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MBRACE APPLICATION GUIDELINES

MBrace Fabric

(INCL CARBON, ARAMID & GLASS)

Version : May 2009

0. General

This document forms a general guide for the application of the MBrace Fabric materials (or FRP sheet systems), including carbon, aramid and glass fibres. This application guideline refers to general principals to be applied to all three fibre types. Refer to a separate application guide for use of MBrace Laminate type FRP systems. It is to be read in conjunction with all associated project specifications (including drawings), by others, and the current material technical data sheets and material safety data sheets (MSDS).

1. General Conditions of Use – Summary of Conditions

- Handle with care: MBrace Fabric can be fragile if improperly handled. Manual handling should always be with protective gloves.

- Delivery: MBrace Fabric is normally delivered to site in rolls, which are wrapped in plastic and contained within cardboard boxes, loaded onto pallets.

- Storage: MBrace Fabric requires protection against heat, sun and weather. It must be stored on a solid, flat and dry surface, inside a ventilated shelter. If stored in the open, protect with opaque waterproof covers. Rolls must be stored only in the horizontal position.

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- Minimum Roll diameter: MBrace Fibre rolls are delivered with a specific roll diameter (150 mm in most cases). This specific diameter is the minimum diameter. In case of re-rolling, the minimum diameter must never be reduced.

- Unpacking of rolls: MBrace Fibre rolls may be delivered with a layer of plastic between successive layers of fibre. This shall be removed prior to bonding.

- Cutting: MBrace Fibre should be cut with good quality shears (scizzors), designed to cut cleanly through the fibre.

- Drilling: Do not drill through MBrace Fibre, otherwise the mechanical properties will be altered.

- Repairs: Any repairs to the substrate and surface preparation required, shall be done to the satisfaction of the specifying consulting engineer and BASF.

- Application Requirements: All work shall be carried out by adequately trained and skilled sub-contractors, under appropriate supervision.

- Safety: Always ensure the appropriate use of adequate PPE (gloves, goggles, long sleeves etc) and comply with all other safety related requirements when applying MBrace materials.

- Quality Systems: The applicator shall operate under a fully compliant quality system, to ensure the on-site quality of applied material. The applicator shall keep fully documented work records for all works undertaken.

- Quality Control: If after application and/or testing, any applied material is deemed as unsatisfactory by the specifying consulting engineer and/or BASF, it may need to be rectified at the applicator's cost.

- Weather: No product application work is to be carried out in temperatures below 5^0C or above 30^0C, unless special precautions are taken.

- Continuity of Process: The dry and/or wet-layup applications shall be done in continuous operations, including first primer coat, through to last saturant coat, without significant delay.

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Summary of Application steps required for MBrace Fibre System.

Sheet System

Apply MBrace Primer onto prepared concrete substrate

Level prepared concrete substrate with MBrace Putty / Levelling Mortar (optional)

Apply first coat of MBrace Saturant

Apply MBrace Fibre Reinfoircement

Apply second coat of MBrace Saturant

Apply MBrace Topcoat (optional)

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1. GENERAL PREPARATION FOR APPLICATION

The contract drawings show locations of FRP (Fibre Reinforced Polymer) reinforcement.

a) Ambient Temperature

Conditions of FRP process application must be examined carefully during the winter season and/or cold zones. DO NOT APPLY CFRP WHEN AMBIENT TEMPERATURES ARE LOWER THAN 5^0C. Auxiliary heat may be applied by a method approved in writing, to raise surface and air temperature to a suitable range. Similarly, when temperatures are in excess of 20^0C, care shall be taken with batch life of epoxies and special precautions may be necessary.

b) Condensation

Presence of moisture may inhibit adhesion of primer and/or resin. DO NOT APPLY FRP WHEN RAINFALL OR CONDENSATION IS ANTICIPATED.
The sub-contractor shall comply with the requirements of dew-point application conditions where the temperature and humidity are taken into account. No application shall take place unless the concrete temperature and air temperature are at least 3 degrees higher than the dew-point temperature.

c) Concrete Surface Defects and Corners

UNEVEN CONCRETE SURFACE IRREGULARITIES (OFF SETS) MUST BE GROUND AND SMOOTHED TO LESS THAN 1mm. WHEN THE FIBRE SHEET IS TO RUN PERPENDICULARLY TO CORNERS, CONCRETE CORNERS MUST BE ROUNDED TO A RADIUS OF AT LEAST 12 mm. INTERNAL CORNERS MUST BE SMOOTHED, BY FORMING A COVE OR CHAMFERED DETAIL. NO SPECIAL DETAILING IS REQUIRED IF SHEET MATREIAL IS RUNNING PARALLEL TO CORNERS.

d) Handling of Primer and Resin

Always refer to BASF technical data sheets and material safety data sheets. DO NOT DILUTE PRIMER OR RESIN WITH SOLVENT. After the resin has been mixed with hardener, the mixed resin batch must be used within its batch-life. The mixed batch resin must not be used after expiration of its batch-life as increased resin viscosity will prevent proper impregnation of the FRP fabric materials. Special consideration may need to be taken when using the MBrace Resicem system, to ensure complete impregnation. This may involve the use of a pre-laminating machine and a wet lay-up process.

e) Handling of FRP Fabric materials

FRP Fabric materials (carbon, aramid and glass) must not be handled roughly. They must be stored either by being rolled to a radius greater than 300 mm or by being dry stacked after cutting. When multiple lengths of fabric materials are adhered to a concrete surface, a minimum of 150 mm OVERLAPPING LENGTH MUST BE APPLIED IN THE LONGITUDINAL FIBRE DIRECTION, unless otherwise noted. No overlapping is required in the lateral direction.

2. SURFACE PREPARATION

a) All substrates must be clean, sound and free of surface moisture and frost. Remove dust, laitance, grease, curing compounds, waxes, impregnations, foreign particles and other bond inhibiting materials from the surface by blast cleaning or equivalent mechanical means. Any steel reinforcement should be cleaned and prepared thoroughly by abrasive cleaning, and the area patched prior to installation of FRP system.

Any deteriorated concrete or corroded reinforcing steel must be repaired as per BASF requirements. Do not cover corroded reinforcing steel embedded in concrete with FRP Systems.

b) Existing uneven surfaces must be filled with an appropriate repair mortar or must be ground smooth.

c) Prior to initiating surface preparation procedures, the contractor shall first prepare a representative sample area. The sample area shall be prepared in accordance with the requirements of this document, and shall be used as a reference standard depicting a satisfactory prepared surface. Normal requirement is the surface must present similar to 60-grit sandpaper. The strength of the concrete or repaired area shall be verified after preparation by random pull-off testing. Minimum tensile strength of substrate required is 1.0 MPa. Refer to testing procedure notes in Appendix A.

d) When required by the contract documents, the contractor shall install a trial or sample area (1m^2 min) of the FRP System for purposes of insitu bond testing to verify preparation, system application and bond.

e) Maintain control of concrete chips, dust and debris in each area of work. Clean up and remove such material at the completion of each day of blasting.

3. APPLICATION STEPS

a) The deteriorated surface layer of the base concrete (weathered layer, laitance, surface lubricants, broken mortar pieces, paint coatings, staining etc.) must be removed and the surface ground using a disc sander or abrasive blasting. Surface must present similar to 60-grit sandpaper on completion and have sufficient profile to satisfy all parties. The surface must expose well-bound aggregate (from fine to coarse).

Dust from surface preparation must be removed using an air blower or other suitable means. If the dust has been removed by means of water washing, the surface must be thoroughly dried.

b) Restoration of Concrete Cross Section

Defects in the base concrete (such as broken pieces, voids, honeycomb, corrosion etc.) must be chipped off and removed. If reinforcing bar has been exposed and corrosion exists, it must be repaired before the concrete restoration commences. Typically defects such as edge spalling, voids, honeycomb & broken corners etc are filled with Concresive 1444 or Emaco Nanocrete R4 depending on the quantity of repairs and the project limitations. Refer to BASF for recommendations if required.

Epoxy resin such as Concresive 1375/1380 must be injected into cracks greater than 0.30 mm wide.

If a significant amount of water leaks through cracks or concrete joints, water protection and a water conveyance or run-off must be provided prior to concrete surface restoration.

c) Environmental Conditions

Measure the moisture content of the concrete substrate. The moisture content of the concrete must be below 4% or it's relative humidity less than 70% according to AS1884-1995. Determination of dew point, air and substrate temperatures and of relative humidity of air, immediately prior to the application is required, if the substrate is exposed to the weather or is in an external environment. If the dew-point temperature differs by less than 3^0C from the substrate temperature, the substrate must be warmed up, or the relative humidity of the air must be reduced. Application may proceed if "concrete temperature > Dew point + 3 deg C".

Under some circumstances, dependant on substrate porosity and environmental factors, out-gassing of air may occur, producing small air-voids under a freshly laid sheet of fabric. If this occurs, pre-priming to seal the surface may be required, as well as application of the fabric on a “falling-thermometer”, to minimize the amount of out-gassing produced. Trialing of the appropriate procedures and tensile bond testing are recommended, prior to moving forward in this situation.

4. MIXING EPOXY RESINS (General)

a) Epoxy based materials used in the FRP composite system may develop a higher viscosity and/or show slow or insufficient curing at low ambient temperatures. Similarly, work done during warmer ambient temperatures will reduce the pot-life of the resins. The ambient temperature of the epoxy components shall be between 10 to 30 degrees C at the time of mixing. Provide necessary environmental protection to protect materials from rain, cold or heat.

b) Premix each component of the epoxy materials according to BASF recommendations. Use appropriate mixing tools, at correct speeds with the most appropriate mixing paddles, to achieve full and consistent mixing, without entraining excessive air. Take care to scrape the sides of the pail during mixing.

c) Components which have exceeded their shelf-life shall not be used.

d) Mixing of full kits is advisable wherever possible. However, mix only that quantity of epoxy that can be used within its pot life. Adopt appropriate techniques for weight and/or volume measuring, when having to mix less than full kits of epoxy resin.

5. APPLICATION TO PREPARED SURFACE

5.1 Primer

No primer (or saturant) coat should be applied if the ambient temperature is lower than 5^0C or surface temperature is lower than 8°C, or if rainfall or condensation is anticipated (refer Cl 1(b)).

a) MBrace Primer must be thoroughly mixed with hardener at the specified ratio in the mixing pot until it is uniformly mixed (about 3 minutes). Agitation shall be by means of electric hand mixer. Volume of primer prepared at one time must be such that it can be applied within its batch life. A mixed batch that has exceeded its batch life must not be used. (The batch life may vary subject to ambient temperature or volume of the mixed primer batch and care must be taken accordingly.)

b) Prime the concrete surface with the penetrating primer prior to application of any subsequent coatings using brush or roller. Alternatively, the primer may be spray applied with airless spray equipment, followed immediately by thorough back rolling to work the primer into the concrete surfaces. The primer shall be applied uniformly in sufficient quantity to fully penetrate the concrete and produce a non-porous film in the surface approximately 100-150 microns (wft) in thickness after full penetration. Volume to be applied may vary depending on the porosity and roughness of the concrete surface.

c) Apply the Concresive 1444 or MBrace Laminate Adhesive as a levelling mortar to the primer, while the primer is still tacky to the touch. If the primer is allowed to dry, the surface must be prepared and re-primed to the satisfaction of all parties and may require additional or renewed preparation.

d) Surface irregularities caused by primer or leveling coating must be ground and removed using disc sander, etc. If any minor protrusions on the concrete surface still remain, such surface defects may be corrected again using Concresive 1444 or thin sections of saturant coat.

5.2 Adhesion of FRP Fabric Sheets

The FRP Fabric Sheets shall not be applied whenever ambient temperature is lower than 5^0C or whenever rainfall or condensation is anticipated.

a) FRP Fabric Sheets must be cut beforehand into prescribed sizes using appropriate scissors and/or cutters. The maximum size of sheet to be cut is preferably less than 3 m in length, but may be longer if access allows.

b) Apply a coat of MBrace Saturant to the primed surface using a medium nap roller (approx. 10 mm) to approximately 500 - 750 microns wet film thickness (1.3-2 m^2 per litre) or sufficient to achieve a wet-out of the FRP Fabric Sheet. This value will vary depending on the weight of the FRP Fabric Sheet used (in gm/m2) as well as the ambient conditions and wastage. A trial on site prior to full application is advisable to establish actual usage rates.

c) The FRP Fabric Sheet is placed fibre side down onto the concrete surface. ALWAYS WORK IN THE DIRECTION OF THE FIBRES AND WORK FROM THE CENTRE OF THE LENGTH OF THE SHEET TO THE ENDS, TO REMOVE ANY ENTRAPPED AIR. After smoothing down by hand, a squeegee or hard roller may be used, over the backing plastic/paper, to enhance the impregnation of the fabric material. The backing plastic/paper is then peeled away. The surface of adhered fabric must be squeezed in the fibre longitudinal direction using a ribbed roller in order to impregnate resin into the fabric material and remove any air bubbles. Then go over the surface with a rubber squeegee/spatula to smooth out any remaining imperfections. Finally use a de-foaming roller to de-foam the resin coat if required.

For joining strips of FRP Fabric Sheets in the fibre longitudinal direction, a 150 mm overlapping length is required. At the overlapping location, additional resin is applied to the outer surface of the fabric layer to be overlapped. No lapping is required in the fibre lateral direction.

Minimise the elapsed time between mixing and application of the saturant to ensure the material is applied to the fabric at least 15 minutes prior to any thickening or gelling.

e) Allow sufficient time between the application of FRP Fabric Sheet on the first coat of wet saturant and the application of the second coat of saturant. This is to allow for epoxy impregnation and is suggested at around ten minutes (depending on ambient conditions). Any lifting or delamination that may occur during this period, must be corrected by pressing down the CFRP using a de-foaming roller or spatula.

f) The second coat of MBrace Saturant must then be applied onto the surface of the FRP Fabric Sheet. Apply the next coat of saturant whilst the first coat is still wet to touch. The surface onto which resin has been applied must be applied in the FRP Fibre longitudinal direction. In order to impregnate and replenish resin into the FRP Fabric Sheet, use a medium nap roller and squeegee/spatula, with the same amount of saturant applied to achieve a wet film thickness as detailed in item c) above.

g) In the case where more than one layer of FRP Fabric Sheet must be used, the processes as detailed in items b) through f) must be repeated in a wet on wet continuous process.

h) In the case of outdoor applications, the work must be protected from rain, sand, dust, etc. by using protective sheeting and other barriers until fully cured. The curing rate of the adhered FRP is temperature dependent.

i) If there is to be a top-coat application of a UV-stable acrylic paint (Masterseal 150/160), provide a sand-seeding, broadcast onto the still-wet, last layer of saturant applied to the MBrace Fabric. Prior to applying the acrylic top-coat, remove any loose sand from the surface. The acrylic top-coat may be applied after a minimum of 48 hours curing of the last coat of saturant.

6. QUALITY CONTROL AND INSPECTION

a) In Process Control

A qualified representative (Paint Inspector or approved alternative) shall observe all aspects of onsite material preparation and application, including surface preparation, resin component mixing, application of primer, resin and FRP Fabric Sheet, curing of composite, and the application of protective coatings.

b) Inspection for Void/Delaminations and Repair of Defective Work

After allowing at least 24 hours for initial resin cure to occur, perform a visual and acoustic tap test inspection of the layered surface. Test all the areas where FP is applied to check for voids, bubbles and delaminations. Repair all voids, bubbles and delaminations by approved methods as per BASF's direction.

Repair of defective works may be done by a number of means, including:

a. Small delaminations, less than 25 mm x 25 mm and which are isolated (maximum two (2) defects in a 300 mm x 300 mm area), do not normally require any corrective action. If the size or number of defects is greater than this, corrective action will need to be taken as per below or as otherwise directed.

b. Corrective Action may consist of two general methods:
   i. Injection of resin into voids.
   This process involves the careful filling, by injection of MBrace Primer, into the voids, without causing more damage than exists in the void. The techniques will vary but may include the use of a large needle arrangement, with an inlet and outlet hole, to ensure that any air can escape. Always aim to minimize any damage to the fibre.

   This method is the preferred method for all repairs.

   ii. Cut-out and replacement of defective area.
   For extreme cases where option i) is not deemed appropriate, areas of large defects may be cut-out and replaced with new material. The repair procedures should be as per "Appendix B: MBrace Fabric - Repair Procedures" document, detailing requirements for preparation and application. In this document, the material referred to as putty could be Concresive 1444 or MBrace Laminate Adhesive.

Repair of all the defective work after the minimum cure time for the FRP. Comply with material and procedural requirements defined in this document and any related specifications. Repair all defects in a manner that will restore the system to the designed level of quality. Repair procedures for conditions that are not specifically addressed in this document or the specification, shall be approved by the Owner's representative. All repairs and touch ups shall be made to the satisfaction of the Owner's representative.

c) Adhesion Testing

The contractor will conduct adhesion testing of the fully cured MBrace Composite System. Conduct direct tensile pull-off tests to verify the tensile bond between the FRP Fabric Sheet material and the existing concrete substrate. Perform a minimum of one tensile pull-off test per 10 m^2 of applied FRP Fabric Sheet material (or as per specification requirements). The tests are to be completed prior to the application of finishes on the FRP system. Inspect the failure surface of the core specimen. Failure at the bond line at a tensile stress below 1.0 MPa is not accepted. Refer to Appendix A for further testing information.

Repair the test areas of the composite system in a trade-like manner to the satisfaction of the Owner's representative.

d) Load Testing

If required by the Engineer, a representative area(s) determined by the Engineer shall be in-situ load tested before and after application of the FRP system to verify results.

e) Report

The qualified representative shall submit a report to the Engineer as required.
The BASF representative may submit a report.

f) Contractor's QA Procedures

The contractor undertaking the application, shall adhere to fully documented QA procedures and maintain fully detailed site records and make completed copies available to BASF and the Engineer as required.

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Appendix A - General Description of Tensile Pull-Off Test

The following is a description of a field test for concrete surface soundness and overlay bond (ex-ACI 503R, Appendix A: Manual of Concrete Practice, Part 5 and AS/NZS 1580.408.5:1994), which have been modified to serve as the in-situ QA/QC test of the MBrace Composite Strengthening System.
The tests are carried out on actual structural members strengthened with the composite FRP system. Although there are variations in the equipment for carrying out pull-off tests, the general procedure can be summarized as follows:

1. After the composite strengthening system has hardened, core drill through the composite material and down 3 – 6 mm into the concrete substrate by means of an electric drill fitted with a carbide-tipped or diamond core bit. The core bit should be of such size as to produce a core the same diameter as the testing dolly, and which will have the appearance of a small island of composite material. The normal size of the dolly is 50 mm diameter. Ensure that the drilling operation does not cause any detrimental effects on the system by using wet drill techniques to minimise heat exposure, and ensure it is perpendicular to the surface.
2. Prepare the top of the core surface to be tested. Preparation includes cleaning of the composite material surface, roughening it with sandpaper, and final cleaning of any dust.
3. Place an aluminium dolly onto the surface of the core with epoxy adhesive (Concresive 1444 or similar). The bottom surface of the dolly has to be sandblasted or sufficiently roughened with sandpaper, and be cleaned and free from any grease or dust. Mix the epoxy components according to the recommendations just prior to use. Apply a small amount of the mixed adhesive to the core surface and to the bonding (properly prepared) face of the dolly by spatula. Place the dolly on the core. In some cases, a disk is bonded to the composite surface prior to core drilling.
4. Allow epoxy adhesive to cure sufficiently (usually 24 hours or as required).
5. Attach a loading frame (Proseq or similar) to the dolly such that a load can be applied at right angles to the surface. A frame around the test area provides the reaction force to the load. Ensure that the attachment of the loading frame does not induce any lateral sideways force onto the dolly, either prior or during testing.
6. Zero the machine and increase the load until a specified level is reached or the specimen fails.
7. At failure, the maximum pull-force is registered and the pull-off tensile strength is calculated by dividing the force by the cross-sectional area of the core. The mode of failure shall be recorded i.e., within the concrete substrate, within the composite material, between substrate and composite material, between composite material and dolly, or any combination of the above.
8. Pull-off tests shall be carried out on each selected area. The average of the values shall be taken as a pull-off strength result.
9. Unless otherwise indicated by project specification requirements, most composite strengthening applications require minimum tensile strengths of the substrate of:
    a. 1.0 MPa for fibre fabric (sheet) material systems.
    b. 1.5 MPa for laminate material systems.

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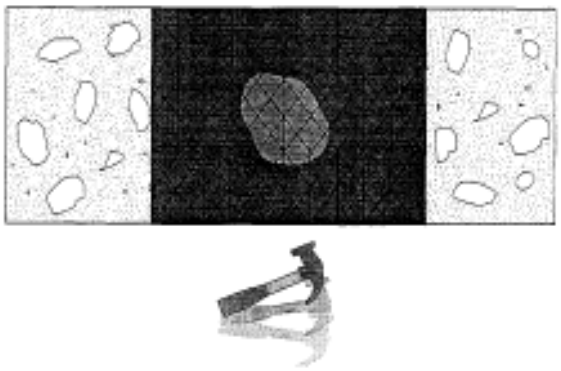
Appendix B:

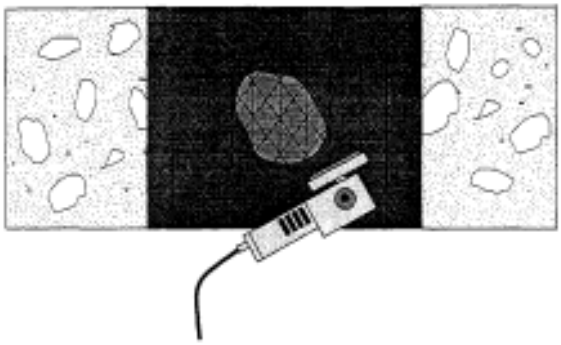
MBrace Composite Strengthening System

Fibre Systems - Repair Procedures



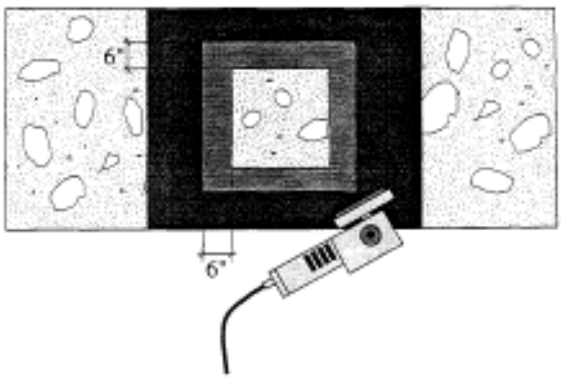
Step 1

- Identify delaminated/ unimpregnated/damaged area by tap testing/tensile testing.



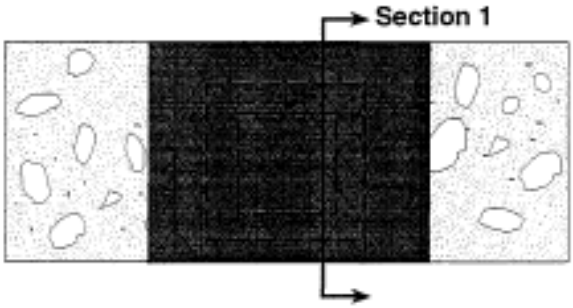
Step 2

- Sawcut/grind perimeter of damaged area and remove composite material.



Step 3

- Lightly sand-grind composite repair lap area.
- Minimum repair lap = 6 inches. (150 mm)



Step 4

- Apply primer. **(MBrace Primer)**
- Apply putty (as required). **(Concresive 1444)**
- Apply saturant & composite sheet per application instructions.

Notes:

1 Fiber orientation must be in same direction as base composite material.

2 For multi-directional applications, the first layer of composite sheet material should match the orientation of the first layer of base composite material. Additional layers of composite sheet repair should be applied in the same orientation as additional layers of base composite material.

Section 1