Strengthening of building structures with FRP-fabrics

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Summary

There is great potential and considerable economic advantages in strengthening existing concrete members with epoxy-bonded composite plates. Composite fabrics and a unidirectional tape can also be used. This paper presents and discusses briefly the use of CFRP (Carbon Fibre Reinforced Polymers) for strengthening concrete structures. A historical background is presented as well as some results from tests on beams strengthened for shear with composite fabrics.

1 General Concept for strengthening and testing

If it is considered the amount of money that are fixed in the existing buildings and infrastructure there are in many situations economically attractive to repair the structure and extend its life. However, it must be considered as a great challenge, to repair and upgrade the transportation infrastructure of the Western world. There are several methods for repairing or strengthening a structure. One such method that has been used quite extensively around the world in the last two decades is steel plate bonding, i.e. when steel plates are epoxy-bonded to the surface of a structure. At Luleå University of Technology, Sweden, research has been carried out in the area of plate bonding. The research work started in 1988 with steel plate bonding and is still continuing, but now with FRP (Fibre Reinforced Polymers) materials. These types of materials have the advantages of being very strong yet lightweight, and having excellent fatigue properties and outstanding corrosion resistance. In addition, composites are formable and can be shaped to any desired form and surface texture. The major disadvantage is that they are expensive (especially CFRP) while another disadvantage can be that the FRP-materials are anisotropic, i.e. they have different material properties in different directions. One very interesting and economic application of currently available advanced composite materials is the strengthening of damaged or structurally inadequate buildings and bridges. In this study three different applications methods were investigated; Hand lay-up, two different systems. System A and B; Pre-preg in combination with heat. System C; and Vacuum injection. System D. Material properties of the systems used are recorded in Table 1.

Table 1 Material data for CFRP-system tested

Property	System A	System B	System C	System D
Fibre system	Tape	Tape	Prepreg	Fabric [0/90°]
E_L, (GPa)	65.6	70.8	100.6	49.0
E_T, (GPa)	4.4	4.8	8.0	49.0
G_{LT}, (GPa)	0.7	1.0	4.1	3.1
ε_{LU}	0.017	0.014	0.014	0.013
σ_{LU}, (MPa)	1053.0	860.0	1450.0	577.0
σ_{TU}, (MPa)	9.6	24.6	29.0	577.0
t, (mm)	0.96	1.03	0.69	2.2
w, (%)	39	39	60	55

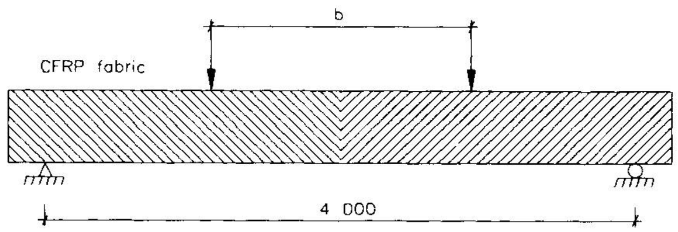

Fig. 1 Test specimens and test arrangement

A total of eight beams were tested, three beams were chosen to be reference beams, two of these beams, R1 and R2 now denoted SR1 and SR2, were strengthened after failure and loaded again. The dimension of the beams together with the test arrangement and the palcement of the CFRP fabric are shown in Fig. 1.

2 Application and test results

Before applying the composite some pre-treatment steps for the beams were necessary. First the beams were sandblasted. After this the surfaces were vacuum cleaned to remove loose particles and dust. For all systems, with the exception of System C, the pre-preg tape, a primer was applied to the concrete surface before the fibre system was applied. The temperature during application was 20 °C in all cases. All of the beams were strengthened with the CFRP-composite at a 45° angle to the horizontal plane.

Table 2 Test results from the four point bending test

Beam	System	b (mm)	Failure	F_{max} (kN)	δ_{max} (mm)	F_{test}/F_{ref}
R1	Reference,	800	Shear	212	10	1.0
R2	Reference,	1600	Shear	241	9	1.0
R3	Reference,	2000	Shear	226	9	1.0
S1	A	1600//2000	II	681//834	32//46	2.8//3.7
S2	C	1600	II/III	548	22	2.3
S3	D	1600	III	546	30	2.3
S4	B	1600	I	662	31	2.7
S5	B	1600//2000	II	695//839	34//39	2.9//3.7
SR1	B	800	III	390	22	1.8
SR2	B	1600	III	486	20	2.0

3 Summary and Conclusions

It is pleasant to present results from the tests performed which show a very good strengthening effect in shear with CFRP-composites bonded to the face of concrete beams. Three different application methods were investigated in the tests; hand lay-up (two systems), pre-preg with heat and vacuum injection. Compared with vacuum injection and pre-pregs, the hand lay-up systems were very easy to apply to concrete beams. Even if the composite has better material properties with injection or pre-preg, the results on site seem to be more controllable for the hand lay-up systems. Nevertheless, in special applications, e.g. with warm surroundings, pre-pregs can have a future since it would be possible to increase the glass transition temperature for the system. For the vacuum injection system, the biggest problem at failure was that the fibres buckled. It should be possible to overcome this with another type of weave. No measurable difference could be registered between the two hand lay-up systems used. Furthermore, it is very important that the condition of the existing structure be thoroughly investigated. Otherwise there is a risk that the failure mode for the structure can be changed, e.g. from a ductile bending failure to a brittle compressive failure.