Guide for the application of S&P FRP Systems

October 2006

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1. Introduction to the design and application of FRP Materials

This document offers a guide to the application of S&P FRP materials used in the strengthening of concrete and timber structures. It addresses strengthening by the application of carbon fibre reinforced polymers (CFRP), aramid fibre reinforced polymers (AFRP) and glass fibre reinforced polymers (GFRP) to the external parts of structural elements, both by bonding to the external surface and/or bonding within slots cut in the surface layers of the substrate. The prestressed S&P FRP systems are not part of this application guide.

Fig. 1: Bonding to the surface

Fig. 2: Bonding with slots

The information contained herein has been researched from many references and is considered current as at the date given at the bottom of this page. As the use of FRPs is the subject of a large number of on-going research programmes around the world, conditions pertaining to their usage may vary from time to time.

The successful application and use of this manual is the sole responsibility of the user and is dependent on the application of sound judgement by a qualified Engineer who has a thorough understanding of structural mechanics and material behaviour, especially as it relates to reinforced concrete. The user of the manual must ensure that the design procedure adopted is relevant for use on the intended application and must select appropriate values suitable for the specific application. Reference to an appropriate set of Design Recommendations is essential (either the German or French General Guidelines, The UK Concrete Society Design Guidance or the draft ACI 440 Recommendations would be appropriate documents for this purpose). Any design carried out must comply with the relevant Codes of Practise for the country concerned.

Both specifier and contractor have to ensure that all working procedures are carried out according to the relevant static dimensioning. Under no circumstances may structural building parts be removed before the FRP strengthening is in place and the responsible engineer has given his approval.

2. S&P FRP Strengthening Systems

The basic fibres used in S&P FRP composites are imbedded in a matrix of epoxy resin and are applied as reinforcements to an existing structural member. The fibres are supplied either as a fabric, known as **sheet form** or as a pre-cured laminate, known as a **laminate form.** When supplied in sheet form, the embedment into the epoxy matrix takes place on site by hand lamination. When supplied as pre-cured laminates, the laminates are adhered directly to the substrate.

S&P offers four types of fibre; carbon, e-glass, ar-glass and aramid. Each has its unique place in the field of structural strengthening, as is explained below.

S&P Sheets must be used in conjunction with approved epoxy resins. Likewise, S&P Laminates must be used in conjunction with approved epoxy adhesive pastes. S&P Systems can supply resins and adhesives, but users are able to source their own resin products, provided they meet with the prior approval of S&P Systems and have been rigorously tested for performance in conjunction with the appropriate S&P Fibre Product.

2.1 S&P Glass and Aramid Fibre Systems

These are supplied in sheet form only. In unidirectional S&P sheets, where the fibres lie mainly in a single direction, the fibres can be considered to be straight, although during hand lamination, they tend to become slightly wave-like in form. Reduction factors are used in designs to allow for irregularities in hand laminating techniques. In bi-directional S&P sheets, the fibres are woven and hence take on a pronounced wave-like form. Again, the appropriate reduction factor used in the design, takes care of this aspect.

2.1.1 S&P Glass Fibre Sheets (GFS) available are:

S&P G-Sheet E 50/50: E-glass, E-modulus = 73,000 MPa, 175 gms/m^2 of fibre in two orthogonal directions.

S&P G-Sheet E 90/10 A: E-glass, E-modulus = 73,000 MPa, 400 gms/m^2 of fibre in the main direction (10 % in the cross direction).

S&P G-Sheet E 90/10 B: E-glass, E-modulus = 73,000 MPa, 800 gms/m^2 of fibre in the main direction (10 % in the cross direction).

S&P G-Sheet AR 50/50: AR-glass, E-modulus = 65,000 MPa, 175 gms/m^2 of fibre in two orthogonal directions.

S&P G-Sheet AR 90/10 A: AR-glass, E-modulus =.65,000 MPa, 400 gms/m^2 of fibre in the main direction (10 % in the cross direction).

S&P G-Sheet AR 90/10 B: AR-glass, E-modulus = 65,000 MPa, 800 gms/m^2 of fibre in the main direction (10 % in the cross direction).

2.1.2 S&P Aramid Fibre Sheet (AFS) available is:

S&P A-Sheet 120 (290): Aramid, E-modulus 120,000 MPa, 290 gms/m^2 of fibre in a single direction.

2.2 S&P Carbon Fibre Systems

These exist in either **sheet** or pre-cured **laminate** form. Carbon fibres with high moduli of elasticity are used in the production. This modulus of elasticity is the decisive parameter when comparing the various types of carbon sheet and carbon laminate.

2.2.1 S&P Carbon Fibre Sheets (CFS) available are:

S&P C-Sheet 240 (200): E-modulus 240,000 MPa, 200 gms/m^2 of fibre in the main direction.

S&P C-Sheet 240 (300): E-modulus 240,000 MPa, 300 gms/m^2 of fibre in the main direction.

S&P C-Sheet 240 (400): E-modulus 240,000 MPa, 400 gms/m^2 of fibre in the main direction.

S&P C-Sheet 640 (400): E-modulus 640,000 MPa, 400 gms/m^2 of fibre in the main direction.

2.2.2 S&P Carbon Fibre Laminates (CFK) are available in two grades as follows:

S&P 200/2000, type 50/1.4: E-modulus 205,000 MPa, 50mm x 1.4mm strip.

S&P 200/2000, type 60/1.4: E-modulus 205,000 MPa, 60mm x 1.4mm strip.

S&P 200/2000, type 80/1.4: E-modulus 205,000 MPa, 80mm x 1.4mm strip.

S&P 200/2000, type 90/1.4: E-modulus 205,000 MPa, 90mm x 1.4mm strip.

S&P 200/2000, type 100/1.4: E-modulus 205,000 MPa, 100mm x 1.4mm strip.

S&P 200/2000, type 120/1.4: E-modulus 205,000 MPa, 120mm x 1.4mm strip.

S&P 150/2000, type 10/1.4: E-modulus 165,000 MPa, 10mm x 1.4mm strip (cut-in laminate)

S&P 150/2000, type 20/1.4: E-modulus 165,000 MPa, 20mm x 1.4mm strip (cut-in laminate)

S&P 150/2000, type 50/1.2: E-modulus 165,000 MPa, 50mm x 1.2mm strip

S&P 150/2000, type 50/1.4: E-modulus 165,000 MPa, 50mm x 1.4mm strip

S&P 150/2000, type 60/1.4: E-modulus 165,000 MPa, 60mm x 1.4mm strip

S&P 150/2000, type 80/1.2: E-modulus 165,000 MPa, 80mm x 1.2mm strip

S&P 150/2000, type 80/1.4: E-modulus 165,000 MPa, 80mm x 1.4mm strip

S&P 150/2000, type 90/1.4: E-modulus 165,000 MPa, 90mm x 1.4mm strip

S&P 150/2000, type 100/1.2: E-modulus 165,000 MPa, 100mm x 1.2mm strip

S&P 150/2000, type 100/1.4: E-modulus 165,000 MPa, 100mm x 1.4mm strip

S&P 150/2000, type 120/1.2: E-modulus 165,000 MPa, 120mm x 1.2mm strip

S&P 150/2000, type 120/1.4: E-modulus 165,000 MPa, 120mm x 1.4mm strip

Special width and thickness on demand.

S&P supplies FRP sheet and laminates in rolls. In special cases, part rolls can be supplied, but this adds to the unit cost.

3. Selection of the S&P FRP Strengthening System

There is no fixed rule as to whether sheet or laminate should be used. Usually economy dictates the choice of one system or the other, but sometimes it is a design choice. Carbon (laminate or sheet) appears to be more economic for use in flexural or shear strengthening. Certainly, carbon has better fatigue properties than glass, so where the strengthening is used to carry often occurring fluctuating live loads, carbon should be chosen. Glass, because of its lower E-modulus, is more suitable for use in confinement of concrete, although it can, in certain circumstances, be used for flexural enhancement. Because of its low modulus, glass is seldom used for shear enhancement. Aramid is usually used for impact and explosion enhancement.

Laminates can only be applied to plane surfaces, therefore carbon, aramid and glass sheets are used on curved surfaces.

Bi-directional glass fabrics are used for increasing the shear strength of masonry walls. Lighter fabrics are used where the substrate strengths are low, such as in old and historic masonry or brick buildings.

The following table sets out typical uses for the various products:

Composite Type	Fibre direction	Fibre arrangement	Typical application
S&P Carbon Fibre Sheet (CFS)	Uni-directional	Straight	Increase in flexural and shear capacity, confinement
S&P Aramid Fibre Sheet (AFS)	Uni-directional	Straight	Impact or explosion enhancement
S&P Glass Fibre Sheet (GFS)	Bi-directional	Woven	Increase in confinement and ductility
S&P Carbon Fibre Laminate (CFK)	Uni-directional	Straight (partially pre-tensioned)	Increase in flexural capacity

Table 1: Sheet application overview

3.1 Demands on the Substrate

The substrate to which the FRP is to be adhered, must have sufficient strength to transfer the loads from the FRP to the structure. Testing of the tensile strength of the substrate by pull-off tests is imperative. The following table sets out the minimum substrate strengths required for each of the FRP materials to be used efficiently:

Product	**Minimum Tensile Strength (MPa)**
S&P Carbon Fibre Sheet (CFS)	> 1.0
S&P Aramid Fibre Sheet (AFS)	> 1.0
S&P Glass Fibre Sheet (GFS)	> 0.2
S&P Carbon Fibre Laminate (CFK)	> 1.5

Table 2: Demands on the bearing substrate

Fig. 3: Proceq Dyna Pull-off Tester used for determining substrate tensile strength

3.2 Types of Fibres used in S&P FRP Systems

S&P FRP materials comprise either single type fibres or a fibre combination (hybrids). The range of mechanical properties as well as some advantages and disadvantages of the various fibre types are as follows:

Type of Fibre	**Modulus of Elasticity** (GPa)	**Tensile Strength** (MPa)
Carbon	240 - 640	2,500 – 4,000
Aramid	120	3,000 – 4,000
Glass	65 - 70	1,700 – 3,000
Steel	190 - 210	250 - 600

Table 3: Material properties

E-glass: Uncoated E-glass corrodes in alkaline environments, thus there is a risk in using E-glass together with freshly cured concrete, unless the E-glass is completely submerged in epoxy. However, there is no problem when E-glass is applied directly to old concrete, which is the majority of cases. A higher reduction factor is used on the E-glass property by the engineer. Because of the low durability of E-glass.

AR-glass: Alkali resistant glass is suited for use as confinement reinforcement in combination with all epoxy resin matrix. A lower reduction factor is recommended by the engineer, because of the higher durability of the AR-glass.

Aramid: Aramid is a very tough material and thus provides benefits when used as a strengthening material for special applications, such as strengthening of rectangular columns and in the field of impact and explosions. Due to its high cost, aramids can be economically replaced by glass or carbon fibres in most cases.

Carbon: Carbon fibre provides a number of benefits over the other materials. It has a high modulus of elasticity, a very low coefficient of thermal expansion (approximately 50 times lower than steel), excellent fatigue properties, excellent resistance to chemical attack. It will not corrode and exhibits a high resistance to freeze/thaw and de-icing salt attack.

Table S&P repair mortars and matrix systems

When total surface wrapping of concrete or masonry (arches) is intended, aspects of building physics must be considered. 30-50% of the surface of the element should remain water vapour permeable. A total surface coverage with an epoxy matrix is therefore not suitable.

S&P Resicem is a newly developed cementitious epoxy matrix. The combined effect of the two binders that have completely different chemical bases, is that the cement particles, due to water vapour pressure, penetrate into the microstructure of the epoxy resin. Thus, the matrix system, which is vapour-proof at the time of its application, becomes vapour-permeable as the water vapour exposure increases. The cement contained in the matrix provides an additional alkali deposit, which protects the internal reinforcement against corrosion. The water vapour diffusion coefficient of an FRP application (thickness 1 mm) with S&P Resicem will eventually level out at approx. 3,000-5,000. Application is possible to substrates with a moisture content of up to 12%.

In the following table the possible S&P repair mortars and matrix systems are listed:

Primer and Resin for injection under FRP Systems
S&P Resin 50 *(shall not be used as a primer under permeable systems)*

Repair mortars FRP Systems	
Vapour permeable	Not vapour permeable
S&P Repcem *(PCC Repair Mortar)*	**S&P Resin 220** *30 Weight % filled with quartz-sand*
Saturant for S&P Sheet	
Vapour permeable	Not vapour permeable
S&P Resicem *(S&P applied for world-wide patent)*	**S&P Resin 55**

Resin for laminates CFK	
S&P Resin 220	Application on dry substrate (Humidity < 4 %)

Table 4: Repair mortars and matrix systems

4. Technical Data of S&P FRP Strengthening Systems

4.1 S&P FRP Sheets (Sheets made of Carbon, Aramid and Glass fibres)

- **Application**

  S&P FRP Sheets made of different types of fibres are used as bonded reinforcement for the strengthening and repair of structural elements made off steel, concrete, stonework and wood as well as for the reinforcement of historical structures.

- **Application Uses**

  Enhancement of load carrying capacity due to changed usage
  Upgrading due to changes in the building code
  Alteration to the intended structural form
  Rectification of mistakes made during design or construction phases

- **Advantages of FRP Strengthening Systems**

  Low unit weight
  Low profile thickness
  Ease of application due to lightness
  High E-modulus – carbon modulus is greater than that of steel
  Excellent fatigue behaviour
  Alkali resistance (in the case of AR-glass:- E-glass has some limitations in this respect)
  Corrosion resistant
  Covering with a variety of paints, coatings etc is possible.

- **Product names**

  Type: **S&P C-Sheet 240 (three weights)**
  S&P C-Sheet 640 (one weight)
  S&P G-Sheet AR (two weights)
  S&P G-Sheet E (two weights)
  S&P A-Sheet 120 (one weight)

5. Application of S&P FRP Strengthening Systems

5.1 S&P Sheets Systems CFS, AFS and GFS (Carbon, Aramid and Glass)

5.1.1 Substrate

A substrate capable of transferring the loads from the FRP to the concrete is a prerequisite for strengthening with laminates. Concrete and other substrates with a pull-off tensile bond strength >1.5 MPa for S&P CFK laminates, > 1.0 MPa for S&P C- and A-Sheets, > 0.2 MPa for S&P G-Sheets is required. The cement laitance must be removed to expose the base substrate. The optimal average surface roughness (amplitude) should lie between 0.5 - 1.0 mm. Suitable roughening methods are sandblasting or grinding. Surface contaminants such as dirt, oil and grease must be removed. After preparation is complete and before applying the primer and adhesive, the surface must be cleaned with oil-free compressed air or by vacuuming.

5.1.2 Flatness of substrate

The flatness of the concrete surface must be checked with a steel straight edge. Over a 2 metre length the out-of-plane measurement must not exceed 5 mm. Greater unevenness requires the use of a system approved levelling mortar (S&P Resin 220 filled with quartz-sand by 30% of weight) at least 1 day prior to the application of the laminate. If a cement based levelling mortar S&P Repcem is used, then a moisture content of the levelling mortar layer less than 4% is required, prior to the application of the S&P Epoxy Matrix.

5.1.3 Improving the pull-off bond stress

Where pull-off bond stresses do not meet the minimum requirement, it is sometimes possible to improve the pull-off bond by impregnating the concrete and especially the masonry with a very low viscosity resin such as S&P Resin 50. Improvement by this method will only occur when the substrate is porous.

5.1.4 Preparation / Quality Control

The concrete surface must be cleaned of dust particles and checked visually.

When using the standard S&P Epoxy Matrix Systems, the substrate moisture content of the concrete should be determined. The moisture content must lie below 4%. Directly before the application, the dew point, surface temperature and surrounding environment temperature, as well as the relative humidity must be determined. If the dew point interval amounts to less than 3° C, then the substrate must be heated or the relative humidity lowered.

During the gluing of the sheet, the minimum temperature should not be less than 8° and a maximum of 35° C. Special adhesives for applications at temperatures down to –10° C are available on request.

5.1.5 Priming

When the substrate is porous the S&P Resin 50 can be used as a primer under the FRP systems. Under the vapour open S&P Resicem Adhesive **no primer** is required. This may be applied with a brush, a roller or an airless spray.

5.1.6 Saturating and application of the Sheet

The importance of the complete saturation of the FRP sheet is emphasised here. For sheets up to 400 gms/m^2, hand lamination can be achieved without the use of a saturator machine to pre-saturate the sheet. The resin is applied to the surface prior the actual application. Hand impregnation can be achieved by rolling the S&P Resin 55 or the S&P Resicem, into the previously placed cloth Alternatively, the resin may be rolled into the sheet while it is laid on a flat surface. It is strongly recommended to remove the protecting folio in all circumstances after the sheet has been applied to the bearing surface. An earlier removal of the protecting folio is not recommendable. It is then transported to the work face and applied. For sheet weights in excess of 400 gms/m^2, proper saturation is best achieved by passing the sheet through an epoxy bath, which features rollers, which control the amount of resin applied to the sheet.

5.1.6.1 Hand saturation

A liberal coating of S&P Resin 55 or S&P Resicem is applied to the substrate and the sheet is pressed and rolled on to the primed substrate. Additional resin is applied by means of a roller until the weave of the sheet is fully saturated. If a second layer of sheet is required, this may be added at a time when the resin in the first layer achieves a stage of cure whereby it will support the second layer without sagging. This period varies according to the ambient temperature, whether the application is overhead or vertical and the weight of the sheet.

Fig. 4: Impregnation of the sheet with S&P Resicem (vapour permeable)

5.1.6.2 Machine saturation

The exact method of using the machine saturator will depend on the type of machine used. In principle, resin is contained in a trough through which the dry sheet is passed. Usually, a set of friction rollers pulls the sheet through the bath, whereby the amount of resin is controlled by the gap between the rollers.

Fig. 5: Machine saturation

The saturated cloth is then carefully folded and stored for transportation to the work face. It is applied using rollers and usually no further resin is required to be added.

It is possible to check visually as to whether the sheet has been impregnated completely with resin.

Resin usage

The table overleaf gives guidelines as to usage of the S&P Saturating Resins. The usage of the primer is depending on the porosity of the substrate (Resin 50:100 - 150 gms/m^2; Resicem: 150 - 250 gms/m^2).

Product	S&P Resin 55 Saturating Resin	S&P Resicem Saturating Resin
S&P G-Sheet 50/50	~ 900 gms/m^2	~ 1'500 gms/m^2
S&P G-Sheet 90/10 A	~ 1'100 gms/m^2	~ 1'600 gms/m^2
S&P G-Sheet 90/10 B	~ 1'900 gms/m^2	~ 3'200 gms/m^2
S&P C-Sheet 240 (200)	~ 600 - 800 gms/m^2	~ 1'100 – 1'500 gms/m^2
S&P C-Sheet 240 (300)	~ 800 – 1'200 gms/m^2	~ 1'300 – 1'600 gms/m^2
S&P A-Sheet 120 (290)	~ 700 – 1'100 gms/m^2	~ 1'100 – 1'500 gms/m^2
S&P C-Sheet 640	~ 900 – 1'300 gms/m^2	-

Table 5: Consumption of S&P Sheet using a saturator

5.1.7 Overlapping / Splicing of S&P FRP Sheets

The following minimum laps should be observed when using S&P FRP Sheets.

Product	Lap/splice distance in the direction of the main fibres	Lap/splice distance at right angles to the main fibres.
S&P G-Sheet 50/50	100 mm	50 mm
S&P G-Sheet 90/10 A	125 mm	70 mm
S&P G-Sheet 90/10 B	150 mm	100 mm
S&P A-Sheet 120	100 mm	N/A
S&P C-Sheet 240	150 mm	N/A
S&P C-Sheet 640	150 mm	N/A

Table 6: Overlapping/splicing

5.1.9 Quality Controls

During the site laminating work and until the saturating resin is touch dry, disruptions to the work process must be avoided in the region of influence of the FRP. After the primer has hardened, the FRP Sheet must be tested for the existence of drummy areas. In addition, the flatness of the FRP laminate must be checked. Any deviations should be no greater than 1 mm on a test length of 300 mm. Concave areas, where the Sheet is curved into the concrete, are not acceptable.

5.1.10 Fire Protection

As FRP systems are only able to support heat up to 50–60° C, special care needs to be taken for fire protection when required by codes or circumstances.

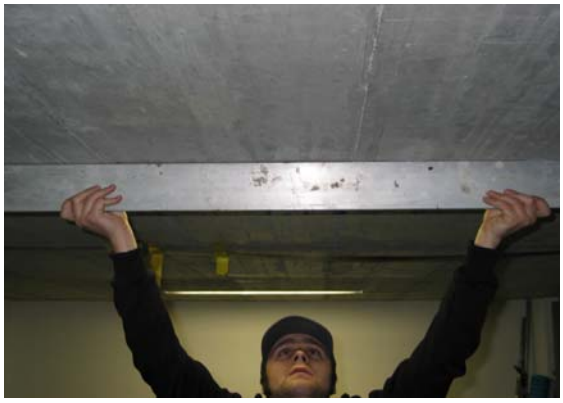
5.2 S&P Carbon Fibre Laminate Systems CFK

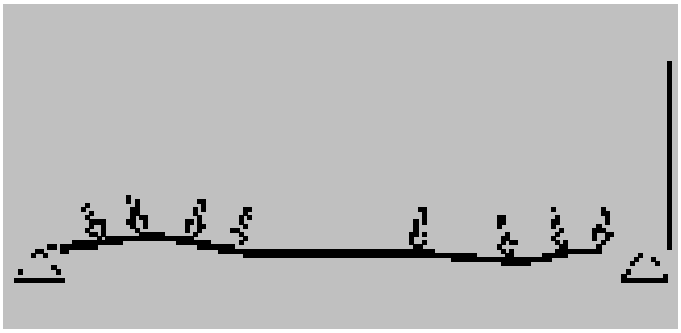
5.2.1 Substrate

A substrate capable of transferring the loads from the FRP to the concrete is a prerequisite for strengthening with laminates. Concrete with a pull-off tensile bond strength according to the information given in section 3.1 is required. The cement laitance must be removed to expose the base substrate. The optimal average surface roughness (amplitude) should lie between 0.5 - 1.0 mm. Suitable roughening methods are sandblasting or grinding. When using S&P Resin 50, the penetration of moisture must be avoided. Surface contaminants such as dirt, oil and grease must be removed. Once preparation is complete and before applying the adhesive, the surface must be cleaned by oil-free compressed air or by vacuuming.

5.2.2 Flatness of substrate

The flatness of the concrete surface must be checked with a steel straight edge. Over a 2 metre length the out-of-plane measurement must not exceed 5 mm. Greater unevenness requires the use of a system approved levelling mortar (S&P Resin 220 filled with quartz-sand by 30% of weight) at least 1 day prior to the application of the laminate. If a cement based levelling mortar S&P Repcem is used, then a moisture content of the levelling mortar layer less than 4% is necessary at the time of FRP application.





5.2.3 Improving the pull-off bond stress

Where pull-off bond stresses do not meet the minimum requirement of >1.5 MPa, it is sometimes possible to improve the pull-off bond by impregnating the concrete with a very low viscosity resin such as S&P Resin 50. Improvement by this method will only occur when the substrate is porous.

5.2.4 Preparation / Quality Control

The concrete surface must be cleaned of dust particles and checked visually for defects.

When using the standard S&P Resin primer, the substrate moisture content of the concrete should be determined. It must lie below 4%. Directly before the application, the dew point, surface temperature and surrounding environment temperature, as well as the relative humidity, must all be determined. If the dew point interval amounts to less than 3° C, then the substrate must be heated or the relative humidity lowered.

During the gluing of the laminate, the minimum temperature must not drop below 5° or exceed 35° C. Special adhesives for applications at temperatures down to –10° C are available on request.

5.2.5 Cleaning / Preparation of the S&P CFK Laminates

The contact surface should be rubbed with a clean white rag moistened with solvent. As well as general impurities, carbonic dust deposits must be removed. The cleaning must be repeated until no traces of black carbonic dust is left on the white rag.

5.2.6 Application of the Adhesive

The cleaned and completely dry S&P laminates CFK are coated with S&P Resin 220 adhesive using a glueingdevice. The adhesive is applied to the laminate in a curved transverse profile, with more adhesive in the centre of the laminate than at the edges. The laminates are then pressed on to the dust free substrate.

	Working time			**Substrate humidity**
Product	**+ 10^0 C**	**+ 20^0 C**	**+ 30^0 C**	
S&P Resin 220	~ 160 min.	~ 80 min.	~ 40 min.	< 4 %

Table 7: Overview of S&P Resin 220

The table overleaf gives guidelines to usage of the S&P Resin 220 (Epoxy Paste).

Width of S&P Laminates CFK	Usage of S&P Resin 220
50 mm	~ 350 gms/m
60 mm	~ 450 gms/m
80 mm	~ 550 gms/m
90 mm	~ 650 gms/m
100 mm	~ 700 gms/m
120 mm	~ 900 gms/m

Table 8: Usage of S&P Resin 220

5.2.7 Fixing of the Laminates to the Concrete

The S&P laminates CFK are pushed with light finger pressure on to the concrete surface. The adhesive is thixotropic and will hold the laminate in place without the need for additional support. Following this initial pressure, a hard rubber roller is used to press the laminate into the adhesive in a manner, which causes the adhesive to be expelled at both edges of the laminate. This guarantees that the adhesive is applied thoroughly eliminating voids. The expelled adhesive can be removed with a suitably shaped spatula. The adhesive layer thickness should average 2mm (with minimum 1mm and maximum 3mm). Edges of the laminate can be cleaned of excess adhesive using solvent, provided the adhesive has not hardened. Adjacent CFK laminates may be placed with a minimum 5 mm spacing.

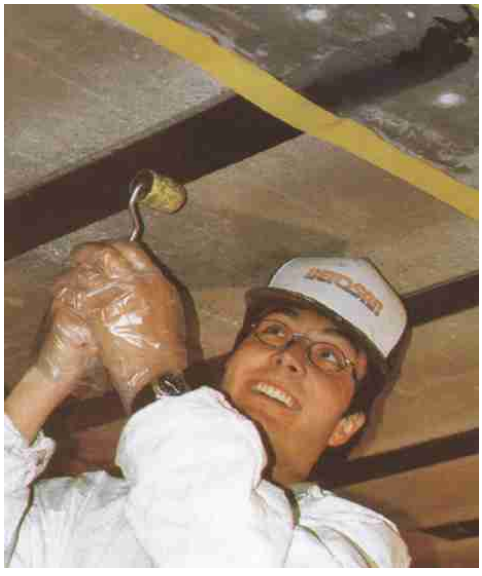


Fig. 6: Application of the S&P Laminate CFK

Fig. 7: Checking of substrate humidity

5.2.8 Quality Control

During the adhesive application and for the first 1 – 2 days of curing of the S&P adhesive, it is preferable that vibrations in the zone of influence of the application area be minimised. After the phase of hardening of the adhesive, the laminates should be tested by means of tapping to locate potential drummy areas. The flatness of the laminate surface after curing must also be checked. Any deviation should not be more than 1 mm over a 300 mm gauge length. Alternatively, on a gauge length of 2 m, any deviation should not exceed 5 mm.

5.2.9 Fire Protection measures

As 2 component adhesives are only able to function up to temperatures of max. 50 – 60° C, special protection measures need to be taken in the situation where fire protection is specified.

Fig. 8: fire protection

Dew point table

Air Tempe-rature	Dew point temperatures in ºC, at 45% relative humidity of air										
[°C]	**45 %**	**50 %**	**55 %**	**60 %**	**65 %**	**70 %**	**75 %**	**80 %**	**85 %**	**90 %**	**95 %**
2	-7.77	-6.56	-5.43	-4.40	-3.16	-2.48	-1.77	-0.98	-0.26	0.47	1.20
4	-6.11	-4.88	-3.69	-2.61	-1.79	-0.88	-0.09	0.78	1.62	2.44	3.20
6	-4.49	-3.07	-2.10	-1.05	-0.08	0.85	1.86	2.72	3.62	4.48	5.38
8	-2.69	-1.61	-0.44	0.67	1.80	2.83	3.82	4.77	5.66	6.48	7.32
10	-1.26	0.02	1.31	2.53	3.74	4.79	5.82	6.79	7.65	8.45	9.31
12	0.35	1.84	3.19	4.46	5.63	6.74	7.75	8.69	9.60	10.48	11.33
14	2.20	3.76	5.10	6.40	7.58	8.67	9.70	10.71	11.64	12.55	13.36
15	3.12	4.65	6.07	7.36	8.52	9.63	10.70	11.69	12.62	13.52	14.42
16	4.07	5.59	6.98	8.29	9.47	10.61	11.68	12.66	13.63	14.58	15.54
17	5.00	6.48	7.92	9.18	10.39	11.48	12.54	13.57	14.50	15.36	16.19
18	5.90	7.43	8.83	10.12	11.33	12.44	13.48	14.56	15.41	16.31	17.25
19	6.8	8.33	9.75	11.09	12.26	13.37	14.49	15.47	16.40	17.37	18.22
20	7.73	9.30	10.72	12.00	13.22	14.40	15.48	16.46	17.44	18.36	19.18
21	8.60	10.22	11.59	12.92	14.21	15.36	16.40	17.44	18.41	19.27	20.19
22	9.54	11.16	12.52	13.89	15.19	16.27	17.41	18.42	19.39	20.28	21.22
23	10.44	12.02	13.47	14.87	16.04	17.29	18.37	19.37	20.37	21.34	22.23
24	11.34	12.93	14.44	15.73	17.06	18.21	19.22	20.33	21.37	22.32	23.18
25	12.20	13.83	15.37	16.69	17.99	19.11	20.24	21.35	22.27	23.30	24.22
26	13.15	14.84	16.26	17.67	18.90	20.09	21.29	22.32	23.32	24.31	25.16
27	14.08	15.68	17.24	18.57	19.83	21.11	22.23	23.31	24.32	25.22	26.10
28	14.96	16.61	18.14	19.38	20.86	22.07	23.18	24.28	25.25	26.20	27.18
29	15.85	17.58	19.04	20.48	21.83	22.97	24.20	25.23	26.21	27.26	28.18
30	16.79	18.44	19.96	21.44	23.71	23.94	25.11	26.10	27.21	28.19	29.09
32	18.62	20.28	21.90	23.26	24.65	25.79	27.08	28.24	29.23	30.16	31.17
34	20.42	22.19	23.77	25.19	26.54	27.85	28.94	30.09	31.19	32.13	33.11
36	22.23	24.08	25.50	27.00	28.41	29.65	30.88	31.97	33.05	34.23	35.06
38	23.97	25.74	27.44	28.87	30.31	31.62	32.78	33.96	35.01	36.05	37.03
40	25.79	27.66	29.22	30.81	32.16	33.48	34.69	35.86	36.98	38.05	39.11
45	30.29	32.17	33.86	35.38	36.85	38.24	39.54	40.74	41.87	42.97	44.03
50	34.76	36.63	38.46	40.09	41.58	42.99	44.33	45.55	46.75	47.90	48.98

The dew point table indicates the surface temperatures at which condensation occurs, depending on air temperature and relative humidity of air. At 20ºC air temperature and 70% relative humidity of air condensation on non-absorbent surfaces, for instance, will occur at surface temperatures of below 14.4ºC.

5.2.10. Quality Assurance Reports

A Report: Concrete bearing surface / Bonding FRP

Structure:			**Position:**				**Contract-No.:**					
Bonding of concrete bearing surface Preparation: ..... Adhesive: ..... Dolly (Ø 50 mm):							**Bonding FRP** Preparation: ..... Adhesive: ..... Dolly (Ø 50 mm):					
Date		Position	Tensile Strength				Date		C	Tensile Strength		
glued	tested	of sample	single value N/mm²	average N/mm²	failure mechanism		glued	tested	FRP A	single value N/mm²	average N/mm²	failure mechanism
Caption for failure mechanism: C: Concrete A: Adhesive							Caption for failure mechanism: C: Concrete FRP: Fibre Reinforcement Polymer A: Adhesive					
Remarks:							Date: Signature:					

B Report: Application of FRP

Structure:	**Structural element:**	**Adhesive:**

Nr.	Date:	Charge-nr. of adhesive	Temperature Adhesive (>5 ^{0} C) ^{0} C	Temperature Air (>5^0 C) ^{0} C	Relative Humidity (<75%) %	Dew point-temperature DP ^{0} C	Temperature Concrete (>5^0 C) (>TP+3^{0}K) ^{0} C	Temperature FRP (>5^{0}C) (>TP+3^{0}K) ^{0} C	Concrete Humidity weight-%	Drummy areas Reported cm x cm	Drummy areas Injected Date	Evenness check √

Drawn up by: Signature:

Date: