An Apparatus and Method for Impregnating A Fluid In-situ Into A Medium

FIELD OF INVENTION

The invention relates broadly to an apparatus for impregnating a fluid into a medium, to a method of impregnating a fluid into a medium and to a method of leakage testing.

BACKGROUND

In the construction industry, cracks may develop in concrete, more particularly in slabs and walls. Current methods of repairing these cracks such as using epoxy injection or pressure grouting have limitations. This is especially so for deep cracks since the penetration of the grout into the cracks during repairing is typically obscured by moisture and air trapped in these cracks. In addition, one problem that may arise for using pressure-grouting is that the ground preparation prior to pressure-grouting is typically tedious and time-consuming.

Furthermore, porous or cracked concrete floor slabs and walls can lead to leakage, especially in wet areas. These floor slabs are typically tiled in wet areas. Prior to tiling in wet areas, the concrete floor slabs are typically applied with first a layer of water-proofing membrane followed by a layer of cement mortar screed with the purpose of "finishing" the floor to a required level. Floor tiles are subsequently bonded onto the cement mortar screed using base grout and the joints between the floor tiles are typically grouted with tile grout. As the water-proofing membrane serves to prevent leakage, the floor finishes comprising the cement mortar screed, the base grout and the tile grout are typically not designed to be water-tight. Thus, cracks and cavities are typically found in these floor finishes. One problem that may arise is that these floor finishes may suffer from leakage, and thus if the water-proofing membrane fails, leakage from the wet area occurs readily.

Furthermore, it is also typical for the walls in wet areas to be tiled. The process of tiling these walls is similar to tiling the floors as described above, except that the water-proofing membrane is typically not applied at all onto the walls. In some cases, the water-proofing membrane is only applied up to a specific height of the walls. Therefore, one problem that may arise for walls in wet areas is that, since the walls are typically subjected to wetting, the walls may suffer from leakage.

When tiled floors or walls in wet areas leak, water typically first permeates through the tile joints that may be porous or cracked. Water leakage in wet areas is typically the result of non-performance of the water-proofing membrane or system. One reason may be due to the water-proofing membrane or system deteriorating with time. Another reason may be due to poor workmanship which can lead to premature failure of the water-proofing membrane or system. In leak repair, replacing the damaged water-proofing membrane or system can give rise to a number of concerns. Replacing the damaged water-proofing membrane or system typically involves hacking and removing the tiles which cannot be reused. In addition, hacking and removing the tiles and thereafter laying new tiles typically cause great inconvenience and also involve monetary cost. Furthermore, in some cases, the existing floor tiles may be too costly to be hacked and removed or the tile designs may no longer be available for replacement.

However, despite the concerns above, repairing leaking floors or walls is still currently carried out by hacking the tiles and replacing the water-proofing membrane or system. A localised repair is only carried out when the leakage source is identified. It is noted that, in general, repairing leaking floors and walls without hacking the tiles is unpopular in view of the lack of confidence in the current "non-hacking" repair techniques.

One such repair technique is to impregnate fluids. Examples of these fluids include grouts, resins, water repelling or other leak-sealing materials. Impregnation of a fluid into a porous medium is typically carried out using a number of different mechanisms such as through gravity flow and capillary action. However, one problem that may arise is that since impregnation through gravity flow and capillary action typically depends on parameters such as pore size and surface tension, these mechanisms may not be consistently reliable. Another problem that may arise is that

impregnation by capillary action is typically not possible if the surface of the porous medium is wet, that is, the pores are filled with water. Yet another problem that may arise is that the depth of impregnation under the mechanisms of gravity flow and capillary action is typically limited and may not be sufficient to meet the impregnation requirements.

Impregnation can be more effectively carried out by applying pressure which drives the fluid into the porous medium. However, one problem that may arise is that if air is trapped in the porous medium, applying pressure may not be effective in driving the fluid into the porous medium.

Applying vacuum prior to pressure impregnation has been carried out in laboratories to impregnate small specimens fully contained within a processing chamber. The impregnation is typically carried out in an enclosed apparatus, such as a desiccator, and the impregnation pressure is typically atmospheric. Such laboratory apparati cannot be used for in-situ impregnation of large surfaces, such as floors and walls in a building, since it is practically impossible to contain these large surfaces within an enclosed apparatus. It is appreciated that impregnation is more often required to be carried out in-situ on large surfaces rather than in laboratory settings.

In addition, one typical technique of repairing leaking floors and walls without hacking the tiles is to use water-proof tile grout such that together with the existing tiles, an impervious layer can be provided for preventing water from seeping into the cement mortar screed and concrete slab underneath the tiles. However, one problem that may arise is that it is relatively tedious to remove and replace the tile grout with a more suitable material.

In addition to the above, repairing of leaks or cracks underwater is typically troublesome and may practically be impossible. Therefore, problems may arise when there are situations when leak repairs are to be carried out underwater such as in water-retaining structures, swimming pools, floating or underwater structures.

Hence, in view of the above discussion, there exists a need for an in-situ impregnation apparatus and method to address at least one of the abovementioned problems.

SUMMARY

In accordance with a first aspect of the present invention, there is provided an apparatus for impregnating a fluid into a medium, the apparatus comprising, one or more main compartments each having an open face for enclosing respective portions of a surface of the medium when a rim of said each compartment contacts the surface of the medium; securing means for securing the main compartments with the rims of the respective compartments contacting the surface of the medium; and one or more conduits in fluid communication with each main compartment.

The apparatus may further comprise a sealing assembly disposed at a contact surface of the respective rims wherein when the main compartments are secured to the surface of the medium, the sealing assembly provides a substantially air-tight seal between the rims and the surface of the medium.

The sealing member assembly may comprise a gasket; one or more retaining plates connected to the gasket and movably connected to the main compartments.

The securing means may comprise one or more auxiliary compartments connected to the main compartments, each auxiliary compartment having an open face to enclose respective portions of the surface of the medium, one or more conduits in fluid communication with each auxiliary compartment, and wherein the auxiliary compartments secure the main compartments to the surface of the medium using suction applied to the auxiliary compartments.

The securing means may comprise a securing assembly for mechanically securing the main compartments to the surface of the medium.

The securing assembly may comprise an anchor member connected to the main compartments for insertion into a cavity of the medium; and a fastening

member connected to the anchor member for frictionally securing the anchor member from movement relative to the cavity such that the main compartments are secured to the surface of the medium.

The surface of the medium may comprise a protruding element, and the securing assembly may comprise a fastening assembly for fastening the main compartments to the protruding element such that the main compartments are secured to the surface of the medium.

The apparatus may further comprise a pressure/suction pump connected to one or more of the conduits.

The apparatus may further comprise a fluid tank connected to one or more of the conduits in fluid communication with the main compartments for channeling the fluid to and from the main compartments.

In accordance with a second aspect of the present invention, there is provided a method of impregnating a fluid into a medium, the method comprising using an apparatus of the first aspect.

In accordance with a third aspect of the present invention, there is provided a method of impregnating a fluid into a medium, the method comprising the steps of enclosing respective portions of a surface of the medium using one or more main compartments, each main compartment having an open face with a rim of said each compartment contacting the surface of the medium; securing the main compartments with the rims of the respective compartments contacting the surface of the medium; and channeling the fluid via one or more conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

The step of securing the main compartments may comprise connecting one or more auxiliary compartments to the main compartments, each auxiliary compartment having an open face to enclose respective portions of the surface of the medium, providing one or more conduits in fluid communication with each

auxiliary compartment, and wherein securing the main compartments to the surface of the medium using the auxiliary compartments by applying suction to the auxiliary compartments.

The method may further comprise the steps of applying suction to the main compartments and the auxiliary compartments via the conduits in fluid communication with the respective compartments; channeling the fluid via the one or more conduits in fluid communication with each main compartment into the main compartments while maintaining suction to the main compartments and the auxiliary compartments; stopping the application of suction to the main compartments and the channeling of the fluid when a desired fluid level is reached in each main compartment; and applying pressure to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium while maintaining suction to the auxiliary compartments.

The step of securing the main compartments may comprise mechanically securing the main compartments to the surface of the medium using a securing assembly.

The mechanically securing may comprise inserting an anchor member connected to the main compartments into a cavity of the medium; and frictionally securing the anchor member from movement relative to the cavity such that the main compartments are secured to the surface of the medium.

The mechanically securing may comprise fastening the main compartments to a protruding element of the surface of the medium such that the main compartments are secured to the surface of the medium.

The method may further comprise the steps of channeling the fluid via the one or more conduits in fluid communication with each main compartment into the main compartments; stopping the channeling of the fluid when a desired fluid level is reached in each main compartment; and applying pressure to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

In accordance with a fourth aspect of the present invention, there is provided a method of impregnating a fluid into a medium, the method comprising the steps of flooding a surface of the medium with the fluid; enclosing respective portions of the surface of the medium using one or more main compartments, each main compartment having an open face with a rim of said each compartment contacting the surface of the medium; applying suction to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

The method may further comprise connecting a pressure/suction pump to one or more of the conduits.

The method may further comprise connecting a fluid tank one or more of the conduits in fluid communication with the main compartments for channeling the fluid to and from the main compartments.

In accordance with a fifth aspect of the present invention, there is provided a method of leakage testing of a medium, the method comprising the steps of enclosing a surface of the medium using a main compartment, the main compartment having an open face with a rim of said compartment contacting the surface of the medium; channeling a fluid via one or more conduits in fluid communication with the main compartment; and applying suction to the main compartment via the conduits in fluid communication with the main compartment for the leakage testing.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1(a) is a schematic cross-sectional view of a apparatus in one example embodiment.

Figure 1(b) is a schematic plan view of the apparatus.

Figure 2 is a schematic perspective view of one sealing element.

Figure 3 (a) is a schematic cross-sectional view of the apparatus when suction is applied to inner and outer compartments.

Figure 3 (b) is a schematic cross-sectional view of the apparatus when pressure is applied to the inner compartment.

Figure 4(a) to (c) are schematic drawings illustrating some different forms of the apparatus.

Figure 5 is a schematic cross-sectional view of a apparatus in another example embodiment.

Figure 6 is a schematic cross-sectional view of a apparatus in yet another example embodiment.

Figure 7(a) is a schematic cross-sectional view of a apparatus in another example embodiment.

Figure 7(b)(i) is a schematic top view of one steel split ring.

Figure 7(b)(ii) is a schematic cross-sectional view of the steel split ring.

Figure 8 is a flowchart illustrating a method of impregnating a fluid into a medium.

Figure 9 is a flowchart illustrating another method of impregnating a fluid into a medium.

Figure 10 is a flowchart illustrating a method of leakage testing of a medium.

DETAILED DESCRIPTION

Example embodiments described below provide an apparatus capable of in-situ impregnation of fluid into porous medium. The apparatus may comprise one or more compartments for pressure/suction purposes. The apparatus may be in any shape or size for use in suitable applications.

Figure 1(a) is a schematic cross-sectional view of an apparatus 100 in one example embodiment, shown in a horizontal configuration on a surface 108. In this example embodiment, the apparatus 100 comprises an inner compartment 102 and an outer compartment 104. Figure 1(b) is a schematic plan view of the apparatus 100. As illustrated in Figure 1(b), the inner compartment 102 is enclosed at its perimeter by the outer compartment 104. The compartments 102, 104 within the apparatus 100 may either be integrally formed or comprises an assembly of connectable compartments connected or disconnected from each other.

The apparatus 100 may be constructed using material such as, but not limited to, glass, Perspex, steel, that can withstand suction and pressure operations that can be carried out in the compartments 102, 104. Referring to Figure 1(a), the compartments 102, 104 each have an opening on one face 106 which is co-planar such that when placed on the surface 108 of a porous medium 110, the compartments 102, 104 are enclosed by the surface 108 and the sides of the apparatus e.g. 112,114,116. As will be appreciated by a person skilled in the art, for situations having porous medium surfaces which are not flat, the face 106 of the compartments 102, 104 may be multi-planar to preferably completely cover and seal the porous medium surface.

The apparatus 100 further comprises sealing elements e.g. 118, 120 disposed at the circumference/rims of the compartments 102, 104 such that, when the apparatus 100 is placed on the surface 108 of the porous medium 110, the apparatus 100 may be sealed air-tight using the sealing elements e.g. 118, 120.

A pressure/vacuum pump 122 is provided for applying pressure and/or suction to the compartments 102, 104 as desired. The pressure/vacuum pump 122 can apply both

pressure and suction simultaneously and can control the levels of pressure and suction as desired. Two gauges 124, 126 are respectively provided for monitoring the pressure and suction applied by the pressure/vacuum pump 122.

With regard to applying suction, the pressure/vacuum pump 122 applies suction to the outer compartment 104 through a first tube 128. The tube 128 may be of any suitable size and material. A first valve 130 is provided in relation to the tube 128 and the pressure/vacuum pump 122 for turning on or off the suction applied to outer compartment 104. The pressure/vacuum pump 122 applies suction to the inner compartment 102 through a second tube 132. The tube 132 may be of any suitable size and material. The suction applied to inner compartment 102 may be turned on or off by using a second valve 134 provided in relation to the tube 132 and the pressure/vacuum pump 122.

With regard to applying pressure, the pressure/vacuum pump 122 applies pressure to the inner compartment 102 with a configuration of opening the second valve 134 and closing a third valve 136.

A reservoir tank 138 is provided to contain fluid for impregnating purposes in this example embodiment. The fluid can be channelled into inner compartment 102 through a third tube 140. The tube 140 may be of any suitable size and material. A fourth valve 142 is provided at the fluid exit opening of the reservoir tank 138 and can be opened or closed to control the flow of the fluid. A flexible tube 144 is coupled to the third tube 140 for the fluid to enter or leave the inner compartment 102. The flexible tube 144 may be made of a flexible material such as, but not limited to, rubber. The material may allow the flexible tube 144 to bend such that the mouth of the flexible tube 144 is substantially at rest at the bottom of the inner compartment 102. As will be appreciated by a person skilled in the art, the above flexible tube arrangement ensures that the fluid can be removed from the inner compartment 102 without lifting or moving the apparatus 100. A nipple 146 is fitted at the tip of the flexible tube 144 to weigh the flexible tube 144 downwards. Thus, the nipple 146 can be at the bottommost portion of the inner compartment 102 regardless of the orientation of the apparatus 100. During fluid removal, the fluid in inner compartment 102 is channelled back into the reservoir tank 138 through opening a fifth valve 148. The fluid passes through a filter 150 before

entering the reservoir tank 138. The filter 150 may remove any foreign particles that are collected along with the fluid during fluid removal from the inner compartment 102.

Figure 2 is a schematic perspective view of one of the sealing elements e.g. 118, 120. On application of suction to the compartments 102, 104 (Figure 1), a mechanical seal 202 in the form of a gasket 202, such as silicon foam, compresses onto the surface 108 (Figure 1) of the porous medium 110 (Figure 1) and provides an airtight seal to prevent air passage into the compartments 102, 104 (Figure 1). The gasket 202 is preferably soft. The gasket 202 is housed between two retaining plates 204, 206 and the retaining plates 204, 206 are provided with slots 208, 210 such that the plates 204, 206 can slide up or down in relation to respective studs 212, 214. The studs 212, 214 are secured to the apparatus 100 (Figure 1). On one hand, the arrangement allows the suction in the compartments 102, 104 (Figure 1) to translate into a downward force causing the rims of the compartments 102, 104 (Figure 1) to compress the gasket 202. On the other hand, the retaining plates 204, 206 prevent the gasket 202 from being sucked into the compartments 102, 104 (Figure 1). Therefore, the above arrangement allows a very soft type gasket to be used. In view of recesses or roughness that can be expected on the surface 108 (Figure 1), a very soft type gasket may assist further in preventing air passage to and from the compartments 102, 104 (Figure 1). It is noted that tiled floors and walls, especially at joints, can have surface roughness of more than 63μm which is the typical threshold value for an effective use of an ordinary gasket or O-ring.

Figure 3 (a) is a schematic cross-sectional view of the apparatus 100 when suction is applied to the inner and outer compartments 102,104. Figure 3 (b) is a schematic cross-sectional view of the apparatus 100 when pressure is applied to the inner compartment 102.

At the start of an in-situ impregnation process, suction is first applied to compartments 102, 104 of the apparatus 100 by using the pressure/vacuum pump 122 (Figure 1). The suction helps to remove any air, moisture and/or debris trapped in any cracks or pores of the porous medium 110. To effect the suction, valves 130, 134 are opened. The suction force and duration is selected through prior usage and experience. In the example embodiment, a suction force of up to about 100kPA can be applied. A

vacuum may be induced in the compartments 102, 104 in about 10 to 20 seconds. After removing any trapped air, moisture and/or debris from the porous medium 110, the fluid for impregnating the porous medium 110 is channelled from the reservoir tank 134 (Figure 1) to the inner compartment 102 via tube 140 and flexible tube 144. The channelling of the fluid is carried out by opening the valve 142 (Figure 1). The suction applied to the inner compartment 102 assists in drawing the fluid from the reservoir tank 138 (Figure 1) to the inner compartment 102. It will be appreciated by a person skilled in the art that suction is still applied to the inner compartment 102 while filling the inner compartment 102 with the fluid so that no air, moisture and/or debris may re-enter into the pores of the porous medium 110.

Once the fluid in the inner compartment 102 is at an adequate level, the suction applied to the inner compartment 102 is turned off by closing the valve 134. At this stage, the valve 142 (Figure 1) is also closed to prevent a back-flow of the fluid from the inner compartment 102 into the reservoir tank 138 (Figure 1). There is no requirement to fill the inner compartment 102 fully with the fluid. Judging whether the level of the fluid is adequate or not in the inner compartment 102 may be based on experience and/or estimation.

Maintaining the application of suction in the outer compartment 104 may have three purposes. Firstly, the suction in the outer compartment 104 provides a reaction force to counter the upward lift of the inner compartment 102 when pressure is applied in later stages. Secondly, the suction in the outer compartment 104 acts as a "vacuum-guard" so that the suction on the porous medium 110 below the inner compartment 102 is not lost when pressure is being applied to the inner compartment 102. Loss of suction can promote moisture migration in the porous medium 110. Thirdly, the suction assists in removing air in the porous medium 110 below the inner compartment 102 and hence can improve the impregnation.

After turning off suction to the inner compartment 102, referring to Figure 3(b), pressure is applied to the inner compartment 102 by using the pressure/vacuum pump 122 (Figure 1) and opening the valve 136. Once pressure is applied, the apparatus 100 experiences an uplift force. However, as will be appreciated by a person skilled in the art, the downward drag force of the suction still applied in the outer compartment 104

can be used to overcome the uplift force by the pressure in the inner compartment 102. A calculation based on the respective applied pressure and suction forces in relation to the respective surface areas under compartments 102, 104 may determine the pressure and suction levels to be applied to prevent uplift of the apparatus 100. As illustrated in Figure 3(b), the complimentary effect of pressure (see numerals 302, 304) and suction (see numerals 306, 308) may boost the impregnation of the fluid into the porous medium 110. It is noted that the pressure in the inner compartment 102 is maintained until impregnation has been effected sufficiently. The pressure level and duration of pressure required for satisfactory impregnation can be established from prior tests. In the example embodiment, a pressure force of about 100 to 200 kPA is applied for about one to ten minutes.

In the event that the fluid in the inner compartment 102 is insufficient for impregnation, the inner compartment 102 can be refilled with the fluid. This is achieved by turning off the pressure by closing the valve 136 and then turning on suction to the inner compartment 102 by opening the valve 134 followed by opening the valve 142 (Figure 1) to allow fluid flow from the reservoir tank 138 (Figure 1). Once the inner compartment 102 is filled with the fluid to a desired level, the valve 142 is closed and suction to the inner compartment 102 is turned off by closing the valve 134. Pressure is next reapplied to the inner compartment 102 by opening the valve 136.

Referring back to Figure 1(a), once impregnation has been satisfactorily effected, the excess fluid in the inner compartment 102 is channelled back into the reservoir tank 138 by opening valve 148. The pressure in the inner compartment 102 can assist in driving the fluid back into the reservoir tank 138. As will be appreciated by a person skilled in the art, since the nipple 146 of the flexible tube 144 is substantially at the bottommost portion of the inner compartment 102, there can be a maximum recovery of the fluid from the inner compartment 102. The fluid, being channelled back into the reservoir tank 138, passes through the filter 150 to remove any foreign particles in the fluid. The filter 150 can be cleaned or replaced periodically, as and when appropriate.

In the example embodiment, once the fluid has been channelled back into the reservoir tank 138 and impregnation has been completed, the corresponding pressure

and suction in the compartments 102, 104 is turned off and the apparatus 100 can be moved to a next location for impregnation operations.

It will be appreciated that that the apparatus 100 can also be used on an inclined or vertical surface. For use on an inclined or vertical surface, the apparatus 100 is preferably placed with the tube 132 at the top (see numeral 152) and the fluid is then introduced into the inner compartment 102 via flexible tube 144 from the bottom. This can allow the inner compartment 102 to be filled with the fluid without any air trapped within the inner compartment 102. It will be appreciated by a person skilled in that art that air should be absent between the fluid and the surface to be impregnated. Otherwise, the application of pressure during impregnation may drive air into the pores of the porous medium 110, thus defeating the purposes of initially applying suction in the inner compartment 102 before fluid flow. In addition, since the tip of the flexible tube 144 is substantially at the bottommost location (compare numerals 146 and 152), the channelling back of the fluid into the reservoir tank 138 after impregnation may be optimised.

As mentioned above, the apparatus may comprise any number of compartments. Pressure and suction may be applied in any permutations in these compartments, depending on the situations. The example embodiment may also be in different forms to provide the same functions, e.g. in cases where a non-planar surface is to be processed. Figure 4(a) to (c) are schematic drawings illustrating some different forms of the apparatus. Figure 4(a) illustrates a apparatus 400 being used on a flat surface 402, Figure 4(b) illustrates a apparatus 404 being used against a wall 406 and Figure 4(c) illustrates a apparatus 408 being used in a corner formed by walls 410, 412.

Furthermore, the described example embodiment may be configured to impregnate coating material to be deeply rooted into a substrate for effective bonding. This may lead to a lamination technology which may produce more integrated laminates. The described example embodiment may also be configured to be used for cleaning pores and/or cracks in a medium by applying a cyclic routine of pressure and suction application. By using suitable cleaning agents with the cyclic routine, deep cleansing of pores and/or cracks in any medium may be possible. Another advantage of this configuration is that the cleansing may be done in-situ.

In addition, the described example embodiment may be used underwater. As will be appreciated by a person skilled in the art, in underwater repairs, repairing leaks from a face exposed to the water is typically more effective than repairing leaks from a rear face since repairing leaks from the rear face is typically proven futile due to the high pressure head of the leaks. Furthermore, the described example embodiment may be applied on inclined surfaces, making it further suitable for underwater applications.

Further, the described example embodiment may be used to impregnate grouts, resins, water repelling and/or other leak-sealing materials into wet concrete that is saturated with water due to ground water ingress, such as basement and diaphragm walls. It is noted that impregnation in such settings by current methods such as by capillary action, epoxy injection or pressure grouting is typically not effective.

The described example embodiment may be used to treat or repair porous surfaces and cracks, whether or not leakage is a concern, as well as to clean away debris and foreign particles from pores and cracks. The described example embodiment may be used to impregnate fluid into a porous medium in-situ regardless of the surface size. The described example embodiment can impregnate a fluid in-situ into a large surface using a combined action of suction and pressure. In addition, the described example embodiment can use the effect of suction to secure onto the surface. The described example embodiment may also be used on uneven and non-flat surfaces. The described example embodiment may also use the effect of suction and pressure to transfer fluid into and out of the apparatus. This may in turn assist in economical use of water-proofing compounds or fluids used during repairs without the need of a separate pump. Furthermore, when pressure or suction is applied in the described example embodiment, there may not be a need for any additional mechanical means to hold down the apparatus since the opposite forces created by these pressure and suction can counteract each other.

The described example embodiment can use a combination of pressure and suction to remove moisture and air to achieve a deeper penetration of grout or repair material. Referring to some problems identified in the Background section, the described example embodiment can make use of water-proofed tile grout together with tiles as an

integral system to water-proof tiled floors and walls. Thus, leaking floors and walls may be repaired without hacking off the existing tiles. The described example embodiment may be used for, but not limited to, repairing toilet floor leakages on floor areas within a range of about three to five square meters.

Impregnation of tile joints with suitable grouts, resins, water repelling or other leak-sealing materials and ensuring that the resultant material is deeply rooted into the tile grout as well as creating a good bond between the tile grout and adjacent tiles may provide a monolithic water-proof "tile grout and tile" floor finish system. Since floor tiles are generally impervious, as discussed in the Background, water-proofing the tile joints using the described example embodiment may give rise to an integral system of an impervious layer for preventing water from seeping into the cement mortar screed and concrete slab underneath the floor tiles. In addition, using the described example embodiment for filling any cavities below the tiles with suitable compounds and water-proofing the underlying substrate in the vicinity of the tile joints and cavities may provide additional warranty against any impending leak. Furthermore, the described example embodiment may enable the impregnation to be carried out in-situ in a speedy process which is both effective and economical thereby being more affordable and less inconvenient.

A number of specific different example embodiments which may be used for impregnating a fluid in-situ into a porous medium under different circumstances are described below.

Figure 5 is a schematic cross-sectional view of a apparatus 500 in another example embodiment. This example embodiment is suitable for use with a continuous opening in a substrate.

In the example embodiment, the apparatus 500 comprises one compartment 502. The apparatus 500 may be in any shape or size for use in suitable applications. The apparatus 500 comprises an integral structure or may comprise an assembly of multiple structures. The apparatus 500 can be constructed using transparent materials such as, but not limited to, glass, Perspex, to withstand suction and/or pressure that can be applied in the apparatus 500. The apparatus 500 comprises an opening 504 on one

face that is co-planar such that when placed on a surface 506 of a substrate 508, the compartment 502 is enclosed by the surface 506 and the sides e.g. 510 of the apparatus 500. The substrate 508 illustrated in this example embodiment can be a tiled floor with a floor-trap. It will be appreciated by a person skilled in the art that although the opening 504 is described as being co-planar, the opening 504 and the sides of the apparatus 500 may also be multi-planar. By being multi-planar, in the event if the porous medium surface is not flat, the apparatus 500 can preferably completely cover and seal the substrate surface 506.

The apparatus 500 further comprises gaskets e.g. 512, 514 disposed at the circumference/rims of the compartment 502. The apparatus 500 also comprises an anchoring bolt 516 provided on a rod 518 and pipe 520 assembly. The rod 518 and pipe 520 assembly is in contact with one or more O-rings e.g. 522, 524. The apparatus 500 further comprises an opening in the form of a nipple 526 and a tightening bolt 528. The nipple 526 can be used to introduce fluids as well as to apply pressure/suction into the compartment 502

In this example embodiment, the apparatus 500 is placed on the surface 506 of the substrate 508 over a continuous opening 530. The apparatus 500 can be sealed air-tight by means of the gaskets e.g. 512, 514. The bolt 516 is tightened causing the rod 518 and pipe 520 assembly to clamp the O-rings e.g. 522, 524. This causes the O-rings e.g. 522, 524 to expand against the continuous opening 530, sealing the opening 528 and providing a reaction force causing the apparatus 500 to be compressed downwards onto the substrate 508. The tightening bolt 528 is tightened causing the apparatus 500 to be further compressed towards the substrate 508. The apparatus 500 compresses the gasket e.g. 512, 514 onto the surface 506 of the substrate 508, thus providing an airtight seal which prevents air passage into the apparatus 500.

A fluid, e.g. water, is introduced into the compartment 502 through the nipple 526 and the compartment 502 is filled to at least or about half of its height. Suction is applied to the compartment 502 through nipple 526 to a required vacuum level. In the example embodiment, a suction force of up to about 100 kPA may be applied. It will be appreciated by a person skilled in the art that, by observing the water in the compartment 502, any sighting of air bubbles released from the substrate 508 indicates

that the substrate 508 is not impervious. This may mean that the substrate 508 is porous and susceptible to water leakage.

With the water in the compartment 502, pressure is then applied into the apparatus 500 through the nipple 526. If a leak occurs elsewhere on the surface 506, the leak can be observed and repaired. It will be appreciated by a person skilled in the art that the example embodiment may also be used to detect leakages in joints e.g. 532 between the substrate 508 and the opening 530.

It will be appreciated by a person skilled in the art that impregnation fluid or fluids for repairing leaks may also be introduced into the compartment 502 and pressure may be applied via the nipple 526 to impregnate the fluid into the substrate. Thus, the apparatus 500, apart from being capable for use in detecting leaks, may also be used to repair leakage of the substrate.

Furthermore, it will be appreciated by a person skilled in the art that an outer compartment may be coupled to the apparatus 500 to apply suction around the impregnation area to e.g. facilitate removal of trapped air in the substrate.

The above example embodiment is suitable for use in a situation when there is a continuous opening, such as a floor-trap, in a substrate. The continuous opening can be used to anchor a reaction mechanism to prevent an uplift of the apparatus 500 when pressure is applied into the compartment 502 e.g. during the process of impregnation. The example embodiment can also make use of a vacuum (ie. suction) to check the porosity or for the presence of leakage, in the substrate or in the assembly of the substrate and the continuous opening.

Figure 6 is a schematic cross-sectional view of a apparatus 600 in another example embodiment. This example embodiment differs from the example embodiment illustrated in Figure 5 in that there is no tightening bolt and anchoring of the apparatus 600 is assisted by further expansion of O-rings.

The apparatus 600 is placed on a substrate 602 and over an opening 604. The opening 604 may be in the form of a pipe of a floor trap. The apparatus 600 comprises a

compartment 606, an anchoring bolt 608, one or more O-rings, e.g. 610, 612, gaskets e.g. 614, 616 and a nipple 618. With regard to anchoring the apparatus 600 to the substrate 602, the anchoring bolt 608 is first tightened such that the O-rings, e.g. 610, 612, are in contact with an inner surface 620 of the opening 604. Suction is applied to the compartment 606 through the nipple 618, causing the apparatus 600 to be compressed downwards such that the gaskets e.g. 614, 616 are compressed against the substrate 602. Following the compression, the anchoring bolt 608 is further tightened to expand the O-rings, e.g. 610, 612 until the reaction of the O-rings, e.g. 610, 612 against the inner surface 620 is sufficient to withstand an uplift of the apparatus 600 when pressure is introduced into the compartment 606 at a later stage.

The processes of applying suction for checking whether the substrate 602 is impervious and of applying pressure to check for leakage or for impregnation processes are similar to the example embodiment described and illustrated above with reference to Figure 5.

Figure 7(a) is a schematic cross-sectional view of a apparatus 700 in another example embodiment. This example embodiment is suitable for use with a pipe protruding through a substrate.

In the example embodiment, the apparatus 700 comprises an assembly of two or more components e.g. 702, 704 that can be joined together to form a compartment 706. The apparatus 700 may be in any shape or size for use in suitable applications.

For description purposes, the apparatus 700 is described herein as an assembly of two symmetrical components e.g. 702, 704. When assembled, the apparatus 700 is substantially conical in shape with the apex cut off substantially parallel to the base. The apparatus 700 may be constructed using materials such as, but not limited to, glass, Perspex, steel, to withstand suction and/or pressure that can be applied to the apparatus 700.

The apparatus 700 also comprises gaskets, e.g. 708, 710 that run continuously along the edges of both symmetrical components e.g. 702, 704. The gaskets, e.g. 708, 710 can assist in sealing the compartment 706 air-tight at a later stage. The apparatus

700 further comprises a nipple 712 for introducing fluids, applying pressure and/or suction into the compartment 706. Furthermore, the apparatus 700 is used in conjunction with a bracket 714, a large steel split ring 716, a small steel split ring 718 and one or more struts e.g. 720, 722.

Figure 7(b)(i) is a schematic top view of one of the steel split rings 716, 718 and Figure 7(b)(ii) is a schematic cross-sectional view of the steel split ring 716. The steel split rings 716, 718 are assembled by connecting two halves 724, 726 using corresponding mating parts 728, 730. Furthermore, the two halves each comprise a connecting hole 732, 734

Returning to Figure 7(a), in the example embodiment, the two symmetrical components e.g. 702, 704, are first placed on opposite sides of a penetrating pipe 736 and brought together to encircle the pipe 736. The two symmetrical components e.g. 702, 704 are then placed on the substrate 738. Suction is applied through the nipple 712 to induce a vacuum in the compartment 706. The induction of vacuum effectively clamps the two components e.g. 702, 704 together along the gaskets e.g. 708, 710. The large steel split ring 716 is assembled and placed on the outside of the apparatus 700. Struts e.g. 720, 722 are then placed into the connecting holes 732, 734of the large steel split ring 716. The small steel split ring 718 is placed on the outside of the apparatus 700 such that the struts e.g. 720, 722 fit into the corresponding connecting holes 732, 734of the small steel split ring 718. Nuts e.g. 740, 742 on the struts e.g. 720, 722 are then tightened to ensure that the struts are taut. The bracket 714 is then secured onto the pipe using bolts 744, 746, with the bracket in contact with the small steel split ring 718. Thus, the assembly comprising the large steel split ring 716, the small steel split ring 718, the struts e.g. 720, 722 and the bracket 714 can prevent the opening and/or uplifting of the apparatus 700 when pressure is applied into the compartment 706.

In this configuration, the apparatus 700 may then be used to detect leakage and/or to carry out impregnation. Fluid, e.g. water, is introduced into the compartment 706 through the nipple 712 and the apparatus 700 is filled to at least or about half of its height. Suction is applied to the compartment 706 through the nipple 712 to the required vacuum level. It will be appreciated by a person skilled in the art that, by observing the water in the compartment 706, any sighting of air bubbles in the water released from the

substrate 730 may indicate that the substrate 730 or the joints e.g. 740 between the substrate 730 and the pipe 728 are not impervious. This may mean that the substrate 730 or joints e.g. 740 is porous and susceptible to water leakage.

With the water in the apparatus 700, pressure is applied into the compartment 706 through the nipple 712. Observations may be made regarding where leakages are located and repairs may then be carried out.

It will be appreciated by a person skilled in the art that impregnation fluid or fluids for repairing leaks may be introduced into the compartment 706 and pressure may be applied via the nipple 712 to impregnate the fluid into the substrate 730. Thus, the apparatus 700, apart from being capable for use in detecting leaks, may also be used to repair any leakage of the substrate.

The above example embodiment is suitable for use in a situation when there is a pipe penetrating through a substrate, such as in the case of sanitary pipes penetrating through a toilet floor. The pipe may be used to secure a reaction mechanism to prevent an uplift of the apparatus 700 e.g. during the process of impregnation. The example embodiment can also make use of a vacuum (ie. suction) to check the porosity or the presence of leakage in the substrate or in the assembly of the substrate and the penetrating pipe.

Figure 8 is a flowchart 800 illustrating a method of impregnating a fluid into a medium. At step 802, respective portions of a surface of the medium are enclosed using one or more main compartments, each main compartment having an open face with a rim of said each compartment contacting the surface of the medium. At step 804, the main compartments are secured with the rims of the respective compartments contacting the surface of the medium. At step 806, the fluid is channelled via one or more conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

Figure 9 is a flowchart 900 illustrating another method of impregnating a fluid into a medium. At step 902, a surface of the medium is flooded with the fluid. At step 904, respective portions of the surface of the medium are enclosed using one or

more main compartments, each main compartment having an open face with a rim of said each compartment contacting the surface of the medium. At step 906; suction is applied to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

Figure 10 is a flowchart 1000 illustrating a method of leakage testing of a medium. At step 1002, a surface of the medium is enclosed using a main compartment, the main compartment having an open face with a rim of said compartment contacting the surface of the medium. At step 1004, a fluid is channeled to the main compartment via one or more conduits in fluid communication with the main compartment. At step 1006; suction is applied to the main compartment via the conduits in fluid communication with the main compartment for the leakage testing.

The example embodiments described can also be advantageously configured for use in an impregnation method that uses only suction for impregnation. Such application of the example embodiments can be used in conjunction with interconnection of pores and cavities beneath tiles. Impregnation using suction takes advantage of the fact that when air is sucked out from one part of a tiled surface, air is sucked in at other parts of the surface. Therefore, by flooding a floor surface and thereafter applying only suction progressively at all locations of the floor, impregnation may be effectively achieved. Such application of the example embodiments may be effective for filling cavities in base grout and may ensure that the cavities are completely filled. It will be appreciated that for this type of impregnation, example embodiments having a single compartment can be sufficient.

The example embodiments described above may be used to repair leaks in tiled floors and walls as well as porous and cracked surfaces. In addition, the example embodiments may be used in other applications for impregnating a fluid into a porous medium in-situ such as applying coatings to a surface. The example embodiments may also be used as a quality control measure to check leak conditions prior to and after leak repair or other applications. Furthermore, the example embodiments may allow for mobility and impregnation operations may be carried out smoothly without causing any damage to surfaces. The example embodiments may allow the impregnation operations

to be carried out speedily since no surface preparation, such as drying of surfaces, drilling holes for bolting, application of bonding aids or vacuum grease, etc., is needed.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. An apparatus for impregnating a fluid into a medium, the apparatus comprising,

one or more main compartments each having an open face for enclosing respective portions of a surface of the medium when a rim of said each compartment contacts the surface of the medium;

securing means for securing the main compartments with the rims of the respective compartments contacting the surface of the medium; and

one or more conduits in fluid communication with each main compartment.

2. The apparatus as claimed in claim 1, the apparatus further comprising a sealing assembly disposed at a contact surface of the respective rims wherein when the main compartments are secured to the surface of the medium, the sealing assembly provides a substantially air-tight seal between the rims and the surface of the medium.

3. The apparatus as claimed in claim 2, wherein the sealing member assembly comprises

a gasket;

one or more retaining plates connected to the gasket and movably connected to the main compartments.

4. The apparatus as claimed in any one of claims 1 to 3, wherein the securing means comprises one or more auxiliary compartments connected to the main compartments, each auxiliary compartment having an open face to enclose respective portions of the surface of the medium, one or more conduits in fluid communication with each auxiliary compartment, and wherein the auxiliary compartments secure the main compartments to the surface of the medium using suction applied to the auxiliary compartments.

5. The apparatus as claimed in any one of claims 1 to 4, wherein the securing means comprises a securing assembly for mechanically securing the main compartments to the surface of the medium.

6. The apparatus as claimed in claim 5, wherein the securing assembly comprises:

an anchor member connected to the main compartments for insertion into a cavity of the medium; and

a fastening member connected to the anchor member for frictionally securing the anchor member from movement relative to the cavity such that the main compartments are secured to the surface of the medium.

7. The apparatus as claimed in claim 5, wherein the surface of the medium comprises a protruding element, and the securing assembly comprises a fastening assembly for fastening the main compartments to the protruding element such that the main compartments are secured to the surface of the medium.

8. The apparatus as claimed in any one of claims 1 to 7, the apparatus further comprising a pressure/suction pump connected to one or more of the conduits.

9. The apparatus as claimed in any one of claims 1 to 8, the apparatus further comprising a fluid tank connected to one or more of the conduits in fluid communication with the main compartments for channeling the fluid to and from the main compartments.

10. A method of impregnating a fluid into a medium, the method comprising using an apparatus as claimed in any one of claims 1 to 9.

11. A method of impregnating a fluid into a medium, the method comprising the steps of:

enclosing respective portions of a surface of the medium using one or more main compartments, each main compartment having an open face with a rim of said each compartment contacting the surface of the medium;

securing the main compartments with the rims of the respective compartments contacting the surface of the medium; and

channeling the fluid via one or more conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

12. The method as claimed in claim 11, wherein the step of securing the main compartments comprises connecting one or more auxiliary compartments to the main compartments, each auxiliary compartment having an open face to enclose respective portions of the surface of the medium, providing one or more conduits in fluid communication with each auxiliary compartment, and wherein securing the main compartments to the surface of the medium using the auxiliary compartments by applying suction to the auxiliary compartments.

13. The method as claimed in claim 12, further comprising the steps of:

applying suction to the main compartments and the auxiliary compartments via the conduits in fluid communication with the respective compartments;

channeling the fluid via the one or more conduits in fluid communication with each main compartment into the main compartments while maintaining suction to the main compartments and the auxiliary compartments;

stopping the application of suction to the main compartments and the channeling of the fluid when a desired fluid level is reached in each main compartment; and

applying pressure to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium while maintaining suction to the auxiliary compartments.

14. The method as claimed in any one of claims 11 to 13, wherein the step of securing the main compartments comprises mechanically securing the main compartments to the surface of the medium using a securing assembly.

15. The method as claimed in claim 14, wherein the mechanically securing comprises:

inserting an anchor member connected to the main compartments into a cavity of the medium; and

frictionally securing the anchor member from movement relative to the cavity such that the main compartments are secured to the surface of the medium.

16. The method as claimed in claim 14, wherein the mechanically securing comprises fastening the main compartments to a protruding element of the surface of the medium such that the main compartments are secured to the surface of the medium.

17. The method as claimed in any one of claims 14 to 16, further comprising the steps of:

channeling the fluid via the one or more conduits in fluid communication with each main compartment into the main compartments;

stopping the channeling of the fluid when a desired fluid level is reached in each main compartment; and

applying pressure to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

18. A method of impregnating a fluid into a medium, the method comprising the steps of:

flooding a surface of the medium with the fluid;

enclosing respective portions of the surface of the medium using one or more main compartments, each main compartment having an open face with a rim of said each compartment contacting the surface of the medium;

applying suction to the main compartments via the conduits in fluid communication with each main compartment for impregnation of the fluid into the medium.

19. The method as claimed in any one of claims 11 to 18, further comprising connecting a pressure/suction pump to one or more of the conduits.

20. The method as claimed in any one of claims 11 to 19, further comprising connecting a fluid tank one or more of the conduits in fluid communication with the main compartments for channeling the fluid to and from the main compartments.

21. A method of leakage testing of a medium, the method comprising the steps of:

enclosing a surface of the medium using a main compartment, the main compartment having an open face with a rim of said compartment contacting the surface of the medium;

channeling a fluid via one or more conduits in fluid communication with the main compartment; and

applying suction to the main compartment via the conduits in fluid communication with the main compartment for the leakage testing.