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ANGELHY

Innovative solutions for design and strengthening of telecommunications and transmission lattice towers using large angles from high strength steel and hybrid techniques of angles with FRP strips

WORK PACKAGE 5 – DELIVERABLE 5.2

Recommendations for construction and design of hybrid members

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TABLE OF CONTENTS

1 General requirements

Good bond strength between the bonding adhesive and the substrate is a key factor in performance of the rigid bonding and structural strengthening systems.

A specific quality of steel substrate after preparation must be achieved.

Steel substrate must be sound, clean, dry and free of rust and all contaminants such as dirt, oil, grease, coatings and surface treatments.

A clean but wet substrate can compromise the adhesion of the bonding and strengthening systems to the substrate, and condensation or a small water film on the interface will prohibit the bonding of the epoxy adhesive.

The FRP plates are most effective if the fibres are as straight as possible. Small and/or large irregularities on the steel members (e.g. strongly corroded) can be filled by using a layer of adhesive resin prior to FRP application.

1.1 Storage of resins and structural strengthening products

The resin Sikadur-30 should be stored in original, unopened, sealed and undamaged packaging in dry conditions at temperatures between +5 °C and +30 °C. Make sure it is also protected from direct sunlight.

The FRP plates Sika CarboDur S should be stored in original, unopened, sealed and undamaged packaging in dry conditions at temperatures of max. +50 °C. Make sure they are also protected from direct sunlight. They should be transported only in the original packaging, or otherwise adequately protected against any mechanical damage.

1.2 Traceability

Each product of the structural strengthening system has a batch number displayed either on its packaging (for resin) or on the product itself (for Sika CarboDur plate). In order to ensure the traceability in case of defective products, it is essential to note the batch of the products applied on each steel member.

Figure 1.1: Sikadur 30 unit

Figure 1.2: Sika CarboDur plate

1.3 Ambient conditions

The ambient temperature must be between + 8°C and + 35°C, and a minimum of 3 °C above the dew point. The dew point is the point at which a surface becomes wet due to condensation, dependent on the ambient temperature and the relative humidity.

The substrate temperature must be between + 8°C and + 35°C. There may be no frozen water on the substrate before application.

The systems cannot be applied if it is raining actively on the substrate in question.

Avoid leaving the system components in the direct sun, as this may shorten the pot life of the resins due to heating, and the UV radiation may damage the FRP products over time.

2 Equipment

2.1 Safety recommendations

For each product, you should refer to their safety data sheets available on www.quickfds.com.

Essential personal protective equipment are the followings:

- Hard hat
- Safety gloves
- Chemical protection coat
- Safety shoes
- Safety glasses

Safety shoes, gloves and other appropriate skin protection should always be worn. The use of disposable or new / clean protective clothing during the materials preparation and application is strongly recommended.

2.2 Tools

Essential tools for application are the followings:

- Sandblaster
- Vacuum
- Adhesive tape
- Sikadur helix
- Trowel
- Application roller

Figure 2.1: Sikadur helix

Figure 2.2: Application roller

2.3 Substrate preparation

Steel members must have a rough, completely rust and coating free surface. Operation of surface preparation by grid blasting or wire brushing only allows to remove the surface corrosion and superficial coatings. The substrate preparation is best achieved by sandblasting (quality Sa 2.5, according to EN ISO 8501-1) in order to get a rough surface.

Table 2.1: substrate preparation

Initial condition – rust grade C	Preparation grade – Sa 2.5
	
Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.	Based on rust grade C, mill scale, rust, paint coatings and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.

Then, cleaning off the residue dust and other particles by using dry wipe or by vacuum.

Galvanisation will be probably affected by sand-blasting, partially or totally removed. Therefore, application of the adhesive or structural strengthening system should be as soon as possible after surface preparation and cleaning, to avoid any corrosion formation or recontamination. If this is not possible, the steel should be coated with a temporary corrosion protection, or a corrosion protection layer that will not compromise the performance of the overall system.

3 Structural strengthening system preparation

3.1 Preparation of the resin

Sikadur-30 used for rigid bonding is a two-parts components (A and B) epoxy resin. Mix components A+B together for at least 3 minutes with the Sikadur helix attached to a slow speed electric drill (max. 300 rpm) until the material becomes smooth in consistency and a uniform grey colour. Avoiding aeration while mixing is essential.

Then, if necessary, pour the whole mix into a clean container and stir again for approximately 1 more minute at low speed to keep air entrapment at a minimum.

3.2 Preparation of the FRP plate

FRP plates Sika CarboDur S must be cut at the size needed to strengthen the steel member.

Just before the application, the FRP plate must be cleaned with an impregnated rag of grease-free, solvent-based cleaning agent (Sika Colma Cleaner).

The Sika CarboDur plates are ordered as continuous roll, so the required lengths should to be cut on site. When unpacking the rolled product on site, it must be handled very carefully to ensure and facilitate controlled uncoiling. Special care should also be taken to avoid splintering of the plate ends. Loose carbon fibres may well also be present, so gloves, masks and goggles are recommended to be worn whilst handling and working with the plate strips.

To cut the plates to length on site, tape the area to be cut to prevent excessive dust generation and use a rotary disc cutter, alternatively a normal hacksaw can be used. Always support the Sika CarboDur plate strip on both sides during cutting to avoid splintering of the ends and cut perpendicular to the fibres.

Clean the surface of the plates with a clean white cloth and Sika Colma Cleaner (or an isopropanol based cleaner) to remove any dust or grease. The solvent must have evaporated, and the surface of the plate must be completely dry before the application of the adhesive.

4 Construction recommendations

4.1 FRP application

With a trowel, apply the Sikadur-30 adhesive onto the Sika CarboDur plate, so it is approximately 1 mm thick on the sides and 2 mm thick in the middle of the plate (see picture below). Apply the adhesive to the plain side so the printed side is facing outwards, with the product name and batch number visible for later inspection.

Figure 4.1: Sikadur 30 applied onto Sika CarboDur plate

Scrape a thin layer (1 mm) of the thoroughly mixed Sikadur-30 adhesive carefully into the prepared, dust free substrate with a spatula, then place the coated Sika CarboDur plate onto the prepared steel surface.

Ensured to have a good contact between substrate, resin and plate and no air enclosed.

Figure 4.2: Application of the resin on the prepared steel member

Using a Sika hard rubber roller, press the plate firmly onto the substrate until the material is forced out on both sides of the plate in order to remove the air enclosed and the excess of resin (see fig. 4.3). Finally remove and dispose of this surplus Sikadur-30 epoxy adhesive and do not re use it.

Figure 4.3: Use of Sika hard rubber roller

The freshly bonded system should not be disturbed for at least 24 hours and any vibrations should normally be kept at a minimum during the curing period of the adhesive. The full design strengths of Sikadur-30 are reached after approximately 7 days at 20 °C.

5 Finition

Once installed, the Sika CarboDur plates must be protected from permanent exposure to direct sunlight to prevent UV degradation of the epoxy matrix, permanent immersion in water and mechanical abrasion or impact, which could affect their mechanical properties.

Therefore, dependent on the anticipated future exposure and environmental conditions of the project, additional protection of the plates may be necessary. This is easily achieved by means of a suitable Sikagard protective coating system.

To apply a protective coating product to the installed Sika CarboDur plates, thoroughly clean the surfaces with Sika Colma cleaner (or an isopropanol based cleaner), allow it to evaporate and the surfaces to dry completely, before applying the selected coating.

Table 5.1 summarizes a few of the coatings that can be used for further protection of the Sika CarboDur plates when this is necessary.

Table 5.1: protective coating systems

Situation	Special need	Sika solution
Direct sunlight	UV protection	Sikagard-550W Elastic Sikagard-675 W ElastoColor
Use in humid or wet environment	Protection against water ingress.	Sikagard-680 S

The steel prepared surface which is not covered by the structural strengthening system could be subjected to corrosion formation. Therefore, an anti-corrosion product could be applied to cover these zones, especially around the contact zone between steel surface and resin.

6 Design recommendations

Hybrid members examined here refer to rolled equal angles reinforced with CFRP plates attached externally or externally and internally to the legs. The resulting member is composed of the steel section and the CFRP plates acting fully compositely to a hybrid member, with no slip between them. For high shear forces at the interface between steel and CFRP plates, as in the case of high bending moments, an end-anchorage of the plates may be required. This may be preferably realized by attaching other FRP material transversely to the CFRP fabric at their ends. Figure 6.1 illustrates an example of such end-anchorage applied in the bending tests performed in WP2 and described in Deliverable 2.3. In this case GFRP fabric was placed transversely in order to confine the CFRP plates. The figure showed the success of this method that restrained slip of the FRP material.

However, for compression members, as legs and bracing members of lattice towers, such an end-anchorage is not necessary since the applied shear forces at the interface are rather small. Indeed, in neither the column tests or in the tower tests, described in Deliverables 2.3 and 2.5, any differential slip between steel and CFRP plates was observed. In addition, the design formulae established in Deliverable 2.4 and outlined in Deliverable 4.4, assume a full connection between the two materials and have been confirmed by the tests.

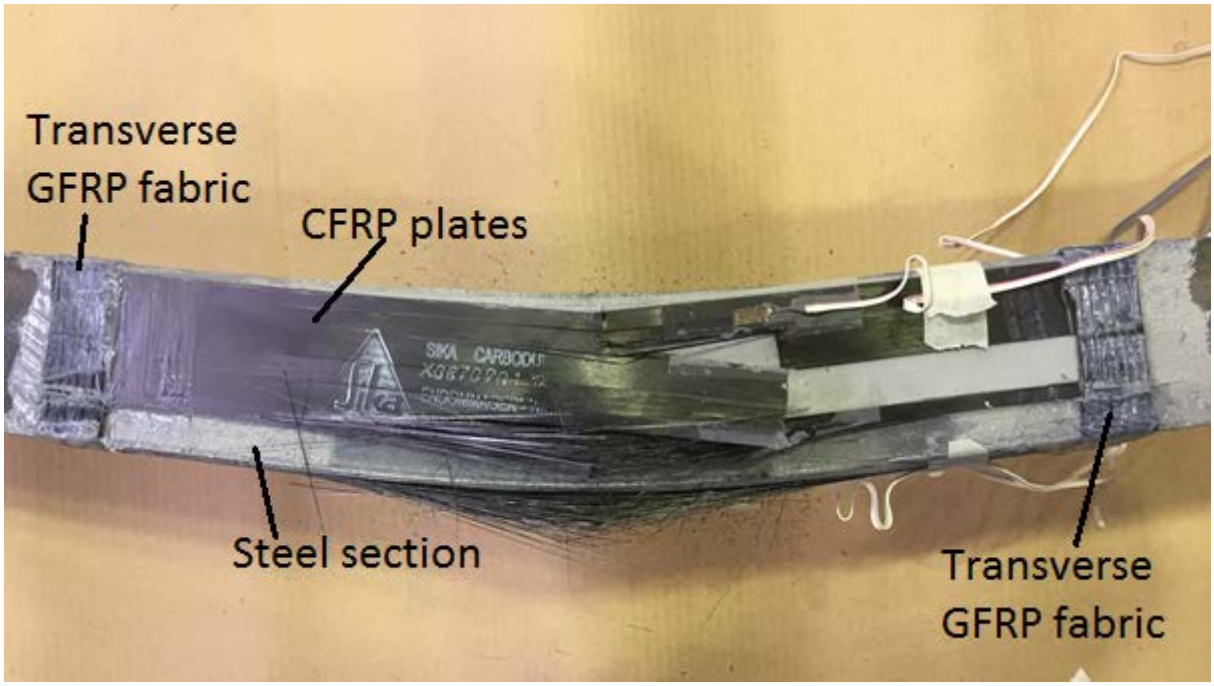

Figure 6.1: Example of end-anchorage of CFRP plates by transverse GFRP strips

List of Figures

List of Tables