9%
Amine Polyol	20%
Vegetable Oil	20%
Hydrophobic Surfactant	5%
Catalyst	0.1%
Water-Repellant Blowing Agent, e.g. Pentane	7%

The mixed viscosity is 4200 cps. The foam density is 0.06 gm/cc. The compressive strength is 60 psi.

[00115] Below are formulations for non-water-repellant rigid, polyurethane foams. They can be used above grade, in dry soils and to make prefabricated footings.

[0100] Example 3

Component 1

4,4'diphenylmethane diisocyanate	100%
----------------------------------	------

Component 2

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Sorbitol Polyol	60%
Polyether Polyol	32%
Non-Hydrophobic Surfactant	3%
Catalyst	1%
Water	4%

The mixed viscosity is 1800 cps. The foam density is 0.05 gm/cc. The compressive strength is 55 psi.

[0101] Example 4

Component 1

4,4'-diphenylmethane diisocyanate	100%
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Component 2

Glycerol Polyol	73.8%
Polypropylene Glycol	20%
Non-Hydrophobic Surfactant	3%
Catalyst	0.2%
Water	3%

The mixed viscosity is 3000 cps. Foam density is 0.085 gm/cc. The compressive strength is 80 psi.

[0102] By adjusting the concentration of the various raw materials, the physical and chemical properties of the foam can be changed. For example, decreasing the catalyst concentration will slow down the gel time. Increasing the water concentration will

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decrease the foam density and decrease the compressive strength. Changing the properties of the foam is easily done by those familiar with the art.

[0103] In the Tables below, the compressive and tensile strength of wood post/foam footings are compared to wood post/concrete footings. Tables 2 and 3 give the compressive and tensile strength of the footing system shown in Figure 5 consisting of wood post 54 in hole 52 held in place by foam 56. The soil 50 was compressed. The 100 psi foam gave values similar to concrete.

TABLE 2**COMPRESSIVE STRENGTH**

FOOTING	PEAK LOAD ON FOOTING	COMPRESSIVE STRENGTH OF FOOTING	SOIL COMPRESSIVE STRENGTH
SOIL	73 lb.	960 PSI	28 PSI
CONCRETE	145 lb.	206 PSI	24 PSI
40 PSI FOAM	99 lb.	141 PSI	21 PSI
100 PSI FOAM	146 lb.	208 PSI	28 PSI

TABLE 3**TENSILE STRENGTH**

FOOTING	PEAK LOAD ON FOOTING	TENSILE STRENGTH OF FOOTING	SOIL COMPRESSIVE STRENGTH

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CONCRETE	40 lb.	57 PSI	28 PSI
40 PSI FOAM	41 lb.	59 PSI	21 PSI
100 PSI FOAM	49 lb.	70 PSI	28 PSI

[0104] Tables 4 and 5 give the compressive and tensile strength for the footing shown in Figure 6. Post 64 and foam 66 were placed over rigid pad 68 in hole 62. The soil 60 was compressed. In a similar manner, a post and concrete was placed over a rigid pad. The pad was 2000 psi concrete or a 2000 psi polymer. Loose gravel was also used. In this system, the 100 psi foam performed best. The concrete performed similarly to the 40 psi foam.

TABLE 4**COMPRESSIVE STRENGTH**

FOOTING	BOTTOM PAD	PEAK LOAD ON FOOTING	COMPRESSIVE STRENGTH OF FOOTING	SOIL COMPRESSIVE STRENGTH
SOIL	Prefab Concrete	83 lb.	1092 PSI	28 PSI
CONCRETE	Prefab Concrete	225 lb.	321 PSI	35 PSI
40 PSI FOAM	Prefab Concrete	234 lb.	331 PSI	28 PSI
100 PSI FOAM	Prefab Concrete	297 lb.	424 PSI	35 PSI

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100 PSI FOAM	Polymer Pad	296 lb.	422 PSI	35 PSI
100 PSI FOAM	Gravel	177 lb.	252 PSI	21 PSI
40 PSI FOAM	Gravel	118 lb.	168 PSI	24 PSI

TABLE 5**TENSILE STRENGTH**

FOOTING	BOTTOM PAD	PEAK LOAD ON FOOTING	TENSILE STRENGTH OF FOOTING	SOIL COMPRESSIVE STRENGTH
CONCRETE	Prefab Concrete	44 lb.	63 PSI	28 PSI
40 PSI FOAM	Polymer Pad	59 lb.	84 PSI	28 PSI
100 PSI FOAM	Polymer Pad	97 lb.	138 PSI	28 PSI

[0105] Tables 6 and 7 give the compressive and tensile strength for the footings shown in Figure 7. The 100 psi foam and the concrete are the footings that have been placed in the hole and extend above grade. The wood post is placed on top of the footing.

[0106] A footing pad was placed on top of the foam to spread the load across the entire surface of the foam. Without the pad, the foam would compress directly under the post when a load greater than the compressive strength of the foam was applied. Both the

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compressive and tensile strength of the 100 psi foam footing was higher than for the concrete footing. The post was attached to the top of the footing with an anchor bolt.

TABLE 6**COMPRESSIVE STRENGTH**

FOOTING	PEAK LOAD	COMPRESSIVE STRENGTH OF FOOTING	SOIL COMPRESSIVE STRENGTH
100 PSI FOAM	514 lb.	170 PSI	28 PSI
CONCRETE	426 lb.	141 PSI	25 PSI

TABLE 7**TENSILE STRENGTH**

FOOTING	PEAK LOAD	TENSILE STRENGTH OF FOOTING	SOIL COMPRESSIVE STRENGTH
100 PSI FOAM	78 lb.	25 PSI	25 PSI
CONCRETE	69 lb.	22 PSI	41 PSI

[0107] The polyurethane foam also provides an abrasive surface to increase friction against soil. This helps prevents movement of the footing through the soil.

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[0108] While the invention has been described with respect to specific examples including presently preferred modes of carrying out the invention, those skilled in the art will appreciate that there are numerous variations and permutations of the above described systems and techniques that fall within the spirit and scope of the invention as set forth in the appended claims.

We Claim:

1. A foundation footing system comprising:
 - a post positioned in a hole defined in a ground, the hole having a bottom and sides, wherein the post extends above the hole, wherein a width of the hole is wider than a width of the post thus forming a gap between sides of the post and the sides of the hole;
 - a cured, closed-cell, polyurethane foam configured to fill the gap between sides of the post and sides of the hole, the polyurethane foam comprising a cured polyurethane composition comprising
 - polyisocyanate,
 - at least one active hydrogen containing compound, and
 - a hydrophobicity inducing surfactant,wherein the cured, closed-cell, polyurethane foam has a compressive strength of greater than 10 psi.
2. The foundation footing system of claim 1 comprising at least two holes and at least two posts, wherein the posts have the same or different diameters, and each hole has a diameter accommodating the diameter of the respective post and gap.
3. The foundation footing system of claim 1 or 2 wherein the cured, closed-cell, polyurethane foam is prepared from mixing the polyurethane composition, pouring the polyurethane composition into the hole, and allowing the polyurethane composition to foam, wherein the polyurethane composition cures to touch in about 1 to 10 minutes after mixing the polyurethane composition.
4. The foundation footing system of claim 1, 2 or 3 wherein the cured, closed-cell, polyurethane foam has a compressive strength of greater than 30 psi.
5. The foundation footing system of claim 1, 2 or 3 wherein the cured, closed-cell, polyurethane foam has a compressive strength of greater than 50 psi.
6. The foundation footing system of any one of claims 1 to 5 further comprising a footing pad underneath the post positioned in the hole.

7. The foundation footing system of any one of claims 1 to 6 wherein the polyurethane composition is hydrophobic.
8. The foundation footing system of any one of claims 1 to 7 wherein the cured, closed-cell, polyurethane foam further comprises at least one water-immiscible component in an amount from 10% to 80% by weight of the total polyurethane composition.
9. The foundation footing system of claim 8 wherein the at least one water-immiscible component comprises 30% to 60% by weight of the total polyurethane composition.
10. The foundation footing system of any one of claims 1 to 9 wherein the polyurethane composition includes the hydrophobicity inducing surfactant in an amount from 0.1% to 5% by weight of the total polyurethane composition.
11. The foundation footing system of claim 10 wherein the hydrophobicity inducing surfactant is a polysiloxane-polyalkylene oxide copolymer.
12. The foundation footing system of any one of claims 1 to 11 wherein the post is positioned at the bottom of the hole.
13. A foundation footing system comprising:
 - a hole in a ground, the hole having a top, a bottom, and sides;
 - a cured, polyurethane foam, wherein the foam fills the hole and extends above the top of the hole, the polyurethane foam comprising a cured mixture of a polyurethane composition comprising isocyanate, at least one active hydrogen containing compound, and a hydrophobicity inducing surfactant; and
 - a post placed on and attached to the top of the foam, or wherein at least a portion of the post is embedded within the foam wherein the cured polyurethane foam has a compressive strength of greater than 10 psi.
14. The foundation footing system of claim 13 comprising at least two holes and at least two posts, wherein the posts have the same or different diameters, and each hole has a diameter accommodating the diameter of the respective post.

15. The foundation footing system of claim 13 or 14 wherein the cured polyurethane foam is prepared from mixing a polyurethane composition, pouring the polyurethane composition into the hole, and allowing the polyurethane composition to foam, wherein the polyurethane foam cures to touch in about 1 to 10 minutes after mixing the polyurethane composition.
16. The foundation footing system of claim 13, 14 or 15 wherein the cured polyurethane foam has a compressive strength of greater than 30 psi.
17. The foundation footing system of claim 13, 14 or 15 wherein the cured polyurethane foam has a compressive strength of greater than 50 psi.
18. The foundation footing system of any one of claims 13 to 17 wherein the polyurethane composition is hydrophobic.
19. The foundation footing system of any one of claims 13 to 18 wherein the cured polyurethane foam further comprises at least one water-immiscible component in an amount from 10% to 80% by weight of the total polyurethane composition.
20. The foundation footing system of claim 19 wherein the at least one water-immiscible component comprises 30% to 60% by weight of the total polyurethane composition.
21. The foundation footing system of any one of claims 13 to 20 wherein the polyurethane composition includes the hydrophobicity inducing surfactant in an amount from 0.1% to 5% by weight of the total polyurethane composition.
22. The foundation footing system of claim 21 wherein the hydrophobicity inducing surfactant is a polysiloxane-polyalkylene oxide copolymer.

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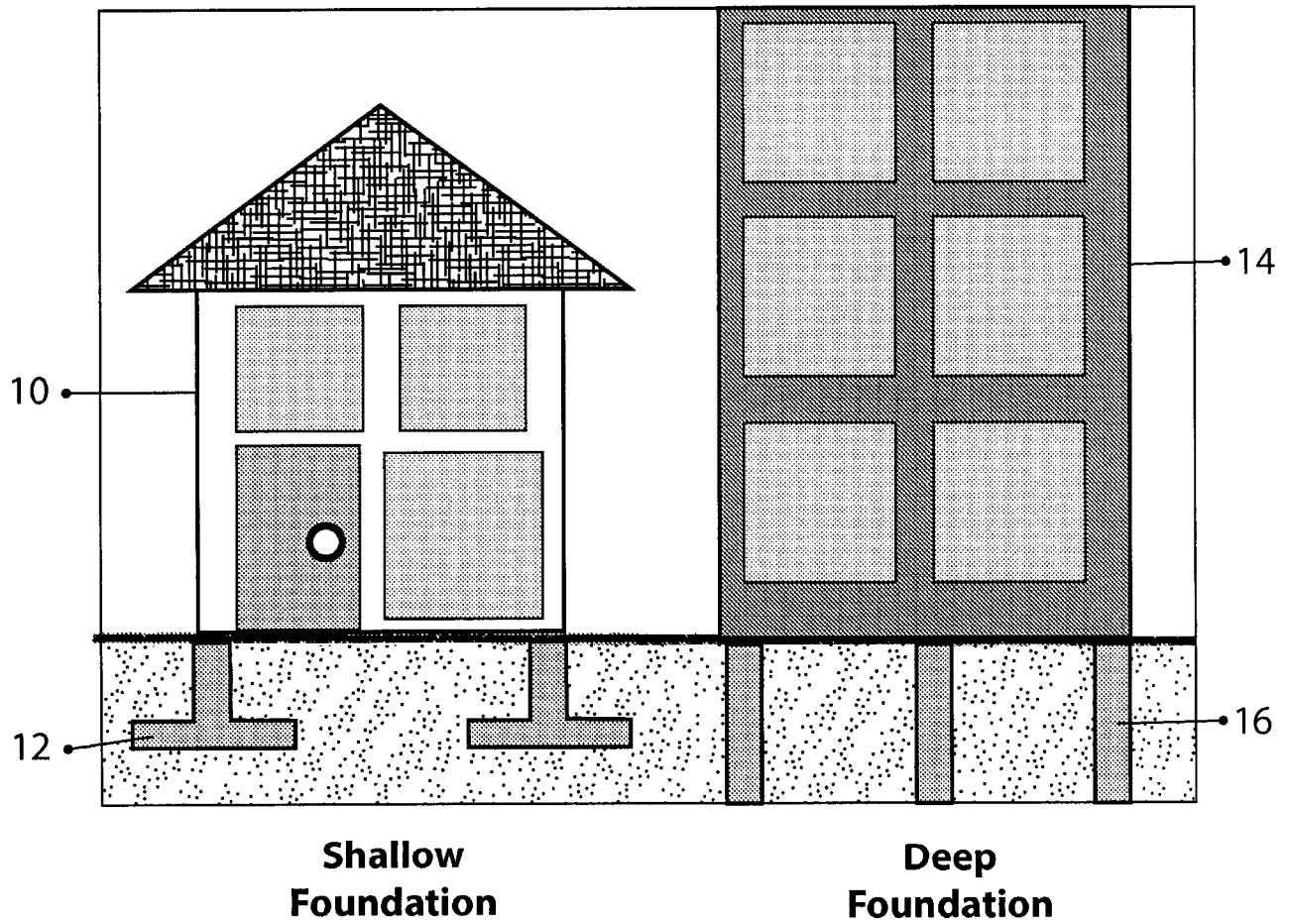


Figure 1

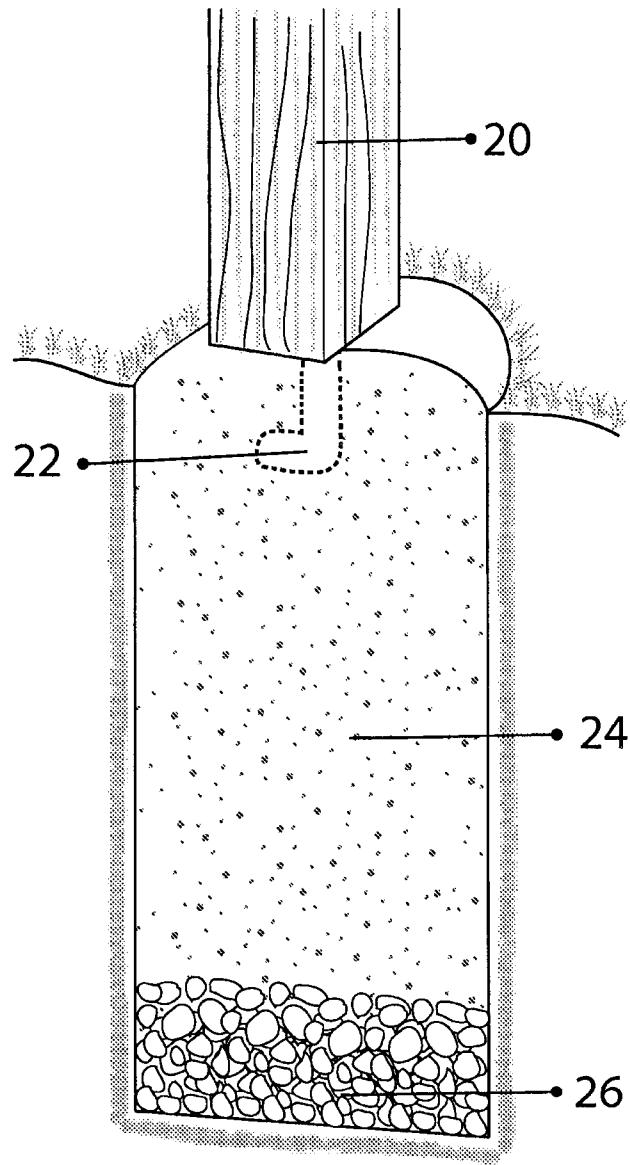
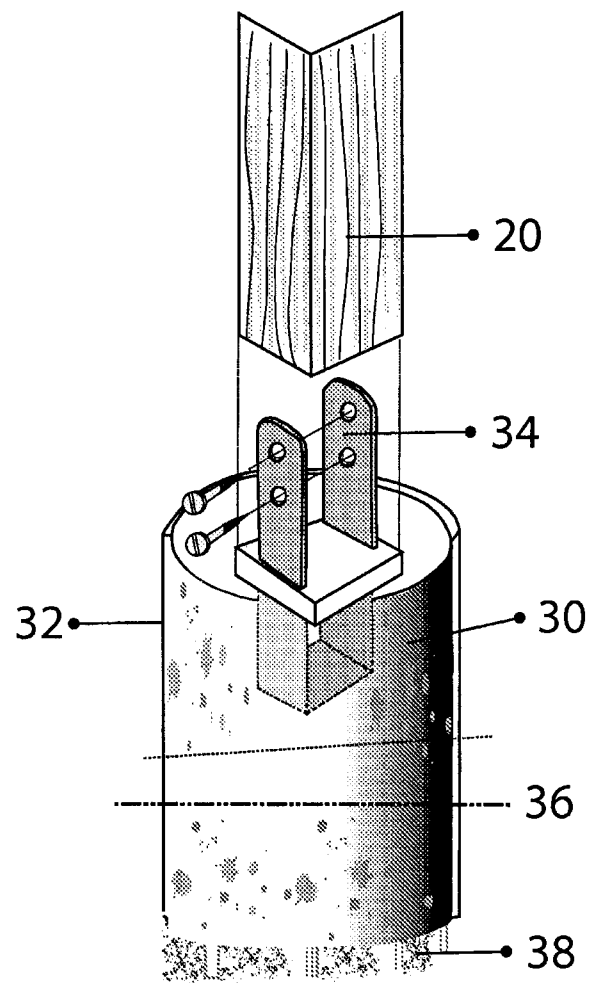


Figure 2

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**Fibre Tube Poured
Concrete Footing**

Figure 3

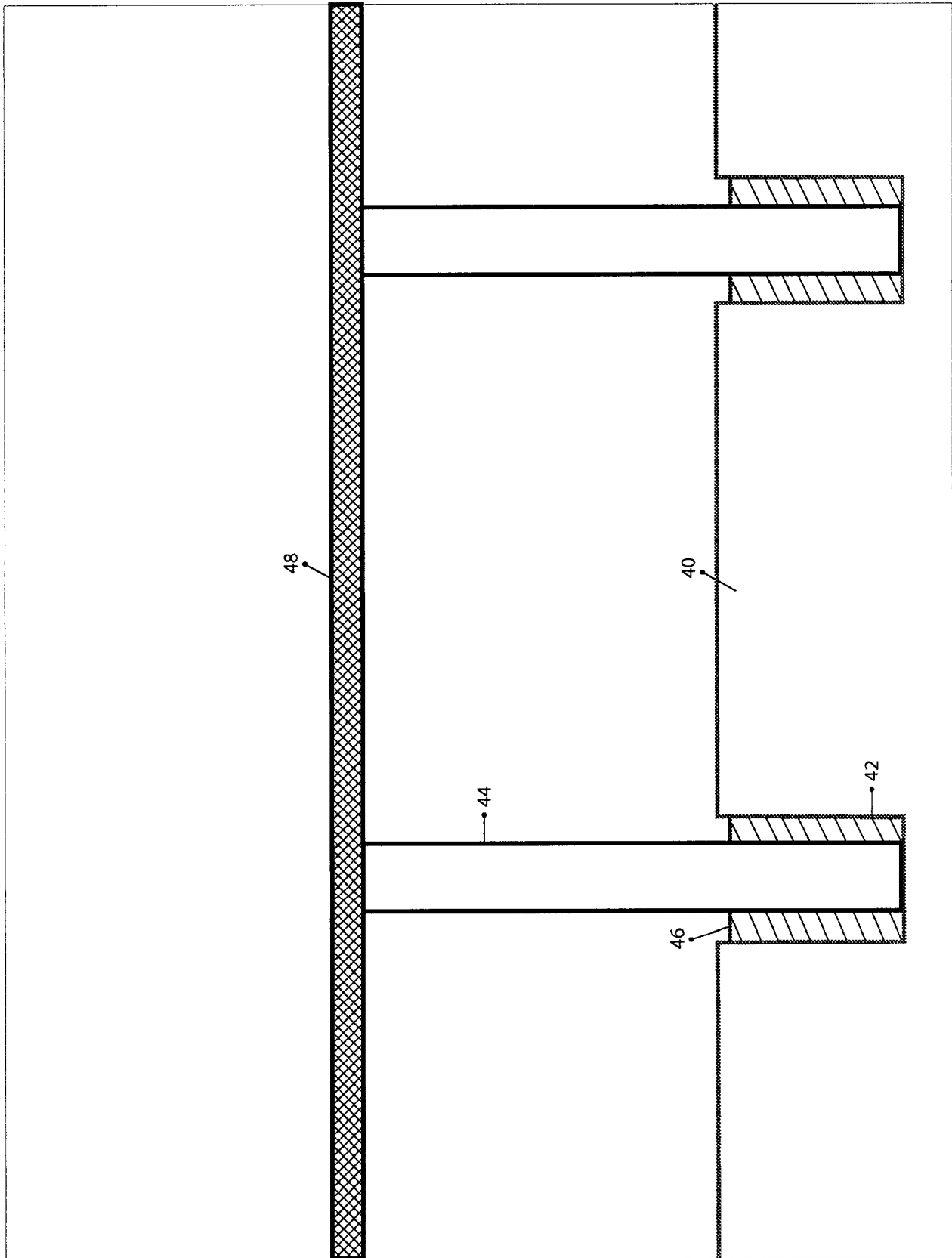


Figure 4

WO 2015/132674

PCT/IB2015/001032

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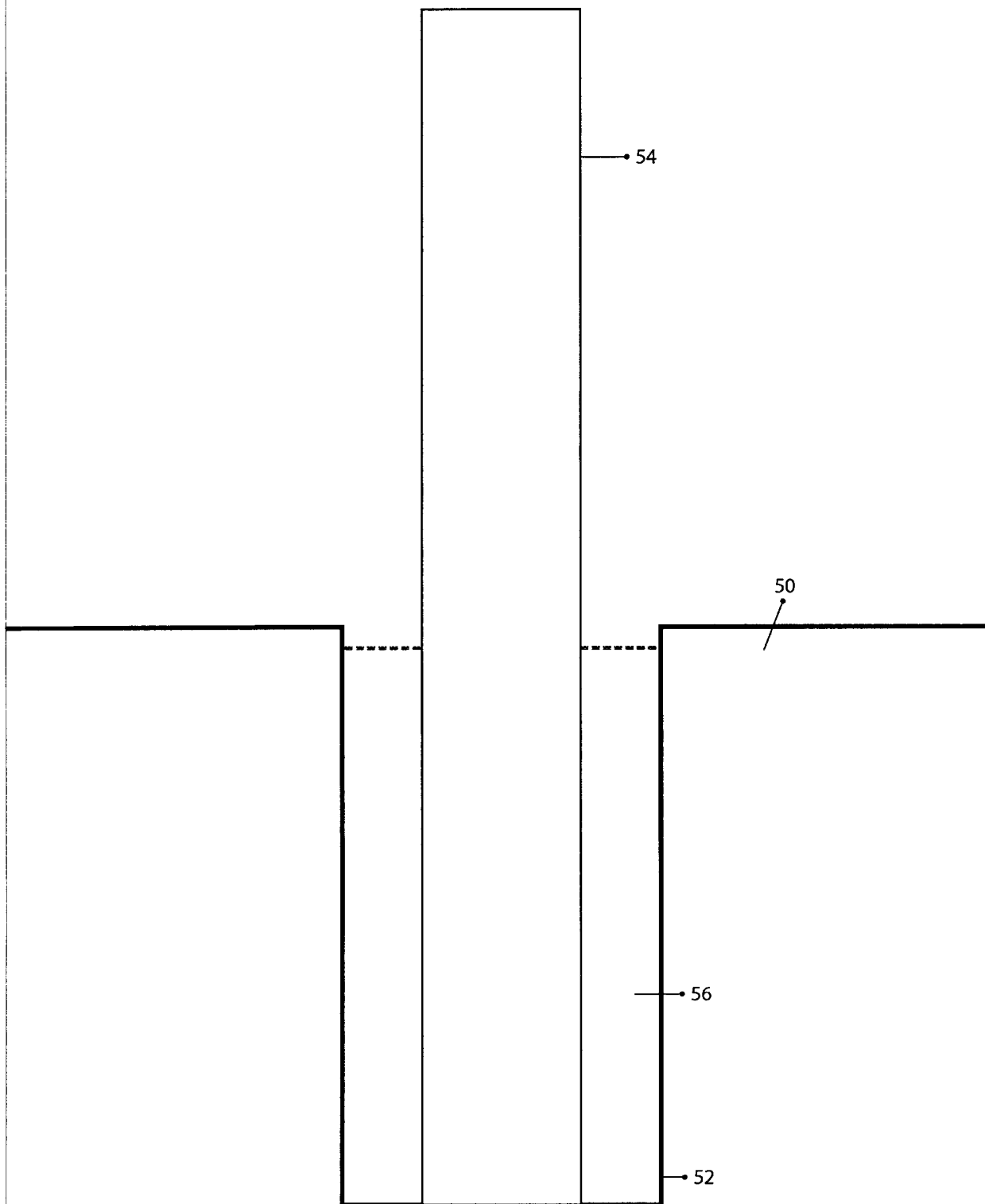


Figure 5

WO 2015/132674

PCT/IB2015/001032

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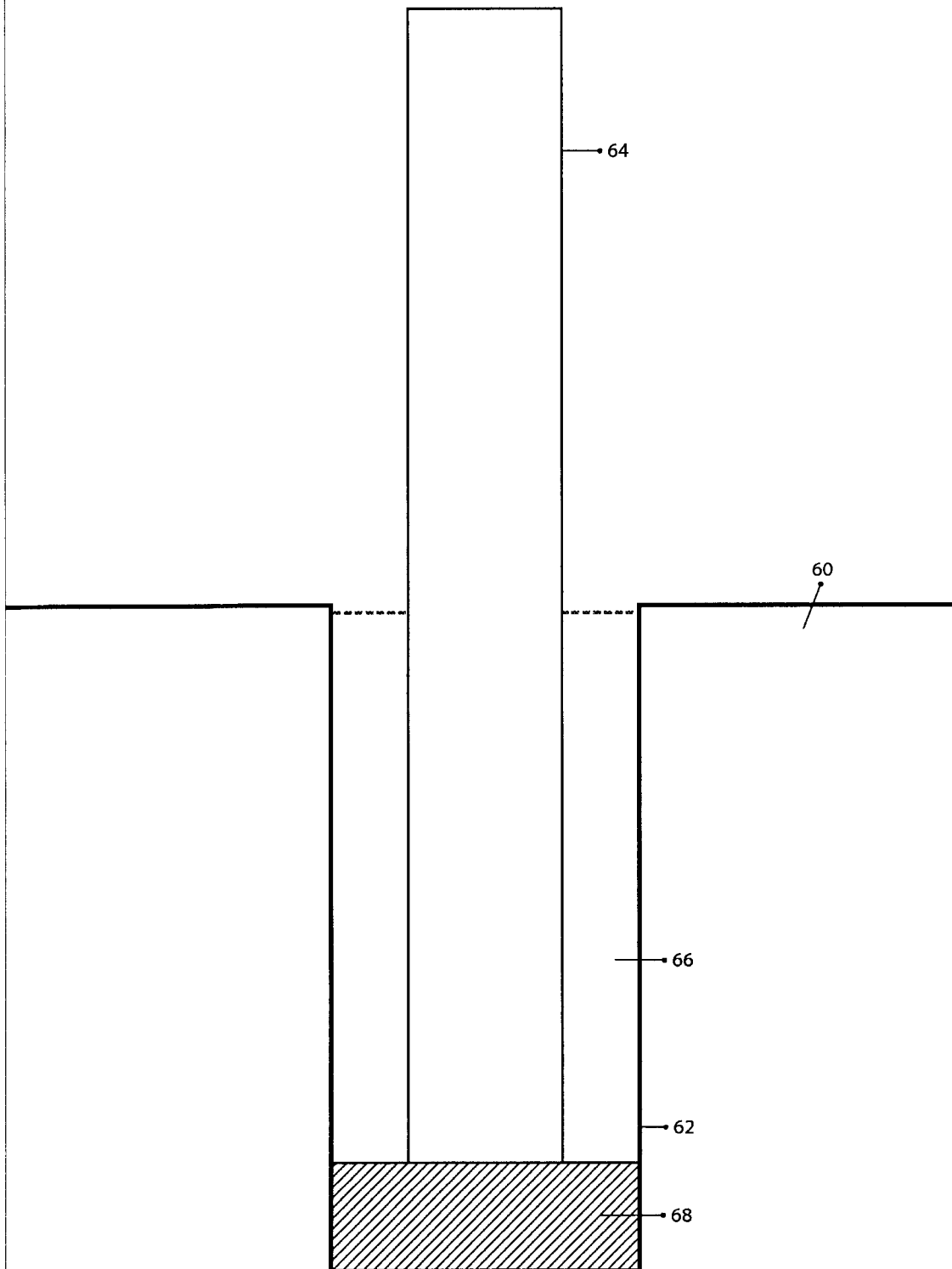


Figure 6

WO 2015/132674

PCT/IB2015/001032

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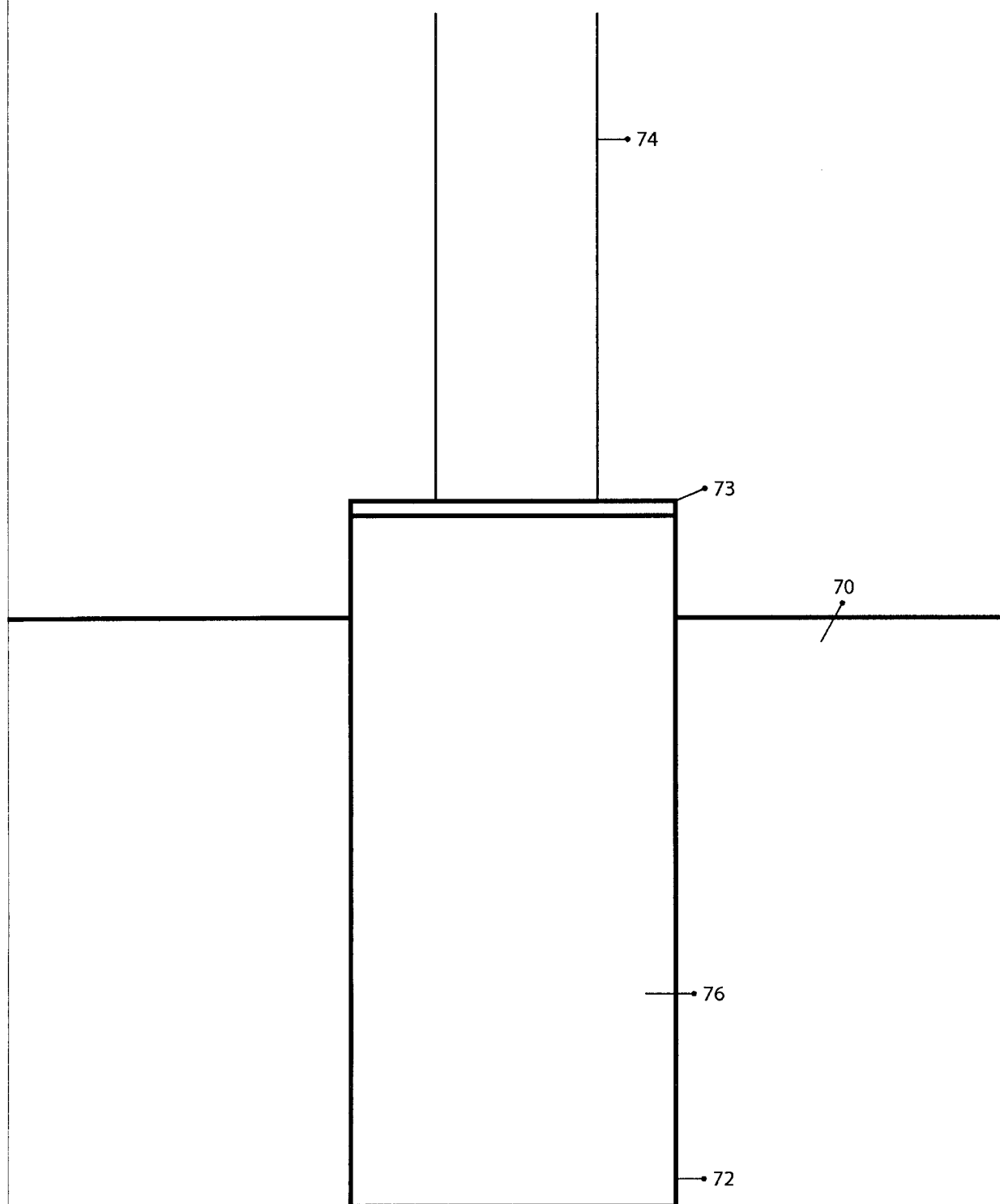


Figure 7

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PCT/IB2015/001032

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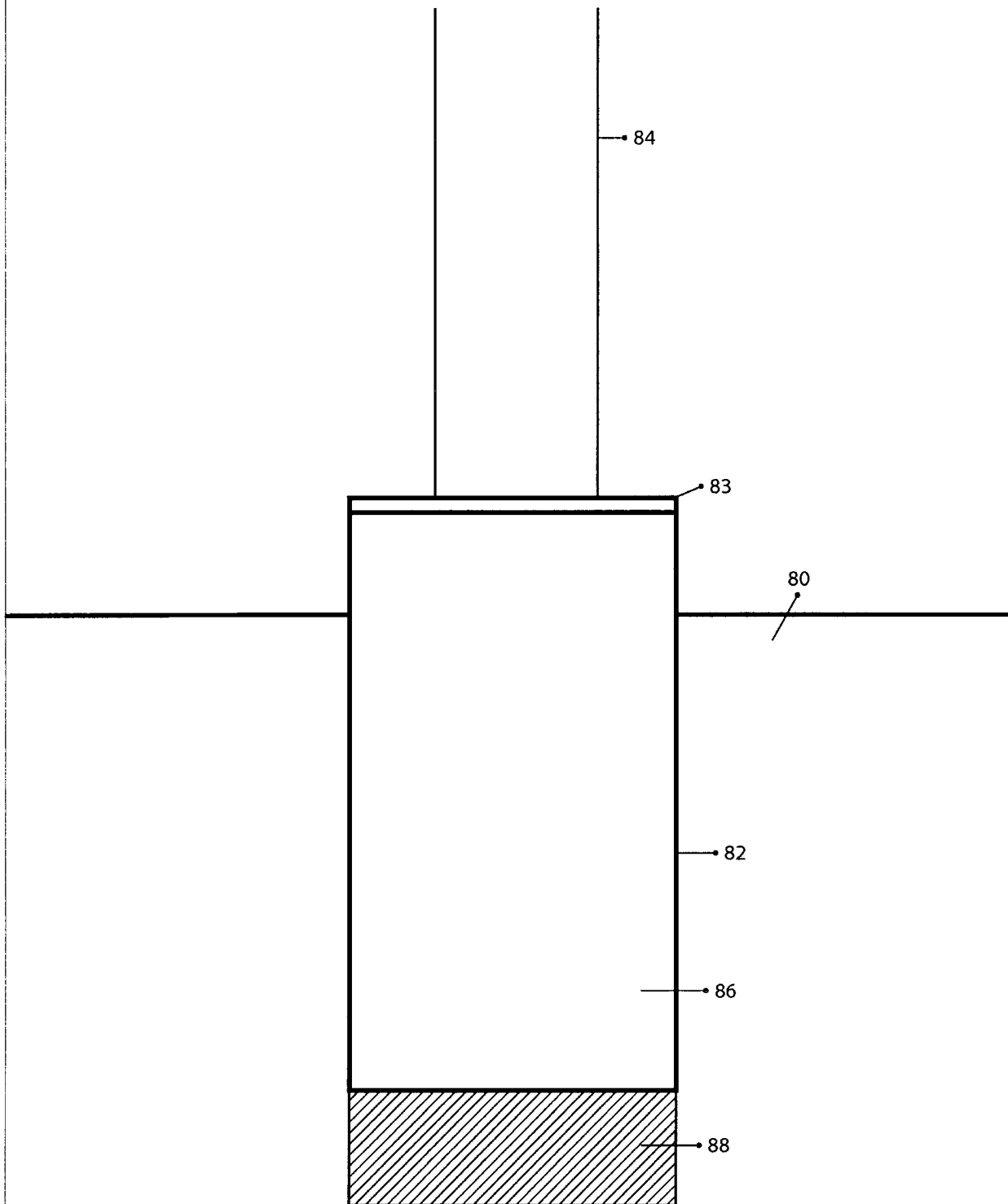


Figure 8

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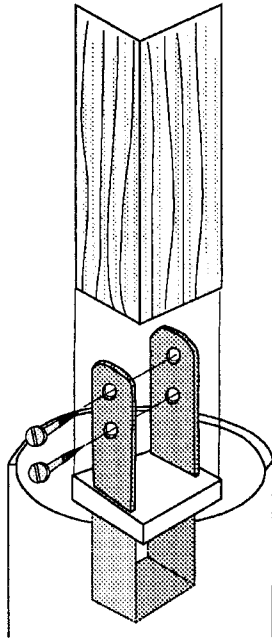


FIGURE 9A

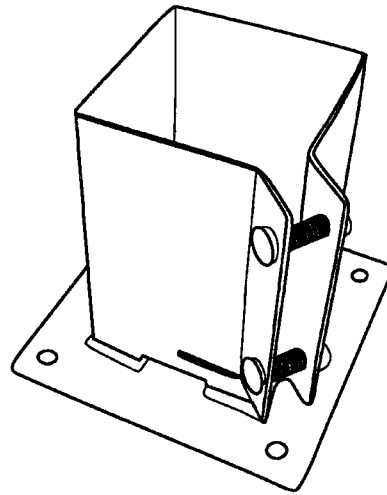


FIGURE 9B

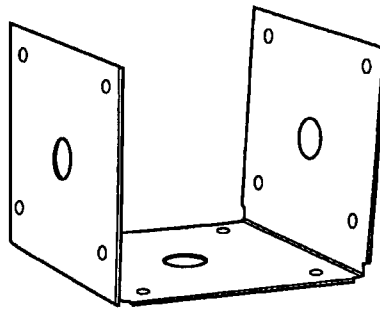


FIGURE 9C

Figure 9

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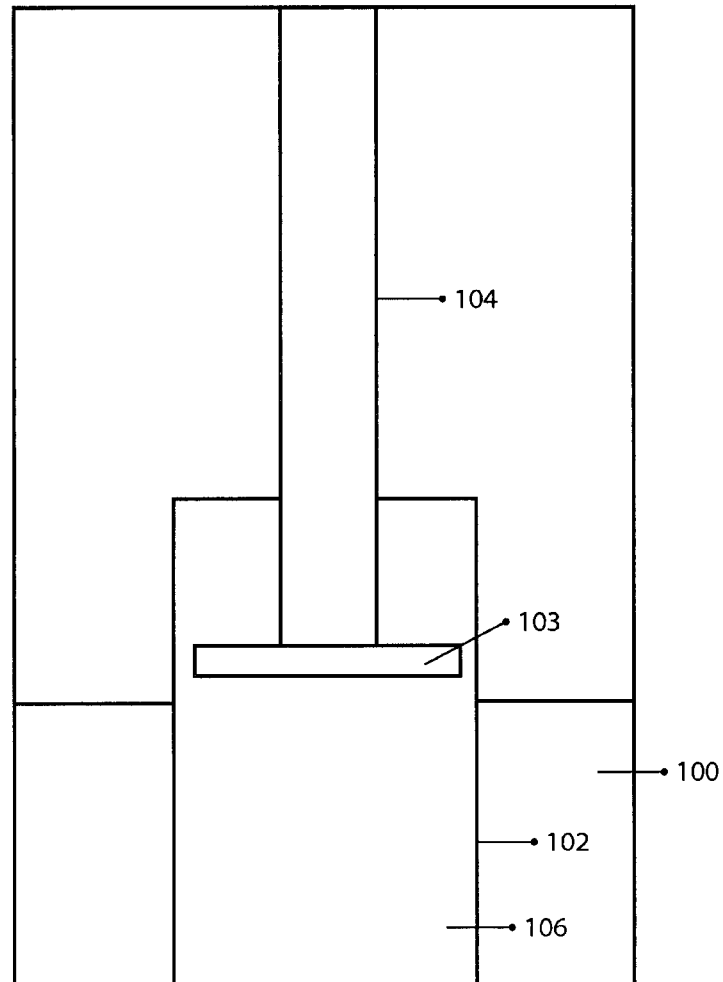


Figure 10

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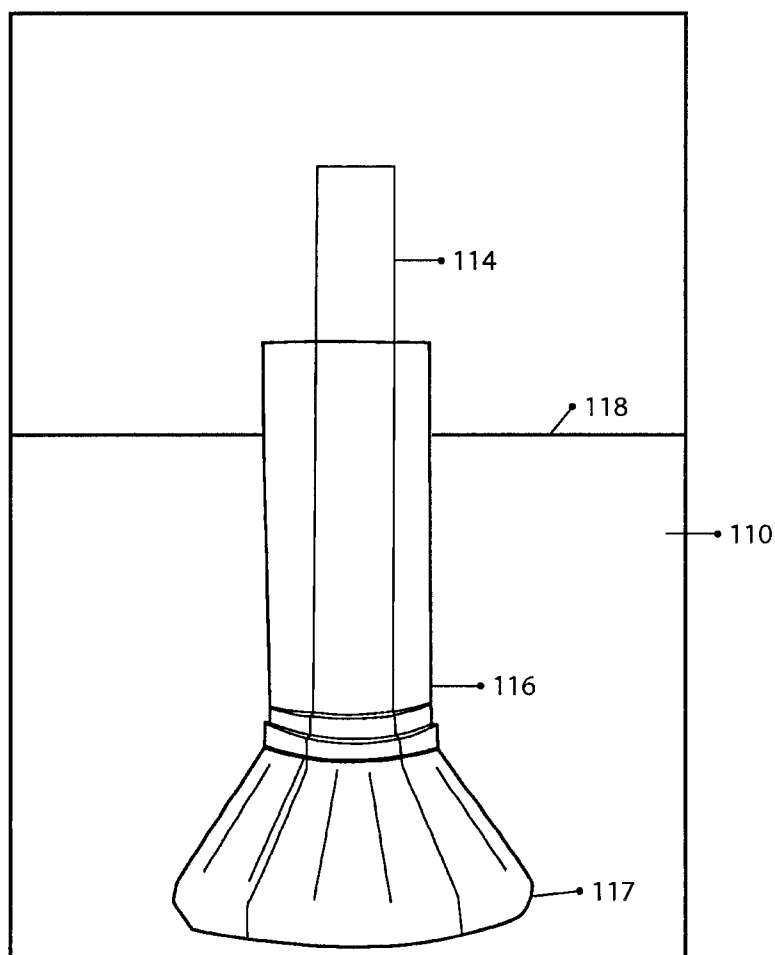


Figure 11

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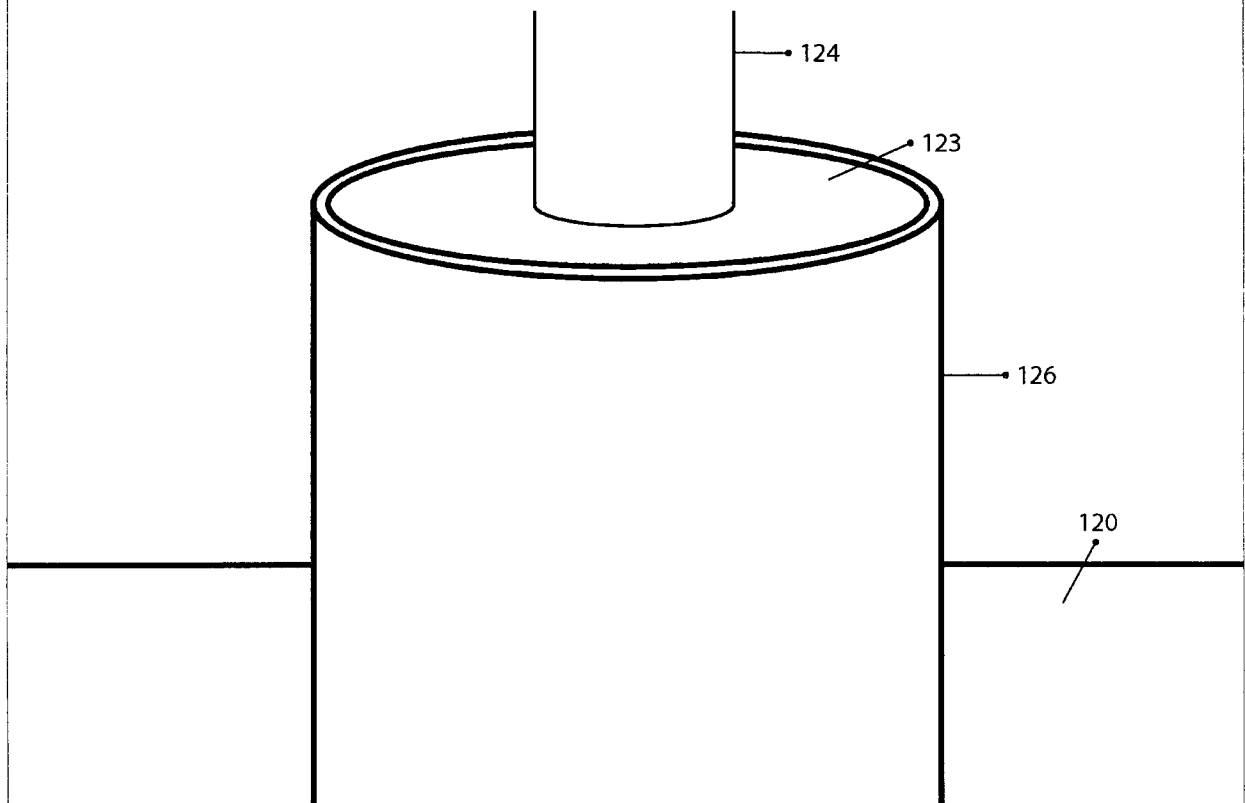


Figure 12

