

Technical Field

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elements. Unfortunately, the use of sealing compounds in these environments is also challenging. Sealing compounds often need a specific temperature and humidity to cure properly. Accordingly, a sealing compound that
5 is durable, structurally secure, and works in environments conducive to corrosion is needed.

Summary

In accordance with a first aspect of the disclosure,
10 there is provided a composite for sealing a substrate. The composite includes a primary carbon fiber layer having a first weave density and a secondary carbon fiber layer having a second weave density that is different from the first weave density of the primary carbon fiber layer. Both
15 primary and secondary carbon fiber layers may be encapsulated in a polymer matrix.

In another aspect, there is provided a polymerisable composition for sealing a substrate comprising a primary carbon fiber layer having a first weave density and a
20 secondary carbon fiber layer having a second weave density that is different from the first weave density of the primary carbon fiber layer and wherein both primary and secondary carbon fiber layers are encapsulated in a curable resin.

Advantageously, the composite and polymerizable
25 composition form a durable seal that is permanent, structurally sound and suitable for industrial use. The composite and polymerizable composition are capable of sealing even pinhole size gaps and defects in a substrate.
30 Furthermore, the composite and polymerizable composition resist corrosion even in environments with high humidity and temperature.

The composite and polymerizable composition may be used to replace (or substitute for) a substrate, such as a conduit, by coating the entire surface. Thus, even if the substrate erodes beneath the surface, the coating formed on the conduit will remain in place of the conduit. Rather than replace a conduit, such as a pipe, in its entirety (which requires removal of the pipe and installing a replacement), the composite and polymerizable composition provide a cost effective method of replacing the substrate. The composite and polymerizable composition are also a cost effective substitute for the sealants of the prior art.

In one embodiment, the composite and polymerizable composition comprises at least two different carbon fiber layers to construct an anticorrosive, durable, permanent sealant.

In another aspect of the disclosure, there is provided a method of sealing a substrate comprising applying a composite over the substrate to seal the substrate, the composite comprising a primary carbon fiber layer having a first weave density and a secondary carbon fiber layer having a second weave density that is different from the first weave density of the primary carbon fiber layer, and wherein both primary and secondary carbon fiber layers are encapsulated in a polymer matrix.

In one embodiment, the disclosed method of sealing a substrate uses a composite comprising at least a primary and secondary carbon fiber layer encapsulated in a polymer matrix.

Definitions

The following words and terms used herein shall have the meaning indicated:

The word "substantially" does not exclude "completely" e.g. a composition which is "substantially free" from Y may be completely free from Y. Where necessary, the word "substantially" may be omitted from the definition of the invention.

Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

As used herein, the term "about", in the context of concentrations of components of the formulations, typically means $\pm 5\%$ of the stated value, more typically $\pm 4\%$ of the stated value, more typically $\pm 3\%$ of the stated value, more typically, $\pm 2\%$ of the stated value, even more typically $\pm 1\%$ of the stated value, and even more typically $\pm 0.5\%$ of the stated value.

As used herein, the phrase "weave density" refers to the weight (in grams per meter squared) of a fiber layer.

As used herein, the "polymer matrix" means a polymer that forms a continuous phase and/or surrounds one or more materials or components.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically

disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

Disclosure of Optional Embodiments

Exemplary, non-limiting embodiments of a composite for sealing a substrate and a polymerizable composition will now be disclosed.

The substrate may be composed of materials selected from the group consisting of: plastic, fiberglass, concrete, ceramic, clay, metal, glass, and the like, and combinations thereof. Plastics may include, for example, polyvinyl chloride (PVC), polybutylene (PB), acrylonitrile butadiene styrene (ABS), polyethylene (PE), polypropylene (PP), fluoroplastics, polyacrylates, polycarbonates, polyesters, and the like, and combinations thereof. Metals may include, for example, lead, copper, steel, iron, brass, aluminium, titanium, and alloys and the like, and combinations thereof. In one embodiment, the substrate is steel.

In embodiments, the primary carbon fiber layer is innermost to the substrate relative to the secondary carbon fiber layer.

The primary carbon fiber layer may be a plain weave carbon fiber material. In embodiments, the primary carbon fiber layer may possess a first weave density in the range of 200g/m² to 400 g/m². In some embodiments, the first weave density may be 200 g/m².

In embodiments, the primary carbon fiber layer may have a thread count per centimetre of from five to 10 in both the warp and weft directions. In some embodiments, the

thread count per centimetre may be five in both the warp and weft directions. The primary carbon fiber layer may be, for example, KDL 8003 (SIGRATEx®). The higher thread count of the primary carbon fiber layer may allow for better conformation to the shape of the substrate and for forming a more impermeable seal.

The secondary carbon fiber layer may be a plain weave carbon fiber material. The secondary carbon fiber layer may have a second weave density. In embodiments, the second weave density may be in the range of 480 g/m² to 960 g/m². In some embodiments, the second carbon fiber layer may have a weave density of 480 g/m². The secondary carbon fiber layer may impart strength and durability due to the higher weight of the fiber.

In embodiments, the secondary carbon fiber layer may have thread count per centimetre in the range of three to four in both the warp and weft directions. In some embodiments, the secondary fiber layer may have a thread count per centimetre of three in both the warp and weft directions. The secondary carbon fiber layer may be, for example, KDL 8001 (SIGRATEx®).

The secondary carbon fiber layer may be alternated with the primary carbon fiber layer and/or layered on itself, i.e., one secondary carbon fiber layer on top of another secondary carbon fiber layer.

The polymer matrix and/or curable resin may be selected from the group consisting of: an elastomer modified epoxy vinyl ester resin, a novolac-based epoxy vinyl ester resin, a bisphenol-A epoxy vinyl ester resin and combinations thereof. In embodiments, the polymer matrix is a cured epoxy resin. In embodiments, the polymerisable composition has a curable resin selected from

the group consisting of: a novolac-based resin, a bisphenol-A resin, and an elastomer modified resin.

Examples of elastomer modified epoxy vinyl resins include EPON® (Momentive Specialty Chemicals), 20-3236 (EPOXIES), and DERAKANE® 8084 (ASHLAND®). Examples of novolac-based epoxy vinyl ester resins include, for example VIPEL® K095-AAA-00 (AOC) and DERAKANE® 470-300 (ASHLAND®). Examples of bisphenol-A epoxy vinyl ester resins include, for example VIPEL® F010 and DERAKANE® 411-350 (ASHLAND®).

In embodiments, the polymer matrix and curable resin include one or more of the elastomer modified epoxy vinyl ester resin, the novolac-based epoxy vinyl ester resin, and the bisphenol-A epoxy vinyl ester resin. In some embodiments, the polymer matrix and/or curable resin include an elastomer modified epoxy vinyl ester resin nearer (or innermost) to the substrate followed by a novolac-based epoxy vinyl ester resin.

In certain embodiments, the composite also includes a glass fiber. In embodiments, the polymerizable composition further includes a glass fiber. The glass fiber may be a fiberglass material selected from the group consisting of: a C-glass veil, a chopped strand mat E-glass, and the like. The glass fiber, in some embodiments, is innermost to the substrate relative to the primary carbon fiber layer. In some embodiments, the glass fiber is outermost to the substrate relative to the secondary carbon fiber layer.

In embodiments, the fiberglass is a C-glass veil. In embodiments, the C-glass veil may have a weight per meter squared that is preferably from about 25 to about 55 g/m², more preferably the C-glass is about 30 g/m².

In embodiments, the fiberglass material is an E-glass. Preferably, the E-glass is a chopped strand mat. In

embodiments, the E-glass material may have a weight per meter squared that is preferably from about 400 to about 500 g/m², more preferably the E-glass is about 450 g/m². In some embodiments one or more types of glass fiber may be used.

The composite and polymerizable composition may comprise at least one type of a glass fiber with the two different carbon fiber layers. In the case of a metal substrate, such as a steel pipe, layers of glass fiber material may be applied directly to the substrate before applying the carbon fiber layers thereon. Thus, the carbon fiber layer does not come into direct contact with the substrate, which would result in oxidation of the substrate, but is applied to the substrate over a glass fiber material to create strength and durability.

In some embodiments, the composite and/or polymerizable composition may further include putty selected from the group consisting of sealing putty, such as clay based putty, epoxy putty or a combination of these. In some embodiments, the putty includes a glass fiber, a viscosity enhancing agent, and a curable resin. In other embodiments, the putty may include, for example, a curable resin, a glass fiber, and viscosity enhancing agent.

In embodiments, the curable resin of the putty is a bisphenol-A epoxy resin. In embodiments, glass fiber material of the putty is a fiberglass chopped strand mat E-glass. In embodiments, the viscosity enhancing agent of the putty is silica. Preferably the silica is fumed silica, such as, for example AEROSIL® (AEROSIL).

In some embodiments, a wax may also be included in the composite and/or polymerizable composition of the disclosure. The wax may be any type of wax for example, a

natural wax such as animal, mineral, or vegetable wax, a synthetic wax such as a polyethylene wax, or a petroleum wax such as paraffin or microcrystalline wax and combinations of waxes. In embodiments, the wax selected
5 from the group consisting of: paraffin wax, polyethylene wax, and combinations of these. An example wax that may be used is BOSNY WAX® (RICHARD LONDON CHEMICAL INDUSTRIES CO., LTD.).

Exemplary, non-limiting embodiments of a method of
10 sealing a substrate will now be disclosed,

In embodiments, the applying step includes sealing and structuring. In embodiments, the sealing step includes sealing a glass fiber to the substrate. For example, a resin may be applied to the substrate, followed by one or
15 more layers of glass fiber and additional resin. In embodiments the resin is an elastomer modified epoxy vinyl ester resin. In some embodiments, the sealing layer includes both a C-glass veil glass fiber and a chopped strand mat E-glass fiber. In embodiments, a layer of C-
20 glass veil is applied followed by one or more layers of chopped strand mat E-glass fiber. In some embodiments, one layer of C-glass veil is applied followed by two layers of chopped strand mat E-glass fiber.

The structuring step may include alternating a primary
25 carbon fiber layer and a secondary carbon fiber layer on the substrate. In some embodiments, the structuring step includes alternating layers of the primary carbon fiber layer and the secondary carbon fiber layer on the substrate. The structuring step may include, for example
30 one or more primary carbon fiber layer(s) and one or more secondary carbon fiber layer(s) alternately applied. In embodiments, the structuring step includes a first primary

carbon fiber layer, a first secondary carbon fiber layer, a second primary carbon layer and a second secondary carbon fiber layer. The primary or secondary carbon fiber layers may be innermost relative to the substrate. In embodiments, the structuring step further includes applying the primary carbon fiber layer innermost relative to the substrate.

The secondary carbon fiber layers provide both strength and durability to the seal.

In some embodiments, the structuring step further includes applying at least one additional secondary carbon fiber layer as compared to the number of primary carbon fiber layers to the substrate. For example, after applying the alternating primary and secondary carbon fiber layers, one or more additional secondary carbon fiber layers may be applied. The number of additional secondary carbon fiber layers applied may range from three to eleven. In embodiments, the number of additional secondary carbon fiber layers applied is four, in some embodiments six, in other embodiments eight secondary carbon fiber layers are applied.

The substrate to which the sealant is applied may be cleaned prior to application of the sealant. The substrate may be cleaned using chemical, physical, or mechanical cleaning methods. In one embodiment, the cleaning method is sandblasting.

The substrate may be primed prior to sealing. Priming may include applying resin, a glass fiber material, and putty. In embodiments, priming includes applying an elastomer modified epoxy vinyl ester resin layer, a C-glass veil, and putty. In some embodiments, the sealing step may occur after priming and be followed by structuring. In

some embodiments, a top coat is applied. The top coat may include a resin containing a wax.

In some embodiments, a glass fiber is layered on top of the final secondary carbon fiber layer. In embodiments, the glass fiber is a C-glass veil. The top coat may include a novolac-based epoxy vinyl ester resin combined with a wax.

In embodiments, the structuring step includes offsetting the layers of primary carbon fiber and secondary carbon fiber on the substrate. Advantageously, this offset method of applying the layers is capable of providing a uniform thickness to the seal and prevent bulking or sagging of the seal. By offsetting and lapping the layers, maximum adhesion of the layers to the substrate and the layers to one another is achieved. Additionally, offsetting and lapping the layers prevents lumping or sagging of the composite at a given location. In embodiments where the substrate is a pipe, the layers are offset by 30°.

In embodiments, the substrate includes a first part and a second part with a conduit extending there between. In some embodiments, the substrate is a conduit.

In embodiments, the substrate may be a conduit. In some embodiments, the conduit may be a pipe, tube, duct, channel, penstock, trough, and the like. When the conduit is cylindrical, the diameter of the cylinder may be used to determine the needed thickness of the composite.

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Brief Description Of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1 is a plan view of a cleaned elbow joint including a primer layer;

Fig. 2 is a plan view of the elbow joint of Fig. 1, further including a putty layer;

Fig. 3 is a plan view of the elbow joint of Fig. 1, further including a layer of glass fiber material;

Fig. 4 is a plan view of the elbow joint of Fig. 1, further including all of the layers of the composite;

Fig. 5 is an alternate view of a pipe showing offset/lapped application of the layers.

Detailed Description of Drawings

Fig. 1 depicts an elbow joint 10 of a steel pipe as a substrate. The elbow joint 10, which includes two butt joints 12/14, is sandblasted and a layer of elastomer modified epoxy vinyl ester resin 16 is applied followed by a single layer of C-glass veil 18. The elastomer modified epoxy vinyl ester resin 16 and C-glass veil 18 are applied to the entire elbow joint 10 including both butt joints 12/14.

As shown in Fig. 2, putty 20 is then applied to the area of the substrate in need of sealing - in this case the butt joints 12/14 of the elbow joint 10. An additional layer of C-glass 22 is then applied only to the areas that

have received putty (Fig. 3). Fig. 4 depicts the C-glass veil 18, putty layer 20, second C-glass veil 22, two E-glass chopped strand mat 24/26, one primary carbon fiber layer 28, one secondary carbon fiber layer 30, a second
5 primary carbon fiber layer 32, followed by seven layers of secondary carbon fiber layer material 34, and a layer of C-glass veil 36. The C-glass veil 36 is covered by a top coat of resin and wax (not shown).

As depicted in Fig. 5, each layer 102 of the composite
10 surrounds the entire diameter of the pipe 100. Furthermore, each layer is applied offset 104 from the previous layer in order to provide a consistent diameter to the substrate each layer laps the previous layer by at least 100 millimetres.

15 Examples

Non-limiting examples of the invention will be further described in greater detail by reference to specific Examples, which should not be construed as in any way limiting the scope of the invention.

20 **Example 1: 30" Diameter 90° Elbow with Two 30" Butt Joints**

Two butt joints of an elbow of a 30" diameter steel pipe used for transporting sea water were repaired using the composite of the invention.

Cleaning

25 The elbow of the steel pipe was sand blasted with sharp edged form to remove oil, grease, rust and scale. All sand and dust were then removed from the surface of the pipe. The surface profile following sand blasting was 50 µm (determined using Press-O-Film (TESTEX)) and surface
30 roughness was achieved.

Each of the materials layered as discussed below was offset by 100 mm from the previous layer and the subsequent layer overlaps the previously applied layer by 30°.

5 Priming

A layer of DERA KANE® 8084 (ASHLAND®) elastomer modified epoxy vinyl ester resin was immediately applied to the surface of the elbow of the steel pipe followed by one layer of C-glass veil (30 g/m²) and the resin was allowed to
10 cure for one and one-half hours.

Next, putty was prepared as follows:

1000 grams DERA KANE® 411-350 (ASHLAND®) bisphenol-A epoxy vinyl ester resin;

one gram 6% cobalt naphthenate;

15 15 grams of chopped strand mat cut into pieces;

150 grams AEROSIL® (AEROSIL) fumed silica; and,

Two to three drops of dimethylaniline (DMA) were mixed until the 6% cobalt naphthenate was completely incorporated. Finally 12 millilitres of methylethylketone
20 peroxide (MEKP) was added to the mixture to form the putty.

The putty was applied to the step from the pipe surface up to the butt joint and at irregularities in the surface of the elbow joint. The putty was allowed to dry, sanded, and the surface of the elbow joint was cleaned to
25 remove dust and debris.

Sealing

A layer of C-glass veil (30 g/m²) was layered onto the puttied areas of the elbow joint.

The following layers were applied sequentially to the
30 elbow joint:

a layer of DERA KANE® 8084 (ASHLAND®) elastomer modified epoxy vinyl ester resin;

- a layer of chopped strand mat E-glass (450 g/m²);
a layer of DERA-KANE[®] 8084 (ASHLAND[®]) elastomer modified epoxy vinyl ester resin;
a layer of chopped strand mat E-glass (450 g/m²); and,
5 a layer of DERA-KANE[®] 8084 (ASHLAND[®]) elastomer modified epoxy vinyl ester resin.

The seal was allowed to cure for 24 hours.

Structuring

- The following layers were sequentially applied
10 following curing of the seal:
a primary carbon fiber layer (200 g/m²);
a layer of DERA-KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
15 a layer of DERA-KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a primary carbon fiber layer (200 g/m²);
a layer of DERA-KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
20 a secondary carbon fiber layer (480 g/m²); and
a layer of DERA-KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

These layers were allowed one and one-half hours to cure.

- 25 Next the following additionally secondary carbon fiber layers were applied:
a secondary carbon fiber layer (480 g/m²);
a layer of DERA-KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
30 a secondary carbon fiber layer (480 g/m²);
a layer of DERA-KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

- a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²); and
5 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

The layers were then allowed to cure for one and one-half hours.

- a secondary carbon fiber layer (480 g/m²);
10 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
15 a layer of C-glass veil (30 g/m²); and
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

Cure for one and one-half hours.

Top Coat

- 20 The following components were combined to form a top coat:
1000 grams DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
one gram 6% cobalt naphthenate;
25 two to three drops DMA; and
40 grams wax.

These components were mixed until the 6% cobalt naphthenate was thoroughly incorporated and then 12 millilitres of MEKP was added to the mixture.

- 30 One layer of top coat was then applied.

Example 2: Tee Joint including a 24" pipe and a 36" pipe

A tee joint including three junctures - two between the tee joint and a 36" pipe and one between the tee joint and a 24" pipe, used for transporting sea water were repaired using the composite and method of the invention.

The cleaning, priming, and sealing of the three junctures of the tee joint were prepared as in Example 1.

Structuring

The structural layer of the juncture of the tee joint and 24" pipe was prepared as follows:

The following layers were sequentially applied following curing of the seal:

a primary carbon fiber layer (200 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a primary carbon fiber layer (200 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²); and

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

These layers were allowed one and one-half hours to cure.

The following additionally secondary carbon fiber layers were sequentially applied:

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a layer of C-glass veil (30 g/m²); and

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

Cure for one and one-half hours.

Top Coat

One layer of top coat, prepared as in Example 1 was then applied to the structural layer.

Structuring

Structuring of the junctures of the tee joint and 36" pipe was as follows:

The following layers were sequentially applied following curing of the seal:

a primary carbon fiber layer (200 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a primary carbon fiber layer (200 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²); and

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

These layers were allowed one and one-half hours to cure.

a secondary carbon fiber layer (480 g/m²);

5 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

10 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²); and

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

15 The layers were then allowed to cure for one and one-half hours:

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

20 a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

25 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a layer of C-glass veil (30 g/m²); and

30 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

These layers were allowed to cure for one and one-half hours.

Top Coat

One layer of top coat, prepared as in Example 1 was
5 then applied to the structural layer.

Example 3: 18" Pipe with Butt Joint

A butt joint of an 18" pipe used for transporting sea water was repaired using the composite and method of the
10 invention.

The cleaning, priming, and sealing of the butt joint of the pipe was as in Example 1.

Structuring

Structuring of the juncture 18" pipes was as follows:

15 The following layers were sequentially applied following curing of the seal:

a primary carbon fiber layer (200 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

20 a secondary carbon fiber layer (480 g/m²);

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a primary carbon fiber layer (200 g/m²);

25 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²); and

a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

30 These layers were allowed one and one-half hours to cure.

The following additional secondary carbon fiber layers were sequentially applied:

- a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
5 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
10 a layer of C-glass veil (30 g/m²); and
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

These layers were allowed to cure for one and one-half hours.

15 Top Coat

One layer of top coat, prepared as in Example 1 was then applied.

Example 4: Tee Joint with two 48" pipes and one 18" pipe

- 20 A tee joint including three junctures - two between the tee joint and a 48" pipe and one between the tee joint and an 18" pipe, used for transporting sea water were repaired using the composite and method of the invention.

- The cleaning, priming, and sealing of the flange joint
25 of the pipe were prepared as in Example 1. Structuring and top coat for the 18" pipe was as described for the 18" pipe of Example 3.

Structuring

- Structuring of the 42" pipe butt. joints of the tee
30 joint was as follows:

The following layers were sequentially applied following curing of the seal:

a primary carbon fiber layer (200 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
5 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a primary carbon fiber layer (200 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
10 a secondary carbon fiber layer (480 g/m²); and
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

These layers were allowed one and one-half hours to cure.

15 The following additional secondary carbon fiber layers were sequentially applied:

a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

20 a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy
25 vinyl ester resin;

a secondary carbon fiber layer (480 g/m²); and
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

Cure for one and one-half hours.

30 a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;

a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
5 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²); and
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

10 Cure for one and one-half hours.

a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
15 a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
a secondary carbon fiber layer (480 g/m²);
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin;
20 a layer of C-glass veil (30 g/m²); and
a layer of DERA KANE[®] 470-300 (ASHLAND[®]) novolac-based epoxy vinyl ester resin.

Cure for one and one-half hours.

Top Coat

25 One layer of top coat, prepared as in Example 1 was then applied.

Applications

The composite of the invention is applicable to myriad
30 substrates for sealing the substrates. The composite may be used to seal leaks in a substrate, conduit joints, damaged or weakened areas of a substrate and the like.

The polymerizable composition of the invention is useful for sealing leaks, joints, damaged areas, and weakened areas of a substrate.

5 The method of the invention is suitable for industrial and commercial applications. Use of the method provides a sealed substrate.

10 It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

Claims

1. A composite for sealing a substrate comprising:
a primary carbon fiber layer having a first weave
density and a secondary carbon fiber layer having
a second weave density that is different from the
first weave density of the primary carbon fiber layer,
and wherein both primary and secondary carbon fiber
layers are encapsulated in a polymer matrix.
2. The composite according to claim 1, wherein the
primary carbon fiber layer is innermost to the
substrate relative to the secondary carbon fiber
layer.
3. The composite according to claims 1 or 2, wherein the
first weave density is in the range of 200 g/m² to 400
g/m².
4. The composite according to any one of claim 1 to 3,
wherein the second weave density is in the range of
480 g/m² to 960 g/m².
5. The composite according to any one of claims 1 to 4,
wherein the polymer matrix is a cured epoxy resin.
6. The composite according to any one of claims 1 to 5,
further comprising a glass fiber.
7. The composite according to claim 6, wherein the glass
fiber is innermost to the substrate relative to the
primary carbon fiber layer.

8. The composite according to any one of claims 6 or 7,
wherein the glass fiber is outermost to the substrate
relative to the secondary carbon fiber layer.

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9. A polymerisable composition for sealing a substrate
comprising a primary carbon fiber layer having a first
weave density and a secondary carbon fiber layer
having a second weave density that is different from
the first weave density of the primary carbon fiber
layer and wherein both primary and secondary carbon
fiber layers are encapsulated in a curable resin.

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10. The polymerisable composition according to claim 9,
wherein the curable resin is selected from the group
consisting of: a novolac-based resin, a bisphenol-A
resin, and an elastomer modified resin.

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11. The polymerizable composition according to any one of
claims 9 or 10, further comprising a glass fiber.

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12. The polymerizable composition according to any one of
claims 9 to 11, further comprising a putty.

13. The polymerizable composition according to claim 12,
wherein the putty comprises: a glass fiber, a
viscosity enhancing agent, and a curable resin.

25

14. The polymerizable composition according to any one of
claims 9 to 13, wherein the first weave density is in
the range of 200 g/m² to 400 g/m².

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15. The polymerizable composition according to any one of claims 9 to 14, wherein the second weave density is in the range of 480 g/m² to 960 g/m².

5 16. A method of sealing a substrate comprising applying a composite over the substrate to seal the substrate, the composite comprising a primary carbon fiber layer having a first weave density and a secondary carbon fiber layer having a second weave density that is
10 different from the first weave density of the primary carbon fiber layer, and wherein both primary and secondary carbon fiber layers are encapsulated in a polymer matrix.

15 17. The method according to claim 16, wherein the applying step comprises sealing and structuring.

18. The method according to claim 17, wherein the sealing step comprises sealing a glass fiber to the substrate.

20 19. The method according to any one of claims 16 or 17, wherein the structuring step comprises alternating layers of the primary carbon fiber layer and the secondary carbon fiber layer on the substrate.

25 20. The method according to any one of claims 16 to 19, wherein the structuring step further comprises applying at least 1 additional secondary carbon fiber layer as compared to the number of primary carbon
30 fiber layers to the substrate.

21. The method according to any one of claims 16 to 20,
wherein the structuring step comprises offsetting the
layers of primary carbon fiber and secondary carbon
fiber on the substrate.

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22. The method according to any one of claims 16 to 21,
wherein the structuring step further comprises
applying the primary carbon fiber layer innermost
relative to the substrate.

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23. The method according to any one of claims 16 to 22,
wherein the substrate comprises a first part and a
second part with a conduit extending there between.

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24. The method according to any one of claims 16 to 23,
wherein the substrate is a conduit.