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Materials Science & Technology

FiReP International AG
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Test Report No. 456494

Test assignment:	**Testing of Injectionbolt J64-25**
Client:	FiReP International AG, Rapperswil, Switzerland
Test objects:	5 Bolts
Client's ref:	Mr. H. Ahari Hashemi
Order dated of:	05.11.2010
Test performed:	18.02.2011
Number of pages:	7
Attachments:	Appendix A and B

Empa, Swiss Federal Laboratories for Materials Science and Technology
Laboratory for Structural Engineering
Dübendorf, March 24, 2011

Expert:
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Contents

0 Units and Symbols

Units

area:	mm^2
deformation:	mm
displacement:	mm
force:	kN
length:	mm, cm, m
strain:	%
stress:	N/mm^2
temperature:	°C
time:	min.
volume:	mm^3
Young's modulus:	N/mm^2

Latin upper case symbols

A	cross section area
A_s	stress section area
D	diameter
D_s	stress section diameter
E	Young's modulus
L	length
L_m	length of the field for the image correlation measurements in bolt direction
N	number of test pieces
F_u	maximum force

Latin lower case symbols

f_u	maximum stress
$\bar{x}$	mean value
x_i	sampling data

Greek upper case symbols

ΔF	difference between the forces at 50% and 20% of the maximum tensile force
$\Delta \varepsilon$	difference between the strains at 50% and 20% of the maximum tensile force

Greek lower case symbols

ε	strain
σ	standard deviation

1 Introduction

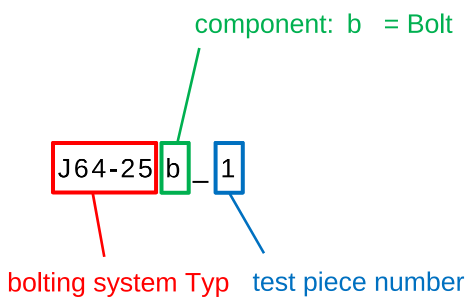
FiReP International AG (Switzerland) commissioned Empa to conduct tests with 4 types of glass reinforced polymer (GRP) bolts and accessories under short term loading. These bolt systems are used in mining, tunneling and ground stabilization.

The test method is based on the ISO 10406-1 standard.

This test report describes tensile tests and its test results for 5 specimens of Injectionbolt J64-25 (D=25 mm, UP resin).

2 Test piece names

Using the following example the explanation is given on how the test piece name is built up:



3 Tests

3.1 General

The test pieces were delivered to Empa on January 24, 2011. The loading was applied with a 1000 kN testing machine (Log-No 60.220) cross head displacement controlled. The measurement uncertainty was smaller than 1% of the load over the 1000 kN measuring domain.

This machine allows for a maximum test piece length of 2.0 m.

The strain rate listed in the table corresponds to the constant machine displacement rate divided by the free length of the GRP bolt.

Table 1: Component to be tested

Component to be tested	Number of test pieces	Test piece designation	GRP strain rate [% / min.]
Bolt	5	J64-25b_1…5	0.8

The temperature was 20° C for all tests.

3.2 Test piece

Figure 1 shows the test piece geometry. The free GRP length was 1000 mm. Both ends of the 2000 mm long GRP bolt were glued into steel sleeves in the factory.

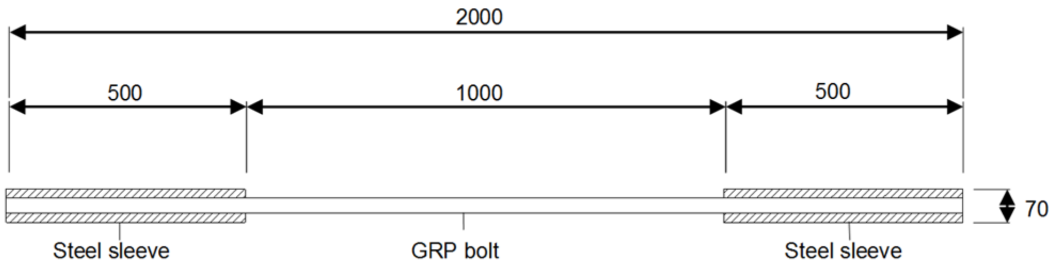


Figure 1: Test piece for the bolt tensile tests [mm].

3.3 Test set up

The test set up is shown in Figure 2, left. The cross head displacement and the force were measured. The measurement of the cross head displacement is subsequently designated as ‚test machine displacement reading'. The strain was measured contactless with an image correlation system within a field with a length of L_m = 300 mm. The image correlation system took pictures with a frequency of 0.4 Hz. The software calculated the surface profile and the displacements in three orthogonal directions. The accuracy of the displacements was ±0.005 mm. The strain was calculated using the relative displacement between two selected points along the bolt axis.

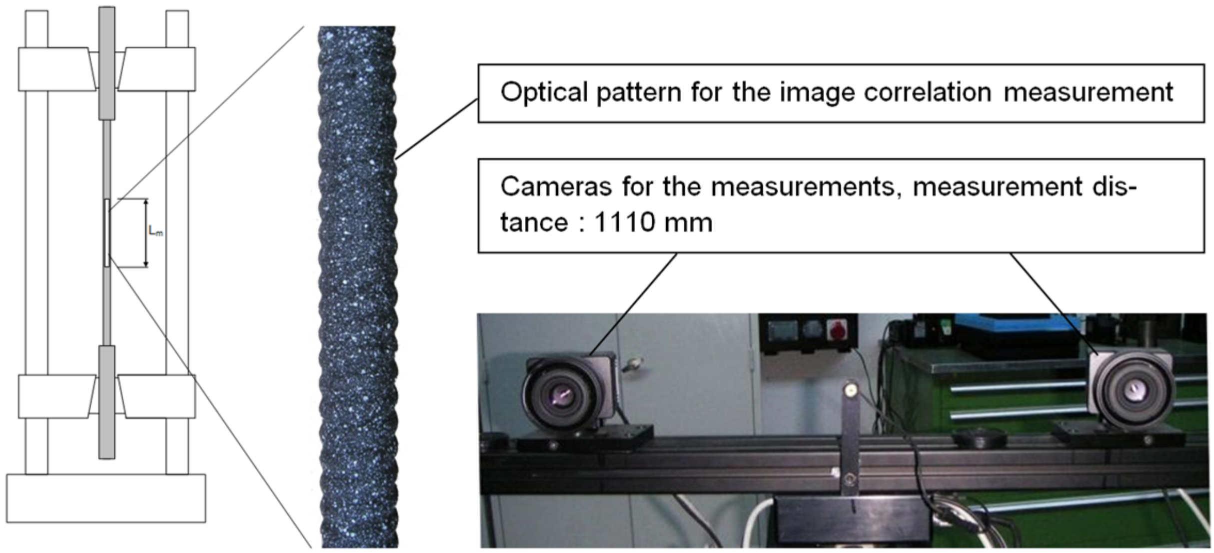


Figure 2: Test set up for the bolt tensile tests with image correlation system.

3.4 Test results

Figure 3a) shows the force-displacement relationships and Figure 3b) the stress – strain relationships of the bolts. The stresses are related to the stress section A_s given in Table 2. The stress – strain relations have a well coincident course.

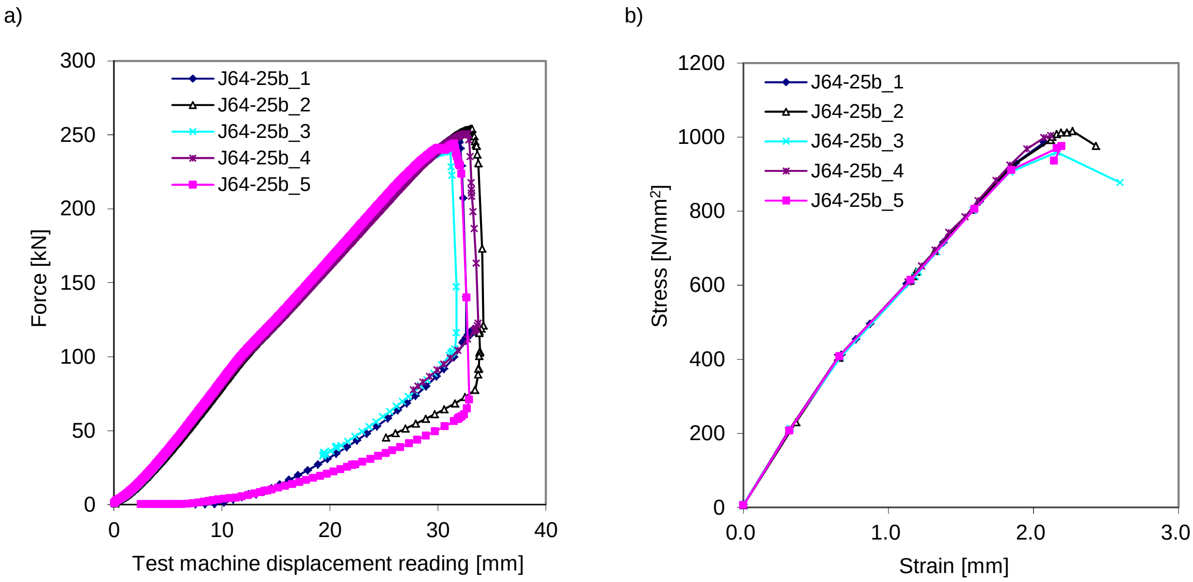


Figure 3: Relationships for a) force – machine displacement reading, b) stress – strain (from the image correlation system).

Figure 4 shows examples of the displacement and strain fields close to maximum force for J64-25b_1.

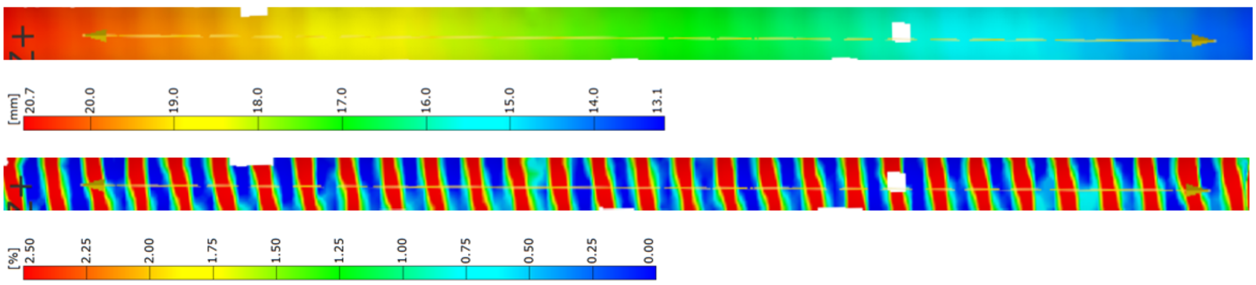


Figure 4: Displacement and strain fields of the image correlation measurement for J64-25b_1 close to maximum force. The arrow line represents the distance for the strain measurements.

Table 2 shows the results of the tensile tests and the Young's moduli. The maximum stress and the Young's modulus were calculated using the stress area shown. Explanations of this area are provided in Appendix 1.

Table 2: Test results for the bolt. Test date: 18.02.2011.

Name	Stress area A_s *) [mm²]	Maximum force F_u [kN]	Maximum stress f_u [N/mm²]	Strain ε @ F_u [%]	Strain ε @ 20 % F_u [%]	Strain ε @ 50 % F_u [%]	Young's modulus [N/mm²]
J64-25b_1	250	248.5	994	2.07	0.30	0.87	51'884
J64-25b_2		254.1	1016	2.27	0.32	0.91	51'972
J64-25b_3		239.7	959	2.16	0.29	0.85	51'772
J64-25b_4		250.6	1002	2.12	0.30	0.88	51'946
J64-25b_5		244.0	976	2.19	0.30	0.85	52'866
mean value: $\bar{x}$		**247.4**	**989**	**2.16**	**0.30**	**0.87**	**52'088**
standard dev.: σ		**5.0**					

*) Stress area specified by the client. See also explanations in Appendix 1.

The maximum stress is calculated according to Equation (1)

$$f_u = \frac{F_u}{A_s}. \tag{1}$$

The mean values were calculated according to Equation (2):

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{2}$$

where N is the number of test pieces and x_i are the sampling data. The standard deviation is defined as given in Equation (3):

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}. \tag{3}$$

The Young's modulus was calculated according to [ISO 10406-1, 2008] by dividing the difference between the stresses by the difference between the strains at 50% and 20% of the maximum tensile force. The Young's modulus was calculated according to Equation (4).

$$E = \frac{\Delta F}{\Delta \varepsilon \cdot A_s}. \tag{4}$$

Figure 5 shows the bolts after the tests.

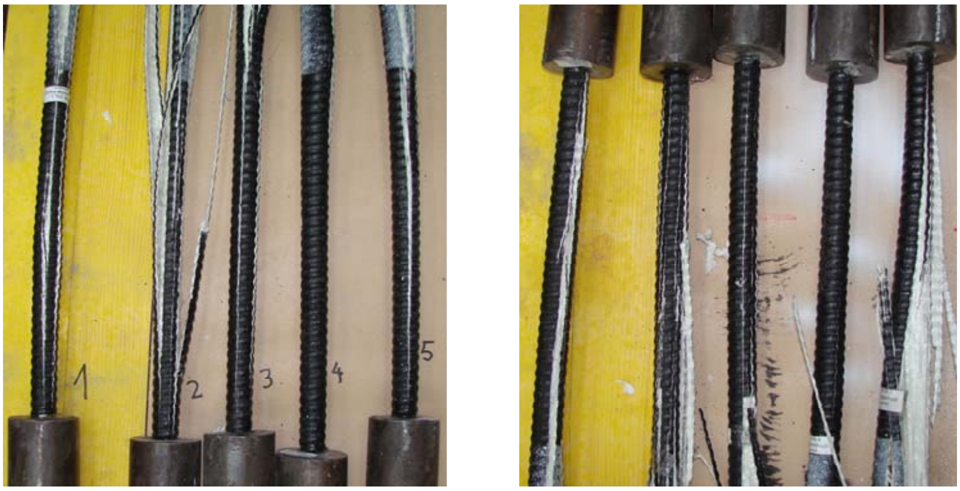


Figure 5: Bolts after the tests. The bolts have not been completely separated by the fracture.

3.5 Failure mechanism and fracture pattern

Failure occurred in a brittle manner with a sequence of loud banging noises. The bolts were delaminated in the free length (Figure 5).

4 Reference

ISO 10406-1 (2008) Fibre reinforced polymer (FRP) reinforcement of concrete – Test methods, Part 1: FRP bars and grids, International Standard.

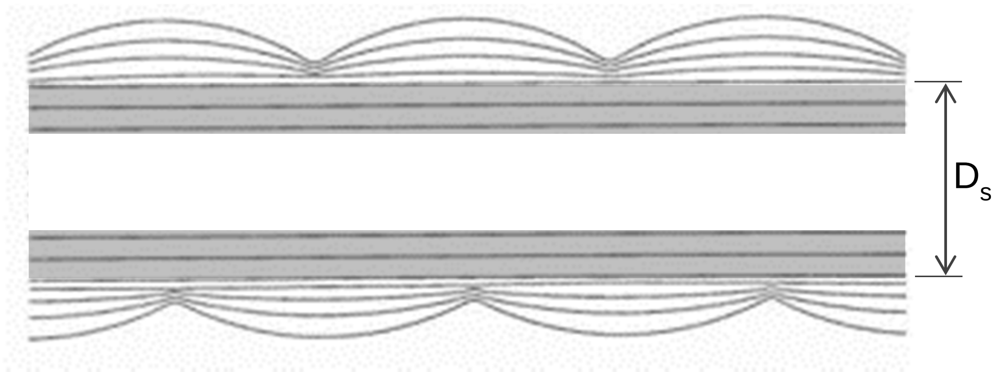
Appendix 1

Explanations for the stress area

Figure 6 schematically shows a longitudinal section of the GRP bolt. The cross section of the anisotropic GRP bolt is composed of a portion of unidirectional fibers within the core cross section, plus a portion of undulated fibers in the outer layer.

The stress section A_s is related to the core cross section with unidirectional fibers.

The stress section in the figure lies within the grey highlighted area of the height D_s.



D_s: Relevant diameter for the determination of the stress section A_s

Figure 6: Schematic longitudinal section of a GRP bolt.

Appendix 2

Mean bolt cross sectional area

3 bolt test pieces (J64-25A_1, J64-25A_2 und J64-25A_3) were trimmed to the length of about 200 mm for the determination of the mean cross sectional area. Subsequently, the lengths were exactly measured and the volume of water displaced was measured using a 250 ml measuring cup (Figure 7). No air bullets were observed at the test piece surface.

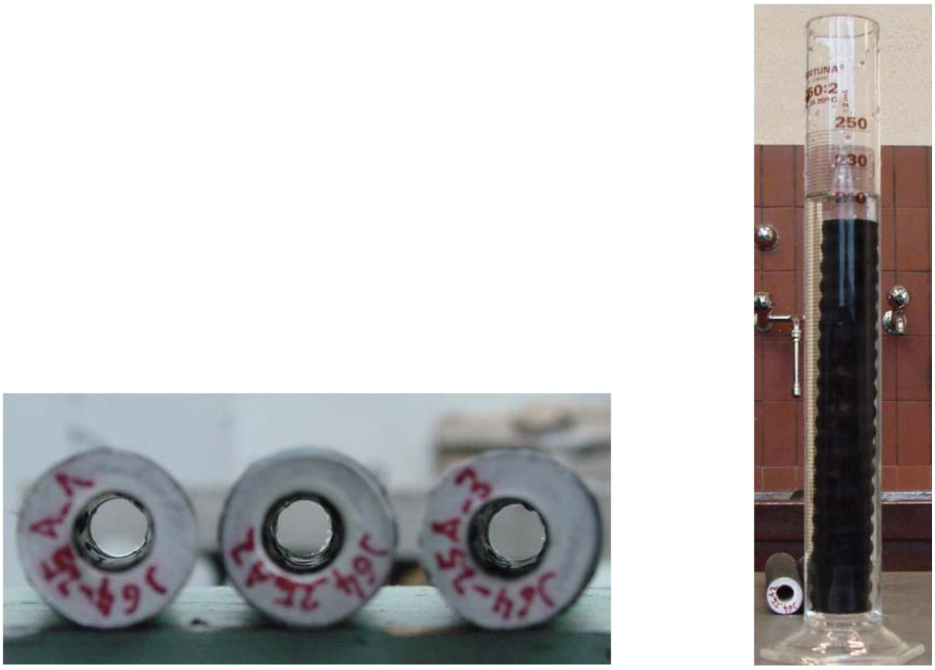


Figure 7: Test pieces with hollow section and measuring cup.

The cross sectional area was calculated by dividing the displaced volume of water by the test piece length. Table 3 shows the measured water volumes and the calculated cross sectional areas.

Table 3: Measured water volumes and the calculated cross sectional areas.

Date			31.01.2011
pure water volume	[mm^3]	Vw	150'000
water + test piece volume	[mm^3]	Vtot_1	218'000
		Vtot_2	218'000
		Vtot_3	218'000
test piece volume (V = Vtot - Vw)	[mm^3]	V_1	68'000
		V_2	68'000
		V_3	68'000
test piece length	[mm]	L_1	200.2
		L_2	199.9
		L_3	200
net section area	[mm^2]	A_1 net	339.7
		A_2 net	340.2
		A_3 net	340.0
mean net section area	**[mm^2]**	**A_mean**	**339.9**