NONWOVEN CEMENTITIOUS COMPOSITE FOR IN-SITU HYDRATION

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 61/554,377, filed November 1, 2011, and U.S. Provisional Patent Application No. 61/703,618, filed September 20, 2012, which are incorporated herein by reference in their entirety.

BACKGROUND

[0002] The present Application relates to composite materials, including textile- and fiber-reinforced cementitious composites. Specifically, the present Application relates to a flexible pre-fabricated textile and fiber reinforced cementitious composite capable of in-situ hydration (i.e. in place, on location, on a construction site, etc.). In-situ hydration allows for a liquid to be topically applied and react with cementitious material while the composite is positioned without disturbing the pre-fabricated nature of the composite. Such a cementitious composite material allows cementitious material to set and harden within the composite without requiring traditional mixing procedures.

[0003] Traditional textile-reinforced composites typically include at least one layer of a two-dimensional textile and a layer of concrete to form a laminated composite. Such laminated composites may exhibit excellent in-plane properties but poor inter-laminar properties due to a lack of reinforcement in the thickness direction (i.e. a direction orthogonal to a planar surface of the composite) or weak bonding of the layers. This deficiency exposes the composite to damage or delamination when experiencing inter-laminar stresses. While traditional composites include plain weave fabrics or multiple layers of fabric to improve performance, these systems may still fail easily under loading.

[0004] Other cementitious composites include woven or knitted three-dimensional textiles configured to entrap cementitious material between two layers. Such woven or knitted three-dimensional textiles may not independently function to secure cementitious materials for in-situ hydration. These woven or knitted layers may need to be formed between other layers before they can entrap cementitious materials.

SUMMARY

[0005] One exemplary embodiment of the present disclosure relates to a cementitious composite material for in-situ hydration having a mesh layer including a first side, a second side, and a plurality of fibers arranged in a nonwoven configuration; a cementitious material having a plurality of cementitious particles disposed within the mesh layer; a sealing layer disposed along the first side of the mesh layer and coupled to the plurality of nonwoven fibers, and a containment layer disposed along the second side of the mesh layer and configured to prevent the plurality of cementitious particles from migrating out of the mesh layer.

reduction may be produced because the nonwoven fibers limit crack propagation by bridging crack faces within the cementitious phase.

[0030] Referring to the exemplary embodiment shown in FIG. 4, structure layer 40 includes a plurality of discontinuous fibers, shown as strands 42. As shown in FIG. 4, strands 42 are arranged in a nonwoven configuration (e.g., randomly distributed, systematically arranged, arranged in a specified pattern, distributed non-uniformly, etc.). Such a structure layer 40 may comprise a structurally independent material. Strands 42 may be coupled where they intersect, overlap, or otherwise interface with one another. According to an exemplary embodiment, structure layer 40 comprises a lofty, open mat material (e.g., a scouring pad manufactured from silicon carbide, aluminum oxide, nylon, etc.). Such open mat materials are discussed in U.S. Patent Nos. 2,958,593; 3,537,121; and 4,437,271, which are incorporated herein by reference in their entirety. According to an exemplary embodiment, the distances between non-overlapping strands 42 is between approximately half a micron and several millimeters.

[0031] As shown in FIG. 4, structure layer 40 includes an interstitial volume (e.g., open volume, void volume, etc.), shown as void 44 formed within structure layer 40 and defined by the interstitial volume between strands 42. According to an exemplary embodiment, void 44 represents between 80 and 99.8 percent by volume of structure layer 40. According to an alternative embodiment, void 44 represents between 95 and 99.8 percent by volume of structure layer 40. The volume of structure layer 40 that is comprised of void 44 impacts the density, weight, and other characteristics of structure layer 40 and nonwoven cementitious composite 10.

[0032] Referring still to the exemplary embodiment shown in FIG. 4, cementitious layer 30 is disposed within void 44 of structure layer 40. As shown in FIG. 4, cementitious layer 30 includes a plurality of constituents, shown as particles 32. According to an exemplary embodiment, cementitious layer 30 may be positioned within void 44 using physical vibration, compaction, or both vibration and compression, or another process. Additionally, the extent that cementitious layer 30 is compacted may impact the ability of water to flow through cementitious layer 30, the time required for hydration, setting, and hardening of cementitious layer 30, the strength of nonwoven cementitious composite 10, and the likelihood that cementitious material will migrate through permeable layer 20. It has been experimentally confirmed that a denser structure layer 40 may reduce the loss of cementitious layer 30 during the transportation and handling of the nonwoven cementitious composite.

[0033] According to an exemplary embodiment, structure layer 40 supports (i.e., holds, contains, reinforces, etc.) cementitious layer 30. By way of example, strands 42 of structure layer 40 may physically support cementitious layer 30 within void 44. Modifying the size, shape, or orientation of strands 42 that support cementitious layer 30 may improve the structural properties or hydration characteristics of nonwoven cementitious composite 10. By way of example, a slightly less open space (e.g., where void 44 is between 80 and 95 percent by volume of structure layer 40) with more densely arranged strands 42 may

without degrading after interacting with the cementitious material. As shown in FIG. 4, impermeable layer 50 is coupled along a side (e.g., a lower side) of structure layer 40. Where impermeable layer 50 is positioned along a lower side of structure layer 40, impermeable layer 50 may experience a portion of the flexural and tensile stresses. Such a position may improve the strength and ductility of nonwoven cementitious composite 10. In some embodiments, impermeable layer 50 is a sheet that comprises a flexible material (e.g., to facilitate rolling nonwoven cementitious composite 10) that is capable of being coupled with structure layer 40 without allowing a fluid to seep through. According to an alternative embodiment, impermeable layer 50 may be integrally formed with or otherwise coupled to structure layer 40. According to an alternative embodiment, impermeable layer 50 may protect cementitious layer 30 from exposure to certain chemicals (e.g., from sulfate introduced by soils in the field, etc.).

[0064] According to an alternative embodiment, impermeable layer 50 comprises a geomembrane. Such a geomembrane may comprise various materials (e.g., synthetic sheeting, single-ply membrane, another type of membrane used for waterproofing, etc.). According to an exemplary embodiment, the geomembrane comprises a polyolefin film having a thickness of between 0.075 and 2.5 millimeters. According to an exemplary embodiment, impermeable layer 50 comprises extruded polypropylene or a reinforced polypropylene that provides improved puncture resistance and tensile strength relative to other materials. Reinforced materials (e.g., externally reinforced with nonwoven polyester fabric, internally reinforced with polyester scrim, reinforced with a woven fabric, reinforced with a non-woven fabric, a geogrid, or otherwise reinforced) allow for the use of a thinner membrane thereby reducing the overall weight or thickness of nonwoven cementitious composite 10. Specific exemplary polypropylene films include TT422 and TG 4000 as manufactured by Colbond or UltraPly TPO XR 100 as manufactured by Firestone.

[0065] According to an alternative embodiment, impermeable layer 50 may comprise another material (e.g., bituminous geomembrane, ethylene propylene diene monomer, low-density polyethylene, high-density polyethylene, polyvinyl chloride, polyurea and polypropylene, etc.). The material selected for impermeable layer 50 may have characteristics that improve the pliability, installation procedures, lifespan, and performance of nonwoven cementitious composite 10. By way of example, polyvinyl chloride is flexible and may conform to uneven surfaces without tearing. According to an exemplary embodiment, a specific manufacturing technique, tensile strength, and ductility may be selected for impermeable layer 50 to best suit a particular application of nonwoven cementitious composite 10.

[0066] According to still another alternative embodiment, impermeable layer 50 may comprise a coating (e.g., elastomeric coatings, acrylic coatings, butyl rubber coatings, hypalon® coatings, neoprene® coatings, silicone coatings, modified asphalt coatings, acrylic lacquer coatings, urethane coatings, polyurethane coatings, polyurea coatings, one of various coatings approved for potable water, any combination of two or more coating materials, etc.) that may be applied through various known techniques (e.g., spraying, etc.).

composites 10 do not include flanges and are instead joined with mortar or an adhesive as shown in FIG. 10d or with stakes, as shown in FIGS. 11d-e.

[0087] According to an exemplary embodiment shown in FIGS. 12a-12e, the joined nonwoven cementitious composites 10 may have a gap, shown in FIG. 12a as space 200 formed above the interfacing flanges. As shown in FIG. 12b, the joint is reinforced by a nonwoven material, shown as structure layer 210 disposed within space 200. According to an exemplary embodiment, a portion of structure layer 210 may be coupled (e.g., adhesively secured, ultrasonically welded, melted, etc.) to the flanges of the adjacent nonwoven cementitious composites 10. According to an alternative embodiment, the joint may not include structure layer 210 or may include another type of reinforcing material.

[0088] As shown in FIG. 12c, cementitious material, shown as cementitious layer 220 is positioned within structure layer 210. According to an exemplary embodiment, cementitious layer 220 may comprise a cementitious mixture discussed above, a faster-setting cementitious material, a cementitious material having fibers at a higher volume fraction for increased toughness, or includes latex to improve the ductility of the joints. Such a cementitious layer 220 may be compacted (e.g., with a mobile compactor or physically compacted, etc.) within structure layer 210. According to an alternative embodiment, cementitious layer 220 may be positioned within space 200 without a structure layer 210.

[0089] In either embodiment, the manufacturer or operator may thereafter hydrate the cementitious layer to form a hydrated layer 230, as shown in FIG. 12d. Such hydration of cementitious layer 220 may occur after or with hydration of nonwoven cementitious composite 10. According to the exemplary embodiment, shown in FIG. 12e, a coating 240 is applied. Such a coating 240 may be applied after in-situ hydration, may provide a non-slip surface, may serve aesthetic purposes, or may serve another purpose. According to an alternative embodiment, a hydrophilic rubber waterstop is disposed within space 200. Such a sealant may include Adeka ultra seal MC-2010mn.

[0090] **Experimental Testing**

[0091] Applicants conducted several experiments during the development process of the subject matter disclosed in this Application. A first experiment evaluated various materials and configurations for the permeable layer, the structural layer, the cementitious layer, and the impermeable layer of the nonwoven cementitious composite. The materials tested for each layer during the various experiments are hereinafter discussed. The first experiment confirmed that the combination of the cementitious material and the nonwoven structure layer provide a composite material having an unexpectedly high strength relative to traditional cementitious composites. The experiment also provided various exemplary materials and mixtures for the various layers of the nonwoven cementitious composite.

[0092] A first portion of the first experiment tested various materials for the permeable layer using a constant mixture of cementitious material. Such materials included geotextile systems provided by Propex (NW 401, NW 601, and NW 801 nonwoven geotextiles and

NM 104-F woven geotextile), Nilex Civil Environmental Group (NW 1601 nonwoven geotextile, GT 4X4 HF, 200 ST, and 315 ST woven geotextile, C-125 erosion control blanket, and P-300 and P-550 erosion control turf), Innegra Technologies (2800d, Absecon 14343, Absecon 14430, and VEL 1200), a polypropylene woven textile, and a knitted textile.

[0093] The first portion involved assembling combinations of the products discussed above into various samples of cementitious composites. Cementitious material is traditionally mixed with a fluid (e.g., water) and thereafter deposited into a form, where the material sets into a rigid structure. The experiment first verified that the cementitious material underwent proper hydration, setting, and hardening without pre-mixing the cementitious material with water. Specifically, the first portion involved constructing samples using each of the permeable layer materials positioned over disks measuring three inches in diameter and 0.25 inches in depth. The disks were filled with dry cementitious material having the composition of Portland cement and sieved fine aggregates.

[0094] The dry cementitious material was compacted with a hydraulic press for five seconds. Immersion in water for twenty four hours allowed for various hydration observations including, among others, that cracking occurred within some of the cementitious materials from lack of reinforcement and that several samples were properly hydrated even without mixing or agitation. A control sample covered with an impermeable membrane showed no hydration.

[0095] A second portion of the experiment tested thirteen cementitious mixtures using a constant permeable layer. The samples were created in a manner discussed above. Such mixtures included the following materials: Portland cement (Type I/II), hydraulic cement having a setting time of approximately five minutes, expansion cement having a setting time of approximately fifteen minutes, patching mortar, fine sand, fly ash, fine bonded sand, gypsum, calcium chloride, superabsorbent polymer, dry accelerator, dry super plasticizer, and Qwix. The combinations tested and relevant observations of the samples are provided below as Table 1.

Table 1

Code	Description	Result
A-1	100% Fast setting mortar mix	Acceptable performance
A-2	100% Portland cement I/II (sieved through #100)	Acceptable performance
A-3	50% Portland cement + 50% fly ash (class F, high alumina)	Acceptable upon modification
A-4	50% Portland cement + 50% fine aggregates	Acceptable upon modification
A-5	50% Portland cement + 50% bonded (polymeric) sand	Acceptable, but not very advantagous
A-6	75% Portland cement + 25% super absorbent powder	Mixture absorbed air moisture and got wet
A-7	75% Portland cement + 25% super absorbent polymer	Mixture expanded as soon as water

the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another.

[0105] It should be noted that the orientation of various elements may differ according to other exemplary embodiments and that such variations are intended to be encompassed by the present disclosure.

[0106] It is important to note that the construction and arrangement of the elements of the systems and methods as shown in the exemplary embodiments are illustrative only. Although only a few embodiments of the present disclosure have been described in detail, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements. It should be noted that the elements and/or assemblies of the enclosure may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Additionally, in the subject description, the word "exemplary" may be used to mean serving as an example, instance or illustration. Any embodiment or design described herein as "exemplary" may be not necessarily to be construed as preferred or advantageous over other embodiments or designs. Rather, use of the word exemplary may be intended to present concepts in a concrete manner. Accordingly, all such modifications are intended to be included within the scope of the present inventions. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Any means-plus-function clause may be intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions, and arrangement of the preferred and other exemplary embodiments without departing from scope of the present disclosure or from the spirit of the appended claims.

What is Claimed is:

1. A cementitious composite material for in-situ hydration, the composite comprising:

a mesh layer having a first side and a second side and including a plurality of fibers arranged in a nonwoven configuration;

a cementitious material disposed within the mesh layer, wherein the cementitious material includes a plurality of cementitious particles;

a sealing layer disposed along the first side of the mesh layer and coupled to the plurality of nonwoven fibers; and

a containment layer disposed along the second side of the mesh layer and configured to prevent the plurality of cementitious particles from migrating out of the mesh layer.

2. The composite of Claim 1, wherein the volume within the mesh layer and between the plurality of nonwoven fibers defines an open space.

3. The composite of Claim 2, wherein the open space defines between 80.0 percent and 99.8 percent by volume of the mesh layer.

4. The composite of Claim 3, wherein the open space defines between 95.0 percent and 99.8 percent by volume of the mesh layer.

5. The composite of Claim 1, wherein the mesh layer includes a first mesh portion including a first plurality of fibers arranged in a nonwoven configuration and a second mesh portion including a second plurality of fibers arranged in a nonwoven configuration.

6. The composite of Claim 5, wherein the first mesh portion is at least one of stacked and intertwined with the second mesh portion.

7. The composite of Claim 6, wherein the second plurality of fibers are more densely arranged than the first plurality of fibers.

8. The composite of Claim 1, wherein the cementitious material includes 39-44 percent by weight cementitious particles, 47-52 percent by weight sand, less than 2 percent by weight calcium chloride, and 5.5-10.5 percent by weight Qwix.

9. The composite of Claim 1, wherein the cementitious material includes a plurality of microfibers having a nominal length of less than 0.1 millimeters and a diameter of less than 10 microns.

10. The composite of Claim 1, wherein the containment layer is at least one of a welded, adhesively secured, and melted onto the second side of the mesh layer.

11. The composite of Claim 10, wherein the containment layer comprises a polypropylene film having a thickness of between 0.075 millimeters and 2.5 millimeters.

12. The composite of Claim 1, wherein the containment layer defines a retaining surface and an aperture configured to facilitate a fluid flow into the cementitious material.

13. The composite of Claim 12, wherein the aperture has an area of between 0.001 millimeters squared and 3.0 millimeters squared.

14. The composite of Claim 12, wherein the containment layer defines a plurality of apertures at a frequency of between one and twelve thousand apertures per square inch.

15. The composite of Claim 1, wherein the plurality of nonwoven fibers are arranged such that the mesh layer has a thickness of between ten millimeters and fifty millimeters.

16. The composite of Claim 1, wherein the containment layer comprises a sheet configured to be removed before or after in-situ hydration.

17. The composite of Claim 1, wherein the impermeable layer is integrally formed with the structural layer.

18. A cementitious composite material for in-situ hydration, the composite comprising:

a mesh layer having a first side and a second side and including a plurality of fibers arranged in a nonwoven configuration intermediate the first side and the second side;

a cementitious material disposed within the mesh layer, wherein the cementitious material includes a plurality of cementitious particles;

a sealing layer disposed along the first side of the mesh layer and coupled to the plurality of nonwoven fibers; and

a coating disposed along the second side of the mesh layer and configured to prevent the plurality of cementitious particles from migrating out of the mesh layer.

19. The composite of Claim 18, wherein the coating defines a retaining surface and an aperture configured to facilitate a fluid flow into the cementitious material.

20. The composite of Claim 18, wherein the coating comprises an elastomeric coating having a thickness of between 0.07 millimeters and 2 millimeters.

21. The composite of Claim 18, wherein the coating includes an outer surface and a three dimensional void extending from the outer surface inward to the aperture.

22. The composite of Claim 21, wherein the three dimensional void is one of cone shaped and tetrahedral shaped.

23. A method for manufacturing a cementitious composite material, the method comprising:

providing a mesh layer having a first side and a second side and including a plurality of fibers arranged in a nonwoven configuration and disposed in at least one of a sheet and a roll, wherein the volume within the mesh layer and between the plurality of nonwoven fibers defines an open space;

providing a membrane coupled to the first side of the mesh layer;

disposing a cementitious material within the open space of the mesh layer; and

positioning a containment layer along the second side of the mesh layer.

24. The method of Claim 23, further comprising forming a perforation within the containment layer with at least one of a point, a pulsed laser, and an electron beam.

25. The method of Claim 23, further comprising spraying the containment layer onto the second side of the mesh layer.

26. The method of Claim 23, further comprising coupling the containment layer to the plurality of nonwoven fibers using at least one of an adhesive, a welding process, and a melting process.

27. The method of Claim 23, further comprising compacting the cementitious material within the mesh layer using at least one of a vibratory system, a compaction roller, and a press plate.

28. The method of Claim 23, further comprising joining two composite materials by coupling the first membrane to a layer of a second composite.

29. The method of Claim 27, further comprising coupling the first membrane to a flange of the second composite with one of an adhesive, a welding process, and a melting process.

30. The method of Claim 29, further comprising positioning a mesh layer between a layer of the first composite and a layer of the second composite.

NONWOVEN CEMENTITIOUS COMPOSITE FOR IN-SITU HYDRATION

BACKGROUND

[0002] The present Application relates to composite materials, including textile- and fiber-reinforced cementitious composites. Specifically, the present Application relates to a flexible pre-fabricated textile and fiber reinforced cementitious composite capable of in-situ hydration (i.e. in place, on location, on a construction site, etc.). In-situ hydration allows for a liquid to be topically applied and react with cementitious material while the composite is positioned without disturbing the pre-fabricated nature of the composite. Such a cementitious composite material allows cementitious material to set and harden within the composite without requiring traditional mixing procedures.

[0003] Traditional textile-reinforced composites typically include at least one layer of a two-dimensional textile and a layer of concrete to form a laminated composite. Such laminated composites may exhibit excellent in-plane properties but poor inter-laminar properties due to a lack of reinforcement in the thickness direction (i.e. a direction orthogonal to a planar surface of the composite) or weak bonding of the layers. This deficiency exposes the composite to damage or delamination when experiencing inter-laminar stresses. While traditional composites include plain weave fabrics or multiple layers of fabric to improve performance, these systems may still fail easily under loading.

[0004] Other cementitious composites include woven or knitted three-dimensional textiles configured to entrap cementitious material between two layers. Such woven or knitted three-dimensional textiles may not independently function to secure cementitious materials for in-situ hydration. These woven or knitted layers may need to be formed between other layers before they can entrap cementitious materials.

SUMMARY

[0005] One exemplary embodiment of the present disclosure relates to a cementitious composite material for in-situ hydration having a mesh layer including a first side, a second side, and a plurality of fibers arranged in a nonwoven configuration; a cementitious material having a plurality of cementitious particles disposed within the mesh layer; a sealing layer disposed along the first side of the mesh layer and coupled to the plurality of nonwoven fibers, and a containment layer disposed along the second side of the mesh layer and configured to prevent the plurality of cementitious particles from migrating out of the mesh layer.

reduction may be produced because the nonwoven fibers limit crack propagation by bridging crack faces within the cementitious phase.

[0030] Referring to the exemplary embodiment shown in FIG. 4, structure layer 40 includes a plurality of discontinuous fibers, shown as strands 42. As shown in FIG. 4, strands 42 are arranged in a nonwoven configuration (e.g., randomly distributed, systematically arranged, arranged in a specified pattern, distributed non-uniformly, etc.). Such a structure layer 40 may comprise a structurally independent material. Strands 42 may be coupled where they intersect, overlap, or otherwise interface with one another. According to an exemplary embodiment, structure layer 40 comprises a lofty, open mat material (e.g., a scouring pad manufactured from silicon carbide, aluminum oxide, nylon, etc.). Such open mat materials are discussed in U.S. Patent Nos. 2,958,593; 3,537,121; and 4,437,271. According to an exemplary embodiment, the distances between non-overlapping strands 42 is between approximately half a micron and several millimeters.

[0031] As shown in FIG. 4, structure layer 40 includes an interstitial volume (e.g., open volume, void volume, etc.), shown as void 44 formed within structure layer 40 and defined by the interstitial volume between strands 42. According to an exemplary embodiment, void 44 represents between 80 and 99.8 percent by volume of structure layer 40. According to an alternative embodiment, void 44 represents between 95 and 99.8 percent by volume of structure layer 40. The volume of structure layer 40 that is comprised of void 44 impacts the density, weight, and other characteristics of structure layer 40 and nonwoven cementitious composite 10.

[0032] Referring still to the exemplary embodiment shown in FIG. 4, cementitious layer 30 is disposed within void 44 of structure layer 40. As shown in FIG. 4, cementitious layer 30 includes a plurality of constituents, shown as particles 32. According to an exemplary embodiment, cementitious layer 30 may be positioned within void 44 using physical vibration, compaction, or both vibration and compression, or another process. Additionally, the extent that cementitious layer 30 is compacted may impact the ability of water to flow through cementitious layer 30, the time required for hydration, setting, and hardening of cementitious layer 30, the strength of nonwoven cementitious composite 10, and the likelihood that cementitious material will migrate through permeable layer 20. It has been experimentally confirmed that a denser structure layer 40 may reduce the loss of cementitious layer 30 during the transportation and handling of the nonwoven cementitious composite.

[0033] According to an exemplary embodiment, structure layer 40 supports (i.e., holds, contains, reinforces, etc.) cementitious layer 30. By way of example, strands 42 of structure layer 40 may physically support cementitious layer 30 within void 44. Modifying the size, shape, or orientation of strands 42 that support cementitious layer 30 may improve the structural properties or hydration characteristics of nonwoven cementitious composite 10. By way of example, a slightly less open space (e.g., where void 44 is between 80 and 95 percent by volume of structure layer 40) with more densely arranged strands 42 may

without degrading after interacting with the cementitious material. As shown in FIG. 4, impermeable layer 50 is coupled along a side (e.g., a lower side) of structure layer 40. Where impermeable layer 50 is positioned along a lower side of structure layer 40, impermeable layer 50 may experience a portion of the flexural and tensile stresses. Such a position may improve the strength and ductility of nonwoven cementitious composite 10. In some embodiments, impermeable layer 50 is a sheet that comprises a flexible material (e.g., to facilitate rolling nonwoven cementitious composite 10) that is capable of being coupled with structure layer 40 without allowing a fluid to seep through. According to an alternative embodiment, impermeable layer 50 may be integrally formed with or otherwise coupled to structure layer 40. According to an alternative embodiment, impermeable layer 50 may protect cementitious layer 30 from exposure to certain chemicals (e.g., from sulfate introduced by soils in the field, etc.).

[0064] According to an alternative embodiment, impermeable layer 50 comprises a geomembrane. Such a geomembrane may comprise various materials (e.g., synthetic sheeting, single-ply membrane, another type of membrane used for waterproofing, etc.). According to an exemplary embodiment, the geomembrane comprises a polyolefin film having a thickness of between 0.075 and 2.5 millimeters. According to an exemplary embodiment, impermeable layer 50 comprises extruded polypropylene or a reinforced polypropylene that provides improved puncture resistance and tensile strength relative to other materials. Reinforced materials (e.g., externally reinforced with nonwoven polyester fabric, internally reinforced with polyester scrim, reinforced with a woven fabric, reinforced with a non-woven fabric, a geogrid, or otherwise reinforced) allow for the use of a thinner membrane thereby reducing the overall weight or thickness of nonwoven cementitious composite 10. Specific exemplary polypropylene films include TT422 and TG 4000 as manufactured by Colbond (TM) or UltraPly (TM) TPO XR 100 as manufactured by Firestone (TM).

[0065] According to an alternative embodiment, impermeable layer 50 may comprise another material (e.g., bituminous geomembrane, ethylene propylene diene monomer, low-density polyethylene, high-density polyethylene, polyvinyl chloride, polyurea and polypropylene, etc.). The material selected for impermeable layer 50 may have characteristics that improve the pliability, installation procedures, lifespan, and performance of nonwoven cementitious composite 10. By way of example, polyvinyl chloride is flexible and may conform to uneven surfaces without tearing. According to an exemplary embodiment, a specific manufacturing technique, tensile strength, and ductility may be selected for impermeable layer 50 to best suit a particular application of nonwoven cementitious composite 10.

[0066] According to still another alternative embodiment, impermeable layer 50 may comprise a coating (e.g., elastomeric coatings, acrylic coatings, butyl rubber coatings, hypalon® coatings, neoprene® coatings, silicone coatings, modified asphalt coatings, acrylic lacquer coatings, urethane coatings, polyurethane coatings, polyurea coatings, one of various coatings approved for potable water, any combination of two or more coating materials, etc.) that may be applied through various known techniques (e.g., spraying, etc.).

composites 10 do not include flanges and are instead joined with mortar or an adhesive as shown in FIG. l0d or with stakes, as shown in FIGS. 11d-e.

[0087] According to an exemplary embodiment shown in FIGS. 12a-12e, the joined nonwoven cementitious composites 10 may have a gap, shown in FIG. 12a as space 200 formed above the interfacing flanges. As shown in FIG. 12b, the joint is reinforced by a nonwoven material, shown as structure layer 210 disposed within space 200. According to an exemplary embodiment, a portion of structure layer 210 may be coupled (e.g., adhesively secured, ultrasonically welded, melted, etc.) to the flanges of the adjacent nonwoven cementitious composites 10. According to an alternative embodiment, the joint may not include structure layer 210 or may include another type of reinforcing material.

[0088] As shown in FIG. 12c, cementitious material, shown as cementitious layer 220 is positioned within structure layer 210. According to an exemplary embodiment, cementitious layer 220 may comprise a cementitious mixture discussed above, a faster-setting cementitious material, a cementitious material having fibers at a higher volume fraction for increased toughness, or includes latex to improve the ductility of the joints. Such a cementitious layer 220 may be compacted (e.g., with a mobile compactor or physically compacted, etc.) within structure layer 210. According to an alternative embodiment, cementitious layer 220 may be positioned within space 200 without a structure layer 210.

[0089] In either embodiment, the manufacturer or operator may thereafter hydrate the cementitious layer to form a hydrated layer 230, as shown in FIG. 12d. Such hydration of cementitious layer 220 may occur after or with hydration of nonwoven cementitious composite 10. According to the exemplary embodiment, shown in FIG. 12e, a coating 240 is applied. Such a coating 240 may be applied after in-situ hydration, may provide a non-slip surface, may serve aesthetic purposes, or may serve another purpose. According to an alternative embodiment, a hydrophilic rubber waterstop is disposed within space 200. Such a sealant may include Adeka ultra seal MC-2010mn.

[0090] **Experimental Testing**

[0091] Applicants conducted several experiments during the development process of the subject matter disclosed in this Application. A first experiment evaluated various materials and configurations for the permeable layer, the structural layer, the cementitious layer, and the impermeable layer of the nonwoven cementitious composite. The materials tested for each layer during the various experiments are hereinafter discussed. The first experiment confirmed that the combination of the cementitious material and the nonwoven structure layer provide a composite material having an unexpectedly high strength relative to traditional cementitious composites. The experiment also provided various exemplary materials and mixtures for the various layers of the nonwoven cementitious composite.

[0092] A first portion of the first experiment tested various materials for the permeable layer using a constant mixture of cementitious material. Such materials included geotextile systems provided by Propex (TM) (NW 401, NW 601, and NW 801 nonwoven geotextiles and NM 104-F woven geotextile), Nilex Civil Environmental Group (NW 1601 nonwoven geotextile, GT 4X4 HF, 200 ST, and 315 ST woven geotextile, C-125 erosion control blanket, and P-300 and P-550 erosion control turf), Innegra Technologies (2800d, Absecon 14343, Absecon 14430, and VEL 1200), a polypropylene woven textile, and a knitted textile.

[0093] The first portion involved assembling combinations of the products discussed above into various samples of cementitious composites. Cementitious material is traditionally mixed with a fluid (e.g., water) and thereafter deposited into a form, where the material sets into a rigid structure. The experiment first verified that the cementitious material underwent proper hydration, setting, and hardening without pre -mixing the cementitious material with water. Specifically, the first portion involved constructing samples using each of the permeable layer materials positioned over disks measuring three inches in diameter and 0.25 inches in depth. The disks were filled with dry cementitious material having the composition of Portland cement and sieved fine aggregates.

[0094] The dry cementitious material was compacted with a hydraulic press for five seconds. Immersion in water for twenty four hours allowed for various hydration observations including, among others, that cracking occurred within some of the cementitious materials from lack of reinforcement and that several samples were properly hydrated even without mixing or agitation. A control sample covered with an impermeable membrane showed no hydration.

[0095] A second portion of the experiment tested thirteen cementitious mixtures using a constant permeable layer. The samples were created in a manner discussed above. Such mixtures included the following materials: Portland cement (Type I/II), hydraulic cement having a setting time of approximately five minutes, expansion cement having a setting time of approximately fifteen minutes, patching mortar, fine sand, fly ash, fine bonded sand, gypsum, calcium chloride, superabsorbent polymer, dry accelerator, dry super plasticizer, and Qwix. The combinations tested and relevant observations of the samples are provided below as Table 1.

Table 1

Code	Description	Result
A-1	100% Fast setting mortar mix	Acceptable performance
A-2	100% Portland cement I/II (sieved through #100)	Acceptable performance
A-3	50% Portland cement + 50% fly ash (class F, high alumina)	Acceptable upon modification
A-4	50% Portland cement + 50% fine aggregates	Acceptable upon modification
A-5	50% Portland cement + 50% bonded (polymeric) sand	Acceptable, but not very advantagous
A-6	75% Portland cement + 25% super absorbent powder	Mixture absorbed air moisture and got wet
A-7	75% Portland cement + 25% super absorbent polymer	Mixture expanded as soon as water

the two members or the two members and any additional intermediate members being integrally formed as a single unitary body with one another or with the two members or the two members and any additional intermediate members being attached to one another.

[0105] It should be noted that the orientation of various elements may differ according to other exemplary embodiments and that such variations are intended to be encompassed by the present disclosure.

[0106] It is important to note that the construction and arrangement of the elements of the systems and methods as shown in the exemplary embodiments are illustrative only. Although only a few embodiments of the present disclosure have been described in detail, those skilled in the art who review this disclosure will readily appreciate that many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.) without materially departing from the novel teachings and advantages of the subject matter recited. For example, elements shown as integrally formed may be constructed of multiple parts or elements. It should be noted that the elements and/or assemblies of the enclosure may be constructed from any of a wide variety of materials that provide sufficient strength or durability, in any of a wide variety of colors, textures, and combinations. Additionally, in the subject description, the word "exemplary" may be used to mean serving as an example, instance or illustration. Any embodiment or design described herein as "exemplary" may be not necessarily to be construed as preferred or advantageous over other embodiments or designs. Rather, use of the word exemplary may be intended to present concepts in a concrete manner.

CLAIMS

1. A cementitious composite material for in-situ hydration, the composite comprising: a mesh layer having a first side and a second side and including a plurality of fibers arranged in a nonwoven configuration;

a cementitious material disposed within the mesh layer, in which the cementitious material includes a plurality of cementitious particles;

a sealing layer disposed along the first side of the mesh layer and coupled to the plurality of nonwoven fibers; and

a containment layer disposed along the second side of the mesh layer and configured to prevent the plurality of cementitious particles from migrating out of the mesh layer.

2. A composite according to Claim 1, in which the volume within the mesh layer and between the plurality of nonwoven fibers defines an open space.

3. A composite according to Claim 2, in which the open space defines between 80.0 percent and 99.8 percent by volume of the mesh layer.

4. A composite according to Claim 3, in which the open space defines between 95.0 percent and 99.8 percent by volume of the mesh layer.

5. A composite according to Claim 1, in which the mesh layer includes a first mesh portion including a first plurality of fibers arranged in a nonwoven configuration and a second mesh portion including a second plurality of fibers arranged in a nonwoven configuration.

6. A composite according to Claim 5, in which the first mesh portion is at least one of stacked and intertwined with the second mesh portion.

7. A composite according to Claim 6, in which the second plurality of fibers are more densely arranged than the first plurality of fibers.

8. A composite according to Claim 1, in which the cementitious material includes 39-44 percent by weight cementitious particles, 47-52 percent by weight sand, less than 2 percent by weight calcium chloride, and 5.5-10.5 percent by weight high alumina clinker.

9. A composite according to Claim 1, in which the cementitious material includes a plurality of micro fibers having a nominal length of less than 0.1 millimeters and a diameter of less than 10 microns.

10. A composite according to Claim 1, in which the containment layer is at least one of a welded, adhesively secured, and melted onto the second side of the mesh layer.

11. A composite according to Claim 10, in which the containment layer comprises a polypropylene film having a thickness of between 0.075 millimeters and 2.5 millimeters.

12. A composite according to Claim 1, in which the containment layer defines a retaining surface and an aperture configured to facilitate a fluid flow into the cementitious material.

13. A composite according to Claim 12, in which the aperture has an area of between 0.001 millimeters squared and 3.0 millimeters squared.

14. A composite according to Claim 12, in which the containment layer defines a plurality of apertures at a frequency of between one and twelve thousand apertures per square inch.

15. A composite according to Claim 1, in which the plurality of nonwoven fibers are arranged such that the mesh layer has a thickness of between ten millimeters and fifty millimeters.

16. A composite according to Claim 1, in which the containment layer comprises a sheet configured to be removed before or after in-situ hydration.

17. A composite according to Claim 1, in which an impermeable layer is integrally formed with the structural layer.

18. A cementitious composite material for in-situ hydration, the composite comprising: a mesh layer having a first side and a second side and including a plurality of fibers arranged in a nonwoven configuration intermediate the first side and the second side;

a cementitious material disposed within the mesh layer, in which the cementitious material includes a plurality of cementitious particles;

a sealing layer disposed along the first side of the mesh layer and coupled to the plurality of nonwoven fibers; and a coating disposed along the second side of the mesh

layer and configured to prevent the plurality of cementitious particles from migrating out of the mesh layer.

19. A composite according to Claim 18, in which the coating defines a retaining surface and an aperture configured to facilitate a fluid flow into the cementitious material.

20. A composite according to Claim 18, in which the coating comprises an elastomeric coating having a thickness of between 0.07 millimeters and 2 millimeters.

21. A composite according to Claim 18, in which the coating includes an outer surface and a three dimensional void extending from the outer surface inward to the aperture.

22. A composite according to Claim 21, in which the three dimensional void is one of cone shaped and tetrahedral shaped.

23. A method for manufacturing a cementitious composite material, the method comprising:

providing a mesh layer having a first side and a second side and including a plurality of fibers arranged in a nonwoven configuration and disposed in at least one of a sheet and a roll, in which the volume within the mesh layer and between the plurality of nonwoven fibers defines an open space;

providing a membrane coupled to the first side of the mesh layer;

disposing a cementitious material within the open space of the mesh layer; and

positioning a containment layer along the second side of the mesh layer.

24. A method according to Claim 23, further comprising forming a perforation within the containment layer with at least one of a point, a pulsed laser, and an electron beam.

25. A method according to Claim 23, further comprising spraying the containment layer onto the second side of the mesh layer.

26. A method according to Claim 23, further comprising coupling the containment layer to the plurality of nonwoven fibers using at least one of an adhesive, a welding process, and a melting process.

27. A method according to Claim 23, further comprising compacting the cementitious material within the mesh layer using at least one of a vibratory system, a compaction roller, and a press plate.

28. A method according to Claim 23, further comprising joining two composite materials by coupling the first membrane to a layer of a second composite.

29. A method according to Claim 28, further comprising coupling the first membrane to a flange of the second composite with one of an adhesive, a welding process, and a melting process.

30. A method according to Claim 29, further comprising positioning a mesh layer between a layer of the first composite and a layer of the second composite.