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(54) WATER CONTAINMENT SYSTEM COMPRISING A HYDROPHILIC COMPOSITE

WASSERBEHÄLTERSYSTEM ENTHALTEND EINEN HYDROPHILEN VERBUNDSTOFF

SYSTÈME DE RÉTENTION D'EAU COMPORTANT UN COMPOSITE HYDROPHILE

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Description

[0001] This invention relates to water management systems that contain a hydrophilic composite component.

[0002] Precipitation that collects on the roofs of buildings or other structures, or on other large horizontal surfaces such as roadways and parking structures, is frequently discharged into local sewer systems. This can put a strain on the sewer system or even overwhelm its capacity, particularly when there is a heavy rainfall or rapid melting of snow or ice. This can result in flooding, discharge of untreated runoff and other problems.

[0003] In response to these problems, it has been proposed to capture some or all of this water so the water either is not sent into the sewer system at all or else can be discharged more gradually, over a prolonged period of time.

[0004] Accordingly, so-called "blue" and "green" roofing structures are being developed. "Blue" roofing structures include ponding mechanisms, which capture and hold the water, allowing it to be released at a controlled rate over time. "Green" roofing structures capture the water and provide at least some of it to a vegetation layer in which living plants are cultivated. The vegetation uses the water in metabolic processes and in addition dissipates water back to the atmosphere through transpiration. Both blue and green roofing systems also usually include mechanisms for controlled discharge of water in excess of what the vegetation can use or in excess of the storage capacity of the system.

[0005] The captured water is often immobilized; having large quantities of standing water on the top of a building structure is normally not wanted. Furthermore, the upper surface of the roof structure should be weight-bearing to tolerate foot traffic (for repairs and maintenance, for example), the weight of building mechanicals such as HVAC, power and other systems, recreational decks, supporting structure and equipment and, in the case of green roofs, the weight of the soil, its containers and the vegetation.

[0006] Hydrophilic foams have been proposed for use in immobilizing captured water. These foams act as "sponges" to absorb and hold the water. In a blue roofing system, the hydrophilic foam forms a continuous or discontinuous layer in all or part of the roofing structure. Because the foams are soft and compressible, it is common to construct a hard, weight-bearing layer directly or indirectly on top of the hydrophilic foam, so the roof structure can bear weight without damaging the foam layer. In green roofing systems, the hydrophilic foam layer is again typically located beneath other roofing structures that may include such a weight-bearing layer as well as the upper vegetation layer.

[0007] When the hydrophilic foam layer is buried, it must bear the weight of the overlying structures. Therefore, the foam is often in some state of compression. Like many spongy materials, hydrophilic foams that have been proposed for use as such a hydrophilic foam layer tend to release water when placed under a compressive force. This reduces its water-holding capacity.

[0008] What is desired is a hydrophilic polyurethane foam and a construction layer material that exhibits a high water-holding capacity and retains a large proportion of that water-holding capacity even when under a compressive force. It is further desired to provide a multilayer structure that is capable of absorbing water in one or more of its layers and holding that absorbed water even while such layer is under compression, and to provide a water management system that includes such a multilayer structure.

[0009] US 2015/0167254 Al discloses to an artificial turf for use in residential and commercial lawns.

[0010] Disclosed herein in one aspect is a composite structure comprising: (a) a three-dimensional random loop (3DL) structure comprising a plurality of random loops of a thermoplastic polymer arranged and bonded together in a three-dimensional orientation and defining spaces within the 3DL structure; and (b) a hydrophilic polyurethane foam that occupies substantially all of the spaces within the 3DL structure.

[0011] In a second aspect, disclosed herein is a method of making a composite structure by carrying out the steps of:

(I) forming a reaction mixture comprising i) at least one polyisocyanate, ii) water, iii) a foam-stabilizing surfactant and iv) optionally one or more at least difunctional isocyanate-reactive materials different from water, wherein the reaction mixture contains 30 to 75% by weight oxyethylene units based on the combined weight of components i) and iv),
(II) impregnating a 3DL structure with the reaction mixture, the 3DL structure comprising a plurality of random loops of a thermoplastic polymer arranged and bonded together in a three-dimensional orientation and defining spaces within the 3DL structure; and
(III) curing the reaction mixture such that the reaction mixture expands and cures to form a hydrophilic polyurethane foam that occupies substantially all of the spaces within the 3DL structure.

[0012] Also disclosed are a single- or multilayer mat, wherein the mat includes at least one layer of a composite structure of the first aspect disclosed and/or made in accordance with the method disclosed in the second aspect.

[0013] The present invention is set out in the appended claims. The invention is a water containment system comprising a composite structure of the disclosure. The water containment system may, for example, a blue roof, a green roof, a blue-green roof, or a system for capturing and containing rainwater falling upon and/or running off of other structures such as a parking lot, a parking garage, a tarmac, a roadway, a bridge and the like.
The water containment system of the invention comprises at least one water barrier layer, at least one layer of a composite

structure of the disclosure, directly or indirectly on top of at least a portion of the water barrier layer, and at least one top surface layer positioned directly or indirectly on top of at least a portion of the composite structure layer, the water containment system comprising means for draining water deposited upon the top surface layer to the composite structure layer.

[0014] The 3DL material comprises thermoplastic polymer fibers that are formed into random loops. The randomly looped fibers are arranged in a three-dimensional orientation and bonded together at contact points to form a three-dimensional structure. Methods for making such a 3DL material are described in US Patent No. 5,639,543, US Patent No. 6,378,150, US Patent No. 7,625,629 and WO 2016/130602. In such processes, a thermoplastic resin is extruded downward through multiple orifices arranged in a three-dimensional array (which may be regular, irregular and/or random) to form multiple fibers. When under little or no tension, the extruded fibers will spontaneously curl to form random loop structures. Contacting the random loop structures and cooling them causes adjacent loop structures to bond to each other at the contact points, forming the 3DL material.

[0015] The 3DL material preferably has an apparent bulk density of at least 0.005 to 0.2 g/cm^3, 0.016 to 0.1 g/cm^3 or 0.016 to 0.05 g/cm^3. The fibers that make up the random loops may have a denier of, for example, 100 to 5000, 200 to 3000, or 300 to 3000. The loops may have diameters of 0.1 to 3 mm, 0.25 to 1.6 mm or 0.4 to 1.6 mm.

[0016] The 3DL material is made of a thermoplastic organic polymer. The thermoplastic polymer can be any that does not melt, dissolve or degrade under the conditions of curing the reaction mixture to form the hydrophilic polyurethane foam. The thermoplastic polymer may be elastomeric (which for purposes of this invention exhibits an elongation to break of at least 50% and when elongated to at least 50% of its original length recovers its original dimensions), non-elastomeric or a combination of one or more elastomeric and one or more non-elastomeric polymers.

[0017] Examples of suitable thermoplastic polymers include polyesters such as polyethylene terephthalate, polyethylene naphthalate, polycyclohexylenendimethylene terephthalate, polycyclohexylenedimethylene naphthalate, polybutylene terephthalate, polybutylene naphthalate, polycaprolactone, glycol/adipate polyesters, glycol succinate polyesters, glycol maleate polyesters, and the like. Other suitable thermoplastic polymers include polyurethanes and polyamides such as polycaprolactam, polyhexamethylene adipamide, polyhexamethylene sebacamide and the like.

[0018] Other suitable thermoplastic polymers include olefin polymers and copolymers. Among these are low density polyethylene; linear low density polyethylene; high density polyethylene; ethylene-α-olefin interpolymers, including those described in US Patent No. 7,622,179 and WO 2016/130602; ethylene-acrylic acid copolymers and polypropylene.

[0019] Other thermoplastic polymers that can be processed into the 3DL structure are also useful.

[0020] The hydrophilic polyurethane foam is characterized in having a water holding capacity of at least 150 g/2.54 cm thickness as measured according to the method described below. The hydrophilic polyurethane foam preferably contains from 30 to 75% by weight oxyethylene units, based on the total weight of the foam. It preferably has a foam density of 16 to 144 kg/m^3, preferably 20 to 80 kg/m^3 and more preferably 20 to 64 kg/m^3, as measured according to ASTM D3574.

[0021] Composite structures for the system of the invention can be made in a process that includes the steps of:

(I) forming a reaction mixture comprising i) at least one polyisocyanate, ii) water, iii) a foam-stabilizing surfactant and iv) optionally one or more at least difunctional isocyanate-reactive materials different from water, wherein the reaction mixture contains 30 to 75% by weight oxyethylene units based on the combined weight of components i) and iv),
(II) contacting the reaction mixture with a 3DL material to impregnate the 3DL structure with the reaction mixture; and
(III) curing the reaction mixture such that the reaction mixture expands and cures to form a hydrophilic polyurethane foam that occupies substantially all of the spaces within the 3DL structure.

[0022] At least one of components i) and iv) (if present) of the reaction mixture contains oxyethylene groups. Oxyethylene groups constitute at least 30 weight-% and may constitute at least 40 weight-%, at least 45 weight-%, at least 50 weight-% or at least 55 weight-% of the combined weight of components i) and iv). Oxyethylene groups constitute up to 75 weight-% of the combined weights of component i) and iv) and may constitute up to 70 weight-%, up to 65 weight-% or up to 60 weight-% thereof.

[0023] The polyisocyanate in some embodiments includes an isocyanate-terminated prepolymer which is a reaction product of an excess of one or more polyisocyanates having an equivalent weight of 350 or less (as measured by titration methods) with a hydroxyl-containing polymer of ethylene oxide. The polyisocyanate in such a case may have an isocyanate content of, for example, at least 1 weight-%, at least 3 weight-%, or at least 5 weight-% and, for example, up to 20 weight-%, up to 15 weight-%. The polyisocyanate in such a case may be a quasi-prepolymer which is a mixture of the prepolymer and unreacted starting polyisocyanate.

[0024] The polyisocyanate used to make such a prepolymer may be any of those described below.

[0025] The hydroxyl-terminated polymer of ethylene oxide may be a homopolymer of ethylene oxide or hydroxyl-terminated random or block copolymer of ethylene oxide and 1,2-propylene oxide. The hydroxyl-terminated polymer of ethylene oxide may have an average oxyethylene content of at least 50% (in the case of a copolymer) or up to 100% (in the case of an ethylene oxide homopolymer) based on the weight of the hydroxyl-terminated polymer. The oxyethylene oxide content of an ethylene oxide polymer or mixture is 100% times the weight ratio oxyethylene (-O-CH_2-CH_2-) units in the polymer or mixture to the total weight of the polymer or mixture.

[0026] In particular embodiments, the oxyethylene content of the ethylene oxide polymer or mixture may be, for example, at least 92% or at least 94% by weight and may be up to 100%, up to 99%, up to 98% or up to 97%. The average equivalent weight of the ethylene oxide polymer may be, for example, at least 350, at least 400 or at least 450 and in some embodiments may be up to 3000, up to 2000, up to 1500, up to 1200, up to 1000 or up to 750. Equivalent weight is determined by measuring the hydroxyl number in mg KOH/g of polymer using well-known titration numbers and calculating the equivalent weight from the hydroxyl number according to the relationship equivalent weight = 56,100 ÷ hydroxyl number. The average nominal hydroxyl functionality of the ethylene oxide polymer may be at least 2.0 or at least 2.1 and may be, for example, up to 3.0, up to 2.7, up to 2.5, up to 2.4 or up to 2.3.

[0027] The polyisocyanate may be or include one or more polyisocyanates that have isocyanate equivalent weights of up to 200. These may be aromatic, aliphatic and/or cycloaliphatic polyisocyanates. Specific examples of useful polyisocyanates having molecular weights of 200 or lower include m-phenylene diisocyanate, toluene-2,4-diisocyanate, toluene-2,6-diisocyanate, naphthylene-1,5-diisocyanate, methoxyphenyl-2,4-diisocyanate, diphenylmethane-4,4'-diisocyanate, diphenylmethane-2,4'-diisocyanate, 4,4'-biphenylene diisocyanate, 3,3'-dimethoxy-4,4'-biphenyl diisocyanate, 3,3'-dimethyl-4-4'-biphenyl diisocyanate, 3,3'-dimethyldiphenyl methane-4,4'-diisocyanate, 4,4',4"-triphenyl methane triisocyanate, polymethylene polyphenylisocyanate (PMDI), toluene-2,4,6-triisocyanate, 4,4'-dimethyldiphenylmethane-2,2',5,5'-tetraisocyanatecyclohexane diisocyanate, 1,3- and/or 1,4-bis(isocyanatomethyl)cyclohexane, 1-methyl-cyclohexane-2,4-diisocyanate, 1-methylcyclohexane-2,6-diisocyanate, methylene dicyclohexane diisocyanate, isophorone diisocyanate and hexamethylene diisocyanate. Modified polyisocyanates that contain urethane, urea, biuret, carbodiimide, uretoneimine, allophonate or other groups formed by reaction of an isocyanate group are also useful. A preferred aromatic polyisocyanate is MDI or PMDI (or a mixture thereof that is commonly referred to as "polymeric MDI"), and so-called "liquid MDI" products that are mixtures of MDI and MDI derivatives that have biuret, carbodiimide, uretoneimine and/or allophonate linkages.

[0028] The reaction mixture contains at least one foam-stabilizing surfactant. The foam-stabilizing surfactant helps stabilize gas bubbles formed during the foaming process until the polymer has cured. A wide variety of silicone surfactants as are commonly used in making polyurethane foams can be used in making composites of this invention. Surfactants that are self-dispersible or soluble in water are preferred. Examples of such silicone surfactants are commercially available under the trade names Tegostab™ (Th. Goldschmidt and Co.), Niax™ (GE OSi Silicones) and Dabco™ (Air Products and Chemicals). Other useful surfactants include block copolymers of ethylene oxide and propylene oxide and/or butylene oxide wherein the poly(ethylene oxide) block or blocks constitute 35 to 75% of the total weight of the block copolymer. Such block copolymers may have one or more hydroxyl groups. The surfactant(s) may be present in an amount of 0.25 to 5 or 0.5 to 2.5 parts by weight per 100 parts by weight of the reaction mixture.

[0029] Component iv) of the reaction mixture is optional except in cases in which the polyisocyanate does not contain oxyethylene units or does not contain enough oxyethylene units. In that case, component iv) is required and will include at least one ethylene oxide polymer as described above, in an amount such that oxyethylene units constitute 30 to 75 weight-% of the combined weight of components i) and iv).

[0030] Alternatively or in addition to such an ethylene oxide polymer, component iv) may include one or more other at least difunctional isocyanate-reactive materials such as polyols, polyamines and aminoalcohols that contain less than 50% by weight oxyethylene units. Examples of such other isocyanate-reactive materials include chain extenders, crosslinkers, polyether polyols containing less than 50% by weight oxyethylene units, amine-terminated polyethers containing less than 50% oxyethylene units, polyester polyols and the like. If such additional isocyanate-reactive materials are present, they preferably are present in minor amounts, such as up to 25%, preferably up to 10%, of the total combined weight of the water and component iv). The additional isocyanate-reactive materials may be absent.

[0031] The reaction mixture may contain a catalyst for the reaction of isocyanate groups toward water and/or hydroxyl groups. Suitable catalysts include, for example, tertiary amines, cyclic amidines, tertiary phosphines, various metal chelates, acid metal salts, strong bases, various metal alcoholates and phenolates and metal salts of organic acids. Examples of metal-containing catalysts are tin, bismuth, cobalt and zinc salts. Catalysts of most importance are tertiary amine catalysts, cyclic amidines, zinc catalysts and tin catalysts. Examples of tertiary amine catalysts include trimethylamine, triethylamine, N-methylmorpholine, N-ethylmorpholine, N,N-dimethylbenzylamine, N,N-dimethylethanolamine, N,N,N',N'-tetramethyl-1,4-butanediamine, N,N-dimethylpiperazine, 1,4-diazobicyclo-2,2,2-octane, bis(dimethylaminoethyl)ether, triethylenediamine and dimethylalkylamines where the alkyl group contains 4 to 18 carbon atoms. Mixtures of these tertiary amine catalysts are often used.

[0032] A reactive amine catalyst such as DMEA (dimethylethanolamine) or DMAPA (dimethylaminopropyl amine), or an amine-initiated polyol, acting as an autocatalytic polyol, may also be used.

[0033] Tin catalysts include stannic chloride, stannous chloride, stannous octoate, stannous oleate, dimethyltin dilaurate, dibutyltin dilaurate, tin ricinoleate and other tin compounds of the formula $SnR_n(OR)_{4-n}$, wherein R is alkyl or aryl and n is 0 to 4, and the like. Zinc and tin catalysts are generally used in conjunction with one or more tertiary amine catalysts, if used at all.

[0034] Catalysts are typically used in small amounts, for example, each catalyst being employed from about 0.0015 to about 5 or 0.1 to 0.5 parts by weight per 100 parts by weight of the quasi-prepolymer, if present at all. The catalyst may be omitted.

[0035] The reaction mixture also may contain various liquid functional ingredients such as colorants, fungicides, insecticides, pigments, selective herbicides, and the like. If present, these preferably constitute up to 10% or up to 5% of the total weight of the reaction mixture.

[0036] The proportions of ingredients are selected to provide an isocyanate index of 0.5 to 150. Isocyanate index is 100 times the ratio of isocyanate groups to isocyanate-reactive groups provided to the reaction mixture (prior to any reaction), with water being considered as having two isocyanate-reactive groups. The isocyanate index may be 0.5 to 50, 0.5 to 25, 1 to 20 or 1 to 15, for example.

[0037] The water index in the reaction mixture may be, for example, at least 25 or at least 50. In some embodiments, an excess of water is present, and in such embodiments the water index may be at least 400, at least 500 or at least 650 and may be, for example, up to 20,000, up to 15,000, up to 12,000, up to 10,000, up to 5,000, up to 2500, up to 1000, up to 500 or up to 100. Water index is 100 times the ratio of equivalents of water to the equivalents of isocyanate groups provided to the reaction mixture (prior to any reaction).

[0038] The surfactant(s) are conveniently combined with the water before the water and polyisocyanate are combined to form the reaction mixture. Alternatively, the surfactant(s) can be combined with the other ingredients at the same time the water and polyisocyanate are combined. The surfactant(s) may be combined with a portion of the water before being combined with the remainder of the water and the polyisocyanate.

[0039] The 3DL structure is impregnated with the reaction mixture. By "impregnated" it is meant that the reaction mixture is incorporated into at least a portion of the spaces defined by the loops of the 3DL structure, such that when the reaction mixture cures and expands the resulting foam occupies substantially all such spaces within the 3DL structure. The foam may occupy at least 90%, at least 95%, at least 98%, at least 99% or even 100% of such spaces within the 3DL structure.

[0040] The impregnation step can be performed in various ways. The 3DL structure may be disposed within a mold, trough or other confined region. The reaction mixture is then poured, sprayed or otherwise introduced into the region containing the 3DL structure, the reaction mixture penetrating into the openings of the 3DL structure where it expands and cures to form the foam. If desired, the 3DL structure can be compressed after being contacted with the reaction mixture to wet out internal surfaces of the 3DL structure before the reaction expands and cures.

[0041] Curing typically occurs spontaneously upon mixing the water with the polyisocyanate, and so a broad range of conditions is suitable for performing the reaction. The curing temperature may be as low as 0°C or as high as, for example, 100°C. Temperatures near room temperature or slightly elevated temperature are entirely suitable and generally preferred. Thus, the curing temperature may be at least 15°C or at least 20°C and up to 50°C, 40°C or 35°C. The curing reaction produces carbon dioxide gas that forms cells and expands the reaction mixture as the curing takes place.

[0042] The curing step may be performed in a confined region such as a mold or trough as described before, which confines the expansion of the reaction mixture such that it expands and cures within the open spaces of the 3DL structure. The cured foam may envelope the 3DL structure, i.e., cover the exterior surfaces thereof.

[0043] The curing step can be performed by dispensing the reaction mixture onto a belt or moving substrate that carries the 3DL structure, gauged to a desired thickness and cured on the belt or on the substrate to form a mat or rollstock.

[0044] In cases in which the amount of water in the reaction mixture is in excess of the amount of isocyanate groups of the polyisocyanate, the cured foam often contains a significant amount of moisture that may be at least partially in the form of a liquid contained in the cells of the foam. A drying step may be performed to remove some or all of this excess water.

[0045] Such a drying step can be performed, for example, by passing a dry gas through the foam, by allowing the foam to sit under a dry atmosphere, and/or by heating the foam to a temperature of, for example, 50 to 150°C. Drying can be performed until any desirable moisture content is achieved. In some embodiments, drying is performed until a constant foam weight is achieved, indicating the removal of residual water from the foam.

[0046] The hydrophilic polyurethane foam may constitute, for example, at least 25% or at least 50% of the combined weight of hydrophilic polyurethane foam and 3DL structure. The foam may constitute, for example, up to 90%, up to 80% up to 75% or up to 70% thereof.

[0047] The composite structure of the disclosure may have a density of, for example, 40 to 288 kg/m^3, as measured according to ASTM D3574. In general, the density of the composite structure may be somewhat higher than that of the hydrophilic polyurethane foam by itself. In some embodiments, the density of the composite structure is 48 to 160 kg/m^3 or 48 to 128 kg/m^3.

[0048] The composite structure of the disclosure absorbs water, generally in amounts as described above with regard to the hydrophilic polyurethane foam by itself. The presence of the embedded 3DL structure has little effect on water absorption.

[0049] The hydrophilic polyurethane foam absorbs water. The foam preferably exhibits a water holding of at least 150 g water/2.54 cm thickness when measured on a 10.16 cm $\times$ 10.16 cm $\times$ 2.54 cm-thick foam sample. The foam may exhibit a water holding of at least 165 g water/2.54 cm thickness or at least 180 g water/2.54 cm thickness.

[0050] The foam preferably exhibits a swelling of at most 150%, preferably at most 125%, when saturated with water, as measured in accordance with the method described in the examples below.

[0051] Water holding and swelling each are measured by drying a rectilinear foam sample (approximately 4 inch × 4 inch × 1 inch thick, (10.16 cm × 10.16 cm × 2.54 cm) at 100°C until a constant weight is obtained (at least 15 hours), and measuring the dimensions and weight of the dried foam. The foam is then submerged in water for at least 12 hours at 22 ±3°C, removed and allowed to sit over a grate or drain for 2 hours at 22±3°C to allow excess water to drain. The samples are then re-weighed and their dimensions re-measured. Swelling is calculated as 100% times the volume gained (volume of the wetted and drained sample minus the volume of the dried sample), divided by the volume of the dried sample.

[0052] Water holding is calculated as a function of sample thickness as:

$$\text{Water Holding (g/in)} = (\text{Weight}_{2hr,dry} - \text{Weight}_{dry}) \div \text{Thickness}_{2hr,dry}$$

wherein $\text{Weight}_{2hr,dry}$ is the weight of the sample after being submerged and drained for 2 hours, Weight_{dry} is the weight of the dried sample before submersion, and $\text{Thickness}_{2hr,dry}$ is the thickness of the sample after being submerged and drained for 2 hours.

[0053] An advantage of the hydrophilic foam used in the system of the invention is its ability to retain absorbed water even when subjected to a compressive force. This characteristic is highly beneficial when the foam is used as a component of a water containment system, in which the foam bears the weight of one or more layers or other structures that are positioned above the foam. Preferably, the foam retains at least 90%, more preferably at least 95% of absorbed water when under an applied compressive force of 75 lb/ft^2 (3.591 kPa), when measured according to the water holding measurement method. The foam in some embodiments retains at least 75% of absorbed water when under an applied compressive force of 150 lb/ft^2 (7.182 kPa).

[0054] Water retention is measured in the same general manner as water holding. After weighing and measuring the submerged and drained sample, the sample is placed under successive loads for 3 minutes. After each loading is applied and removed, the weight of the foam is measured, with weight loss being attributed to the loss of water due to the compression of the foam. The water retention at any given compressive force is calculated as a percentage of the water weight of the submerged and drained foam, which in turn is equal to $\text{Weight}_{2hr,dry}$- Weight_{dry}.

[0055] Because of this ability to hold absorbed water even when under compressive force, the composite structure of the disclosure has particular benefit when used as a component of a water containment system. In such a water containment system, water entering the system is transferred by, for example, draining, pumping or otherwise, to the composite structure, where it is absorbed and retained. The water is reversibly absorbed and can be removed from the composite structure through various mechanisms such as under the force of gravity; wicking through other layers and/or components of the containment system; drying; and the like.

[0056] A water containment system of the invention may be, for example, a blue roof, a green roof, a blue-green roof, or a system for capturing and containing precipitation falling upon and/or running off of other structures such as a parking lot, a parking garage, a tarmac, a roadway, a bridge and the like.

[0057] The water containment system comprises the composite structure of the disclosure in the form of one or more layers contained within the water containment system. If in the form of a layer, the composite structure may have a thickness, for example, of at least 10 mm, at least 25 mm or at least 50 mm and, for example, up to 1 meter or more, up to 250 cm, up to 100 cm, up to 50 cm or up to 25 cm.

[0058] The water containment system includes at least one top surface layer positioned directly or indirectly on top of at least a portion of the composite structure. The top surface layer, as in the case of outdoor structures such as buildings, parking lots, roadways etc., may be open to the atmosphere such that precipitation (rain, hail, sleet and snow, for example) falls onto it. The composite structure may directly or indirectly bear some or all of the weight of the top surface layer and/or any intermediate layers as may be present.

[0059] The composition and structure of the top surface layer will of course be selected in accordance with the function of the particular installation. The top surface layer may be, for example, a walkway or roadway. Such a walkway or roadway may be constructed of, for example, concrete, reinforced concrete, stone, ceramic tile, macadam, polymer concrete, steel, aluminum, other metal, wood or other suitable material.

[0060] The top surface layer may be a vegetation layer. Such a vegetation layer will include at least a soil layer, and may contain one or more containers for holding the soil as well as the vegetation itself (at least during the growing season). The soil layer and/or its container may reside directly atop the composite structure of the disclosure. Alternatively, one or more additional layers or structures may reside between the top surface layer and the layer of the composite structure. These may include various structural layers, such as supports for the top layer, or other structural or functional features.

[0061] The water containment system comprises means for draining water falling upon the top surface layer to the composite structure of the disclosure. In some embodiments, such means includes pores or other openings in those layers, so that the water penetrates through the layer(s) to the composite structure below. When the water containment system forms all or part of a green roof system, for example, water may drain from the top vegetation layer by percolating through the soil and soil container, if any, to the underlying composite structure. In other embodiments, such means may include drains or other openings, optionally coupled to one or more conduits, through which the water may flow down to the composite structure.

[0062] The water containment system further comprises at least one water barrier layer directly or indirectly underneath the composite structure to capture water that permeates from the composite structure and prevent it from permeating farther downward to the underlying structure. In a green or blue roof, for example, this water barrier material may be, for example, the roof membrane itself or other barrier layer.

[0063] The Figure illustrates an embodiment of a water containment system of the invention. Water containment system 9 includes, generally, support structure 1; optional insulation/root barrier structure 2; water barrier layer 3; drainage layer 4; filter or separation fabric 5; growth medium layer 6 and vegetation layer 7. The composite structure of the disclosure forms all or a portion of drainage layer 4.

[0064] Support structure 1 is a load-bearing layer that supports the overlying structures. It can be of concrete, reinforced concrete, wood or other building material that is capable of bearing the superimposed weight. It may be, for example, a roof, a paved area, the ground or other underlying structure that bears the weight of the other elements.

[0065] Optional insulation/root barrier structure 2, when present, serves to prevent water from passing downward to support structure 1 and/or to prevent roots from plants growing in vegetation layer 7 from penetrating to and into support structure 1. In the illustrative embodiment shown, insulation/root barrier structure 2 includes waterproof membrane 2A and board insulation layer 2B. Waterproof membrane 2A is generally a thermoplastic rubber such as thermoplastic olefin, ethylene-propylene-diene terpolymer and polyvinylchloride. Board insulation layer 2B may be, for example, a foamed rigid polymer board such as foamed polystyrene, foamed polyurethane, foamed polyisocyanurate and the like.

[0066] Water barrier layer 3 may be, for example, a waterproof membrane as describe with respect to waterproof membrane 2A.

[0067] In the illustrative embodiment shown, drainage system 4 includes layer 4A of a geotextile, *i.e.*, a semi-porous fabric whose function is to facilitate flow of water into one or more drainage means (not shown) through which water can be removed from the water containment system into a sewer or other system. The drainage means may include any drain or other conduit system through which water passing through drainage system 4 is removed from the water containment system. It may consists of drains, pipes, troughs or other fluid conduits, as well as associated flow management devices such as plugs, values, pumps, flow control systems and the like.

[0068] The geotextile may be, for example, an American Association of State Highway and Transportation Officials Class 1 or Class 2 geotextile. An example of a suitable geotextile is a polypropylene fabric weighing from 50 to 500 g/m^2 such as is available commercially as Optigreen Separation Fabric. Layer 4A is optional and its function can be performed by the composite structure 4B. For example, composite structure 4B can be produced with one or more channels on its bottom surface, which channels form pathways through which water can flow toward the drainage means and be removed from the water containment system.

[0069] In the illustrative embodiment shown, drainage system 4 further includes porous fabric 4C and mechanical reservoir system 4D, each of which is optional and each of which can be replaced by composite structure 4B. Mechanical reservoir system 4D may be, for example, a dimpled sheet or fabric, in which water is collected in the dimples. Such a dimpled sheet is sometimes referred to as an "egg carton" structure, and may be engineered with openings through which excess water can flow to lower layers when the dimples have been filled.

[0070] Thus, drainage system 4 may consist solely of composite structure 4B, or may comprise composite structure 4B with any one or more of layers 4A, 4C and 4D, as well as other optional layers as may be desirable.

[0071] In the illustrative embodiment shown, layer 5 of water containment system 9 is a separation fabric that functions to prevent soil from washing down to lower layers while letting water pass. The separation fabric therefore is porous to water but has openings small enough to prevent soil from passing through. Separation fabric 5 may be a geotextile as described above, or other woven or non-woven fibrous material.

[0072] Layer 6 is a growth medium layer that includes organic matter and may include inorganic matter. Layer 6 preferably has moisture content at maximum holding capacity of at least 35% and a porosity at maximum water holding capacity of at least 6%, in each case as measured according to ASTM E2399.

[0073] The following examples are provided to illustrate the invention, but are not intended to limit the scope thereof. All parts and percentages are by weight unless otherwise indicated.

Example 1 and Comparative Samples A-B

[0074]

3DL A is an ethylene-α-olefin copolymer 3-dimensional loop structure having a density of 2 pounds per cubic foot (32

kg/m³). It is made according to the general method described in WO 2016/130602.
3DL B is an ethylene-α-olefin copolymer 3-dimensional loop structure having a density of 3 pounds per cubic foot (48 kg/m³). It is made according to the general method described in WO 2016/130602.
Foam Formulation A (FF-A) contains an isocyanate-terminated quasi-prepolymer, water and surfactants. The quasi-prepolymer contains 40% oxyethylene units and has an isocyanate content of about 7%. The water index is approximately 10,000.
Foam Formulation B (FF-B) contains an isocyanate-terminated quasi-prepolymer, water and surfactants. The quasi-prepolymer contains 63% oxyethylene units and has an isocyanate content of about 7%. The water index is approximately 10,000.
Foam Formulation C (FF-C) contains an isocyanate-terminated quasi-prepolymer, water and surfactants. The quasi-prepolymer contains 58% oxyethylene units and has an isocyanate content of about 10%. The water index is approximately 2,000.
Comparative Foams A-C and Foam Examples 1-6 are prepared by mixing the ingredients of the respective foam formulation to from a reaction mixture. The resulting reaction mixture in each case is poured into a 11.2 cm × 11.2 cm × 2.54 cm open mold and allowed to rise freely. For Examples 1-6, the mold contains either 3DL A or 3DL B, cut to fit the internal cavity of the mold, when the reaction mixture is poured into the mold. The 3DL material is held in place within the mold so it cannot rise with the rising foam formulation. The foam formulation rises and cures to form a foam that occupies the entire internal space of the 3DL material (when present) and fills the mold. After the foaming is complete the composite is allowed to rest for 10 minutes. The crown is removed to produce an 11.2 cm × 11.2 cm × 2.54 cm composite structure.

[0075] The composite structures are conditioned overnight at ambient temperature and humidity before performing property testing. Water holding, water retention and swelling are measured as described above. Results of the testing are as indicated in the following Tables 1-3.

Table 1-Composite Structures Made with Foam Formulation A

	Designation		
	Comp. A*	Ex. 1	Ex. 2
FF-A, parts by weight	100	67.4	60.2
3DL, type, parts by weight	None	A, 32.6	B, 39.8
Water holding (no applied pressure), g/2.54 cm thickness	227	182	164
Water retention, %, under applied pressures as follow:			
50 lb/ft² (2.394 kPa)	87	92	98
75 lb/ft² (3.591 kPa)	67	80	84
112.5 lb/ft² (5.387 kPa)	56	72	79
150 lb/ft² (7.182 kPa)	44	62	70
Total Swelling, %	153	62	47

Table 2-Composite Structures Made with Foam Formulation B

	Designation		
	Comp. B*	Ex. 3	Ex. 4
FF-B, parts by weight	100	70.1	60.7
3DL, type, parts by weight	None	A, 29.9	B, 39.3
Water holding (no applied pressure), g/2.54 cm thickness	192	160	156
Water retention, %, under applied pressures as follow:			
50 lb/ft² (2.394 kPa)	97	96	97
75 lb/ft² (3.591 kPa)	94	93	94
112.5 lb/ft² (5.387 kPa)	01	90	92
150 lb/ft² (7.182 kPa)	81	82	86

(continued)

	Designation		
	Comp. B*	Ex. 3	Ex. 4
Total Swelling, %	112	56	37

Table 3-Composite Structures Made with Foam Formulation C

	Designation		
	Comp. C*	Ex. 5	Ex. 6
FF-C, parts by weight	100	65.6	55.1
3DL, type, parts by weight	None	A, 34.4	B, 44.9
Water holding (no applied pressure), g/2.54 cm thickness	193	183	172
Water retention, %, under applied pressures as follow:			
50 lb/ft^2 (2.394 kPa)	87	86	91
75 lb/ft^2 (3.591 kPa)	57	69	77
112.5 lb/ft^2 (5.387 kPa)	46	53	69
150 lb/ft^2 (7.182 kPa)	36	45	56
Total Swelling, %	74	40	27

[0076] As the data in Tables 1-3 show, incorporating a 3DL structure into foams produced by any of Foam Formulations A-C has little effect on water holding. However, total swelling is reduced substantially with Examples 1-6, as compared to the corresponding comparative samples. Also, water holding under pressure is equal or improved in all instances, even when the foam formulation is adapted (as is Foam Formulation B) to have very good water holding power under pressure. The combination of initial water holding capacity, ability to hold the water under pressure and low swelling is highly beneficial and not obtained with any of the hydrophilic foams by themselves.

Claims

1. A water containment system (9) comprising

at least one water barrier layer (3),
at least one layer of a composite structure (4B) directly or indirectly on top of at least a portion of the water barrier layer (3), wherein the composite structure (4B) comprises: (a) a three-dimensional random loop (3DL) structure comprising a plurality of random loops of thermoplastic polymer fibers arranged and bonded together in a three-dimensional orientation and defining spaces within the 3DL structure; and (b) a hydrophilic polyurethane foam that occupies substantially all of the spaces in the 3DL structure;
and at least one top surface layer (6, 7) positioned directly or indirectly on top of at least a portion of the hydrophilic polyurethane foam;
the water containment system (9) comprising drainage means for draining water falling upon the top surface layer to the hydrophilic polyurethane foam;
and wherein the hydrophilic polyurethane foam is a reaction product of a reaction mixture comprising i) at least one polyisocyanate, ii) water, iii) a foam-stabilizing surfactant and iv) optionally one or more at least difunctional isocyanate-reactive materials different from water, wherein at least one of components i) and iv) contains oxyethylene units and the reaction mixture contains 30 to 75% by weight oxyethylene units based on the combined weight of components i) and iv).

2. The water containment system (9) of claim 1 wherein the top surface layer (6, 7) includes soil and vegetation layers and the drainage means include pores in the soil layer in fluid communication with the composite structure (4B).

3. The water containment system (9) of claim 1 or 2 wherein the hydrophilic polyurethane foam has one or more channels on a bottom surface, which channels form pathways through which water can flow and be removed from the water containment system (9).

4. The water containment system (9) of any of claims 1-3 further comprising a support structure (1) directly or indirectly below the water barrier layer (3).

5. The water containment system (9) of claim 4 wherein the support structure (1) is a roof structure.

6. The water containment system (9) of claim 1 further comprising a support structure (1), wherein the at least one water barrier layer (3) is directly or indirectly above at least a portion of the support structure (1), the water containment system (9) further comprising a separation fabric (5) directly or indirectly on top of at least a portion of the hydrophilic polyurethane foam and at least one top surface layer (6, 7) positioned directly or indirectly on top of at least a portion of the separation fabric (5).

7. The water containment system (9) of claim 6 wherein the hydrophilic polyurethane foam has one or more channels on a bottom surface, which channels form pathways through which water can flow and be removed from the water containment system (9).

Patentansprüche

1. Wasserrückhaltesystem (9), umfassend

mindestens eine Wasserbarriereschicht (3),
mindestens eine Schicht einer Verbundstruktur (4B) direkt oder indirekt auf mindestens einem Abschnitt der Wasserbarriereschicht (3), wobei die Verbundstruktur (4B) umfasst: (a) eine dreidimensionale Zufallsschleifenstruktur (3DL), umfassend eine Vielzahl von Zufallsschleifen aus thermoplastischen Polymerfasern, die in einer dreidimensionalen Orientierung angeordnet und miteinander verbunden sind und Räume innerhalb der 3DL-Struktur definieren; und (b) einen hydrophilen Polyurethanschaumstoff, der im Wesentlichen den gesamten Raum in der 3DL-Struktur einnimmt;
und mindestens eine obere Oberflächenschicht (6, 7), die direkt oder indirekt auf mindestens einem Abschnitt des hydrophilen Polyurethanschaumstoffs positioniert ist;
das Wasserrückhaltesystem (9) umfassend Abflussmittel zum Abfließenlassen von Wasser, das auf die obere Oberflächenschicht fällt, zu dem hydrophilen Polyurethanschaumstoff;
und wobei der hydrophile Polyurethanschaumstoff ein Reaktionsprodukt einer Reaktionsmischung ist, umfassend i) mindestens ein Polyisocyanat, ii) Wasser, iii) ein schaumstoffstabilisierendes Tensid und iv) optional ein oder mehrere mindestens difunktionelle, isocyanatreaktive Materialien, die sich von Wasser unterscheiden, wobei mindestens eine der Komponenten i) und iv) Oxyethyleneinheiten enthält und die Reaktionsmischung zu 30 bis 75 Gew.-% Oxyethyleneinheiten enthält, bezogen auf das kombinierte Gewicht der Komponenten i) und iv).

2. Wasserrückhaltesystem (9) nach Anspruch 1, wobei die obere Oberflächenschicht (6, 7) Erd- und Vegetationsschichten einschließt und die Abflussmittel Poren in der Erdschicht einschließen, die in Flüssigkeitskommunikation mit der Verbundstruktur (4B) stehen.

3. Wasserrückhaltesystem (9) nach Anspruch 1 oder 2, wobei der hydrophile Polyurethanschaumstoff einen oder mehrere Kanäle auf einer unteren Oberfläche aufweist, wobei die Kanäle Wege bilden, durch die Wasser fließen und aus dem Wasserrückhaltesystem (9) entfernt werden kann.

4. Wasserrückhaltesystem (9) nach einem der Ansprüche 1 bis 3, ferner umfassend eine Trägerstruktur (1) direkt oder indirekt unterhalb der Wasserbarriereschicht (3).

5. Wasserrückhaltesystem (9) nach Anspruch 4, wobei die Trägerstruktur (1) eine Dachstruktur ist.

6. Wasserrückhaltesystem (9) nach Anspruch 1, ferner umfassend eine Trägerstruktur (1), wobei sich die mindestens eine Wasserbarriereschicht (3) direkt oder indirekt über mindestens einem Abschnitt der Trägerstruktur (1) befindet, das Wasserrückhaltesystem (9) ferner umfassend ein Trenngewebe (5), das direkt oder indirekt auf mindestens einem Abschnitt des hydrophilen Polyurethanschaumstoffs ist, und mindestens eine obere Oberflächenschicht (6, 7), die direkt oder indirekt auf mindestens einem Abschnitt des Trenngewebes (5) positioniert ist.

7. Wasserrückhaltesystem (9) nach Anspruch 6, wobei der hydrophile Polyurethanschaumstoff einen oder mehrere Kanäle auf einer unteren Oberfläche aufweist, wobei die Kanäle Wege bilden, durch die Wasser fließen und aus dem Wasserrückhaltesystem (9) entfernt werden kann.

Revendications

1. Système de confinement d'eau (9) comprenant

au moins une couche de barrière d'eau (3),
au moins une couche d'une structure composite (4B) directement ou indirectement sur au moins une partie de la couche de barrière d'eau (3), dans lequel la structure composite (4B) comprend : (a) une structure tridimensionnelle à boucles aléatoires (3DL) comprenant une pluralité de boucles aléatoires de fibres de polymère thermoplastique disposées et liées entre elles dans une orientation tridimensionnelle et définissant des espaces à l'intérieur de la structure 3DL ; et (b) une mousse de polyuréthane hydrophile qui occupe la quasi-totalité des espaces de la structure 3DL ;
et au moins une couche de surface supérieure (6, 7) placée directement ou indirectement sur au moins une partie de la mousse de polyuréthane hydrophile ;
le système de confinement d'eau (9) comprenant des moyens de drainage pour évacuer l'eau tombant sur la couche de surface supérieure vers la mousse de polyuréthane hydrophile ;
et dans lequel la mousse de polyuréthane hydrophile est un produit de réaction d'un mélange réactionnel comprenant i) au moins un polyisocyanate, ii) de l'eau, iii) un agent de surface stabilisant la mousse et iv) éventuellement une ou plusieurs matières réactives à l'isocyanate au moins difonctionnelles différentes de l'eau, dans lequel au moins un des composants i) et iv) contient des unités d'oxyéthylène et le mélange réactionnel contient de 30 à 75 % en poids d'unités d'oxyéthylène sur la base du poids combiné des composants i) et iv).

2. Système de confinement d'eau (9) selon la revendication 1, dans lequel la couche de surface supérieure (6, 7) comporte des couches de sol et de végétation et les moyens de drainage comportent des pores dans la couche de sol en communication fluide avec la structure composite (4B).

3. Système de confinement d'eau (9) selon la revendication 1 ou 2, dans lequel la mousse de polyuréthane hydrophile a un ou plusieurs canaux sur une surface inférieure, lesquels canaux forment des voies à travers lesquelles l'eau peut s'écouler et être évacuée du système de confinement d'eau (9).

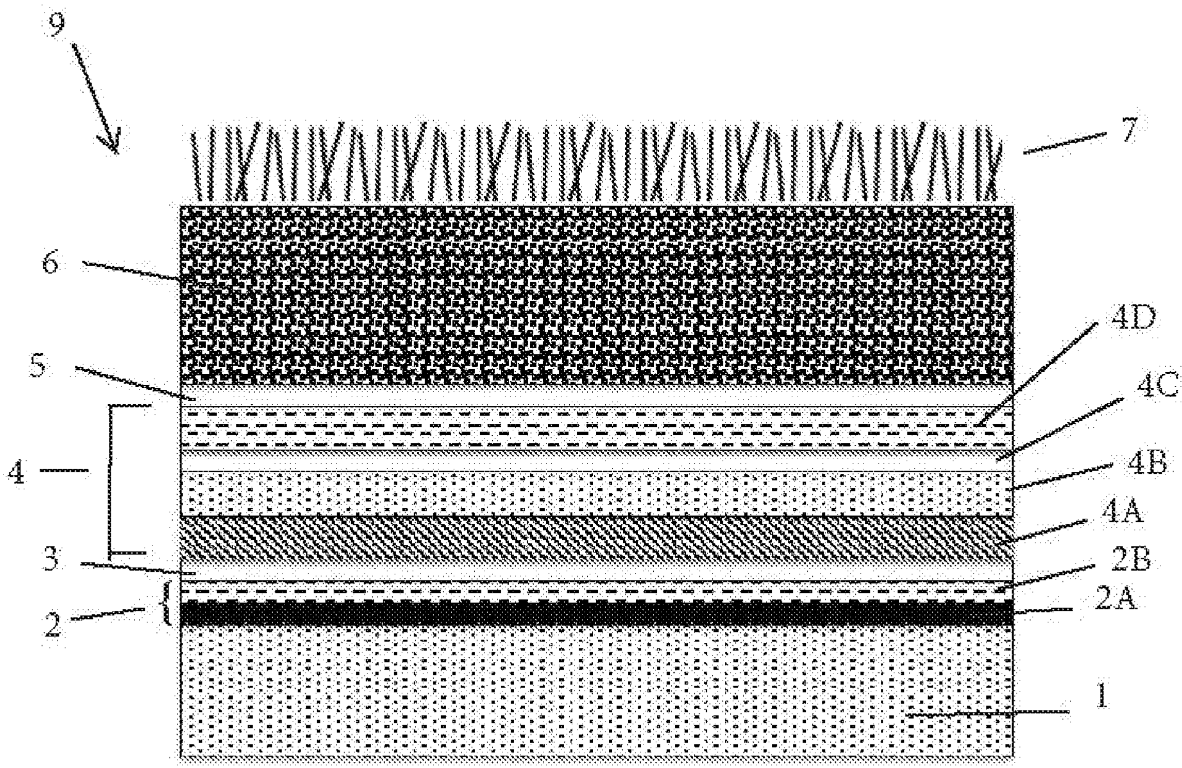
4. Système de confinement d'eau (9) selon l'une quelconque des revendications 1 à 3, comprenant en outre une structure de support (1) située directement ou indirectement sous la couche de barrière d'eau (3).

5. Système de confinement d'eau (9) selon la revendication 4, dans lequel la structure de support (1) est une structure de toit.

6. Système de confinement d'eau (9) selon la revendication 1, comprenant en outre une structure de support (1), dans lequel au moins une couche de barrière d'eau (3) est directement ou indirectement au-dessus d'au moins une partie de la structure de support (1), le système de confinement d'eau (9) comprenant en outre un tissu de séparation (5) directement ou indirectement au-dessus d'au moins une partie de la mousse de polyuréthane hydrophile et au moins une couche de surface supérieure (6, 7) positionnée directement ou indirectement au-dessus d'au moins une partie du tissu de séparation (5).

7. Système de confinement d'eau (9) selon la revendication 6, dans lequel la mousse de polyuréthane hydrophile a un ou plusieurs canaux sur une surface inférieure, lesquels canaux forment des voies à travers lesquelles l'eau peut s'écouler et être évacuée du système de confinement d'eau (9).

FIGURE



REFERENCES CITED IN THE DESCRIPTION

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