

English translation of Untersuchungsbericht Nr. 3360-04-96 by Dr. R.E. Beddoe in

TECHNISCHE UNIVERSITÄT MÜNCHEN

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LEHRSTUHL FÜR BAUSTOFFKUNDE UND WERKSTOFFPRÜFUNG
UND PRÜFAMT FÜR BITUMINÖSE BAUSTOFFE UND KUNSTSTOFFE**

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REPORT

No.: 3360-04-96

Commissioned by: DuPont de Namours (Luxembourg) S.A.
DuPont Nonwovens
L-2894 Luxembourg

Subject: Reusability of the formwork liner
"Zemdrain MD"

Reference: Order placed on 4.12.95

This report contains 9 pages including enclosures

Munich, 25.09.96 / Bc

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1 Commission

On 4.12.95 we received a fax from F.L. Serafini, DuPont de Namours (Luxembourg) S.A., in which we were commissioned in accordance with our quote of 23.11.95 to investigate the effect of reuse of the formwork liner "Zemdrain MD". on the depth of carbonation, the surface strength (rebound hammer according to Schmidt, DIN 1048 Part 2) and the water impermeability (DIN 1048 Part 5) of surface concrete. The specimens were to be made using two concrete compositions with blast furnace cement at w/c ratios of 0.45 and 0.55. For comparison, the same tests were to be performed on concrete surfaces which had not been prepared using formwork liners. Measurements were also required on the amount of water drained out of the fresh concrete with the formwork liner.

2 Material

On 21.11.95 F.L. Serafini handed us over a roll of the formwork liner "Zemdrain MD" for the investigations. This material was a composite comprising a 0.4 mm thick grey polymer fibre mat backed by a plastic net 2 mm in thickness.

3 Specimen Preparation

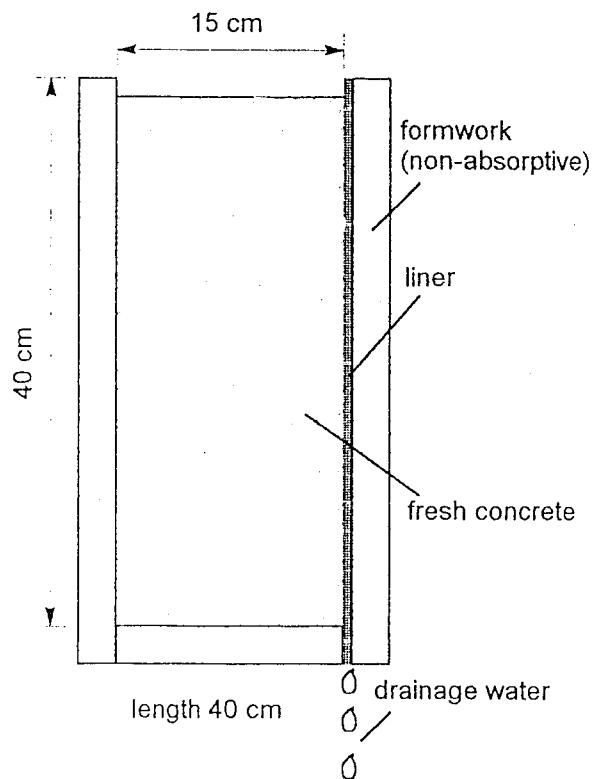
The following concrete compositions were used:

Concrete 1:	Cement:	CEM III/A 32,5 according to DIN 1164 Part 1
	w/c ratio:	0.55
	Cement content:	355 kg/m ³
	Aggregate:	Munich gravel and sand with grading curve A/B 16 according to DIN 1045
	Consistency:	KR (regular consistency, DIN 1045), slump test according to DIN 1048 Part 1
Concrete 2:	Cement:	CEM III/A 32,5 according to DIN 1164 Part 1
	w/c ratio:	0.45
	Cement content:	402 kg/m ³
	Aggregate:	Munich gravel and sand with grading curve A/B 16
	Plasticizer (FM):	1% (with respect to cement content)
	Consistency:	KR (regular consistency), adjusted with plasticizer (FM)

A formwork made of non-absorptive plastic-coated plywood, measuring $40 \times 40 \times 15 \text{ cm}^3$, was used for each type of concrete. One vertical $40 \times 40 \text{ cm}^2$ side of the formwork was lined with "Zemdrain MD" so that the grey fibre mat was adjacent to the fresh concrete. The opposite side was left without a liner as a control surface. The joints were sealed with silicone so that the drainage water could only leave the formwork through the liner.

After placement the fresh concrete was compacted with an internal vibrator. The specimens were demoulded after 24h and stored until testing at 20°C and a relative humidity of 65%.

Fig. 1:
Formwork



For each type of concrete the same piece of formwork liner was used 3 times without cleaning or removing it from the shuttering.

Furthermore, a specimen ($40 \times 40 \times 15 \text{ cm}^3$) was made completely without a formwork liner for each type of concrete.

4 Measurement of the Drainage Water

The amount of water was recorded which drained out of the fresh concrete through the formwork liner over a period of 2 hours after placement and compaction. The drainage water volumes are listed in Tab. 1. The values are normalized to a fresh concrete surface of 1 m² next to the liner.

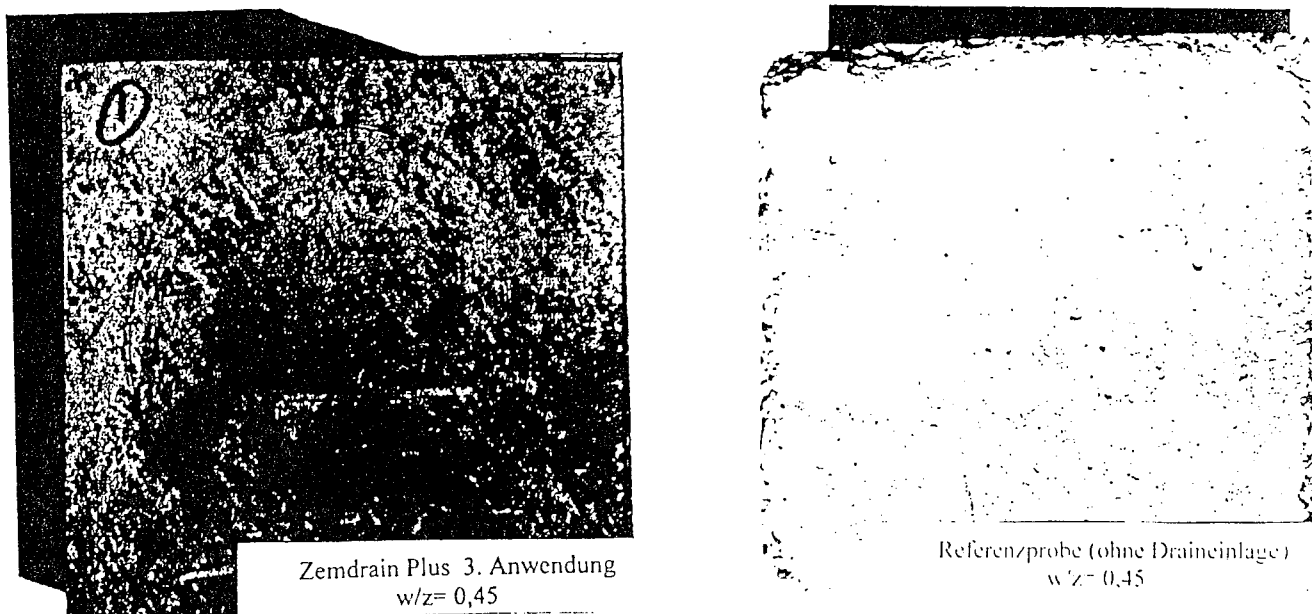
*Tab. 1:
Water removed from fresh concrete with "Zemdrain MD"*

No. of times used	Concrete 1: w/c=0.55 [Litre/m ²]	Concrete 2: w/c=0.45 [Litre/m ²]
1	1.22	0.40
2	1.19	0.35
3	1.11	0.46

5 The Concrete Surfaces

After each individual use, the liner "Zemdrain MD" was removed during demolding without any problems from the concrete surfaces for both compositions (Concrete 1 or Concrete 2). In all cases, the surfaces made with "Zemdrain MD" were smooth and almost without surface voids.

*Fig. 2:
Concrete surface after 3rd. usage of "Zemdrain MD" (left).
Control surface made without liner (right)*



The examples shown in Fig 2. are the surfaces of specimens (cut out from the large blocks) for water impermeability measurements (see section 7). The rings are from grease used to produce a water-tight seal.

A pale area several centimetres in width was visible directly beneath the top edge of surfaces which had been made with a formwork liner. The width of the pale area increased several centimetres after each new use of the liner. Using the rebound hammer, no difference in strength was found between the pale area and the rest of the surface produced by the liner. The discolouration could be removed with a steel wire brush.

6 Testing Surface Strength with the Rebound Hammer

The Schmidt (Model N) rebound hammer was used according to DIN 1048 Part 2 to compare the strength of surface concrete made with formwork liners which had been used up to three times. In order to reduce the scatter of the results as much as possible, an average over 16 measurements was taken for each specimen. The specimens were approximately 4 months old. Individual values were recorded at points distributed over an area of $22 \times 22 \text{ cm}^2$ in centre of the test surface. Data were recorded in the same manner for the specimen surfaces which had been made without a formwork liner. The rebound distance is given in terms of scale divisions (sd). The standard deviation of the recorded values was 2.6 sd.

Tab. 2:

Rebound distances for concrete surfaces after repeated use of "Zemdrain MD"

No. of times used	Concrete 1: w/c=0.55		Concrete 2: w/c=0.45	
	Side with liner [sd]	Side without liner [sd]	Side with liner [sd]	Side without liner [sd]
1	46.3	36.2	45.5	36.8
2	40.9	33.6	43.0	38.9
3	40.0	35.8	42.6	37.5

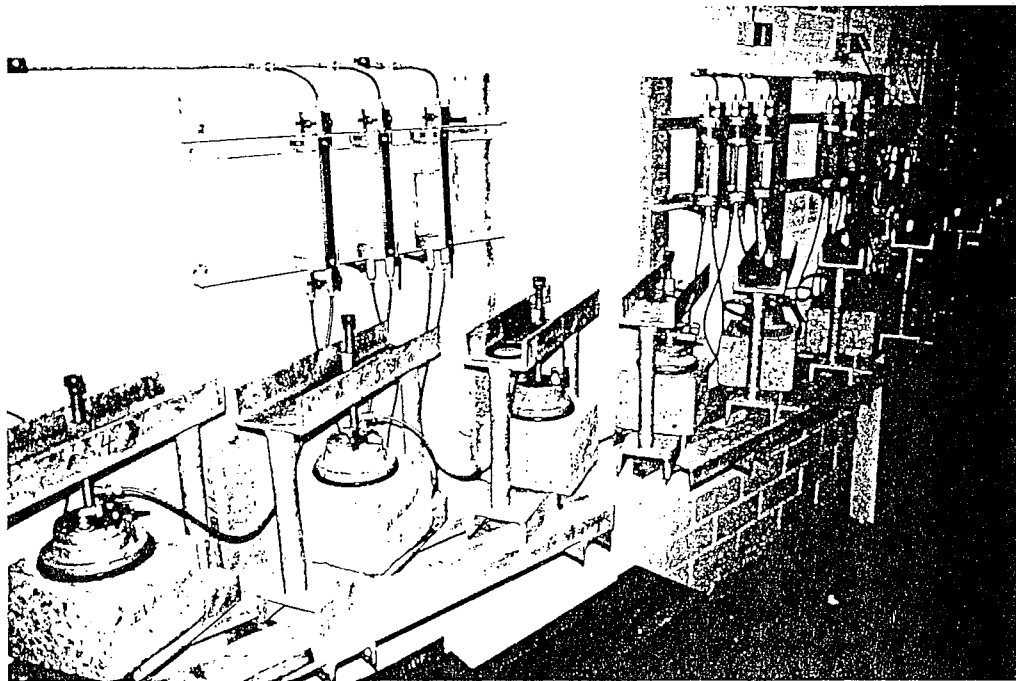
According to DIN 1048 Part 2, a rebound distance of at least 43 sd corresponds to a concrete in strength class B35, at least 33 sd corresponds to B15.

7 Water Impermeability

To determine the degree of water penetration (see DIN 1048 Part 5), specimens measuring $22 \times 22 \times 15 \text{ cm}^3$ were sawn out of the centre of the $40 \times 40 \times 15 \text{ cm}^3$ blocks.

After storing the specimens for approximately 1 week under water, a constant water pressure of 0.5 N/mm^2 was applied to a circular area, 100 mm in diameter, on each test surface (Fig. 3). After 3 days, the reduction of the amount of water in the reservoirs was measured. This is equivalent to the amount of water which had penetrated into the specimens.

*Fig. 3:
Specimens undergoing testing for water penetration*



Since only a small quantity of water had entered the specimens, the testing period was extended and the amount of water was measured after 6 days. In Tab. 3 the results are compared with the appropriate control values.

Tab 3:
Effect of repeated use of "Zemdrain MD" on the volume of penetrated water.
Specimen age: ca. 5 months

No. of times used	Concrete 1: w/c=0.55		Concrete 2: w/c=0.45	
	After 3 days [cm ³]	After 6 days [cm ³]	After 3 days [cm ³]	After 6 days [cm ³]
1	10	10	10	15
2	40	50	15	20
3	50	60	20	25
Without liner	410	550	60	70

The specimens were approximately 8 months old when the depths of water penetration were measured (renewed subjection to water pressure 0.5 N/mm² for 3 days).

Tab 4:
Effect of repeated use of "Zemdrain MD" on the depth of water penetration
according to DIN 1048 Part 5. Specimen age: ca. 8 months

No. of times used	Concrete 1: w/c=0.55 [cm]	Concrete 2: w/c=0.45 [cm]
1	2.0	1.0
2	2.5	1.0
3	2.5	1.5
Without liner	8.0	4.0

8 Depth of Carbonation

The depth of carbonation was determined according to the guideline of the "Deutscher Ausschuß für Stahlbeton" (DAfStb, Volume 422, Point 2.5) by spraying a phenolphthalein solution on freshly fractured surfaces. At the time of testing, the specimens made from Concrete 1 and Concrete 2 had been stored for 7 and 5 months, respectively, at atmospheric CO₂ concentration under standard climatic conditions 20°C/65 %RH.

Tab 5:

Effect of the formwork liners "Zemdrain MD" and "Zemdrain" on the depth of carbonation

No. of times used	Concrete 1: w/c=0.55		Concrete 2: w/c=0.45	
	Side with liner [mm]	Side without liner [mm]	Side with liner [mm]	Side without liner [mm]
1	3	11	3	6
2	4	9	5	7
3	6	9	6	10

9 Summary

Although the formwork liner "Zemdrain MD" had previously been used twice, smooth surfaces with very few visible pores were also made on the third use of the liner for the two concrete compositions of regular consistency (KR according to DIN 1045) with w/c ratios of 0.55 and 0.45.

In the case of Concrete 1 (w/c ratio 0.55), the amount of water which drained off the third time the liner was used was 9% smaller than during the first time of use. In view of the present results, sufficient water was also drained off during the third time of use in order to significantly improve the surface concrete. The strength of all the surfaces produced with a formwork liner were well above that of the corresponding opposite surfaces made without a formwork liner. After the third time of use, the degree of water penetration was still very much smaller than for the control surfaces made without a liner. The depth of carbonation was 50% of the value for surfaces which had not been prepared with a formwork liner.

Even though the amounts of drainage water measured for Concrete 2 (w/c ratio 0.45) were not very large, the surface strength was clearly higher after all three usages of the formwork liner "Zemdrain MD" than for the control surfaces. The strength increased by roughly a strength class according to DIN 1045. The degree of water penetration was not appreciably affected by the number of times the liner was used and was, in all cases, much lower than for the control surfaces. The progress of carbonation was clearly reduced after the third use of the formwork liner, too.