

## **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 Repecem 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<sup>2</sup>, 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<sup>2</sup>, 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<sup>2</sup>; Resicem: 150 - 250 gms/m<sup>2</sup>).

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

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.

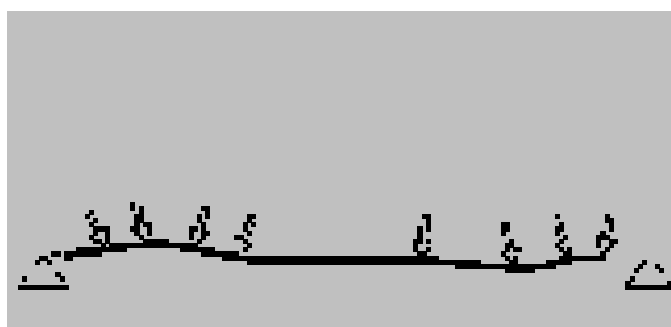
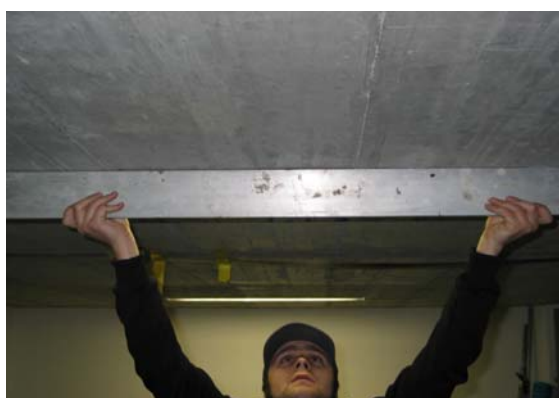
## 5.2 S&P Carbon Fibre Laminate Systems CFK

### 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 Repecem 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 glueing device. 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.

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

Table 7: Overview of S&P Resin 220

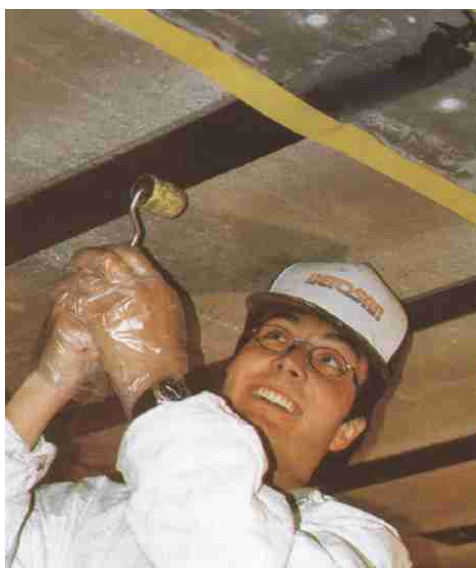
The table overleaf gives guidelines to usage of the S&P Resin 220 (Epoxy Paste).

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 Temperature	Dew point temperatures in °C, at 45% relative humidity of air										
[ °C ]	45 %	50 %	55 %	60 %	65 %	70 %	75 %	80 %	85 %	90 %	95 %
<b>2</b>	-7.77	-6.56	-5.43	-4.40	-3.16	-2.48	-1.77	-0.98	-0.26	0.47	1.20
<b>4</b>	-6.11	-4.88	-3.69	-2.61	-1.79	-0.88	-0.09	0.78	1.62	2.44	3.20
<b>6</b>	-4.49	-3.07	-2.10	-1.05	-0.08	0.85	1.86	2.72	3.62	4.48	5.38
<b>8</b>	-2.69	-1.61	-0.44	0.67	1.80	2.83	3.82	4.77	5.66	6.48	7.32
<b>10</b>	-1.26	0.02	1.31	2.53	3.74	4.79	5.82	6.79	7.65	8.45	9.31
<b>12</b>	0.35	1.84	3.19	4.46	5.63	6.74	7.75	8.69	9.60	10.48	11.33
<b>14</b>	2.20	3.76	5.10	6.40	7.58	8.67	9.70	10.71	11.64	12.55	13.36
<b>15</b>	3.12	4.65	6.07	7.36	8.52	9.63	10.70	11.69	12.62	13.52	14.42
<b>16</b>	4.07	5.59	6.98	8.29	9.47	10.61	11.68	12.66	13.63	14.58	15.54
<b>17</b>	5.00	6.48	7.92	9.18	10.39	11.48	12.54	13.57	14.50	15.36	16.19
<b>18</b>	5.90	7.43	8.83	10.12	11.33	12.44	13.48	14.56	15.41	16.31	17.25
<b>19</b>	6.8	8.33	9.75	11.09	12.26	13.37	14.49	15.47	16.40	17.37	18.22
<b>20</b>	7.73	9.30	10.72	12.00	13.22	14.40	15.48	16.46	17.44	18.36	19.18
<b>21</b>	8.60	10.22	11.59	12.92	14.21	15.36	16.40	17.44	18.41	19.27	20.19
<b>22</b>	9.54	11.16	12.52	13.89	15.19	16.27	17.41	18.42	19.39	20.28	21.22
<b>23</b>	10.44	12.02	13.47	14.87	16.04	17.29	18.37	19.37	20.37	21.34	22.23
<b>24</b>	11.34	12.93	14.44	15.73	17.06	18.21	19.22	20.33	21.37	22.32	23.18
<b>25</b>	12.20	13.83	15.37	16.69	17.99	19.11	20.24	21.35	22.27	23.30	24.22
<b>26</b>	13.15	14.84	16.26	17.67	18.90	20.09	21.29	22.32	23.32	24.31	25.16
<b>27</b>	14.08	15.68	17.24	18.57	19.83	21.11	22.23	23.31	24.32	25.22	26.10
<b>28</b>	14.96	16.61	18.14	19.38	20.86	22.07	23.18	24.28	25.25	26.20	27.18
<b>29</b>	15.85	17.58	19.04	20.48	21.83	22.97	24.20	25.23	26.21	27.26	28.18
<b>30</b>	16.79	18.44	19.96	21.44	23.71	23.94	25.11	26.10	27.21	28.19	29.09
<b>32</b>	18.62	20.28	21.90	23.26	24.65	25.79	27.08	28.24	29.23	30.16	31.17
<b>34</b>	20.42	22.19	23.77	25.19	26.54	27.85	28.94	30.09	31.19	32.13	33.11
<b>36</b>	22.23	24.08	25.50	27.00	28.41	29.65	30.88	31.97	33.05	34.23	35.06
<b>38</b>	23.97	25.74	27.44	28.87	30.31	31.62	32.78	33.96	35.01	36.05	37.03
<b>40</b>	25.79	27.66	29.22	30.81	32.16	33.48	34.69	35.86	36.98	38.05	39.11
<b>45</b>	30.29	32.17	33.86	35.38	36.85	38.24	39.54	40.74	41.87	42.97	44.03
<b>50</b>	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 20°C air temperature and 70% relative humidity of air condensation on non-absorbent surfaces, for instance, will occur at surface temperatures of below 14.4°C.



**5.2.10. Quality Assurance Reports**

**A Report: Concrete bearing surface / Bonding FRP**

<b>Structure:</b>			<b>Position:</b>			<b>Contract-No.:</b>					
<b>Bonding of concrete bearing surface</b>						<b>Bonding FRP</b>					
Preparation: .....						Preparation: .....					
Adhesive: .....						Adhesive: .....					
Dolly (Ø 50 mm): .....						Dolly (Ø 50 mm): .....					
Date		Position of sample	Tensile Strength			Date		C FRP A	Tensile Strength		
glued	tested		single value N/mm <sup>2</sup>	average N/mm <sup>2</sup>	failure mechanism	glued	tested		single value N/mm <sup>2</sup>	average N/mm <sup>2</sup>	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**

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

Drawn up by:	Signature:  Date:
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