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Report submitted to Indo Spark Construction Services on the

Load Testing of Chemical Resins EASF, VESF, Pure Epoxy 3:1 and 1:1 with Anchors Sizes M8, M12 and M20 In accordance with European Organisation Technical Approval (EOTA) guideline, ETAG No. 001, Part 5, Edition March 2002, amended February 2008

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Forward

In accordance with instructions from Mr. Sandeep Ingale of Indo spark construction services, tensile load tests have been carried out on ICFS Chemical resins EASF, VESF, Pure Epoxy 3:1 and 1:1 with anchors sizes M8, M12 and M20 in accordance with the European Organisation of Technical Approval (EOTA) Guideline (ETAG), ETAG No. 001, 1997 and Part 5, 2008.

The load testing was carried out by Dr S Popo-Ola of the Civil & Environmental Engineering Department with assistant by Mr L Clark of the Civil & Environmental Engineering Department all at Imperial College London.

This report contains details of the test specimens, the test procedure and the results of the tests carried out in the Concrete Structures Laboratory of the Imperial College of Science, Technology and Medicine between March and April 2009.

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1.0 Introduction

In accordance with instructions from Mr. Sandeep Ingale of Indo Spark Construction Services, tensile load tests have been carried out on ICFS Chemical anchors sizes M8, M12 and M20 (See figure 1) in accordance with the European Organisation of Technical Approval (EOTA) Guideline (ETAG), ETAG No. 001, 1997 and Part 5, 2008. Each anchor diameter was carried out using 4 different chemicals, namely EASF, VESF, Pure Epoxy 3:1 and 1:1.

This report contains details of the test specimens, the test procedure and the results of the tests carried out in the Concrete Structures Laboratory of the Imperial College of Science, Technology and Medicine between March and April 2009.

Figure 1: ICFS Chemical Anchors

2.0 Aim of the tests

The purpose of the tests was to:

- Determine the Admissible Service Load for Tension loading on a single anchor not influenced by edge and spacing effects (Test type A1-T) in Cleaned (Dry) holes in Low strength normal weight/non-cracked concretes grades C20/25.
- Determine the Admissible Service Load for Tension loading on a single anchor not influenced by edge and spacing effects (Test type F1-T) in Uncleaned (Wet) holes in Low strength normal weight/non-cracked concretes grades C20/25.
- Determine the Admissible Service Load for Tension loading on a single anchor not influenced by edge and spacing effects (Test type F1-T) in Diamond drilled holes in Low strength normal weight/non-cracked concretes grades C20/25.

The tests were carried out with M8/60, M12/90, M12/110, M20/120 and M20/170 studding installed at standard and shallow embedment depths with 4 resins EASF, VESF, Pure Epoxy 3:1 and Pure Epoxy 1:1.

2.1 Programme of Testing

2.1.1 Test types

The tests reported herein follow the test programme given in Table 2.1 and the direction of loading is as shown in Figure 2.1.

Table 2.1: Summary of load tests on through bolt anchors in C20/25 Concretes

Test Type	Test Description	Anchor diameter/embedment depth				
		M8/60	**M12/90**	**M12/110**	**M20/120**	**M20/170**
A1-T	Tensile in cleaned holes					
	EASF	5		5		5
	VESF	10		5		10
	Pure Epoxy 3:1	5	10	5	5	
	Pure Epoxy 1:1	5	5		5	
F1-T	Tensile in uncleaned holes Pure Epoxy 3:1		5		5	
D1-T	Tensile in diamond drilled holes Pure Epoxy 3:1		5		5	
Total		25	25	15	20	15

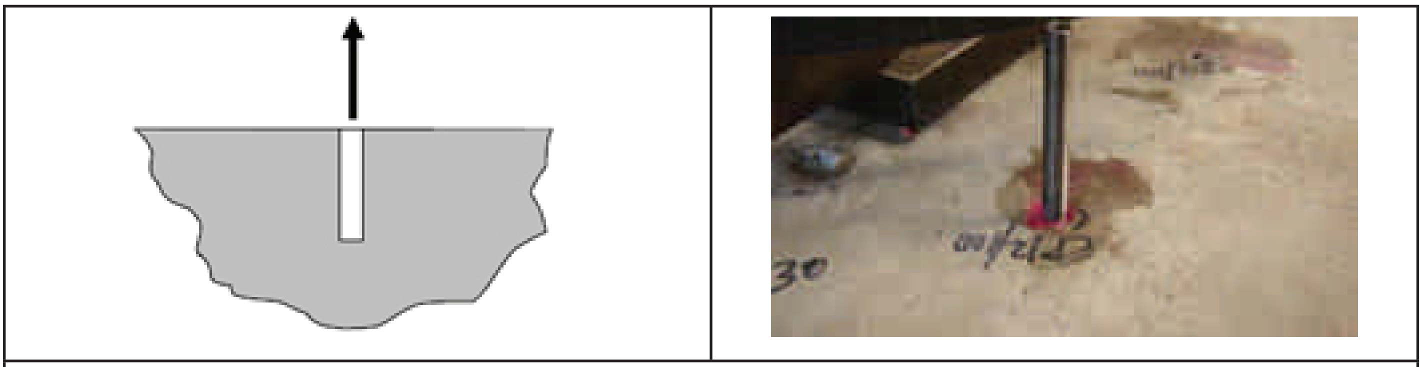


Figure 2.1: - Direction of Loading of Anchor

2.1.2 Identification of anchors

The geometries of the anchors used in the test programme are shown in Table 2.2.
Table 2.2: Characteristics of ICFS chemical anchors

	M8/60	M12/90	M12/110	M20/120	M20/170
Drill bit diameter (d_o)	10	14	14	24	24
Minimum hole depth (B_T)	70	100	120	130	180
Depth of embedment (h_{nom})+	60	90	110	120	170
Max. thickness fastened (t_{fix})	25	25	25	25	25
Anchor length (L)	100	180	180	300	300
Maximum Tightening torque ($M_{d.max}$)(Nm)*	30	50	50	100	100
Clearance hole (D_o) (mm)	12	16	16	26	26
Head style (Hexagon, Hex)	Hex	Hex	Hex	Hex	Hex

All dimensions are in millimetres unless otherwise stated
*All anchors were hand tightened as requested by the manufacturer.
+Shallow embedment was used for all M8 tests and for the pure epoxy M12 and M20 tests to ensure resin bond failure

The geometries of the anchors used in the test programme are given in Table 2.2. It is a typical threaded stud whereby the diameter of the stud is used to describe each anchor sizes, i.e. M8, M12 and M20. The studs were high strength grade 12.9 to ensure resin failure occurred to determine the bond strength of each resin type.

Table 2.3 gives further details of the test samples as supplied by the manufacturer.

Table 2.3: Properties of Anchors

Anchor type	**Manufacturer Code Number**	**Diameter of thread, d (mm)**	**Crosssectional Area A_s (mm^2)**	**Yield Stress f_y (N/mm^2)**	**Tensile Strength f_u (N/mm^2)**	**Date of Delivery**
M8	Alloy steel M1.6-M100 grade 12.9	8	36.6	1080	1220	5/Mar/09
M12		12	84.3	1080	1220	5/Mar/09
M20		20	244.8	1080	1220	5/Mar/09

3.0 Test Rig, Methods and Data logging Equipment

3.1 Tensile test in Non-cracked Concrete

The test rig for the tension tests in non-cracked concrete consists of a 250 kN servocontrolled Instron actuator mounted on a steel rig, as shown on Figure 3.1. The loading fixtures are specifically designed and fabricated for the anchor used, as shown in Figure 3.2. Both the rigs and the loading fixtures conformed to Section 4 of ETAG Annex A, 1997. A system of displacement-control was used to apply axial tensile load to the anchor.

Figure 3.1: - The Tensile loading rig

Figure 3.2: - Tensile loading fixture

4.0 Test Members

4.1 Concrete Slabs

Concrete slabs of dimensions 2400 x 1200 x 400 mm deep were cast for the concrete grade C20/25. The maximum aggregate size used was 20 mm. The slabs were cast vertically to allow the possible use of both slab faces without introducing any casting error. The wooden moulds were manufactured by Imperial College but the mix was delivered by Ready Mixed Concrete Limited. A minimum reinforcement mesh was located in the mid-depth of the noncracked concrete slabs for lifting purposes. Figure 4.1 shows the casting of typical concrete slab.

The mix constituents, casting and curing of the members and control specimens were in accordance with ETAG, Annex A, Section 2, 1997. For each casting, 12 control specimens (100 x 300 mm cylinders and 100 x 100 x 100 cubes) were prepared according to British Standard BS 1881: 1983. Table 4.1 below gives the mix compositions for the test units.

Table 4.1 : Composition and characteristics of concrete mix

Material Type	Source	Batch Weights (kg/m^3) C20/25
Sand	SASAG Alresford	755
10 mm Flint Gravel	HA (SE) Colnbrook	345
20 mm Flint Gravel	HA (SE) Colnbrook	805
Portland Cement	BCI - Northfleet	240
Free water/cement ratio	-	0.68
Density	-	2350
Gravel/sand	-	1.523
Aggregate/cement	-	4.792
Slump	-	50-60 mm
Date of casting	-	August 2008

Figure 4.1: – Casting of concrete slab

4.2 Concrete Strength Measurement

The compressive strength of the concrete in the units was determined in accordance with BS 181: 1983 using the control specimens prepared during casting as follows:

- After 7 days with the specimen stored in water for seven days at 20^{o}C.
- After 28 days with the specimen stored in laboratory air after the initial 7 days.
- On the day of testing of anchors with the specimen stored in laboratory air and under the sme environmental condition as the test slabs.

Table 4.2 gives the compressive strength of the C20/25 concrete. The cube compressive strength on the day of testing is the average value of three specimens measured. Each specimen was a 100mm cube.

Table 4.2: Strength of concrete

Concrete Slab Type	7 days Compressive Strength (N/mm^2)	28 days Compressive Strength (N/mm^2)	Average Cube Compressive Strength on the day of testing (N/mm^2)
L19 C20/25	20.4	29.1	32.7
	22.9	26.5	33.1
	21.6	25.7	31.9
L20 C20/25	19.9	27.4	33.2
	20.2	28.5	31.6
	21.2	29.2	32.8

5.0 Anchor Installation

Each slab was of a size sufficient to install twenty (24) individual anchors for testing. The spacing between individual anchor tests was at least 400mm and the edge distance was at least 300mm.

The hole for each anchor diameter was drilled using the drill bit as recommended by the manufacturer and set out in Section 3 of ETAG, Annex A.

The holes were thoroughly cleaned and measured for diameter (dcut, m) and depth (h o) as per
ETAG Part 5 such as:

- Dry cleaned holes – 4 blows, 4 brushes, 4 blows
- Wet, un-cleaned holes – 2 blows, 1 brush

The hole was then filled with the resin before the anchor was inserted into the tip of the hole and gradually pushed by turning the stud into the filled hole with resin. The stud was pushed into the hole until the embedment depth was reached and the excessive resin was cleaned. The anchor was then left to cure for at least 24 hours.

The confined loading plate and fixture were then placed (to ensure bond failure is maximised) and the washer and nut was tightening to secure the assembly in place. Figures 5.1, 5.2 and 5.3 show respectively the installation of the resin, insertion of anchor and the location of the confined loading plate. Other measurements taken during installation are recorded on the test result sheets in Figures 7.1 to 7.14.

Figure 5.1: Installation of resin and insertion of anchor studs

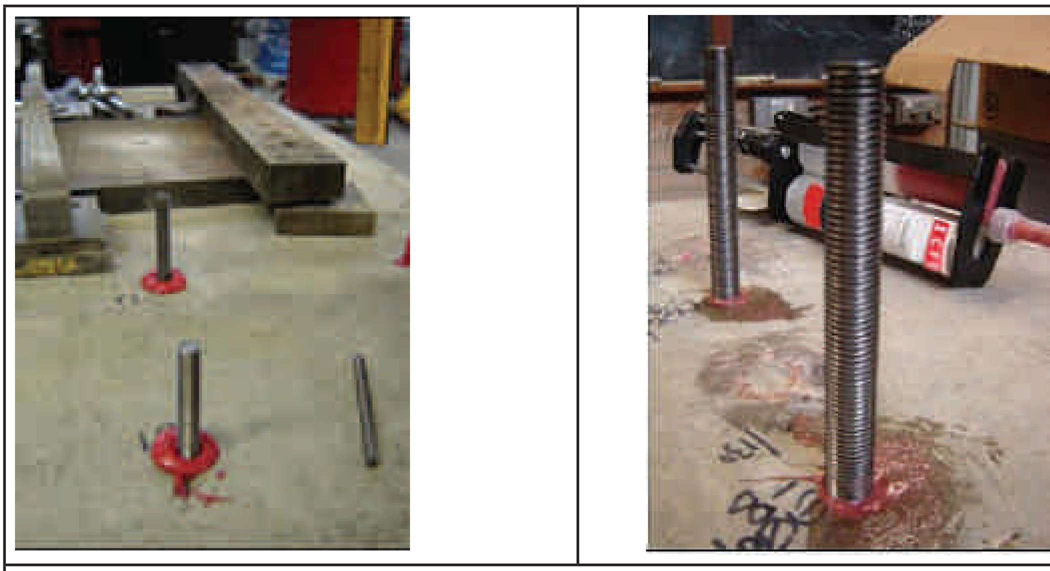


Figure 5.2: Insertion of anchor studs

Figure 5.3: Location of the confined loading plate

6.0 Measured Values

6.1 Applied Load

The tensile load applied to the anchor using the Instron actuator (250 kN capacity and 150 mm stroke, see Figure 3.1) through the loading fixture was measured by a load cell inserted between the jack and the loading fixture. The test load was applied continuously (displacement-controlled loading) and the corresponding movement of the jack and the anchor was monitored.

6.2 Displacement of Anchor

The vertical displacement of the anchor head relative to the concrete surface was measured by two Linear Voltage Displacement Transducers (LVDT). The transducers were positioned on a steel plate fixed to the loading fixture and close to the anchor head as shown on Figure 6.1 below.

Figure 6.1: Location of the displacement transducers

6.3 Data Acquisition System

The data acquisition system employed in all tests consisted of:

- a datascanner unit with 10 volts power supply
- a PC running specially developed software (DATAGEN).

Figure 6.2 shows the layout of the acquisition system with the load cell and transducers connected to the datascanner box, which is, in turn, connected to the computer. With this set-up the output voltages from the load cell and transducers were fed through the scanner to the computer for storage. The computer received and stored data using software called DATAGEN.

DATAGEN was developed at Imperial College with pre-conditioned keys which allows changes to parameters such as; the rate of scanning and storage (i.e. every one second), the number of scanned units and the maximum number of readings to be stored. The computer screen also displays the graph of load-displacement as the test progresses. Appendix A shows the calibration graph of the load cells and the transducers.

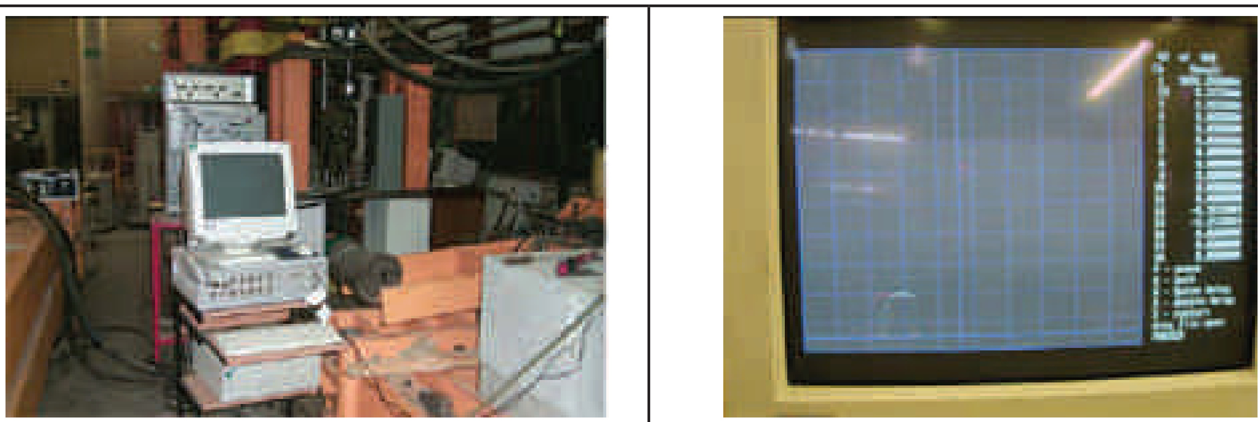


Figure 6.2: Data acquisition system and computer output.

7.0 Test Results

The test results are summarised in Tables 7.1 and 7.4 and the graphs of load-displacement are shown in Figures 7.1 to 7.16. In these tables the following legends are used to describe the failure modes.

R = **R**esin-bond failure;
S = **S**teel stud failure in tension;

The results of these tests are presented as a relationship between applied load (kN) and displacement (mm) in Figures 7.1 and 7.16 which provide the following information:

- The type of tests as given in Table 2.1 and 2.2
- Test parameters (such as; hole diameter, effective depth, edge distances, spacing, crack width, concrete strength, tightening torque and loading speed)
- Load vs. displacement graphs for each test in the series
- The ultimate load and displacement for each test (F^t_u and d^t_u)
- The displacement at 50% of the maximum failure load ($d_{0.5Fut}$)
- Point of lost of adhesion as describe in ETAG001 Part 5 or load at 0.1mm
- The failure mode (R for Resin-bond failure and S, means Steel failure)
    * For each series of tests, the following has been calculated :
    * the mean of the maximum failure load ($F^t_{u, mean}$)
    * the standard deviation of failure load (σ)
    * the variance of failure load (v)

The general failure mode observed during the tests series was by resin-bond failure between concrete wall and the resin in low strength concrete. However, there were some instances where steel failure occurred due to the resin bond strength exceeding the ultimate strength of the studding, see Figures 8.1 to 8.14.

The test results were normalised to grade 25 N/mm² concrete as required by ETAG 001, because the concrete strength at testing was approximately 32.5 N/mm²

TABLE 7.1: TENSILE load for Single anchor without spacing and edge effects in non-cracked concrete grade C20/25 SERIES - A1 – Dry Cleaned Test

Anchor dia./ / Length (mm)	Embedment / Hole depth (mm)	Curing Hours (hrs)	Test Ref No.	Test Load (kN)	Failure modes
M8 / 60 EASF	60/65	24	EF8-A1-4	34.75	Resin failure
			EF8-A1-5	31.95	Resin failure
			EF8-A1-6	34.98	Resin failure
			EF8-A1-7	34.17	Resin failure
			EF8-A1-8	34.53	Resin failure
M12 / 110 EASF	110/120	24	EF12-A1-4	84.19	Resin failure
			EF12-A1-5	74.06	Resin failure
			EF12-A1-6	90.67	Resin failure
		96	EF12-A1-7	88.79	Resin failure
		96	EF12-A1-8	84.36	Resin failure
M20 / 170 EASF	170/180	24	EF20-A1-1	184.89	Resin failure
			EF20-A1-2	160.17	Resin failure
			EF20-A1-3	186.22	Resin failure
			EF20-A1-4	192.29	Resin failure
			EF20-A1-5	185.64	Resin failure
M8 / 60 VESF	60/65	24	VF8-A1-4	34.31	Resin failure
			VF8-A1-5	41.94	Steel failure
			VF8-A1-6	35.86	Resin failure
			VF8-A1-7	42.07	Resin failure
			VF8-A1-8	39.17	Resin failure
M8 / 60 VESF Repeat	60/65	24	VF8-A1-9	36.77	Resin failure
			VF8-A1-10	35.40	Resin failure
			VF8-A1-11	38.35	Resin failure
			VF8-A1-12	36.66	Resin failure
			VF8-A1-13	38.17	Resin failure
M12 / 110 VESF	110/120	24	VF12-A1-4	107.26	Resin failure
			VF12-A1-5	98.33	Resin failure
			VF12-A1-6	104.41	Resin failure
			VF12-A1-7	106.91	Resin failure
			VF12-A1-8	107.57	Steel failure
M20 / 170	170/180	24	VF20-A1-1	225.98	Resin failure
			VF20-A1-2	193.22	Resin failure
			VF20-A1-3	239.63	Resin failure
			VF20-A1-4	213.76	Resin failure
			VF20-A1-5	183.70	Resin failure
M20 / 170 VESF Repeat	170/180	24	VF20-A1-6	184.22	Resin failure
			VF20-A1-7	182.00	Resin failure
			VF20-A1-8	185.59	Resin failure
			VF20-A1-9	172.89	Resin failure
			VF20-A1-10	170.08	Resin failure

TABLE 7.2: TENSILE load for Single anchor without spacing and edge effects in non-cracked concrete grade C20/25 SERIES – A1 – Dry Cleaned Test

Anchor dia. / Length (mm)	Embedment / Hole depth (mm)	Curing Hours (hrs)	Test Ref No.	Test Load (kN)	Failure modes
M8 / 60 EP31 Pure Epoxy 3:1	60/65	24	EP8-A1-4	41.68	Resin failure
			EP8-A1-5	38.26	Resin failure
			EP8-A1-6	41.18	Resin failure
			EP8-A1-7	41.74	Steel failure
			EP8-A1-8	39.27	Resin failure
M12 / 110 EP31 Pure Epoxy 3:1	110/120	24	EP12-A1-4	96.16	Resin failure
		24	EP12-A1-5	91.20	Resin failure
		24	EP12-A1-6	94.50	Resin failure
		48	EP12-A1-7	105.80	Steel failure
		48	EP12-A1-8	101.07	Resin failure
M12 / 90 EP31 Repeat Pure Epoxy 3:1	90/100	24	EP12-A1-11	92.07	Resin failure
	Shallow		EP12-A1-12	103.10	Resin failure
	Embedment		EP12-A1-13	105.80	Resin failure
			EP12-A1-14	97.46	Resin failure
			EP12-A1-15	105.47	Resin failure
M12 / 90 EP31 Repeat 48 hrs Pure Epoxy 3:1	90/100	48	EP12-A1-16	99.36	Resin failure
	Shallow		EP12-A1-17	102.97	Resin failure
	Embedment		EP12-A1-18	102.12	Resin failure
			EP12-A1-19	95.20	Resin failure
			EP12-A1-20	98.61	Resin failure
M20 / 120 EP31 Pure Epoxy 3:1	120/130	24	EP20-A1-1	213.70	Resin failure
		24	EP20-A1-2	213.54	Resin failure
		24	EP20-A1-3	210.28	Resin failure
		48	EP20-A1-4	220.29	Resin failure
		48	EP20-A1-5	244.78	Resin failure
M8 / 60 EX11 Pure Epoxy 1:1	60/65	24	EX8-A1-1	41.72	Steel failure
			EX8-A1-2	37.99	Resin failure
			EX8-A1-3	41.13	Resin failure
			EX8-A1-4	42.14	Steel failure
			EX8-A1-5	40.24	Resin failure
M12 /90/110 EX11 Pure Epoxy 1:1 Shallow Embedment	110/120	24	EX12-A1-1	106.97	Steel failure
	90/100		EX12-A1-2	99.60	Resin failure
	90/100		EX12-A1-3	101.49	Resin failure
	90/100		EX12-A1-4	102.15	Resin failure
	90/100		EX12-A1-5	103.53	Resin failure
M20 / 120 EX11 Pure Epoxy 1:1	120/130	72	EX20-A1-1	229.89	Resin failure
		24	EX20-A1-2	253.49	Resin failure
		24	EX20-A1-3	262.52	Resin failure
		24	EX20-A1-4	237.47	Resin failure
		24	EX20-A1-5	235.02	Resin failure

TABLE 7.3: TENSILE load for Single anchor without spacing and edge effects in non-cracked concrete grade C20/25 SERIES – F1 – Wet Uncleaned Tes

Anchor dia. / Length (mm)	Embedment / Hole depth (mm)	Curing Hours (hrs)	Test Ref No.	Test Load (kN)	Failure modes
M12 / 110 EP31 Pure Epoxy 3:1	110/120	24	EP12-F1-1	100.93	Resin failure
			EP12-F1-2	81.49	Resin failure
			EP12-F1-3	104.37	Resin failure
			EP12-F1-4	95.97	Resin failure
			EP12-F1-5	89.96	Resin failure
M20 / 120 EP31 Pure Epoxy 3:1	120/130	72	EP20-F1-1	179.17	Resin failure
			EP20-F1-2	174.00	Resin failure
			EP20-F1-3	188.94	Resin failure
			EP20-F1-4	208.59	Resin failure
			EP20-F1-5	188.84	Resin failure

TABLE 7.4: TENSILE load for Single anchor without spacing and edge effects in non-cracked concrete grade C20/25 SERIES –D1–Diamond Drill Hole Tests

Anchor dia. / Length (mm)	Embedment / Hole depth (mm)	Curing Hours (hrs)	Test Ref No.	Test Load (kN)	Failure modes
M12 / 90 EP31 Pure Epoxy 3:1	90/100	72	EP12-D1-1	87.87	Resin failure
			EP12-D1-2	97.42	Resin failure
			EP12-D1-3	106.37	Resin failure
			EP12-D1-4	101.25	Resin failure
			EP12-D1-5	106.8	Resin failure
M20 / 120 EP31 Pure Epoxy 3:1	120/130	72	EP20-D1-1	249.34	Resin failure
			EP20-D1-2	201.84	Resin failure
			EP20-D1-3	221.31	Resin failure
			EP20-D1-4	219.58	Resin failure
			EP20-D1-5	228.65	Resin failure

8.0 Analysis of Test Results

8.1 5% Fractile of the ultimate loads

The 5% fractile of the ultimate loads (or characteristic load) measured in the tensile test series A1, F1 and D1 are calculated according to the statistical procedures for a confidence level of 90%.

8.2 Characteristic load:

$$F_{ck} = F^{t}_{u,m}\,(1 - k_{5\%}\, v) \qquad (8.1)$$

where F_{ck} = Characteristic load based on 5% fractile of ultimate test loads
$F^{t}_{u,m}$ = Mean value of the ultimate test loads
$k_{5\%}$ is the coefficient with respect to number of tests (= 3.4 for n=3)
v is the coefficient of variance in % (=σ / $F^{t}_{u,m}$)
σ is the standard deviation of a test series

Tables 8.1 to 8.4 give the characteristic tensile load resistances for all test series, bond resistance and steel resistance using equations 8.3 and 8.4 given below. These characteristic loads can then be used to calculate design resistance and safe working load to be specified in the manufacturer's design manual.

8.2.1 Characteristic tensile bond resistance for pull-out/resin-bond failure mode:

$$NRk,0 = \tau_{Rk}\ \pi d\ h_{ef} \qquad (8.2)$$

Where: $N_{Rk},0$ = characteristic anchor resistance under tension load.
d = diameter of embedded part.
h_{ef} = embedment depth.
τ_{Rk} = characteristic bond resistance.

For pullout failure (including pullout failure of single anchors with a typical shallow cone at the loaded end) a characteristic bond resistance τRk instead of a characteristic resistance NRk may be given in the ETA; therefore the Equations (6.17.1) given below as Equation (8.3) applies.

$$\tau^{i}_{Rk} = \alpha setup\ \frac{N_{u(}C20/25)}{\pi\ d\ h_{ef}} \qquad (8.3)$$

αsetup = 0.75 if service condition tests in non-cracked concrete are performed as confined tests

From the results of the tension tests for admissible service conditions, the bond strength of each test is calculated according to Equation 6.17.1 of ETAG 001: Part 5.

8.2.2 Characteristic tensile load for steel failure mode:

$$V_{Rk} = A_s f_t \qquad 8.4$$

Where: V_{Rk} = characteristic anchor resistance under shear load.
A_s = effective stress area of the steel stud
f_t = tensile strength of the steel stud (= 1220N/mm^2)

TABLE 8.1: Calculated Characteristic (Steel) Resistance

Anchor dia. / Length (mm)	Anchor Diameter d, (mm)	Area of Studs A_s (mm^2)	Characteristic resistance $N_{Rk,s}$ (kN)
M8/60	8	36.6	44.65
M12/90	12	84.3	102.85
M20/170	20	244.8	298.66

8.3 Conversion of ultimate loads to take account of concrete and steel strength

In ETAG 001 Clause 6.0(b) it is required in some cases to convert the results of a test series to correlate with a concrete strength which different from that of the test member. In these tests series the strength of the concrete test members used for the testing was measured to be 32.5N/mm2 as compared with 25 N/mm2 concrete strengths for normalisation. It is therefore required to normalise the test results in accordance with clause 6.0(b) of ETAG001 Part 1.

In the case of concrete and pull-out failure: Low grade concrete C20/25

$$F_{Ru}(f_c) = F^t_{Ru} \, (f_c / f_{c,\,test})^{0.5} \qquad 8.5$$

Where: $F_{Ru}(fc)$ = failure load at concrete compression strength fc
F^t_{Ru} = ultimate load of tension test series
$f_{c,\,test}$ = concrete compressive strength of the test member at the time of testing

In these tests the tensile strength of the steel studs was not measured, but the stud manufacturer certificate shows that the studs are of normal strength steel grade 12.9, with approximate yield strength of 1080 N/mm^2.

Tables 8.2 to 8.4 give a summary and analysis of the test results including mean ultimate load, standard deviation, coefficient of variation and the calculated characteristic and normalized load.

8.4 Tensile tests in low strength non-cracked concrete

Typical axial load-displacement curves of pullout (tensile) loading tests are shown on Figures 7.1 to 7.16 for low strength non-cracked concrete tests series A1, F1 and D1. For all fixing tested, the highest coefficient of variance calculated on the average failure load was 9.62% (with the maximum allowable being 20% as stated in Clause 6.1.2.1(c) of ETAG 001 Part 5). Also, the standard deviation on all tensile test values is less than 17.1kN. In majority of cases, fixings failure was by pull-out coupled with shallow cone at the loaded end (see Figures 8.1 to 8.16).

TABLE 8.2: Analysis of Tensile load tests in Dry Cleaned hole tests - SERIES- A1

Anchor dia. / Length (mm)	**Resin type**	**Mean Ult. load $F^t_{u,m}$ (kN)**	**Standard deviation σ (kN)**	**Coeff. of variance υ (%)**	**Characteristic Load F_{ck} (kN)**	**Normalised Load $F_{ck(fc)}$ (kN)**
M8 – A1	EASF	34.08	1.23	3.60	29.91	26.23
	VESF	37.07	1.21	3.27	32.94	28.89
	Pure Epoxy 3:1	40.43	1.57	3.89	35.08	30.77
	Pure Epoxy 1:1	40.64	1.65	4.05	35.05	30.74
M12/110 – A1 M12/90 – A1	EASF	84.41	6.43	7.62	62.54	54.85
	VESF	104.90	3.88	3.70	91.71	80.44
	Pure Epoxy 3:1	97.75	5.74	5.87	78.23	68.61
	Pure Epoxy 3:1	100.78	5.90	5.86	80.70	70.78
	Pure Epoxy 3:1	99.65	3.09	3.10	89.16	78.20
	Pure Epoxy 1:1	102.75	2.75	2.68	93.39	81.91
M20/170 – A1 M20/120 – A1	EASF	181.84	12.47	6.86	139.45	122.31
	VESF	178.96	7.01	3.92	155.12	136.05
	Pure Epoxy 3:1	220.52	14.04	6.37	172.78	151.53
	Pure Epoxy 1:1	243.68	13.73	5.64	196.97	172.75

TABLE 8.3: Analysis of Tensile load tests in Wet Uncleaned hole tests - SERIES- F1

Anchor dia. / Length (mm)	**Resin type**	**Mean Ult. load $F^t_{u,m}$ (kN)**	**Standard deviation σ (kN)**	**Coeff. of variance υ (%)**	**Characteristic Load F_{ck} (kN)**	**Normalised Load $F_{ck(fc)}$ (kN)**
M12/110 – F1	Pure Epoxy 3:1	94.54	9.09	9.62	63.63	55.80
M20/120 – F1	Pure Epoxy 3:1	187.91	13.22	7.04	142.95	125.37

TABLE 8.4: Analysis of Tensile load tests in Diamond Drilled hole tests - SERIES- D1

Anchor dia. / Length (mm)	**Resin type**	**Mean Ult. load $F^t_{u,m}$ (kN)**	**Standard deviation σ (kN)**	**Coeff. of variance υ (%)**	**Characteristic Load F_{ck} (kN)**	**Normalised Load $F_{ck(fc)}$ (kN)**
M12/90 – D1	Pure Epoxy 3:1	99.94	7.78	7.79	73.49	64.45
M20/120 – D1	Pure Epoxy 3:1	224.14	17.19	7.67	165.71	145.34

Figure 8.1: - Pull-out failure of Test No. EF8-A1 after tensile loading in dry cleaned hole

Figure 8.2: - Pull-out failure of Test No. EF12-A1 after tensile loading in dry cleaned holes

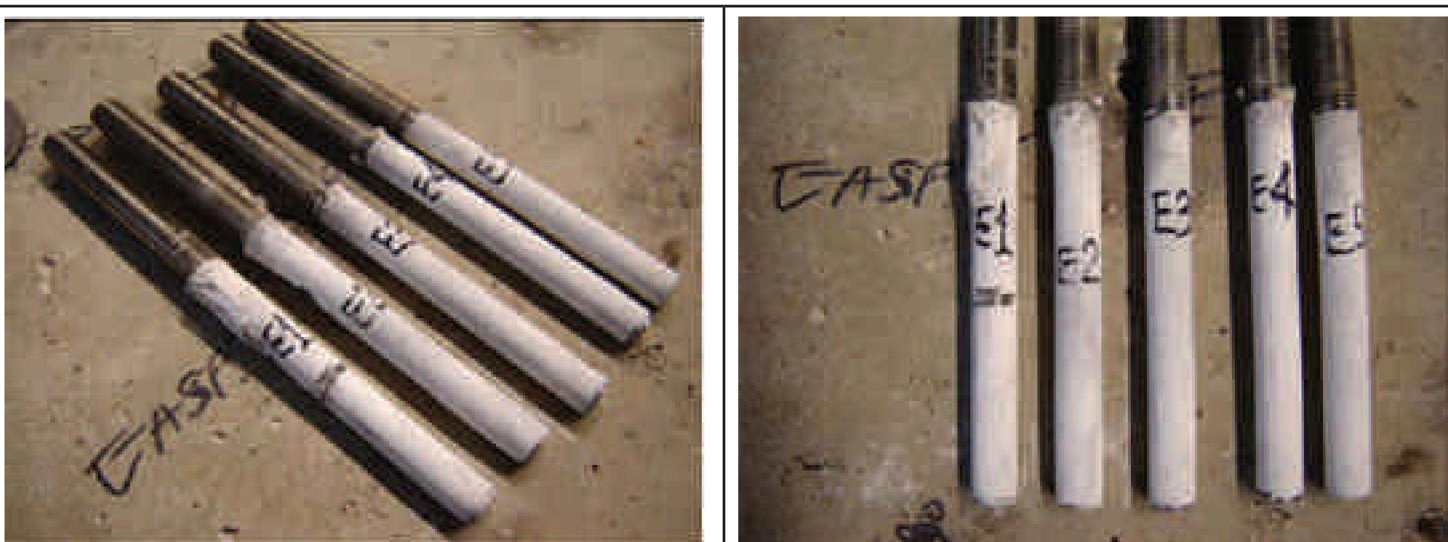


Figure 8.3: - Pull-out failure of Test No. EF20-A1 after tensile loading in dry cleaned holes

Figure 8.4: - Pull-out failure of Test No. VF8-A1 after tensile loading in dry cleaned holes

Figure 8.5: - Pull-out failure of Test No. VF12-A1 after tensile loading in dry cleaned holes

Figure 8.6: - Pull-out failure of Test No. VF20-A1 after tensile loading in dry cleaned holes


Figure 8.7: - Pull-out failure of Test No. EP8-A1 after tensile loading in dry cleaned holes


Figure 8.8A: - Pull-out failure of Test No. EP12-A1 after tensile loading in dry cleaned holes


Figure 8.8B: - Pull-out failure of Test No. EP12-A1 after tensile loading in dry cleaned holes –
Repeat Tests with 90mm embedment

Figure 8.8C: - Pull-out failure of Test No. EP12-A1 after tensile loading in dry cleaned holes – Repeat Test with 90mm embedment and 48 hours curing

Figure 8.9: - Pull-out failure of Test No. EP20-A1 after tensile loading in dry cleaned holes

Figure 8.10: - Pull-out failure of Test No. EX8-A1 after tensile loading in dry cleaned holes

Figure 8.11: - Pull-out failure of Test No. EX12-A1 after tensile loading in dry cleaned holes

Figure 8.12: - Pull-out failure of Test No. EX20-A1 after tensile loading in dry cleaned holes

Figure 8.13: Pull-out failure of Test No. EP12-F1 after tensile loading in wet unclean holes

Figure 8.14: - Pull-out failure of Test No. EP20-F1 after tensile loading in wet unclean holes

Figure 8.15: - Pull-out failure of Test No. EP12-D1 after tensile loading in diamond drilled holes

Figure 8.16: - Pull-out failure of Test No. EX20-D1 after tensile loading in diamond drilled holes

9.0 Summary and Conclusions

9.1 This report presents the results and analysis of tests carried out on the ICFS resin anchors, EASF, VESF, Pure Epoxy 3:1 and Pure Epoxy 1:1 (using studs sizes M8, M12, and M20) in accordance with the requirement of ETAG No. 001, 1997. The tests were conducted in the Concrete Structures Section within Imperial College, London.

9.2 For all tensile tests carried out on the anchors installed as per the manufacturer's instruction in dry cleaned holes in non-cracked concrete, the coefficient of variance calculated on the average failure load is less than 7.6% and therefore the fixing all resins comply with the requirement of ETAG No. 001: 1997 that the maximum coefficient should not be greater than 20%. In general these tests the anchor failure was by resin bond/pull-out failure coupled with shallow cone at the concrete surface. In some instances when testing the M8 and M12 anchors steel failure occurred indicating the bond strength exceeded the steel strength of the stud. The resultant calculated bond strengths are therefore on the conservative side.

9.3 For all tensile tests carried out on the anchors installed as per the manufacturer's instruction in wet uncleaned holes in non-cracked concrete, the coefficient of variance calculated on the average failure load is less than 9.6% and therefore all resins comply with the requirement of ETAG No. 001: 1997 that the maximum coefficient should not be greater than 15%. In general, the failure capacities of these tests were approximately 82% of the capacity of those tests in dry cleaned holes; this therefore meets the ETAG requirements (75%) of the installation safety test in wet concrete. The failure modes observed were by resin bond/pull-out failure coupled with shallow cone at the concrete surface.

9.4 For all tensile tests carried out on anchors installed as per the manufacturer's instruction in diamond drilled holes in non-cracked concrete, the coefficient of variance calculated on the average failure load is less than 7.8% and therefore all resins comply with the requirement of ETAG No. 001: 1997 that the maximum coefficient should not be greater than 15%. In these tests, fixings failure was by pullout failure coupled with coupled with shallow cone at the concrete surface. In general, the failure capacities of these tests were approximately between 91% and 95% of the capacity of those tests in dry cleaned hammer drilled holes.

9.5 Some repeat tests were carried out for the following reasons: In the VESF resin, although the initial tests met the ETAG criteria, additional tests were carried out to achieve a more predictable and accurate bond strength which improved the coefficient of variance from 9% to 3.3% for M12 anchors and from 11% to 3.9% for M20 anchor tests. For the Pure Epoxy 3:1 M12 diameter, repeated tests were carried out at a reduced embedment to ensure that all tests failed by resin bond failure and not steel stud failure. Further repeat tests were carried out with Pure Epoxy 3:1 after 48 hours to evaluate the effect of curing time which therefore resulted in 14% increase in failure load when compared to standard embedment tests which were cured for 24 hours.

9.6 Additional tests were carried out with reduced embedment from the standard depth to ensure resin bond failure was achieved.

9.7 The table 9.1 below shows the summary of the characteristic bond resistance for all resin types. EASF and VESF bond strength decreases with increase in stud size, while Epoxy resins have fairly constant bond strength across all diameters which therefore render them suitable for larger studs/rebar's application.

TABLE 9.1: Calculated Characteristic Bond Resistance (N/mm^2)

Anchor dia. / Length (mm)	**M8/60**	**M12/90**	**M12/110**	**M20/120**	**M20/170**
Cleaned holes					
EASF	13.0		9.9		8.6
VESF	14.4		14.6		9.6
Pure Epoxy 3:1	15.3	15.7		15.1	
Pure Epoxy 1:1	15.3	18.1		17.2	
Uncleaned holes					
Pure Epoxy 3:1		12.3		12.5	
Diamond drilled holes					
Pure Epoxy 3:1		14.3		14.5	

Test Results
and
Graphs of Load against Displacement for

Tensile Test Series A1
(Dry Cleaned Holes in Non-Cracked Concrete)

ICFS resin anchors

Graphs of Load against Displacement for Tensile Test Series A1

EASF-M8-grade 12.9-A1 test

Imperial College of Science, Technology and Medicine. London

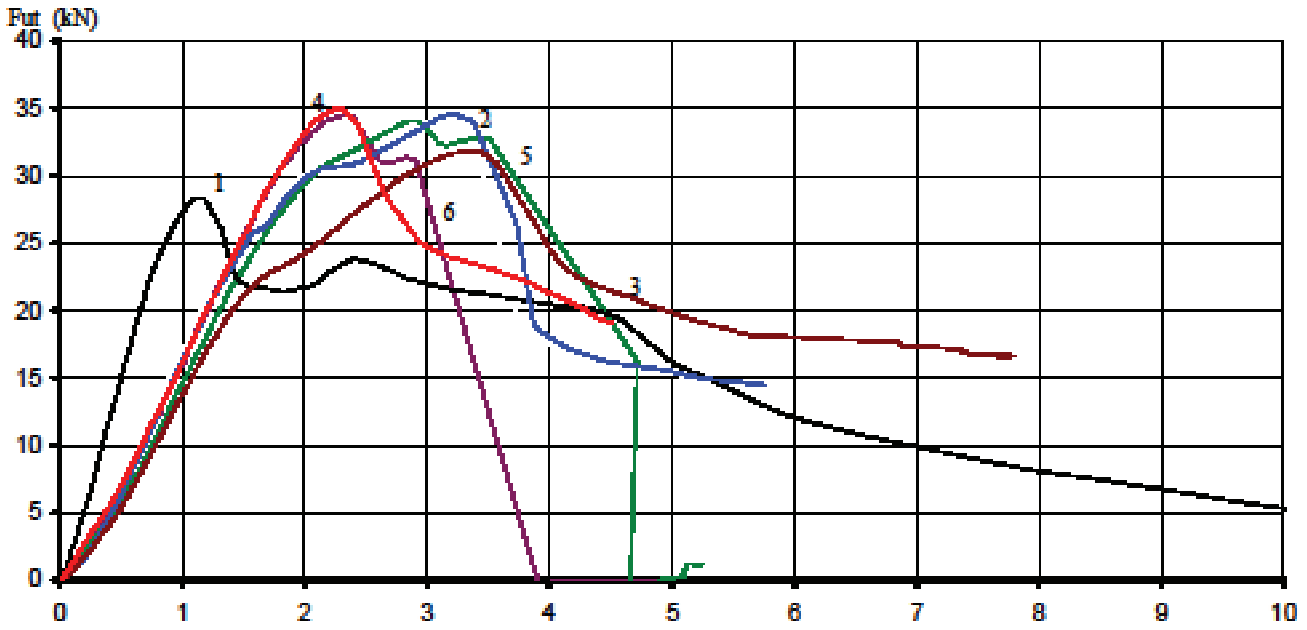
Imperial College London Consultants

Tests of ICFS Resin M8 anchors in accordance with EOTA Guideline, ETA No. 001.Part 5

Figure 1

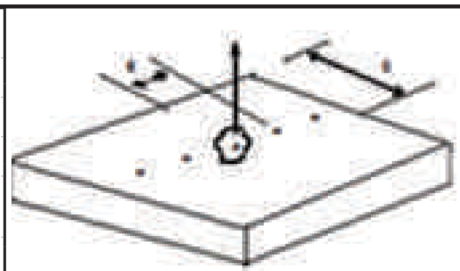
Anchor Type :	Date :	Test No :	No. of Tests :	Tensile Tests on M8
ESAF M8/60	04/03/2009	EF8-A1-4-8	5	Steel Grade : 12.9

Confined Test in Non-cracked Concrete C20/25. Type :
$S > s_{cr}$, $C > C_{cr}$, $h >= h_{min}$ - Tensile Test with single anchors in C20/25 concrete **A1**



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = 10.35mm	Concrete	**L19 Grade**	**C20/25**
Effective Depth :	h_{ef} = 60mm		**type**	**NWC**
			Days at Test	**> 28**
Slab Depth :	h = 400mm	**Strength**	**f_{cw} (N/mm²)**	**32.5**
		Cracked Width (mm)		Δ_m = 0
Edge Distance :	c = 250mm	Tightening Torque		T_{inst} **Hand Tight**
Spacing :	s = 300mm	Loading Speed (N/s)		V = 1000
Research Engineer S. Popo-Oia		Technician L.Clark		



Location

Test Number	4	5	6	7	8	9
F_{ut}	~~28.48~~	34.75	31.95	34.98	34.17	34.53
$d_{@fut}$ (mm)	~~1.11~~	3.21	3.32	2.24	2.86	2.33
$d_{@0.5fut}$ (mm)	~~0.47~~	1.01	1.12	1.04	1.12	1.06
Load @ 0.1mm	~~2.54~~	1.15	1.38	1.93	1.42	1.09
Failure Mode	Resin	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	34.08
$\sigma(F_{ut})$	kN	1.22
$\nu(F_{ut})$	(%)	**3.59%**

Resin bond with concrete failure

EASF-M12-grade 12.9-A1 test

Imperial College of Science, Technology and Medicine. London

Imperial College London Consultants

Tests of ICFS Resin M8 anchors in accordance with EOTA Guideline, ETA No. 001.Part 5

Figure 2

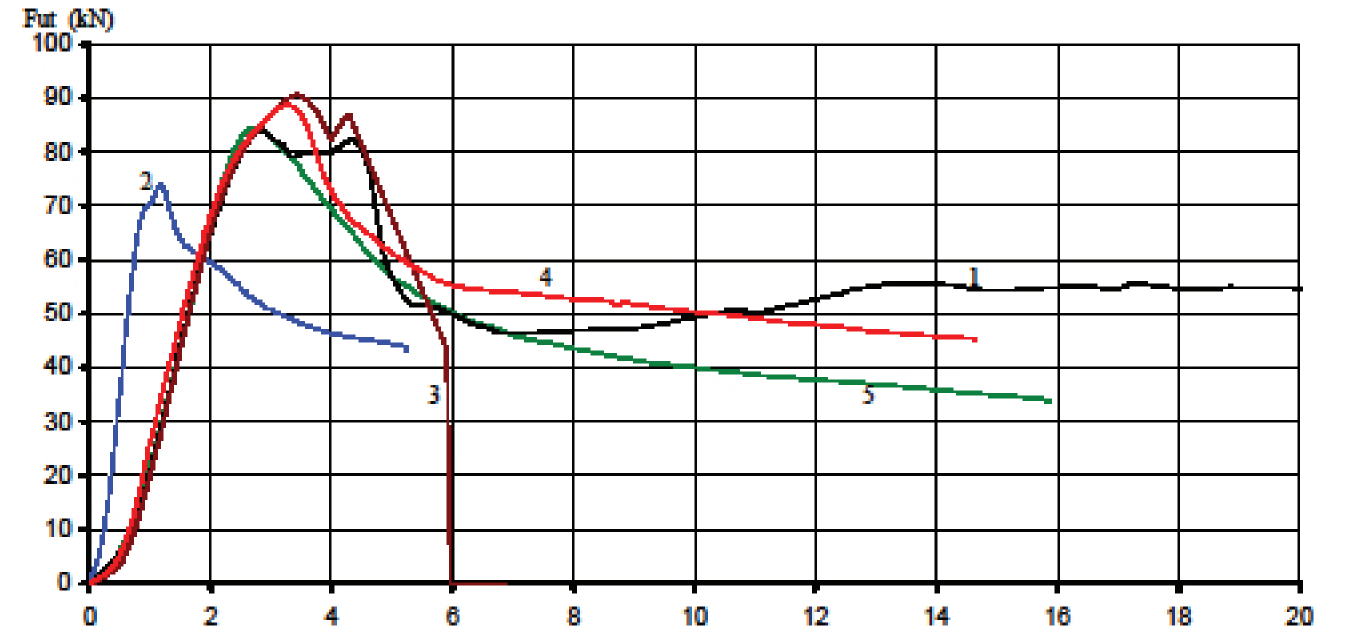
Tensile Tests on M12

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
ESAF M12/110	04/03/2009	EF12-A1-4-8	5

Confined Test in Non-cracked Concrete C20/25. Type :

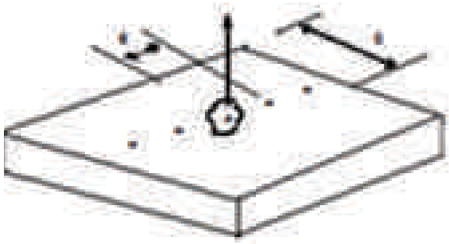
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$ - Tensile Test with single anchors in C20/25 concrete **A1**



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = 14.35mm
Effective Depth :	h_{ef} = 110mm
Slab Depth :	h = 400mm
Edge Distance :	c = 250mm
Spacing :	s = 300mm

Concrete	L19	Grade	C20/25
		type	NWC
		Days at Test	> 28
Strength		f_{cw} (N/mm²)	32.5
Cracked Width (mm)			Δ_m = 0
Tightening Torque			T_{inst} Hand Tight
Loading Speed (N/s)			V = 1000



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8	9
F_{ut}	84.19	74.06	90.67	88.79	84.36	0.00
$d_{@fut}$ (mm)	2.80	1.14	0.00	3.26	2.70	
$d_{@0.5fut}$ (mm)	1.44	0.52	2.24	1.40	1.45	0.00
Load @ 0.1mm	1.54	3.44	1.98	0.96	0.61	
Failure Mode	Resin	Resin	Resin	Resin	Resin	

F_{ut} (mean)	kN	**84.41**
$\sigma(F_{ut})$	kN	**6.43**
$\nu(F_{ut})$	(%)	**7.62%**

Resin bond with concrete failure

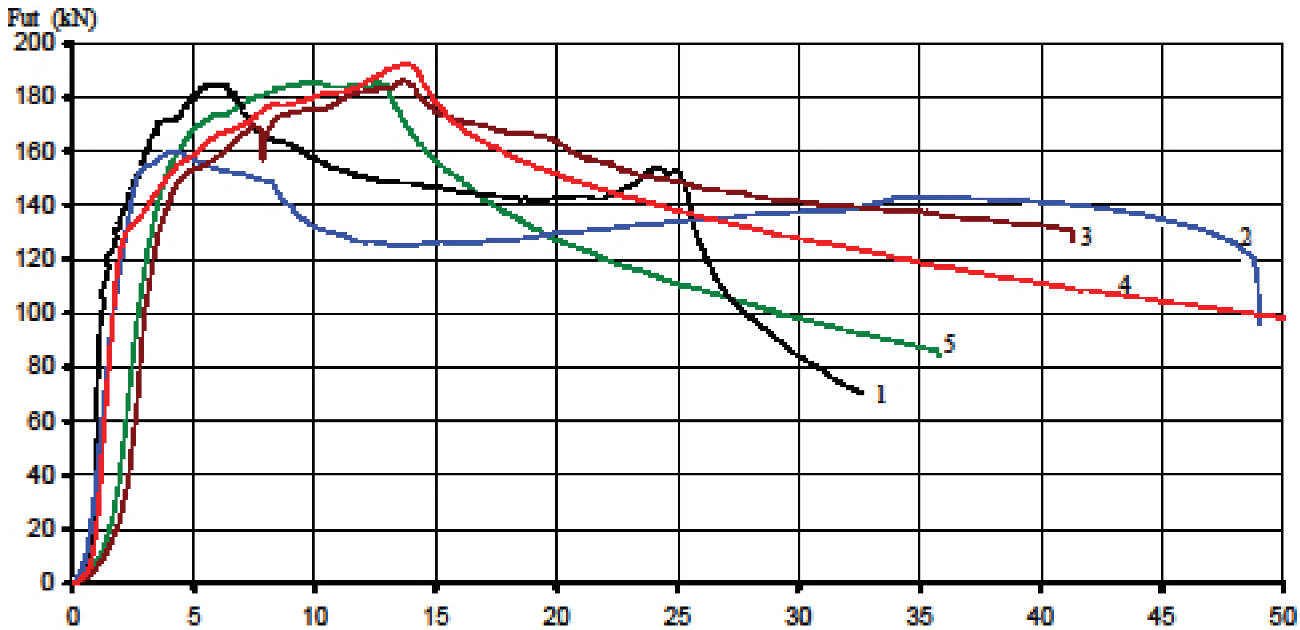
EASF-M20-grade 12.9-A1 test

Imperial College of Science, Technology and Medicine. London

Imperial College London Consultants

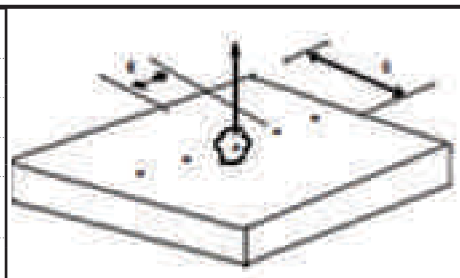
Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001.Part 5				Figure 3
Anchor Type : **ESAF M20/170**	Date : **04/03/2009**	Test No : **EF20-A1-4-8**	No. of Tests : **5**	*Tensile Tests on M20* *Steel Grade : 12.9*

Confined Test in Non-cracked Concrete C20/25. Type :
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete **A1**



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = **24.35mm**	Concrete	**L19**	**Grade**	**C20/25**
Effective Depth :	h_{ef} = **170mm**			**type**	**NWC**
				Days at Test	**> 28**
Slab Depth :	h = **400mm**	**Strength**		f_{cw} **(N/mm²)**	**32.5**
		Cracked Width (mm)			Δ_m = **0**
Edge Distance :	c = **250mm**	Tightening Torque			T_{inst} **Hand Tight**
Spacing :	s = **300mm**	Loading Speed	(N/s)		V = **1000**
Research Engineer S. Popo-Oia		Technician L.Clark			



Location

Test Number	**4**	**5**	**6**	**7**	**8**	**9**
F_{ut}	**184.89**	**160.17**	**186.22**	**192.29**	**185.64**	**0.00**
$d_{@fut}$ (mm)	**5.74**	**3.98**	**13.61**	**13.50**	**2.73**	
$d_{@0.5fut}$ (mm)	**1.12**	**1.42**	**2.64**	**1.61**	**0.00**	**0.00**
Load @ 0.1mm	**1.23**	**0.84**	**1.36**	**0.42**	**8.37**	
Failure Mode	**Resin**	**Resin**	**Resin**	**Resin**	**Resin**	

F_{ut} (mean)	kN	**181.84**
$\sigma(F_{ut})$	kN	**12.47**
$\nu(F_{ut})$	(%)	**6.86%**

Resin bond with concrete failure

VESF-M8-grade 12.9-A1 test

Imperial College of Science, Technology and Medicine. London

Imperial College London Consultants

Tests of ICFS Resin M8 anchors in accordance with EOTA Guideline, ETA No. 001.Part 5

Figure 4

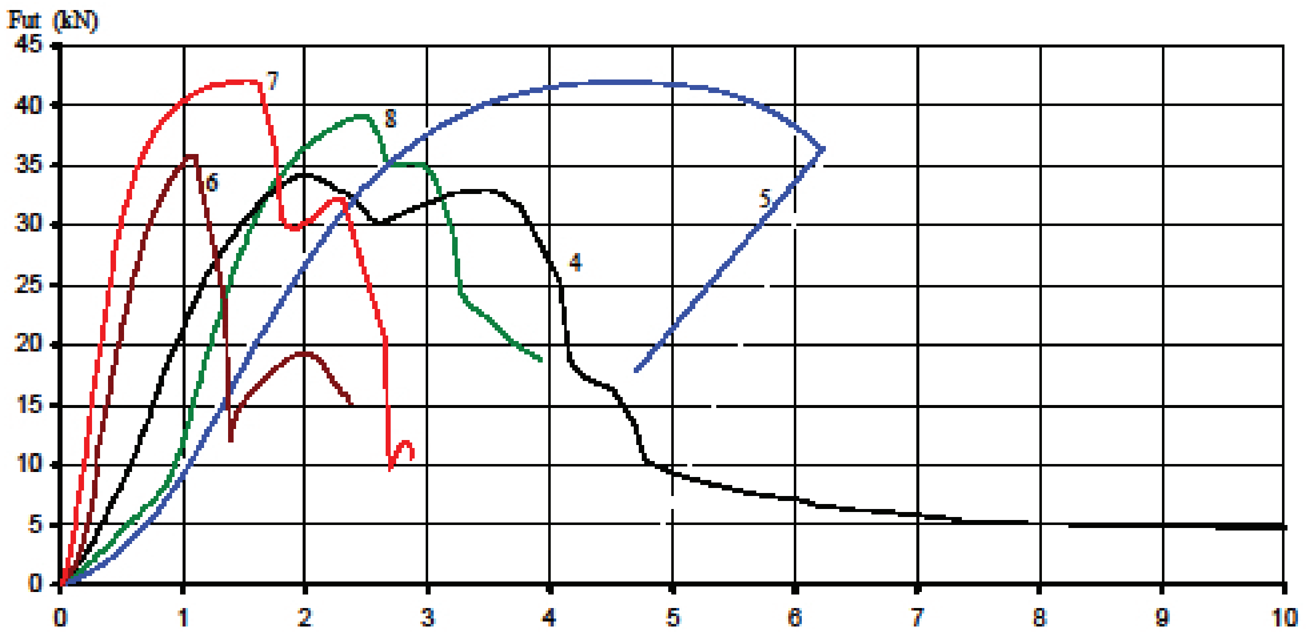
Tensile Tests on M8

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
VESF M8/60	12/03/2009	VF8-A1-9-13	3

Confined Test in Non-cracked Concrete C20/25. Type : **A1**

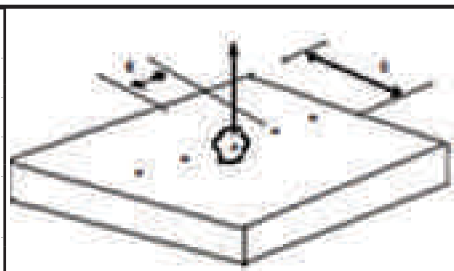
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = 10.35mm
Effective Depth :	h_{ef} = 60mm
Slab Depth :	h = 400mm
Edge Distance :	c = 200mm
Spacing :	s = 300mm

Concrete	L20	Grade	C20/25
		type	NWC
		Days at Test	> 28
Strength		f_{cw} (N/mm²)	32.5
Cracked Width (mm)			Δ_m = 0
Tightening Torque			T_{inst} Hand Tight
Loading Speed	(N/s)		V = 1000



Location

Research Engineer S. Popo-Oia	Technician L.Clark

Test Number	4	5	6	7	8	9
F_{ut}	34.31	41.94	35.86	42.07	39.17	0.00
$d_{@fut}$ (mm)	1.95	4.56	1.05	1.50	2.46	
$d_{@0.5fut}$ (mm)	0.80	1.59	0.42	0.33	1.19	0.00
Load @ 0.1mm	1.81	0.55	1.91	4.31	0.85	
Failure Mode	Resin	Resin	Resin	Resin	Resin	

F_{ut} (mean)	kN	38.67
$\sigma(F_{ut})$	kN	3.52
$\nu(F_{ut})$	(%)	9.09%

Resin bond with concrete failure

VESF-M8-grade 12.9-A1 test

Imperial College of Science, Technology and Medicine. London

Imperial College London Consultants

Tests of ICFS Resin M8 anchors in accordance with EOTA Guideline, ETA No. 001.Part 5

Figure 4A

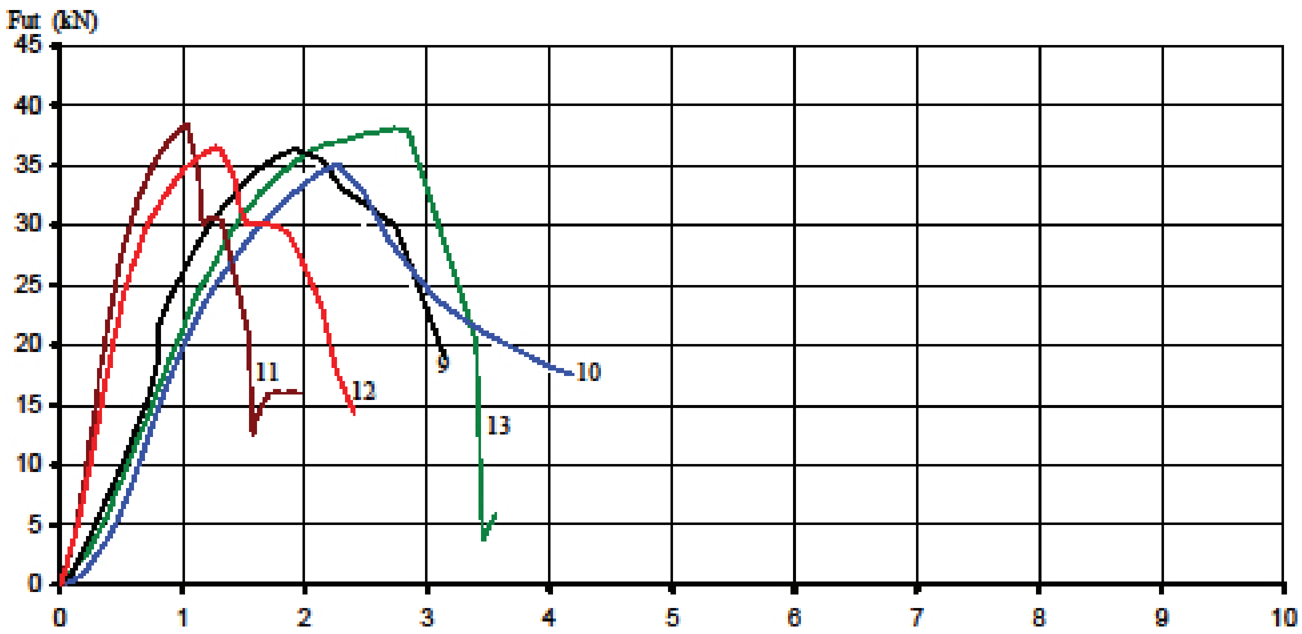
Tensile Tests on M8

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
VESF M8/60	**27/03/2009**	**VF8-A1-9-13**	**3**

Confined Test in Non-cracked Concrete C20/25. Type : **A1**

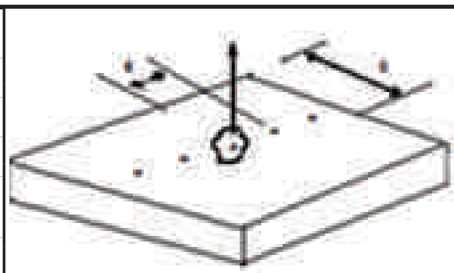
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	**$d_{cut,m}$ = 10.35mm**
Effective Depth :	**h_{ef} = 60mm**
Slab Depth :	**h = 400mm**
Edge Distance :	**c = 200mm**
Spacing :	**s = 300mm**

Concrete	**L20**	**Grade**	**C20/25**
		type	**NWC**
		Days at Test	**> 28**
Strength		**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)			**Δ_m = 0**
Tightening Torque			**T_{inst} Hand Tight**
Loading Speed (N/s)			**V = 1000**



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8	9
F_{ut}	36.77	35.40	38.35	36.66	38.17	0.00
$d_{@fut}$ (mm)	1.92	2.26	1.00	1.27	2.73	
$d_{@0.5fut}$ (mm)	0.80	0.86	0.33	0.39	0.81	0.00
Load @ 0.1mm	1.83	0.54	4.20	3.96	1.64	
Failure Mode	Resin	Resin	Resin	Resin	Resin	

F_{ut} (mean)	kN	**37.07**
$\sigma(F_{ut})$	kN	**1.21**
$\nu(F_{ut})$	(%)	**3.27%**

Resin bond with concrete failure

VESF-M12-grade 12.9-A1 test

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Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 5

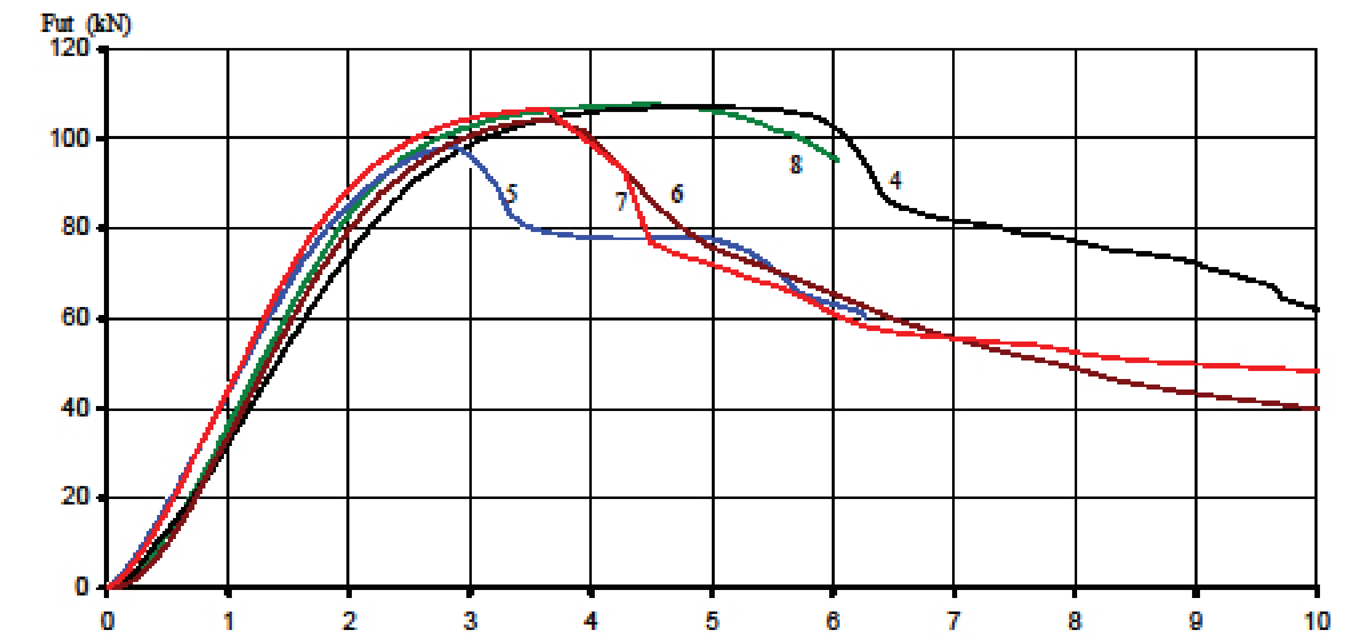
Tensile Tests on M12

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
VESF M12/110	**12/03/2009**	**VF12-A1-4-8**	**5**

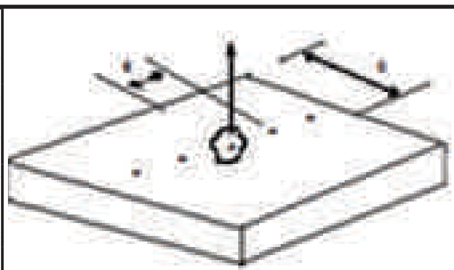
Confined Test in Non-cracked Concrete C20/25. Type : **A1**

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Hole Core Dia :	$d_{cut,m}$ = **14.35mm**
Effective Depth :	h_{ef} = **110mm**
Slab Depth :	**h** = **400mm**
Edge Distance :	**c** = **200mm**
Spacing :	**s** = **300mm**

Concrete	**L19 Grade**	**C20/25**
	type	**NWC**
	Days at Test	**> 28**
Strength	**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)		Δ_m = **0**
Tightening Torque		T_{inst} **Hand Tight**
Loading Speed (N/s)		**V** = **1000**



Location

Research Engineer S. Popo-Oia	Technician L.Clark

Test Number	**4**	**5**	**6**	**7**	**8**
F_{ut}	**107.36**	**98.33**	**104.41**	**106.91**	**107.57**
$d_{@fut}$ (mm)	**5.06**	**2.80**	**3.65**	**3.63**	**4.39**
$d_{@0.5fut}$ (mm)	**1.46**	**1.07**	**1.38**	**1.13**	**1.32**
Load @ 0.1mm	**1.03**	**2.97**	**2.33**	**3.18**	**1.52**
Failure Mode	**Resin**	**Resin**	**Resin**	**Resin**	**Steel**

F_{ut} (mean)	kN	**104.90**
$\sigma(F_{ut})$	kN	**3.88**
$\nu(F_{ut})$	(%)	**3.70%**

Steel Stud Failure
Resin bond with concrete failure

VESF-M20-grade 12.9-A1 test

Imperial College of Science, Technology and Medicine. London

Imperial College London Consultants

Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 6

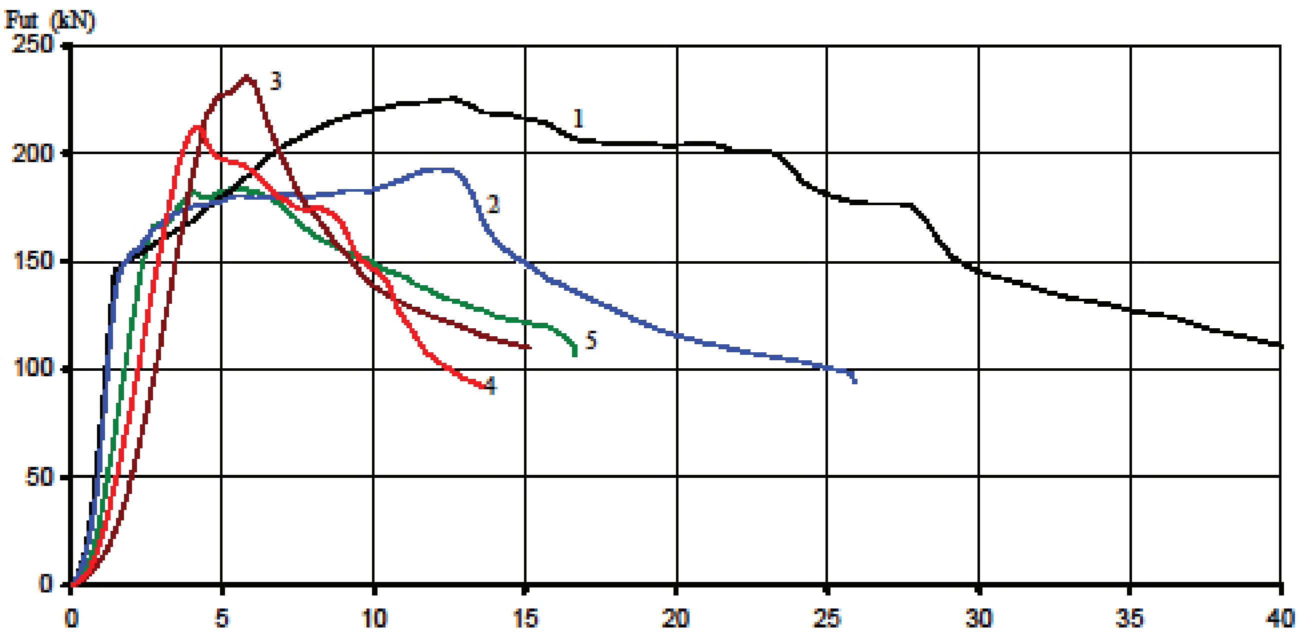
Tensile Tests on M20

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
VESF M20/170	**10/03/2009**	**VF20-A1-1-5**	**5**

Confined Test in Non-cracked Concrete C20/25. Type : **A1**

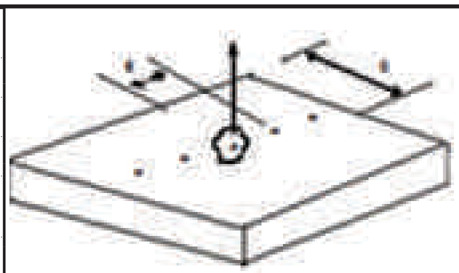
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = **24.35mm**
Effective Depth :	h_{ef} = **170mm**
Slab Depth :	h = **400mm**
Edge Distance :	c = **300mm**
Spacing :	s = **300mm**

Concrete	**L20**	**Grade**	**C20/25**
		type	**NWC**
		Days at Test	**> 28**
Strength		**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)			Δ_m = **0**
Tightening Torque			T_{inst} **Hand Tight**
Loading Speed	(N/s)		V = **1000**



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8
F_{ut}	225.98	193.22	239.63	213.76	183.70
$d_{@fut}$ (mm)	12.23	12.02	5.83	4.12	5.46
$d_{@0.5fut}$ (mm)	1.19	1.16	3.01	2.22	1.64
Load @ 0.1mm	6.37	2.36	1.24	1.91	1.23
Failure Mode	Resin	Resin	Resin	Rwsin	Resin

F_{ut} (mean)	kN	**211.26**
$\sigma(F_{ut})$	kN	**22.98**
$\nu(F_{ut})$	(%)	**10.889%**

Resin bond with concrete failure

VESF-M20-grade 12.9-A1 test

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Imperial College London Consultants

Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 6A

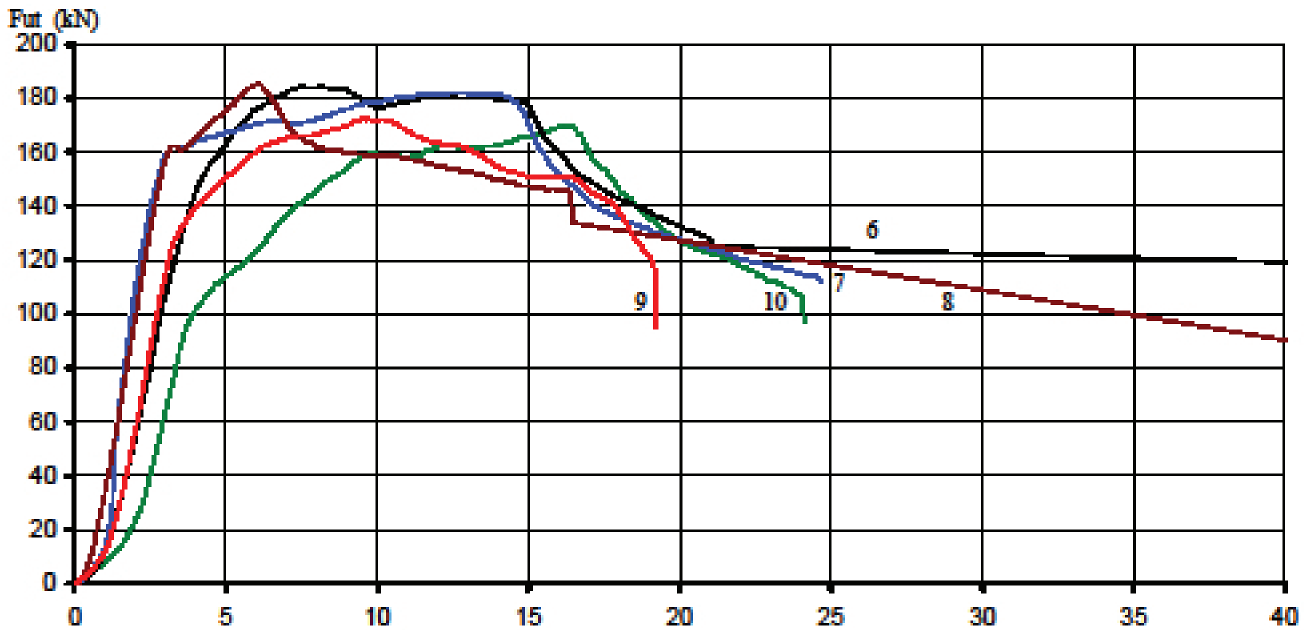
Tensile Tests on M20

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
VESF M20/170	**31/03/2009**	**VF20-A1-6-10**	**5 Repeat**

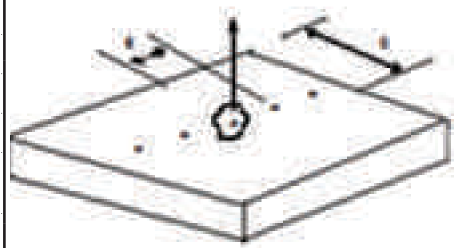
Confined Test in Non-cracked Concrete C20/25. Type : **A1**

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Hole Core Dia :	$d_{cut,m}$ = 24.35mm
Effective Depth :	h_{ef} = 170mm
Slab Depth :	h = 400mm
Edge Distance :	c = 300mm
Spacing :	s = 300mm

Concrete	**L20 Grade**	**C20/25**
	type	**NWC**
	Days at Test	**> 28**
Strength	**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)		Δ_m = 0
Tightening Torque		T_{inst} Hand Tight
Loading Speed (N/s)		V = 1000



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8
F_{ut}	184.22	182.00	185.59	172.89	170.08
$d_{@fut}$ (mm)	7.37	12.50	6.04	9.51	16.33
$d_{@0.5fut}$ (mm)	2.68	1.76	1.89	2.48	3.28
Load @ 0.1mm	0.25	0.23	0.71	0.99	1.91
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	**178.96**
$\sigma(F_{ut})$	kN	**7.01**
$\nu(F_{ut})$	(%)	3.92%

Resin bond with concrete failure

PURE EPOXY 3-1-M8-grade 12.9-A1 test

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Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 7

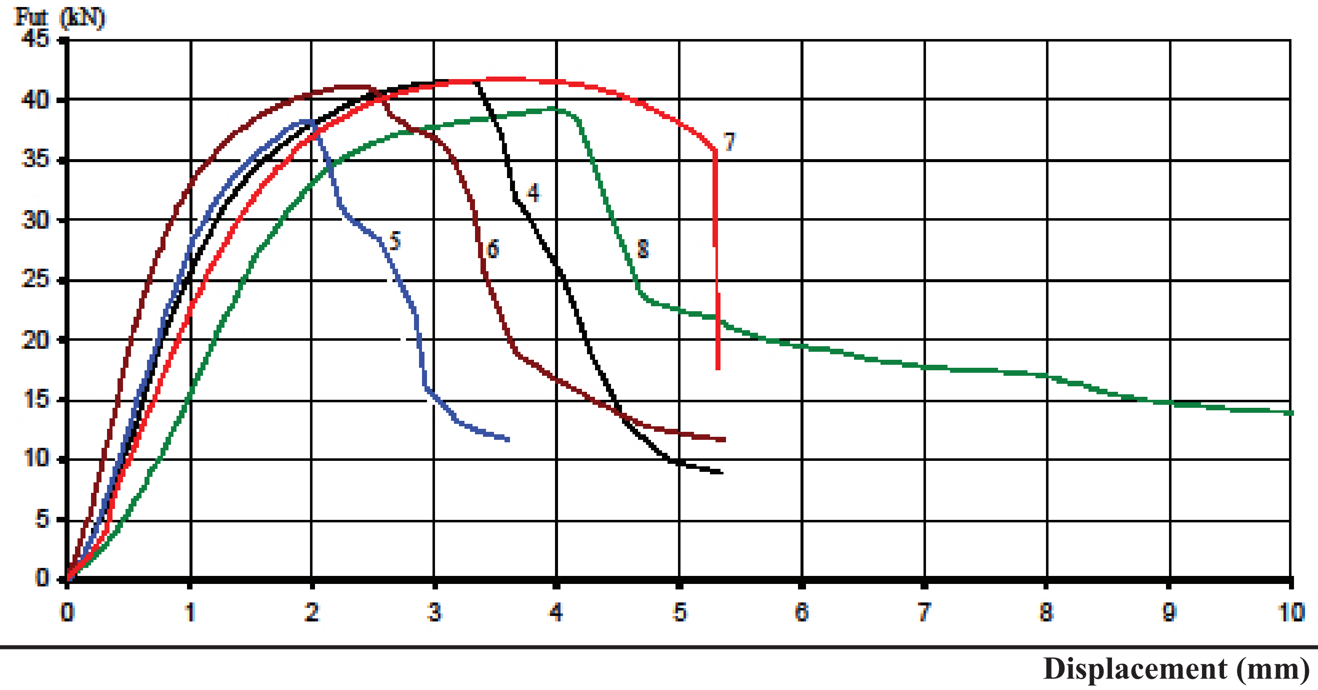
Tensile Tests on M8

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M8/60	**12/03/2009**	**EP8-A1-4-8**	**5**

Confined Test in Non-cracked Concrete C20/25. Type : **A1**

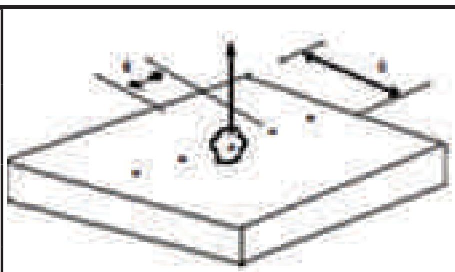
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Hole Core Dia :	$d_{cut,m}$ = 10.35mm
Effective Depth :	h_{ef} = 60mm
Slab Depth :	h = 400mm
Edge Distance :	c = 260mm
Spacing :	s = 300mm

Concrete	**L19 Grade**	**C20/25**
	type	**NWC**
	Days at Test	**> 28**
Strength	**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)		Δ_m = 0
Tightening Torque		T_{inst} Hand Tight
Loading Speed (N/s)		V = 1000

Research Engineer	Technician
S. Popo-Oia	L.Clark



Location

Test Number	4	5	6	7	8
F_{ut}	41.68	38.36	41.18	41.74	39.27
$d_{@fut}$ (mm)	3.18	1.92	2.28	3.54	1.91
$d_{@0.5fut}$ (mm)	0.77	0.67	0.52	0.90	0.64
Load @ 0.1mm	2.11	1.64	3.54	3.30	0.44
Failure Mode	Resin	Resin	Resin	Steel	Resin

F_{ut} (mean)	kN	**40.45**
$\sigma(F_{ut})$	kN	**1.54**
$\nu(F_{ut})$	(%)	3.80%

Steel Stud Failure
Resin bond with concrete failure

PURE EPOXY 3-1-M12-grade 12.9-A1 test

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Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

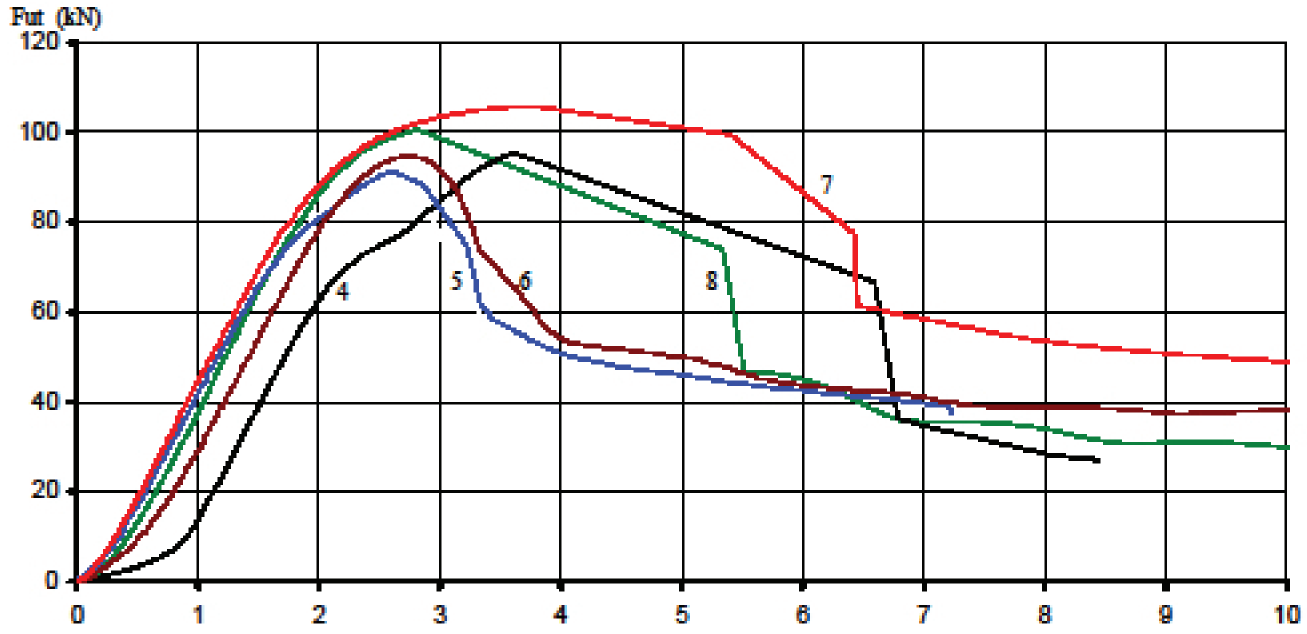
Figure 8

Tensile Tests on M12

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M12/110	**24/04/2009**	**EP12-A1-11-14**	**5**

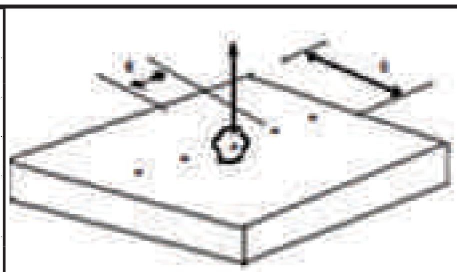
Confined Test in Non-cracked Concrete C20/25. Type :
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete **A1**



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = **14.35mm**
Effective Depth :	h_{ef} = **110mm**
Slab Depth :	h = **400mm**
Edge Distance :	c = **200mm**
Spacing :	s = **300mm**

Concrete	**L19**	**Grade**	**C20/25**
		type	**NWC**
		Days at Test	**> 28**
Strength		f_{cw} **(N/mm²)**	**32.5**
Cracked Width (mm)			Δ_m = **0**
Tightening Torque			T_{inst} **Hand Tight**
Loading Speed		(N/s)	V = **1000**



Location

Research Engineer S. Popo-Oia	Technician L.Clark

Test Number	4	5	6	7	8
F_{ut}	**96.16**	**91.20**	**94.50**	**105.80**	**101.07**
$d_{@fut}$ (mm)	**3.61**	**2.56**	**2.75**	**3.76**	**2.82**
$d_{@0.5fut}$ (mm)	**1.67**	**1.07**	**1.36**	**1.15**	**1.23**
Load @ 0.1mm	**1.06**	**2.95**	**2.10**	**2.56**	**2.86**
Failure Mode	**Resin**	**Resin**	**Resin**	**Steel**	**Resin**

F_{ut} (mean)	kN	**97.75**
$\sigma(F_{ut})$	kN	**5.74**
$\nu(F_{ut})$	(%)	5.879**%**

Steel Stud Failure
Resin bond with concrete failure

PURE EPOXY 3-1-M12-grade 12.9-A1 test

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Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 8a

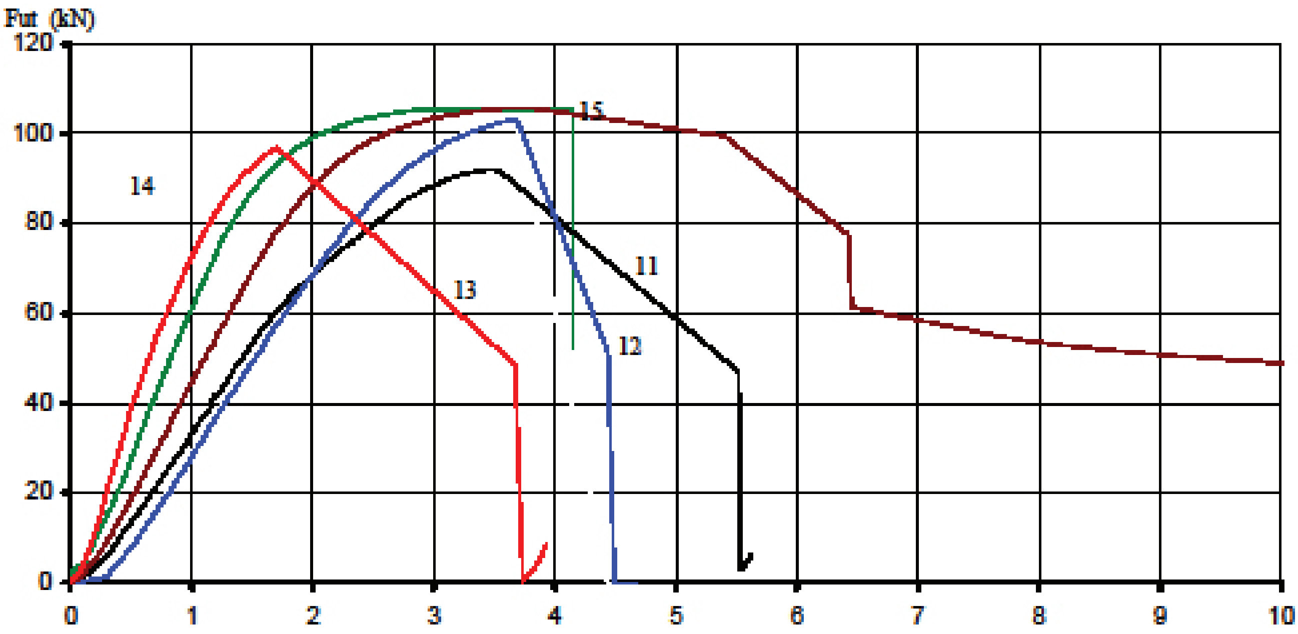
Tensile Tests on M12

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M12/90	**24/04/2009**	**EP12-A1-11-14**	**5**

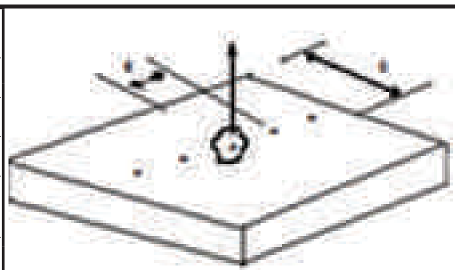
Confined Test in Non-cracked Concrete C20/25. Type : **A1**

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	**$d_{cut,m}$= 14.35mm**	Concrete	**L19 Grade C20/25**
Effective Depth :	**h_{ef} = 90mm**		**type NWC**
Slab Depth :	**h = 400mm**		**Days at Test > 28**
Edge Distance :	**c = 200mm**	**Strength**	**f_{cw} (N/mm^2) 32.5**
Spacing :	**s = 300mm**	Cracked Width (mm)	**Δ_m = 0**
		Tightening Torque	**T_{inst} Hand Tight**
		Loading Speed (N/s)	**V = 1000**



Research Engineer S. Popo-Oia	Technician L.Clark

Location

Test Number	4	5	6	7	8
F_{ut}	92.07	103.10	105.80	97.46	105.47
$d_{@fut}$ (mm)	3.46	3.66	3.76	1.70	2.97
$d_{@0.5fut}$ (mm)	1.29	1.58	1.15	0.61	0.86
Load @ 0.1mm	1.54	0.56	2.56	5.49	4.97
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	100.78
$\sigma(F_{ut})$	kN	**5.91**
$\nu(F_{ut})$	(%)	5.86**%**

Resin bond with concrete failure

PURE EPOXY 3-1-M12-grade 12.9-A1 test

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Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 8b

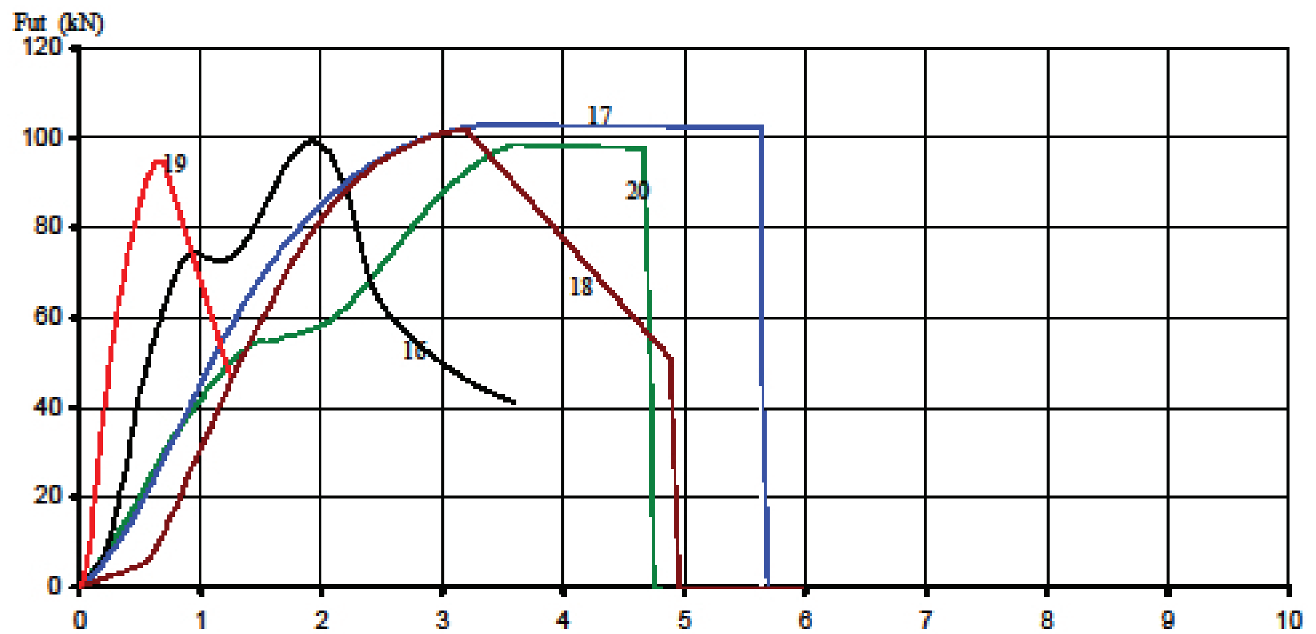
Tensile Tests on M12

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M12/90 Repeat after 48 hrs	26/04/2009	EP12-A1-16-20	5

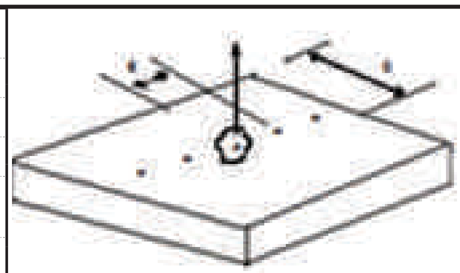
Confined Test in Non-cracked Concrete C20/25. Type : **A1**

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia : $d_{cut,m}$ = 14.35mm	Concrete	L19 Grade	C20/25	
Effective Depth : h_{ef} = 90mm		type	NWC	
		Days at Test	> 28	
Slab Depth : h = 400mm	**Strength**	f_{cw} (N/mm²)	32.5	
	Cracked Width (mm)		Δ = 0	
Edge Distance : c = 200mm	Tightening Torque		T_{inst} Hand Tight	
Spacing : s = 300mm	Loading Speed (N/s)		V = 1000	
Research Engineer S. Popo-Oia	Technician L.Clark			



Location

Test Number	4	5	6	7	8
F_{ut}	99.36	102.97	102.12	95.20	98.61
$d_{@fut}$ (mm)	1.92	3.31	3.20	0.67	3.63
$d_{@0.5fut}$ (mm)	0.55	1.11	1.35	0.23	1.23
Load @ 0.1mm	3.63	3.44	1.38	10.68	4.13
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	99.65
$\sigma(F_{ut})$	kN	**3.08**
$\nu(F_{ut})$	(%)	3.10%

Resin bond with concrete failure

PURE EPOXY 3-1-M20-grade 12.9-A1 test

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Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 9

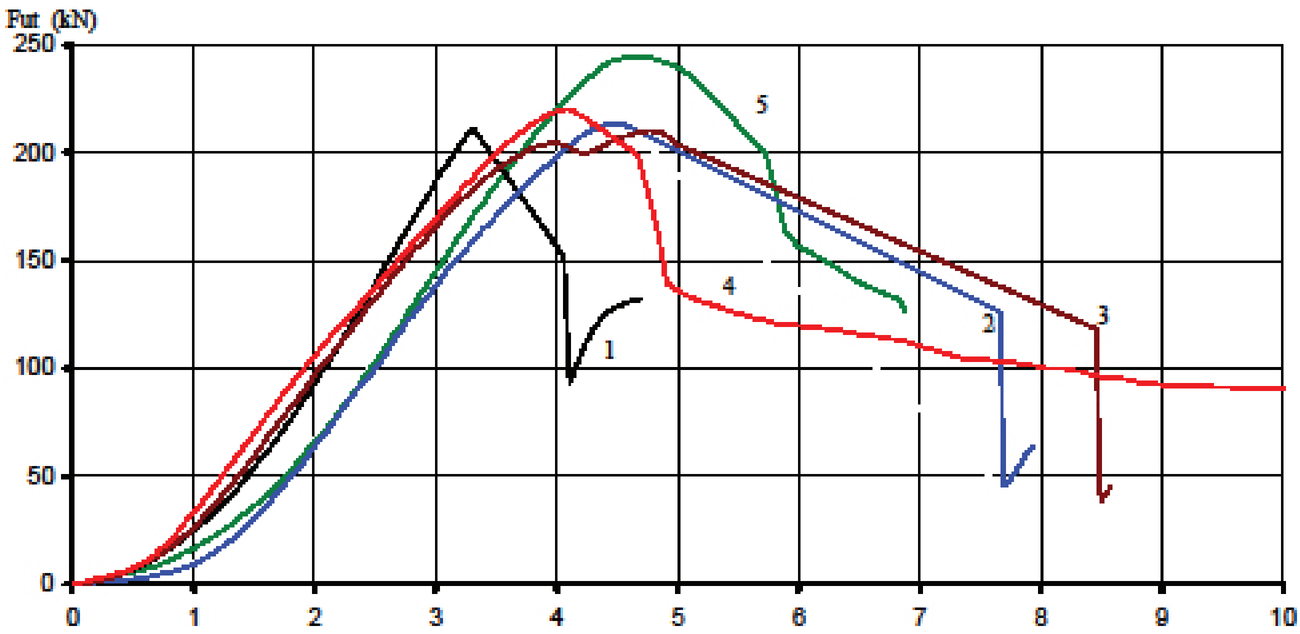
Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M20/120	27/03/2009	EP20-A1-1-5	5

Tensile Tests on M20

Steel Grade : 12.9

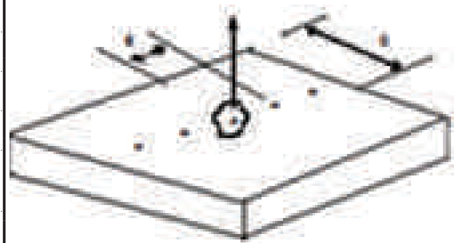
Confined Test in Non-cracked Concrete C20/25. Type : **A1**

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia : $d_{cut,m}$ = 24.35mm	Concrete	L20 Grade	C20/25
Effective Depth : h_{ef} = 120mm		type	NWC
		Days at Test	> 28
Slab Depth : h = 400mm	Strength	f_{cw} (N/mm²)	32.5
	Cracked Width (mm)		Δ_m = 0
Edge Distance : c = 300mm	Tightening Torque		T_{inst} Hand Tight
Spacing : s = 300mm	Loading Speed (N/s)		V = 1000
Research Engineer S. Popo-Oia	Technician L.Clark		



Location

Test Number	4	5	6	7	8
F_{ut}	213.70	213.54	210.28	220.29	244.78
$d_{@fut}$ (mm)	3.31	4.39	4.72	4.02	4.06
$d_{@0.5fut}$ (mm)	2.11	2.54	2.13	2.04	2.71
Load @ 0.1mm	0.54	0.82	0.55	1.93	1.05
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	220.52
$\sigma(F_{ut})$	kN	**14.04**
$\nu(F_{ut})$	(%)	6.379**%**

Resin bond with concrete failure

PURE EPOXY 1-1-M20-grade 12.9-A1 test

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Tests of ICFS Resin M8 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 10

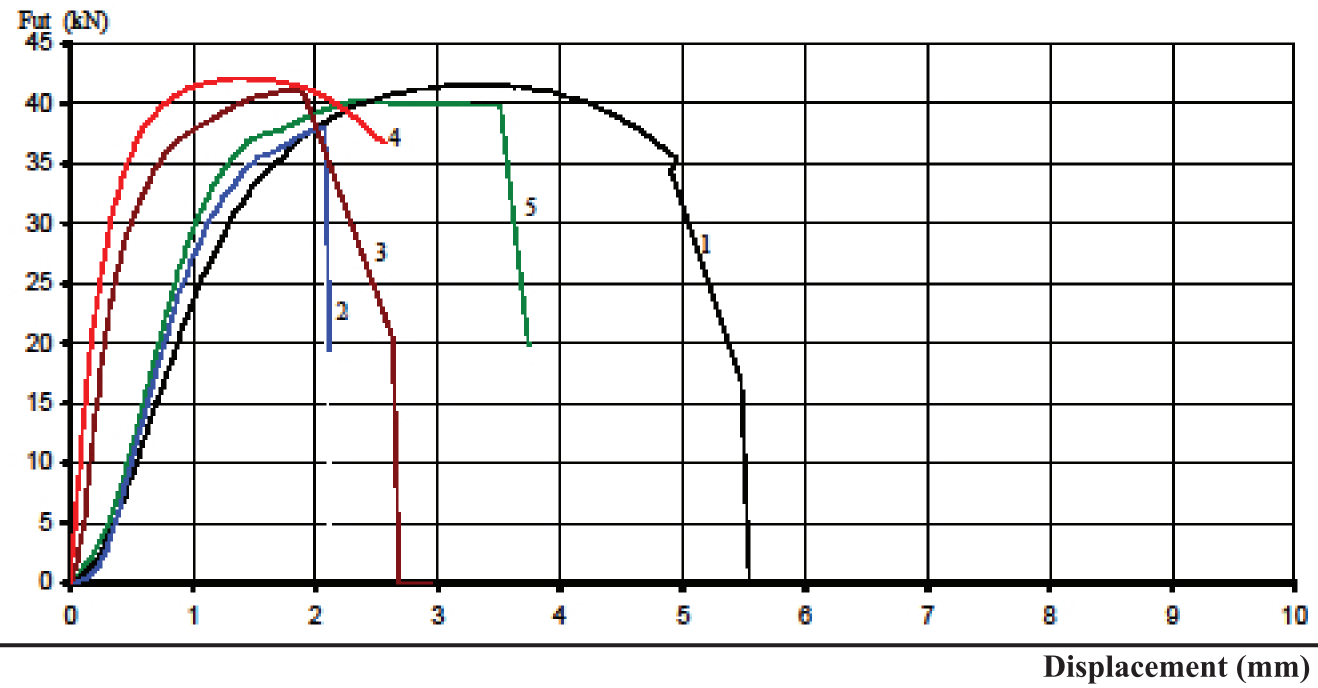
Tensile Tests on M8

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 1:1 M8/60	19/03/2009	EX8-A1-1-5	5

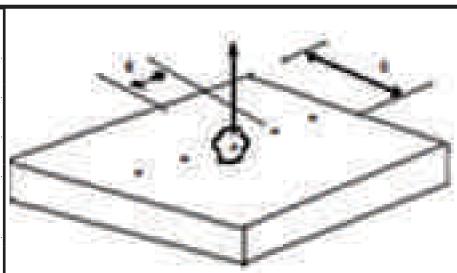
Confined Test in Non-cracked Concrete C20/25. Type : **A1**

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Hole Core Dia :	$d_{cut,m}$ = 10.35mm
Effective Depth :	h_{ef} = 60mm
Slab Depth :	h = 400mm
Edge Distance :	c = 250mm
Spacing :	s = 300mm

Concrete	L19	Grade	C20/25
		type	NWC
		Days at Test	> 28
Strength		f_{cw} (N/mm²)	32.5
Cracked Width (mm)			Δ_m = 0
Tightening Torque			T_{inst} Hand Tight
Loading Speed (N/s)			V = 1000



Location

Research Engineer S. Popo-Oia	Technician L.Clark

Test Number	4	5	6	7	8
F_{ut}	41.72	37.99	41.13	42.14	40.24
$d_{@fut}$ (mm)	3.41	2.03	1.79	1.36	2.31
$d_{@0.5fut}$ (mm)	0.87	0.74	0.28	0.18	0.73
Load @ 0.1mm	1.03	0.38	4.70	7.33	1.38
Failure Mode	Steel	Resin	Resin	Steel	Resin

F_{ut} (mean)	kN	40.64
$\sigma(F_{ut})$	kN	**1.65**
$\nu(F_{ut})$	(%)	4.059%

Steel Stud Failure

Resin bond with concrete failure

PURE EPOXY 1-1-M12-grade 12.9-A1 test

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Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 11

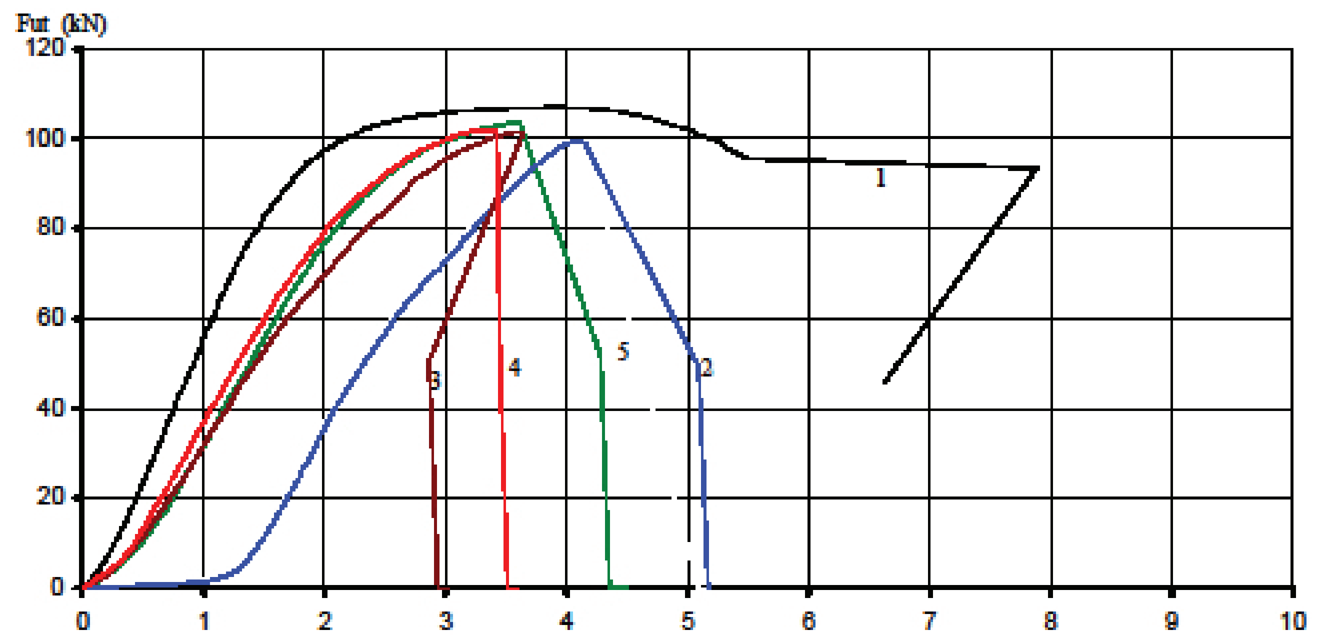
Tensile Tests on M12

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 1:1 M12/90	12/03/2009	EX12-A1-1-5	5

Confined Test in Non-cracked Concrete C20/25. Type : **A1**

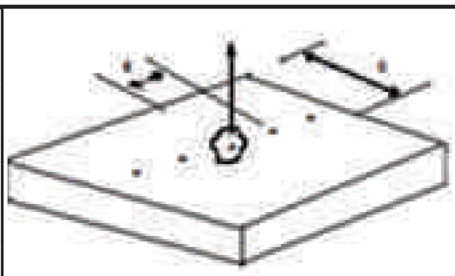
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = 14.35mm
Effective Depth :	h_{ef} = 90mm
Slab Depth :	h = 400mm
Edge Distance :	c = 200mm
Spacing :	s = 300mm

Concrete	L19	Grade	C20/25
		type	NWC
		Days at Test	> 28
Strength		f_{cw} (N/mm²)	32.5
Cracked Width (mm)			Δ_m = 0
Tightening Torque			T_{inst} Hand Tight
Loading Speed (N/s)			V = 1000



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8
F_{ut}	106.97	99.60	101.49	102.15	103.53
$d_{@fut}$ (mm)	3.86	4.00	3.57	3.32	3.54
$d_{@0.5fut}$ (mm)	0.94	2.27	1.44	1.29	1.38
Load @ 0.1mm	3.61	0.36	3.57	2.14	1.29
Failure Mode	Steel	Resin	Resin	Steel	Resin

F_{ut} (mean)	kN	102.75
$\sigma(F_{ut})$	kN	**2.75**
$\nu(F_{ut})$	(%)	2.68**%**

Steel Stud Failure
Resin bond with concrete failure

PURE EPOXY 1-1-M20-grade 12.9-A1 test-REPEAT

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Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

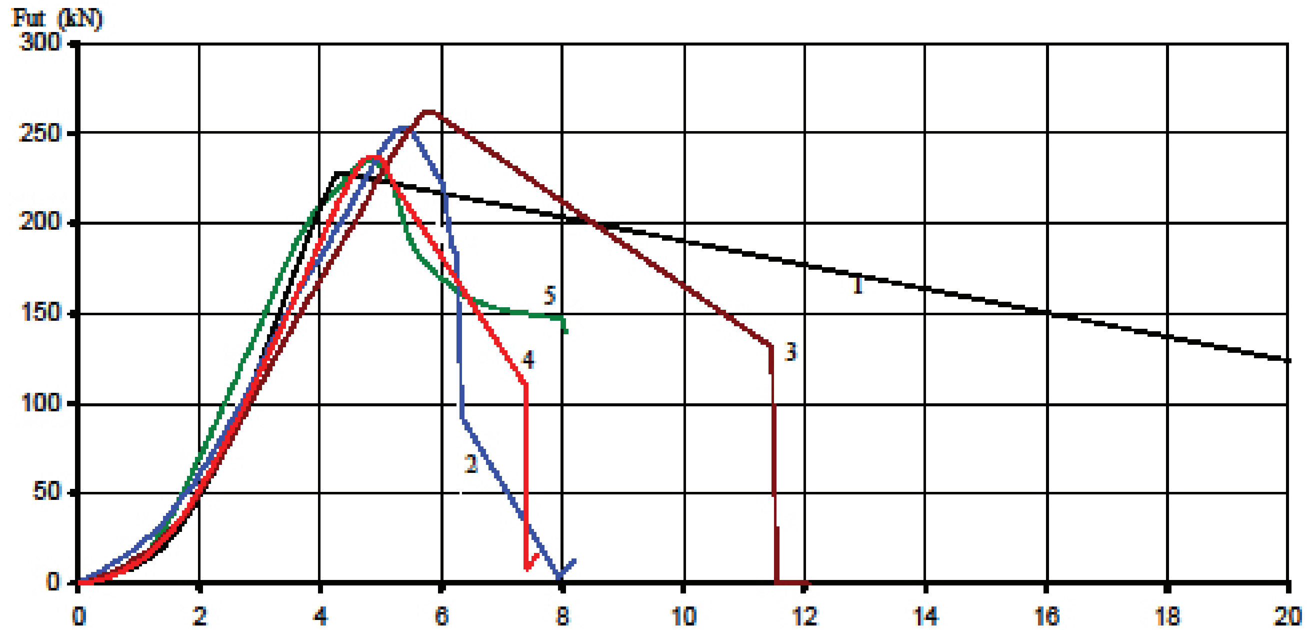
Figure 12

Tensile Tests on M20

Steel Grade : 12.9

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 1:1 M20/120	**06/04/2009**	**EX20-A1-1-5**	**5**

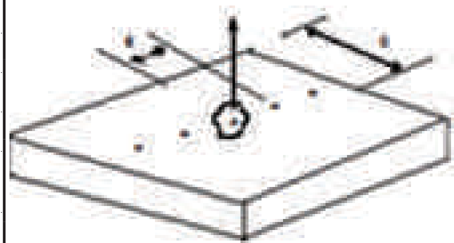
Confined Test in Non-cracked Concrete C20/25. Type : $S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete **A1**



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = **24.35mm**
Effective Depth :	h_{ef} = **120mm**
Slab Depth :	**h** = **400mm**
Edge Distance :	**c** = **300mm**
Spacing :	**s** = **300mm**

Concrete	**L20 Grade**	**C20/25**
	type	**NWC**
	Days at Test	**> 28**
Strength	**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)		Δ_m = **0**
Tightening Torque		T_{inst} **Hand Tight**
Loading Speed (N/s)		**V = 1000**



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	**4**	**5**	**6**	**7**	**8**
F_{ut}	**229.89**	**253.49**	**262.52**	**237.47**	**235.02**
$d_{@fut}$ **(mm)**	**4.28**	**5.37**	**5.75**	**4.83**	**4.80**
$d_{@0.5fut}$ **(mm)**	**2.94**	**3.02**	**3.34**	**3.01**	**2.62**
Load @ 0.1mm	**1.38**	**2.50**	**1.29**	**0.67**	**0.39**
Failure Mode	**Resin**	**Resin**	**Resin**	**Resin**	**Resin**

F_{ut} (mean)	kN	243.68
$\sigma(F_{ut})$	kN	**13.74**
$\nu(F_{ut})$	(%)	5.64%

Resin bond with concrete failure

Test Results and Graphs of Load against Displacement for

Tensile Test Series F1 (Wet Uncleaned Holes in Non-Cracked Concrete)

ICFS resin anchors

Graphs of Load against Displacement for Tensile Test Series F1

PURE EPOXY 3-1-M20-grade 12.9-A1 test

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Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

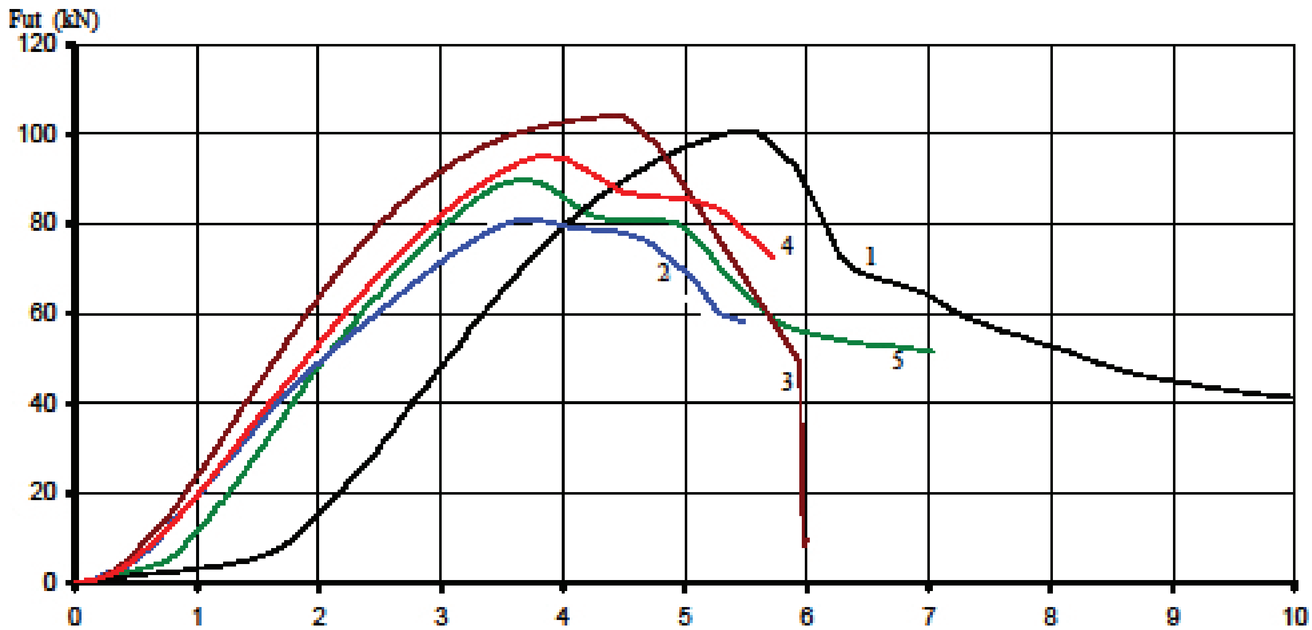
Figure 13

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M12/110	01/04/2009	EP12-F1-1-5	5

Tensile Tests on M12

Steel Grade : 12.9

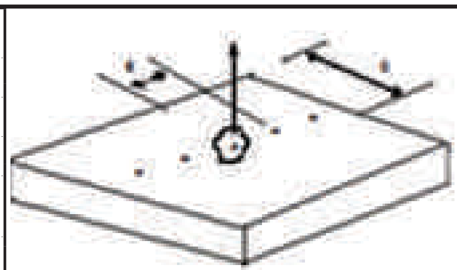
Confined Test in Non-cracked Concrete C20/25- Wet Uncleaned Hole.Type : **F1**
$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = 14.35mm
Effective Depth :	h_{ef} = 110mm
Slab Depth :	h = 400mm
Edge Distance :	c = 200mm
Spacing :	s = 300mm

Concrete	L19 Grade	C20/25
	type	NWC
	Days at Test	> 28
Strength	f_{cw} (N/mm²)	32.5
Cracked Width (mm)		Δ_m = 0
Tightening Torque		T_{inst} Hand Tight
Loading Speed (N/s)		V = 1000



Research Engineer S. Popo-Oia	Technician L.Clark

Location

Test Number	4	5	6	7	8
F_{ut}	100.93	81.49	104.37	95.97	89.96
$d_{@fut}$ (mm)	5.44	3.67	4.42	3.81	3.64
$d_{@0.5fut}$ (mm)	3.05	1.63	1.70	1.79	1.88
Load @ 0.1mm	0.37	1.11	0.67	1.12	0.71
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	94.55
$\sigma(F_{ut})$	kN	**9.10**
$\nu(F_{ut})$	(%)	9.62**%**

Steel Stud Failure
Resin bond with concrete failure

PURE EPOXY 3-1-M20-grade 12.9-F1 test

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Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 14

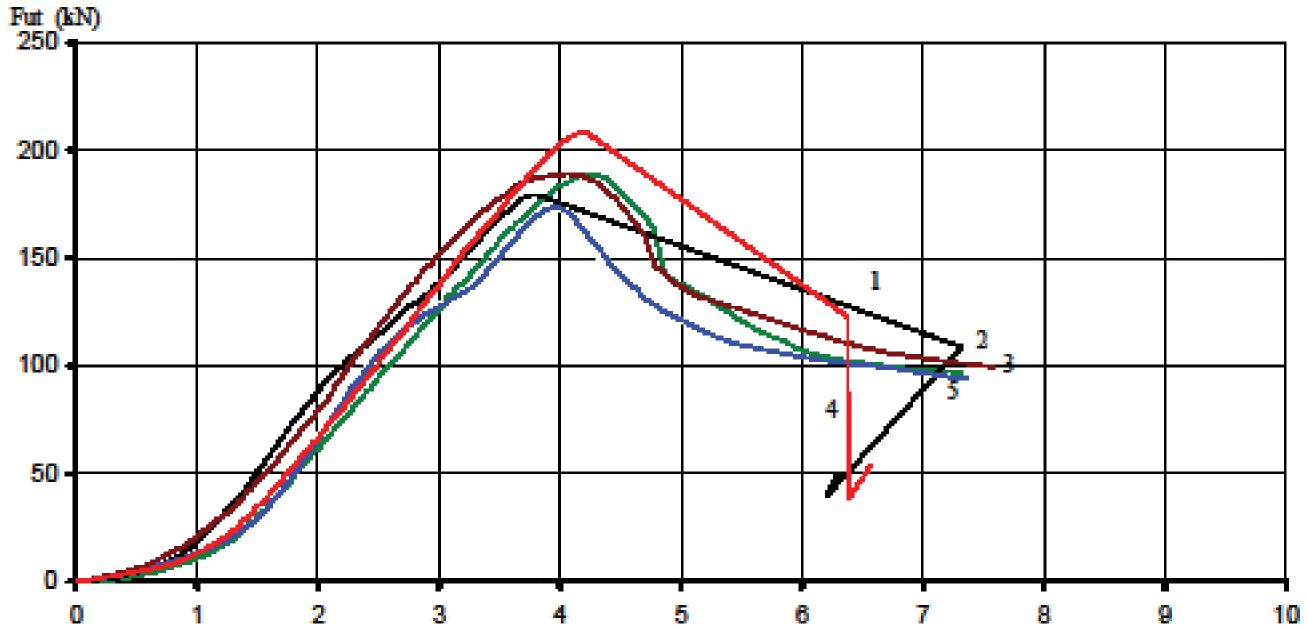
Tensile Tests on M20

Steel Grade : 12.9

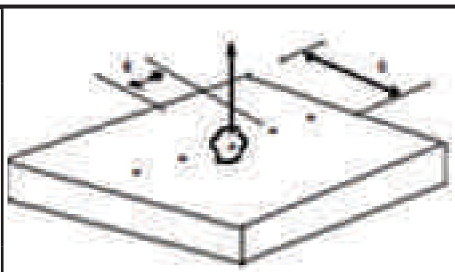
Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M20/120	06/04/2009	EP20-F1-1-5	5

Confined Test in Non-cracked Concrete C20/25- Wet Uncleaned Hole.Type : F1

$S>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Hole Core Dia :	$d_{cut,m}$ = 24.35mm	Concrete	L20 Grade	C20/25
Effective Depth :	h_{ef} = 120mm		type	NWC
Slab Depth :	h = 400mm		Days at Test	> 28
Edge Distance :	c = 300mm	Strength	f_{cw} (N/mm²)	32.5
Spacing :	s = 300mm	Cracked Width (mm)		Δ_m = 0
		Tightening Torque		T_{inst} Hand Tight
		Loading Speed (N/s)		V = 1000



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8
F_{ut}	179.17	174.00	188.94	208.59	188.84
$d_{@fut}$ (mm)	3.74	3.93	4.05	4.17	4.22
$d_{@0.5fut}$ (mm)	1.99	2.24	2.18	2.51	2.50
Load @ 0.1mm	0.74	1.29	1.02	0.85	0.05
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	187.91
$\sigma(F_{ut})$	kN	**13.22**
$\nu(F_{ut})$	(%)	7.04%

Resin bond with concrete failure

Test Results
and
Graphs of Load against Displacement for

Tensile Test Series D1 (Diamond Drilled Holes in Non-Cracked Concrete)

ICFS resin anchors

Graphs of Load against Displacement for Tensile Test Series D1

PURE EPOXY 3-1-M12-grade 12.9-F1 test

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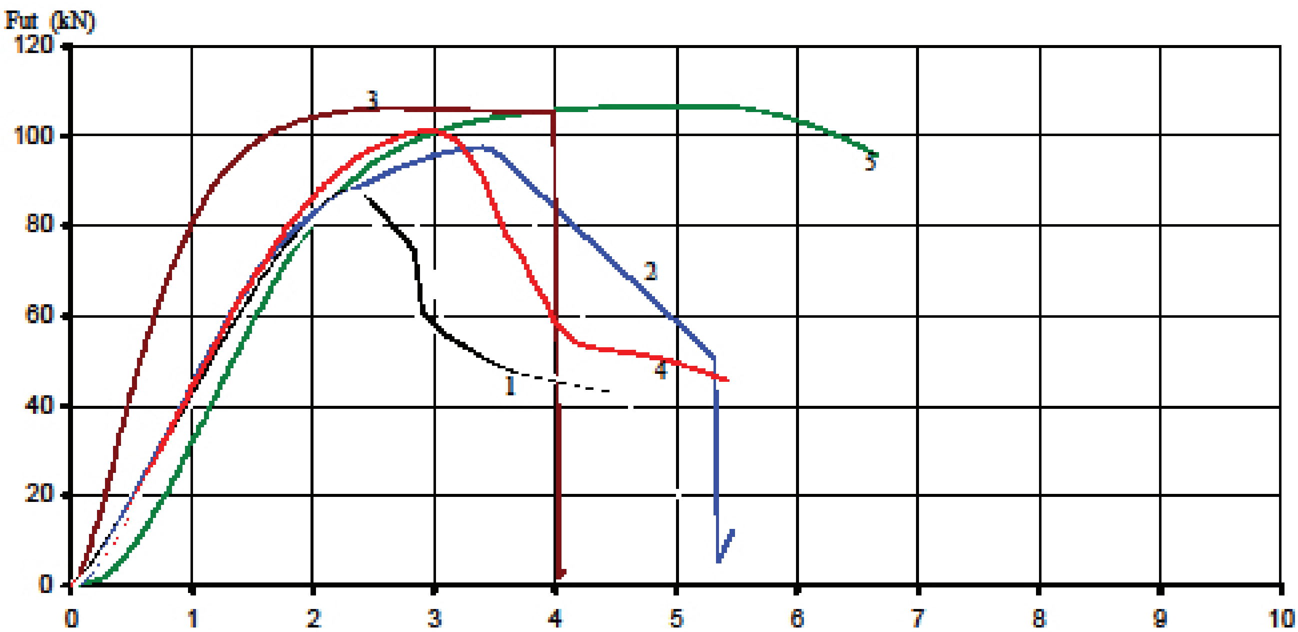
Tests of ICFS Resin M12 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 15

Anchor Type :	Date :	Test No :	No. of Tests :	*Tensile Tests on M12*
PURE EPOXY 3:1 M12/120 Diamond Drilled Holes	**11/05/2009**	**EP12-D1-1-5**	**5**	*Diamond Drilled Holes* *Steel Grade : 12.9* *Test after 48 hrs*

Confined Test in Non-cracked Concrete C20/25- Wet Uncleaned Hole.Type : A1

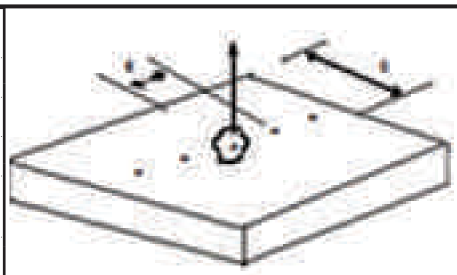
$AS>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = **14.35mm**
Effective Depth :	h_{ef} = **90mm**
Slab Depth :	h = **400mm**
Edge Distance :	c = **200mm**
Spacing :	s = **300mm**

Concrete	**L19**	**Grade**	**C20/25**
		type	**NWC**
		Days at Test	**> 28**
Strength		**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)			Δ_m = **0**
Tightening Torque			T_{inst} **Hand Tight**
Loading Speed (N/s)			V = **1000**



Location

Research Engineer S. Popo-Oia	Technician L.Clark

Test Number	4	5	6	7	8
F_{ut}	87.87	97.42	106.37	101.25	106.80
$d_{@fut}$ (mm)	2.32	3.40	2.62	2.94	4.97
$d_{@0.5fut}$ (mm)	1.02	1.07	0.60	1.14	1.39
Load @ 0.1mm	2.64	1.20	5.61	2.21	0.52
Failure Mode	Resin	Resin	Resin	Resin	Resin

F_{ut} (mean)	kN	99.94
$\sigma(F_{ut})$	kN	**7.78**
$\nu(F_{ut})$	(%)	7.79**%**

Resin bond with concrete failure

PURE EPOXY 3-1-M20-grade 12.9-F1 test

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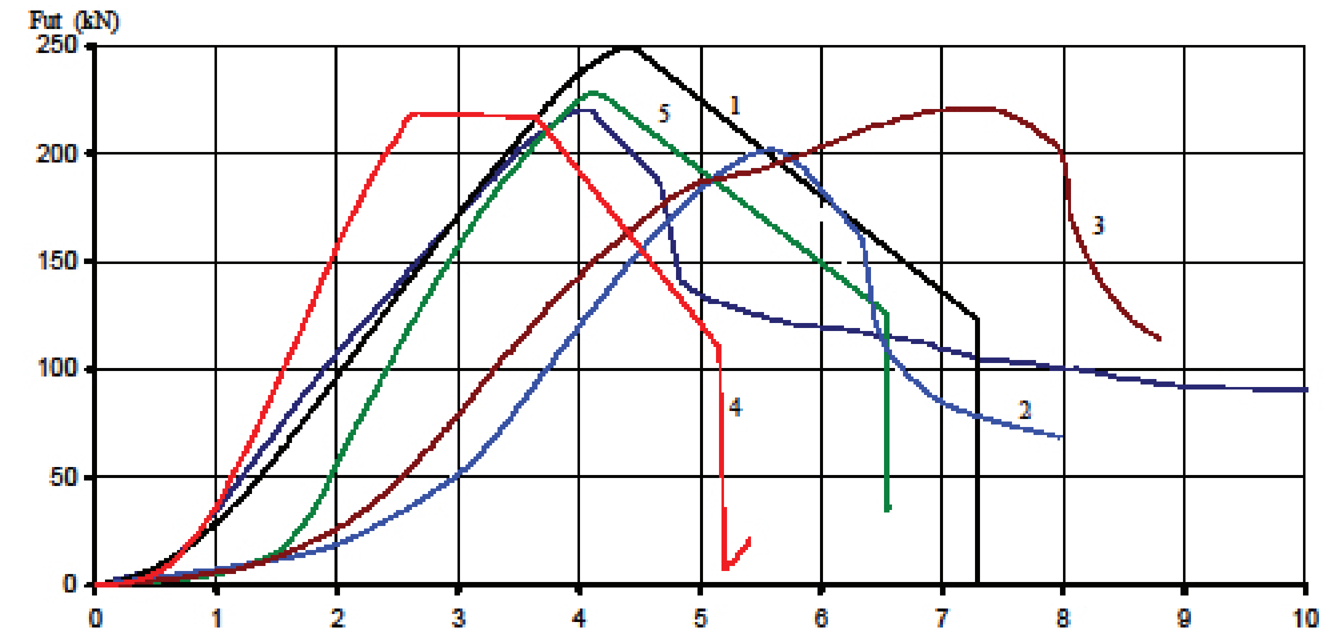
Tests of ICFS Resin M20 anchors in accordance with EOTA Guideline, ETA No. 001,Part 5

Figure 16

Anchor Type :	Date :	Test No :	No. of Tests :
PURE EPOXY 3:1 M12/120 Diamond Drilled Holes	**11/05/2009**	**EP20-D1-1-5**	**5**

Tensile Tests on M20
Diamond Drilled Holes
Steel Grade : 12.9

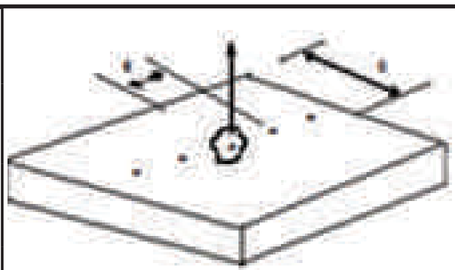
Confined Test in Non-cracked Concrete C20/25- Wet Uncleaned Hole.Type : **A1**
$AS>s_{cr}$, $C>C_{cr}$, $h>=h_{min}$- Tensile Test with single anchors in C20/25 concrete



Displacement (mm)

Hole Core Dia :	$d_{cut,m}$ = **24.35mm**
Effective Depth :	h_{ef} = **120mm**
Slab Depth :	**h** = **400mm**
Edge Distance :	**c** = **300mm**
Spacing :	**s** = **300mm**

Concrete	**L20**	**Grade**	**C20/25**
		type	**NWC**
		Days at Test	**> 28**
Strength		**f_{cw} (N/mm²)**	**32.5**
Cracked Width (mm)			Δ_m = **0**
Tightening Torque			T_{inst} **Hand Tight**
Loading Speed (N/s)			**V** = **1000**



Location

Research Engineer	Technician
S. Popo-Oia	L.Clark

Test Number	4	5	6	7	8	
F_{ut}	249.34	201.84	221.31	219.58	228.65	
$d_{@fut}$ (mm)	4.37	5.54	7.18	0.00	0.00	
$d_{@0.5fut}$ (mm)	2.37	3.76	3.48	5.38	3.06	
Load @ 0.1mm	1.12	0.63	4.95	7.69	0.36	
Failure Mode	**Resin**	**Resin**	**Resin**	**Resin**	**Resin**	

F_{ut} (mean)	kN	224.14
$\sigma(F_{ut})$	kN	**17.19**
$\nu(F_{ut})$	(%)	7.67**%**

Resin bond with concrete failure

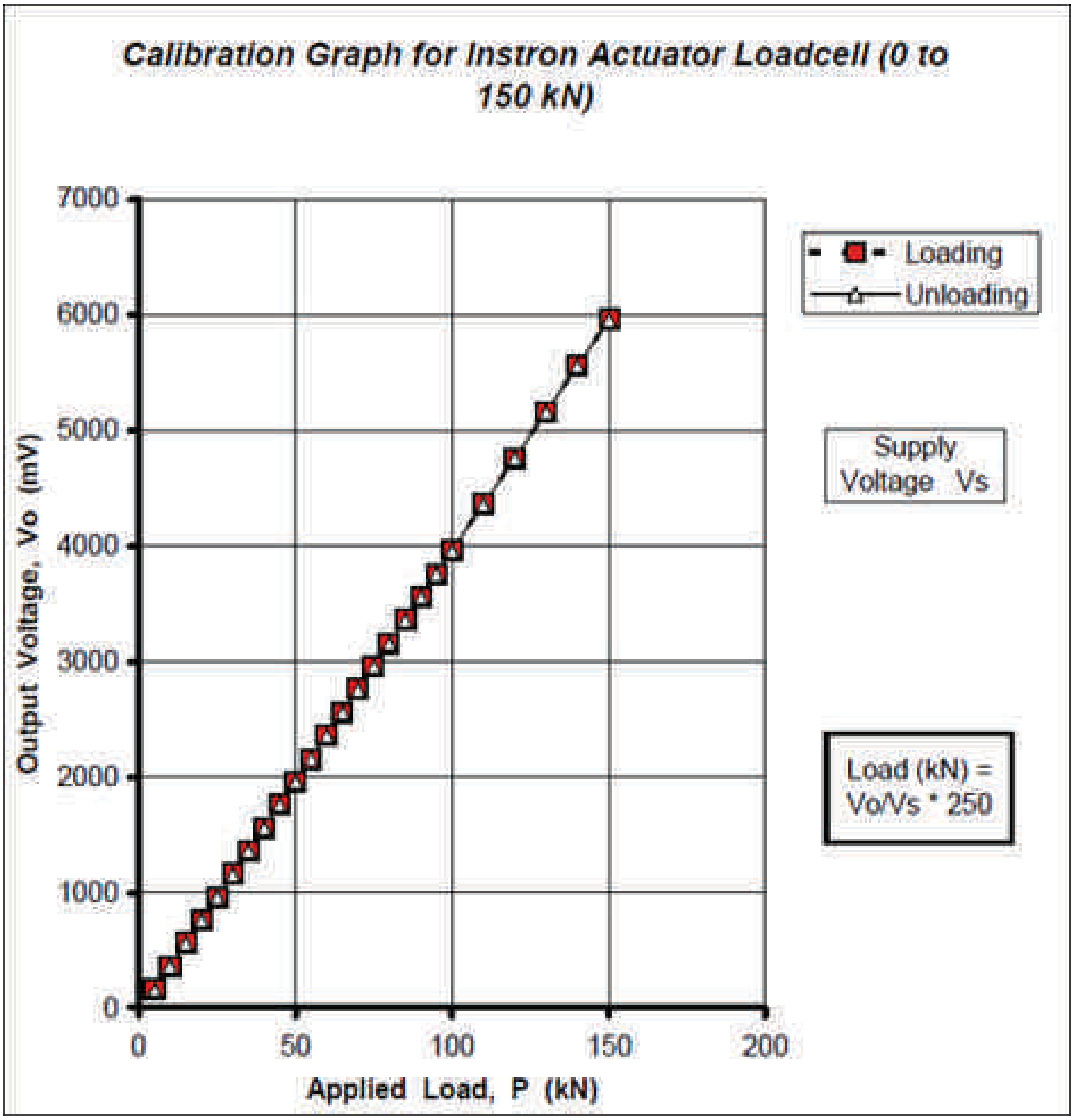
Calibration Graphs of Load Cells and Displacement Transducers

Appendixes : Calibration graphs of load cell and transducers

APPENDIX A1

TABLE A1 : DETAILS OF INSTRON JACK LOADCELL

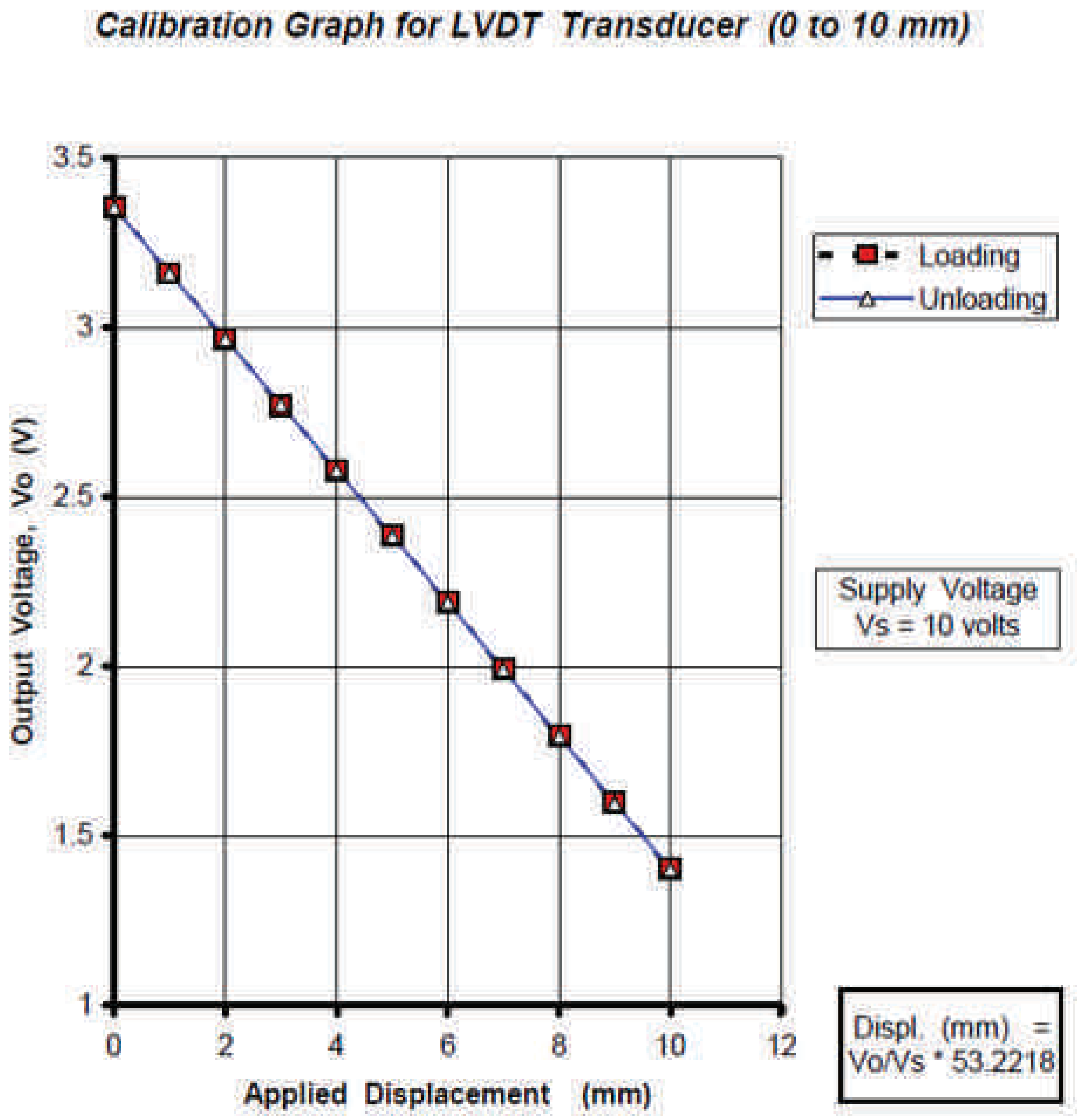
EQUIP SERIAL No :	3269N-440
CAPACITY :	500 kN (static), 250 kN (dynamic)
LOCATION :	Concrete Structures Laboratory. Imperial College.
DATE CALIBRATED :	3-Jul-04
ACCURACY :	+-0.05% (Applied Load)
CALIBRATED by :	Mr L. Clark
APPROVED by :	Mr K. Mitchell



APPENDIX A2

TABLE A2 : DETAILS OF (LVDT) TRANSDUCER

EQUIP SERIAL No :	705687 & 705690
CAPACITY :	50 mm
LOCATION :	Concrete Structures Laboratory. Imperial College.
DATE CALIBRATED :	3-Jul-04
ACCURACY :	+-0.15% (Applied displacement)
CALIBRATED by :	Mr L. Clark
APPROVED by :	Mr K. Mitchell



APPENDIX A3

TABLE A2 : DETAILS OF VOLTAGE SUPPLY

EQUIP SERIAL No :	Voltage Supply
CAPACITY :	10 Volts (10,000 mV)
LOCATION :	Concrete Structures Laboratory. Imperial College.
DATE CALIBRATED :	3-Jul-04
ACCURACY :	+-0.05% (Applied Load)
CALIBRATED by :	Mr L. Clark
APPROVED by :	Mr K. Mitchell