TESTING OF UNDERWATER CONCRETE WITH ANTI-WASHOUT ADMIXTURE RESCON T (FINAL REPORT)

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Summary

Testing of Rescon Mapei AS's anti-washout admixture Rescon T (AUV) for underwater castings has been performed at Vattenfall Utveckling AB in accordance with Vägverket's (the Swedish Road Administration's)
publication number 2002:50.

The project was divided up so that Rescon Mapei was responsible for ordering and manufacture of the concrete, and also provided a concretepump.
Vattenfall Utveckling AB was responsible for the necessary equipment in the laboratory and for performing the required testing.

The testing worked well and all requirements placed on the fresh concrete and hardened concrete were fulfilled.

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1 Introduction

Testing of Rescon Mapei AS's anti-washout admixture Rescon T (AUV) for underwater castings has been performed at Vattenfall Utveckling AB in accordance with Vägverket's (the Swedish Road Administration's) publication number 2002:50.

The testing was performed at Vattenfall Utveckling AB, Concrete Testing, in Älvkarleby on 3 February 2004 and was conducted in the laboratory at +20° C.

The project was divided up so that Rescon Mapei was responsible for ordering and manufacture of the concrete, and also provided a concretepump.
Vattenfall Utveckling AB was responsible for the necessary equipment in the laboratory and for performing the required testing.

2 Equipment

Two different types of formwork filled with water were used, type 1 and type 2, the designs of which are presented in **Appendix 1**.

The formworks were manufactured in accordance with the requirements specified in the Swedish Road Administration's publication number 2002:50.

The concrete pump's pump unit was made by Putzmeister.
The diameter of the pipes and orifice valve was 100 mm.

3 Concrete

The mix proportions for the concrete used in the testing are shown in Table 3.1.
The composite grading curve for the ballast material is presented in **Appendix 2**.

Table 3.1: Mix proportions

Component:	**Kg/m³**
Macadam 16-32	619
Macadam 8-16	205
Gravel 0-8	895
Ground limestone, Nordkalk Limus 40	20
CEM I 42,5 BV/SR/LA	402
Water	216.6
Rescon T	***18***

4 Mixing

The concrete was delivered by Grus & Betong in Forsbacka and mixing on the testing date of 3 February 2004 was conducted as follows:

- Mixing started at 07:40 hours with the mixing of 1m^3 concrete. Ballast, cement and water were added to the mixer in the normal way. 18 kg of Rescon T were added on the ballast weighing machine.
- After 7 litres of extra water were added, the mixing ended at 07:46 hours and the consistency was measured at 600 mm through measuring the spread on a concrete cake obtained from a slump cone in accordance with SS-EN 12350-2.
- At 07:57 hours, 72 kg of Rescon T (4 x 18 kg) were added direct into the rotator of the concrete-mixer lorry.
- Thereafter, two batches of concrete were mixed each of 2 m^3, ready at 08:00 hours and 08:04 hours respectively.
- The concrete was subsequently mixed for 15 minutes in the concrete-mixer lorry. The speed of the rotor was 12.5 rpm.
- The concrete temperature was measured at 18°C.
- At 08:35 hours, the consistency was measured as above at 580 mm.

The time from when mixing started to when the lorry left the concrete factory was 60 minutes (including testing of the concrete).
The transport distance to the laboratory was approx. 50 km. Transport took place in a truck mixer.

5 Casting

The test began with the casting of formwork type 1 (with reinforcement). Casting took place in one stage up to approx. 1 metre above the bottom at the short side nearest the tremie pipe. When measuring level 10 minutes after completion of casting, a maximum level difference of 33 mm was measured.
The highest permitted value is 50 mm, **and the requirement is therefore fulfilled.**

Time:	Event:
09:50 hours	Casting starts.
10:05 hours	Casting completed, tremie pipe lifted cautiously.
10:15 hours	Measurement of level begins from the short side furthest from the casting place.

Formwork type 2 (without reinforcement) was cast after formwork type 1. Casting was performed in two stages. The first stage consisted of approx. 600 litres and the second stage of approx. 400 litres.

The maximum level difference after the first stage was 70 mm and after the second stage 35 mm. The highest permitted value after stage two is 100 mm, **and the requirement is therefore fulfilled.**
Another requirement is that the concrete shall have reached the short side furthest from the pump pipe after the first stage, which was the case **and the requirement is therefore fulfilled.**

The results from the level measurement are shown in **Appendix 3**.

Time: Event:
10:29 hours Casting starts.
10:32 hours Casting of stage 1 completed, tremie pipe kept immersed in the concrete.
10:42 hours Measurement of level begins from the short side furthest from the casting place.
10:48 hours Casting continues.
10:50 hours Casting completed, tremie pipe lifted cautiously.
11:00 hours Measurement of level begins from the short side furthest from the casting place.

6 Testing of the fresh concrete

Testing of the fresh concrete was performed from 10:10 hours to 10:15 hours.
The consistency of the concrete was measured through slump and spread.
Determining slump was conducted in accordance with SS-EN 12350-2 with the following exceptions and additions:

- Slump greater than 150 mm is accepted.
- Measurements were performed one and three minutes after the slump cone was lifted and when the levelling of the fresh concrete had ceased.
- The concrete's dispersion was also measured.

Spread in accordance with SS-EN 12350-5 was measured.

The results are shown in Table 6.1.

Table 6.1: Testing of the fresh mortar

Time after lifting of slump cone [min]	1 min.	3 mins.	Stop
Slump [mm]	260	265	265
Dispersion measured on slump [mm]	490	530	560
Spread [mm]			530

The air content in accordance with SS-EN 12350-7 was measured at 1.3%.

7 Inspection and splitting of test specimens after 21 days

During inspection of the test specimens (prior to splitting) there was no blistering or crack formation. On the surface of the test specimens, only a very thin layer of sludge could be scraped away.

Splitting of test specimen type 1 was performed by staff from the Concrete Laboratory at Vattenfall Utveckling AB using Finja Bemix Betonamit Snigeldynamit.
On inspection, there was no sludge formation or blistering at the reinforcement bar. Connection between reinforcement and concrete looked fine. **The set requirement is therefore fulfilled.**

Some ballast separation has occurred, but this does not affect the properties of the concrete in general, see "Test loading of core samples" Section 9. See also photos in **Appendix 4**.

On inspection of the test specimens 91 days after casting, no crack formation could be observed.

8 Test loading of cubes

21 cubes (150 mm) were pressure tested at the Concrete Laboratory at Vattenfall Utveckling AB. The results of the test loading are shown in Table 8.1.

Table 8.1: Development of strength

Age [days]	Density [Kg/m³]	Compressive strength Individual values [MPa]			Compressive strength Mean [MPa]
1	2330	**4.8**	**5.8**	**5.9**	6
2	2340	16.3	15.6	15.6	16
3	2340	21.4	21.3	21.1	21
7	2340	33.3	33.2	35.0	34
14	2320	40.3	41.5	39.9	41
28	**2300**	**46.7**	**47.1**	**46.0**	**47**
91	2300	51.1	50.1	50.9	**51**

The results at 28 days shall meet the requirements for strength class C28/35 in accordance with SS-EN 206-1 (SS 13 70 03).
Since the cubes have been stored in accordance with SS 13 72 10 (stored dry) recalculation of the result at 28 days gives 0.92 x 47 = 43 MPa.

The mean value shall be 35+4 MPa =39 MPa and individual value > 35-4=31 MPa.
The requirement regarding compressive strength is fulfilled.

9 Drilling and test loading of cylinders

Drilling out and test loading of cylinders from test specimen type 1 were performed by staff at the Concrete Laboratory at Vattenfall Utveckling AB.

This testing shall fulfil two requirements; firstly requirements on maximum spread in accordance with publication 2002:50, secondly requirements for strength class C 28/35 in accordance with BBK, section 7.3.3.3. conditions B.

The results are presented in Table 9.1. A figure showing where the test positions are situated on the test specimens is shown in **Appendix 5**.

Table 9.1: Result from test loading of drilled out cylinders

Core number (direction of flow)	Position	Compressive strength [MPa]	Mean value [MPa]	Standard deviation [MPa]	Coefficient of Variation [%]
1	Ö[A]	42.1			
1	M[B]	42.7			
1	U[C]	42.5	42.4	0.35	0.8
2	Ö	42.2			
2	M	42.5			
2	U	43.8	42.8	0.85	2.0
3	Ö	40.8			
3	M	40.5			
3	U	42.1	41.1	0.85	2.1
4	Ö	42.7			
4	M	41.6			
4	U	39.3	41.2	1.73	4.2
Mean value [MPa]		41.9			
Standard deviation [MPa]		1.20			
Coefficient of variation [%]		2.9			

[A] Ö = Upper edge

[B] M = Middle

[C] U = Lower edge

Evaluation

Evaluation in accordance with BBK 94 section 7.3.3.3 conditions B.

The concrete's strength class is C 28/35 $\Rightarrow$ f_{KK} = 28 MPa
Mean value (m) = 41.9 MPa
Standard deviation (s) = 1.20 MPa
Lowest individual value = 39.3 MPa

The mean value shall be $\geq f_{KK}$ exp (1.4 s/m) = **28.8** MPa
Individual test shall be $\geq f_{KK}$ –5 MPa = **23** MPa

The concrete fulfils the requirements for concrete quality C28/35.

In accordance with publication 2002:50, the coefficient of variation for the entire series shall be below 7 % and the coefficients of variation within each core be below 10 %. The coefficient of variation is 2.9 % for the entire series and 0.8 %, 2.0 %, 2.1 % and 4.2 % for the respective series.
The concrete fulfils the requirements regarding the coefficients of variation.

10 Ballast content in sludge

Samples have been taken out by scraping the upper edge down to a depth of roughly 1.5 mm. The samples (of approx. 10 grams each) have then been dried, weighed, prepared with phosphoric acid, rinsed with water, and dried and weighed again. This has resulted in a ballast content in a percentage by weight.

Three test samples have been taken from test specimen type 1: one at each end and one in the middle of the test specimen. The results are shown in Table 10.1.

Table 10.1: Ballast content in sludge

Sample position	Ballast content in percentage by weight
At tremie pipe	75 %
Middle of test specimen type 1	76 %
Beyond 2nd bar	67 %

The requirement is that the ballast content in the sludge shall be at least 50 %.
The requirement regarding sludge content is fulfilled.

11 Summary

Results achieved in comparison with the requirement values in Table 11.1.

Table 11.1: Results achieved in comparison with the requirement values

	Require-ment value	Value achieved	Result Appd[A] or Not appd[B]
Level difference formwork type 1 [mm]	≤50	33	Appd
Level difference formwork type 2 [mm]	≤100	35	Appd
Strength 28 days, cubes, mean value as per SS-EN 206-1[MPa]	≥39	47	Appd
Strength 28 days, cubes, indiv. value as per SS-EN 206-1 [MPa]	≥31	46	Appd
Strength, cylinders, mean value as per BBK [MPa]	≥28.8	41.9	Appd
Strength, cylinders, indiv. value as per BBK [MPa]	≥23.0	39.3	Appd
Strength, cylinders, coefficient of variation within cores as per BBK [%]	≤10	4.2	Appd
Strength, cylinders, coefficient of variation all cylinders as per BBK [%]	≤7	2.9	Appd
Ballast content of sludge [percentage by weight]	≥50	>67-76	Appd

[A] Appd = Approved

[B] Not appd = Not approved

12 References

1[2]. Boverket, 1994, "*Concrete Structures, BBK 94*"
(The National Board of Housing, Building and Planning)

2[1]. Vägverket, publication 2002:50
(the Swedish Road Administration)

Formwork types

Formwork dimensions

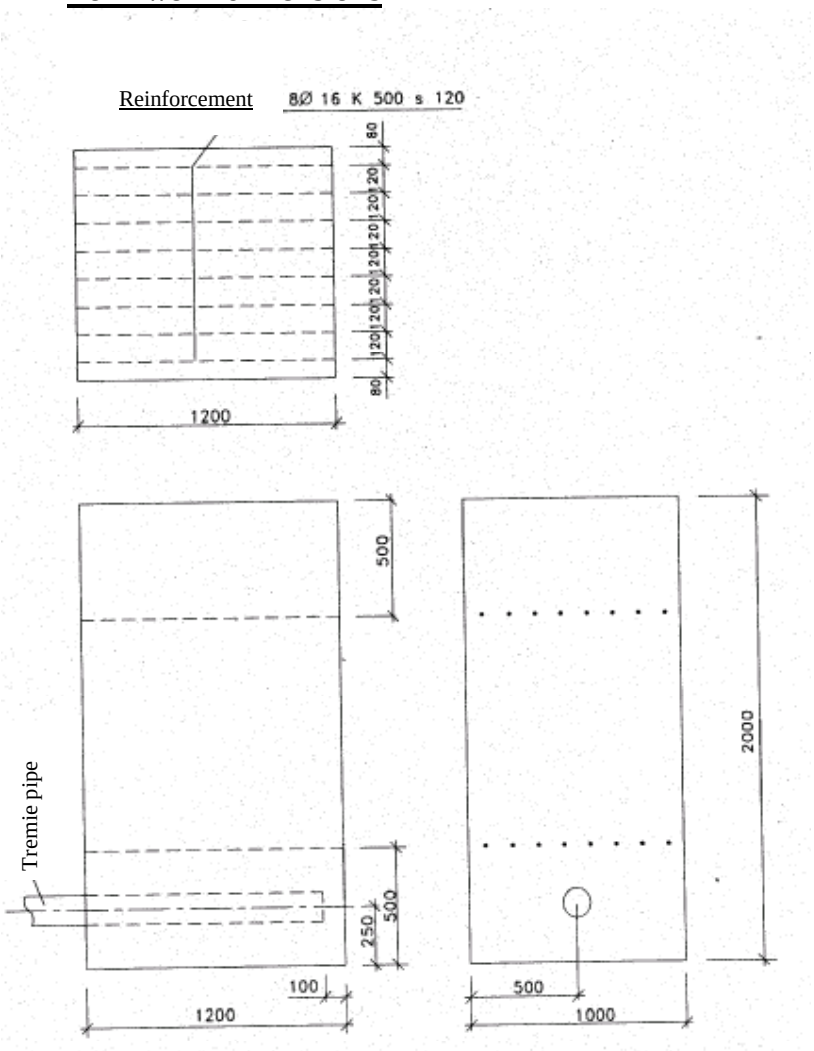


Figure 1.1: Dimensions of formwork type 1 (in mm)

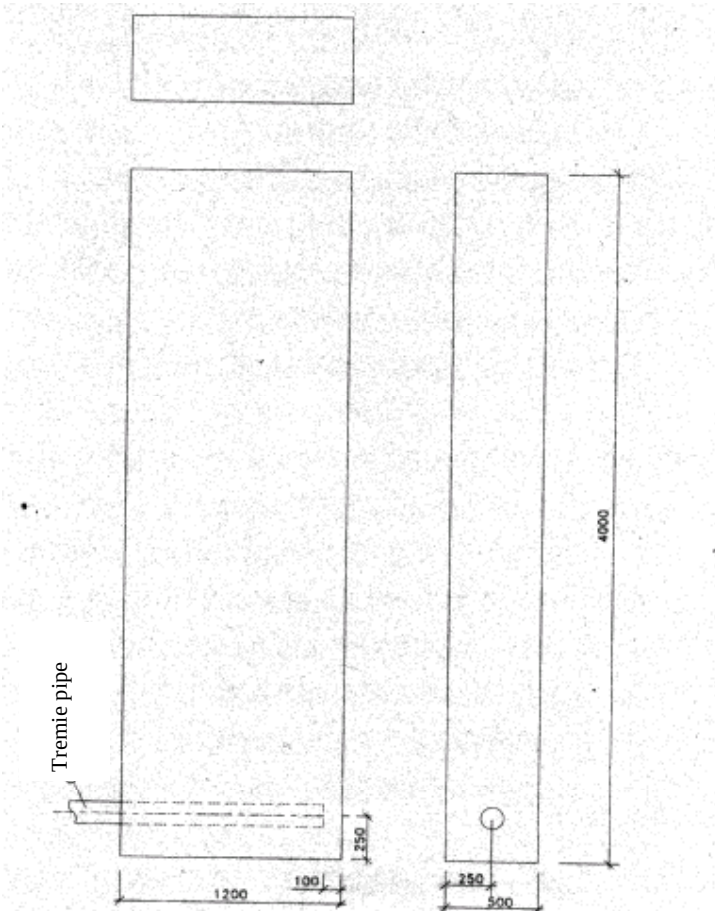
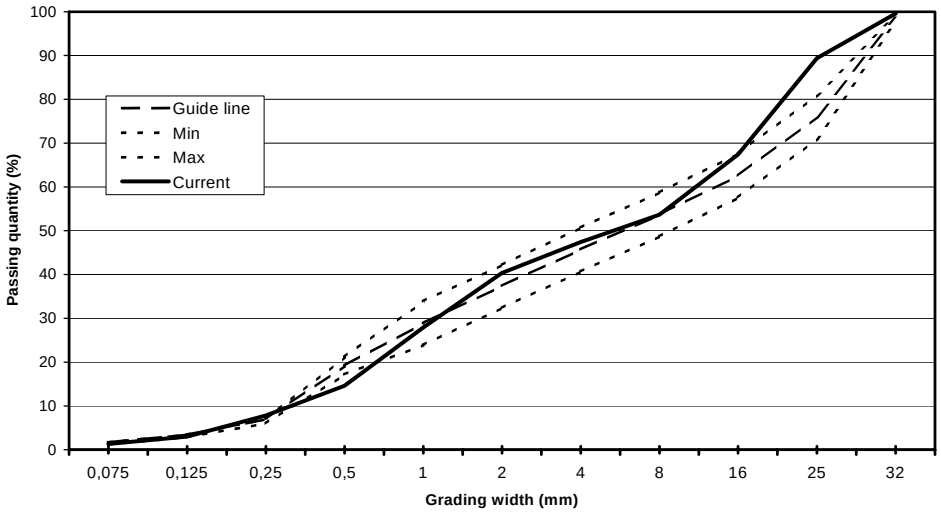


Figure 1.2: Dimensions of formwork type 2 (in mm)

Composite grading curve



Figur 2.1: Composite grading curve of ballast material

Grading width [mm]	Passing quantity [%]			
Data	Guide line	Min	Max	**Current**
0,075	1,7	1,2	1,7	**1,3**
0,125	3,4	2,9	3,4	**3,0**
0,25	7	6	7	**7,8**
0,5	19,2	17,2	21,2	**14,6**
1	28,9	23,9	33,9	**27,9**
2	37,4	32,4	42,2	**40,4**
4	45,7	40,7	50,7	**47,4**
8	53,7	48,7	58,7	**53,7**
16	62,6	57,6	67,6	**67,4**
25	76	71	81	**89,4**
32	98,6	97,6	99,1	**99,6**

Table 2.1: Composite grading curve of ballast material

Result of level measurements

The distance between a horizontal plane cutting the highest level of the formwork bottom is shown in table and diagram form. The measurements have been performed with an accuracy of 2 mm.
The level difference for formwork type 1 was 33 mm and for formwork type 2 was 35 mm.

The tables show the level of the concrete surface in cm. The horizontal row refers to distance from the short side in metres, whilst the vertical column refers to the distance from the left long side, viewed in direction of flow, stated in metres.

Formwork type 1

Table 3:1 **Concrete surface level after casting in formwork type 1.**

	5	**45**	**55**	**100**	**145**	**155**	**195**
5	99,0	99,0	99,0	100,0	101,0	101,4	102,0
50	99,0	100,3	100,5	100,8	101,4	101,5	102,3
95	99,2	100,0	100,3	101,5	101,8	101,8	102,3

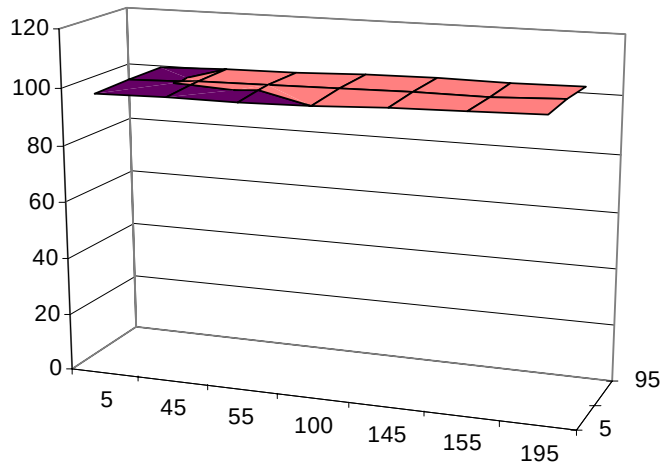


Figure 3:1 **Concrete surface level after casting in formwork type 1, measured in cm.**

Formwork type 2

Table 3:2 **Concrete surface level after casting in formwork type 2, stage 1.**

	5	50	100	150	200	50	300	350	395
5	26,5	27,0	25,6	24,2	23,0	21,9	21,0	20,4	20,2
25	26,5	27,0	25,7	24,5	23,2	22,0	21,0	20,5	20,0
45	26,4	26,6	25,7	23,7	22,5	21,4	20,7	20,0	20,2

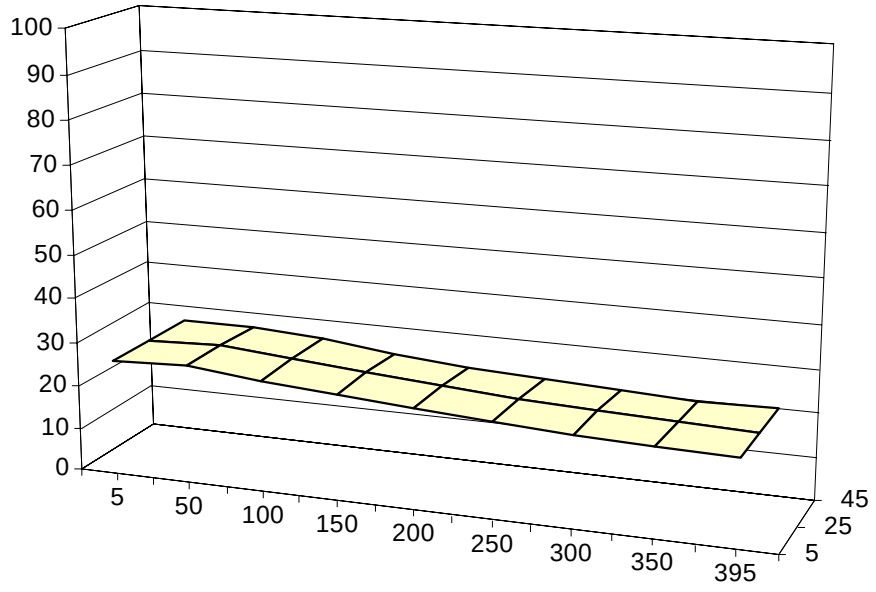


Figure 3:2 **Concrete surface level after casting in formwork type 2, stage 1, measured in cm.**

Table 3:3 **Concrete surface level after casting in formwork type 2, stage 2.**

	5	**50**	**100**	**150**	**200**	**250**	**300**	**350**	**95**
5	46,3	46,0	45,1	44,3	44,0	43,9	44,0	43,3	43,8
25	46,3	46,5	44,5	44,5	43,4	43,8	43,6	43,6	44,0
45	46,5	45,4	44,6	44,0	43,5	43,3	43,2	43,2	43,8

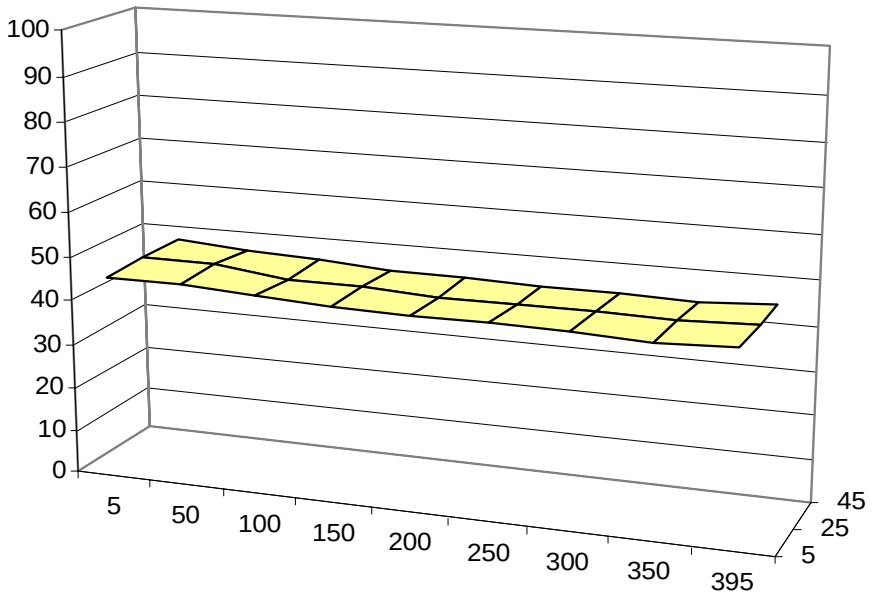


Figure 3:3 **Concrete surface level after casting in formwork type 2, stage 2, measured in cm.**

Photos from the inspection

Figure 4:1 **Drill cores from test positions up to and including 4 (4 at top)**

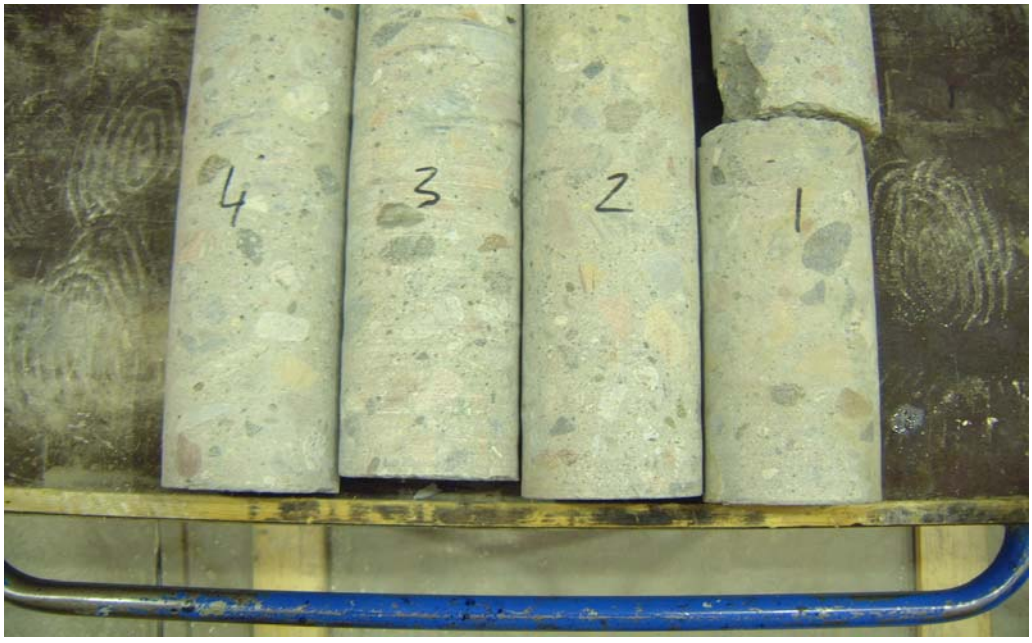


Figure 4:2 **Bottom edge of drill cores from test positions up to and including 4 (from left to right)**

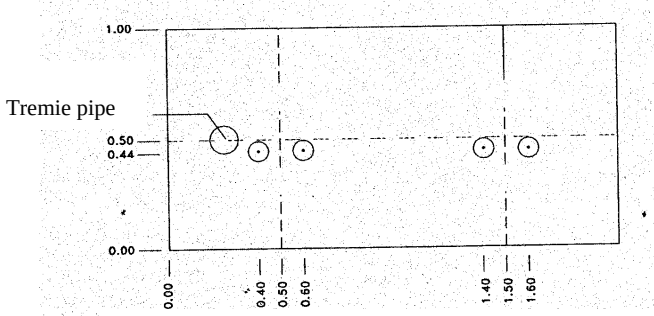
Figure 4:3 **Upper edge of drill cores from test positions up to and including 4 (from right to left)**

Figure 4:4 **Section at first reinforcement row in relation to placing of the tremie pipe.**

Figure 4:5 **Section at second reinforcement row in relation to placing of the tremie pipe.**

Test positions for drilling out cores

Splitting lines and orientation of drill cores



Position of the reinforcement and splitting lines for the concrete

The drill holes shall be placed right before one of the reinforcement bars nearest the centre line in the test specimen´s long side.

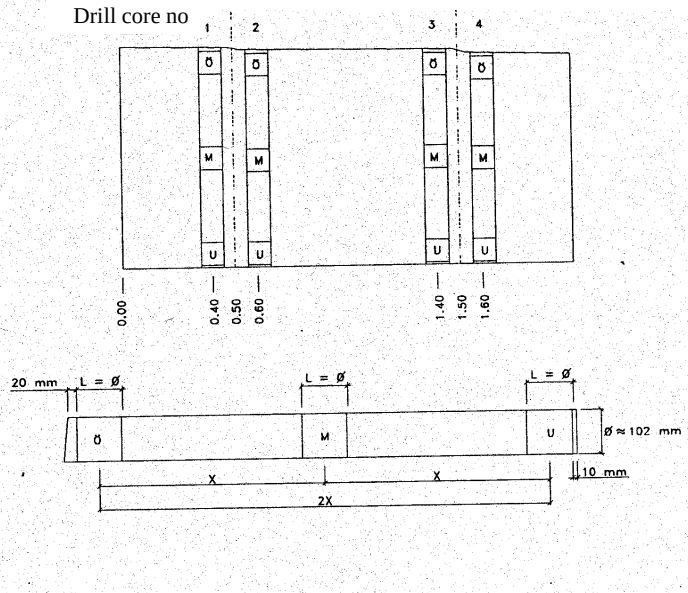


Figure 5:1 Splitting lines and orientation of drilled out cores from casting in formwork type 1