FUEL PENETRATION COMPARED TO WATER PENETRATION INTO CONCRETE

VERGLEICH DES EINDRINGVERHALTENS VON WASSER UND KRAFTSTOFFEN IN BETON

COMPARAISON DE LA PÉNÉTRATION D'EAU ET CARBURANTS DANS LE BÉTON

Hans-Wolf Reinhardt, Arno Pfingstner

SUMMARY

Two concretes with a water-cement ratio of 0.50 and a water-binder ratio of 0.29 have been tested with respect to the water penetration according to DIN 1048 and ISO 7031 as well as to the absorption of diesel and gasoline according to the german guideline ″Concrete structures for the handling of water contaminating substances″. The test series are described and the results are discussed.

ZUSAMMENFASSUNG

Zwei Betone mit einem Wasserzementwert von 0,50 und einem Wasserbindemittelwert von 0,29 wurden der Wassereindringprüfung nach DIN 1048 und ISO 7031 unterworfen und auch der Eindringprüfung von Diesel- und Ottokraftstoff nach der Richtlinie ″Betonbau beim Umgang mit wassergefährdenden Stoffen″. Die Versuchsserien werden beschrieben und die Ergebnisse werden interpretiert.

RESUME

Deux bétons avec un rapport eau-ciment de 0,50 et un rapport eau-liant de 0,29 ont été soumis à des essais de pénétration d'eau selon les normes DIN 1048 et ISO 7031, ainsi qu'à des essais de pénétration de diesel et d'essence selon la directive allemande ″Structures en béton pour le maniement de substances contaminantes pour l'eau″. Les séries d'essais sont décrites et les résultats sont discutés.

KEYWORDS: Fuel penetration, concrete

1. INTRODUCTION

The water penetration test according to DIN 1048 and ISO 7031 are standard tests whereas the penetration test for organic liquids according to [DEUTSCHER AUSSCHUSS FÜR STAHLBETON 1996] is a rather specialised test which requires for special equipment. To check whether the results of both testing methods are similar, tests on two concrete mixtures were performed with water and with diesel and gasoline.

2. TEST METHODS

2.1 Water

Tests were performed on plates 200 mm x 200 mm x 120 mm with water penetration in the casting direction. ISO [ISO/DIS 7031, 1963] stipulates a pressure sequence of 0.1 MPa during 2 days, 0.3 MPa another day and 0.7 MPa one more day. DIN [DIN 1048 TEIL 5, 06.91] prescribes a constant pressure of 0.5 MPa for 3 days.

A series of specimens was kept under water for 27 days after demoulding and tested. Another series was demoulded after one day, wrapped in plastic sheet during 6 days and stored at 20°C/65% RH during 49 days.

2.2 Diesel and gasoline

Diesel and gasoline penetrations were tested according to [DEUTSCHER AUSSCHUSS FÜR STAHLBETON, 1996]. The cylindrical specimen (∅ 100, h=150 mm) were cored from cubes which were demoulded after 1 day, wrapped in plastic sheet during 6 days, and stored at 20°C/65% RH during 49 days. The cylinders were sealed on the perimeter with epoxy resin. A glass funnel was glued on top of the cylinder and connected to a glass tube in order to allow an almost constant fluid head of 500 mm. After this whole procedure the specimen were 70 d old.

3. CONCRETE

A limited series of tests comprised two concretes the composition of which is given in Table 1.

Table 1: *Composition of two concretes tested, amount/m^3*

Component	Unit	Amount	
		Concrete I	Concrete II
CEM I 32,5 R	kg	320	-
CEM I 42,5 R	kg	-	465
Water [1)]	l	160	138
Aggregate			
0/1 mm	kg	387	289
1/2 mm	kg	221	238
2/4 mm	kg	249	262
4/8 mm	kg	356	305
8/16 mm	kg	690	625
Silica fume [2)]	kg	-	46,5
Super-plasticizer	l	2,3	24,0
Retarder	l	-	1,5

[1)] Water of slurry included
[2)] Dry mass of slurry

Concrete I is a so-called liquid tight concrete according to [DEUTSCHER AUSSCHUSS FÜR STAHLBETON, 1996], while concrete II is a high performance concrete with water-cement ratio of 0.32.

The 28 days cube strength measured on 150 mm cubes amounted to 52.1 MPa and 78.9 MPa for concrete I and II.

4. PENETRATION OF LIQUIDS INTO CONCRETE

4.1 Water

The tests were performed after 28 and 56 days as mentioned above. The values in Table 2 are maximum values measured on the specimen after splitting.

Table 2: *Penetration of water in mm*

	Concrete I		Concrete II	
	DIN	ISO	DIN	ISO
Individual tests after 28 d	15	13	15	14
	12	18	14	14
	14		15	13
	14	15		
Mean	13.8	15.3	14.7	13.7
Individual tests after 56 d	23	23	18	-
	23	23	27	25
	30		17	16
	19	22		
Mean	23.8	22.7	20.7	20.5

4.2 Organic liquids

The two liquids diesel and gasoline ("Super") are rather different with respect to their physical properties which govern penetration into a porous medium. The viscosity η of diesel is about five times higher than that of gasoline, while the surface tension σ of both is similar. The relevant parameter $(\sigma/\eta)^{1/2}$ of diesel is about 0.44 times the one of gasoline, i.e. diesel should penetrate only half as much as gasoline does. Table 3 shows the absorbed volume after 72 h.

Table 3: *Absorbed volume [l/m^2] after 72 h*

	Concrete I		Concrete II	
	Diesel	Gasoline	Diesel	Gasoline
Individual tests	0.56	1.48	0.15	0.73
	0.56	1.29	0.22	0.52
	0.56	-	0.32	0.80
	0.50	1.41	0.34	0.85
	0.52	1.65	0.32	0.78
Mean	0.54	1.46	0.27	0.74

The relation between absorbed volume and time is given in Figs. 1 and 2.

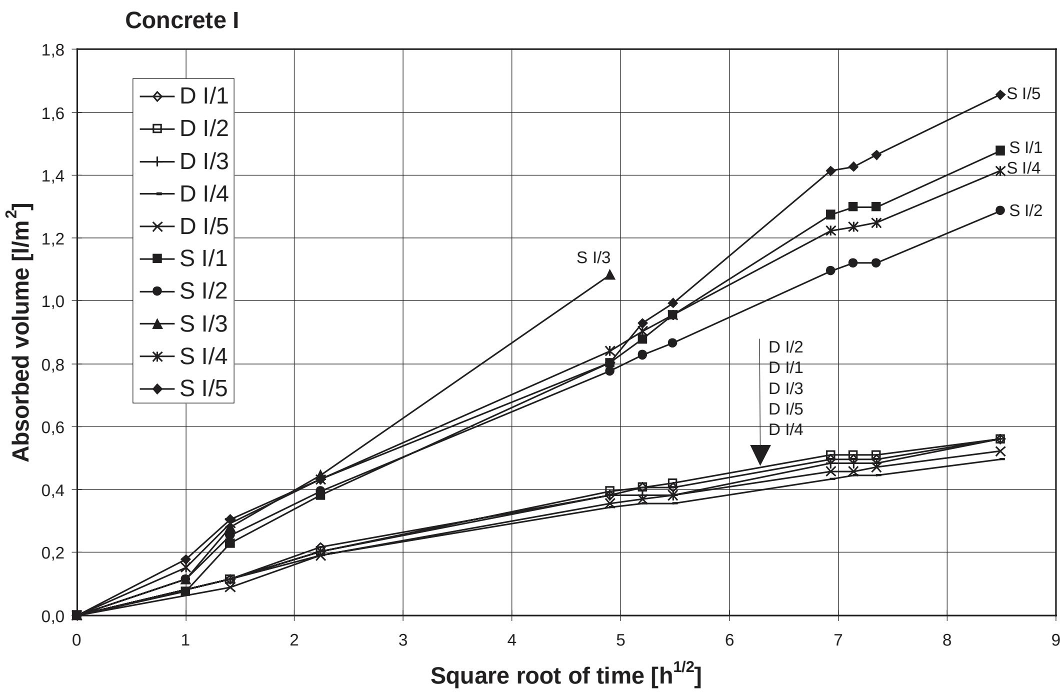

Fig. 1: *Absorbed volume vs. time for individual tests, concrete I, D = diesel, S = Super*

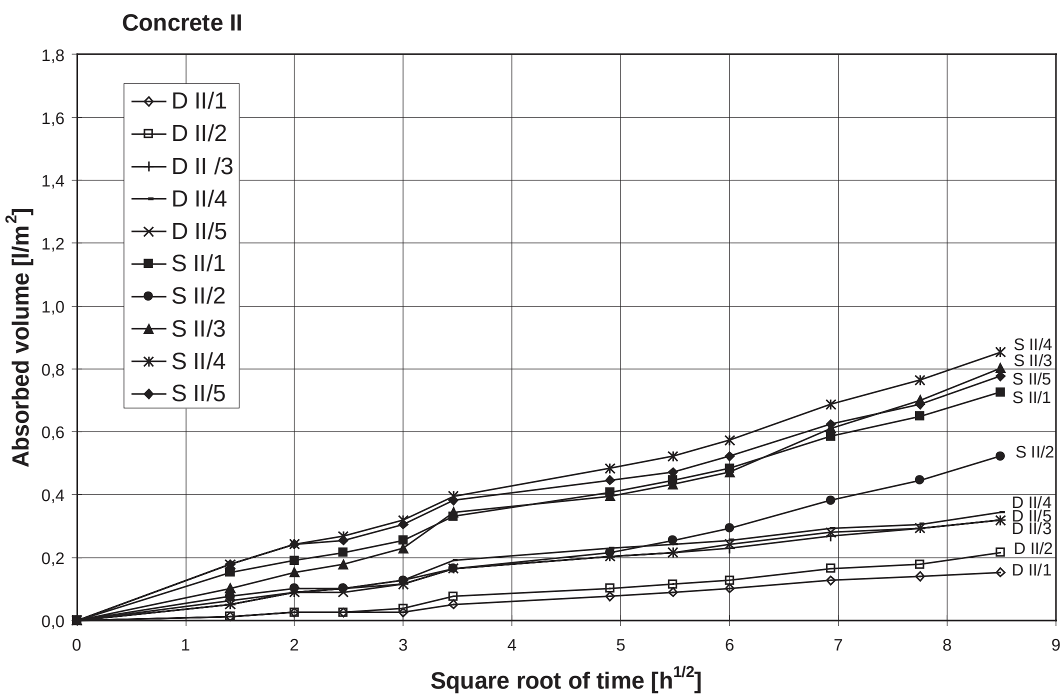

Fig. 2: *Absorbed volume vs. time for individual tests, concrete II, D = diesel, S = super*

The penetration depth could only be measured after the specimen was split after 72 h. Diesel had an average penetrated 14.4 mm into concrete I and

14.8 mm into concrete II. Gasoline evaporated too quickly and did not permit a reading.

5. DISCUSSION OF RESULTS

5.1 Time function of penetration

Theory predicts that absorption should be proportional to the square root of time. Figs. 1 and 2 support this relation approximately. This allows extrapolation of testing results to larger durations.

5.2 Comparison of diesel and gasoline

If one compares the mean absorbed volume of diesel and gasoline one finds a ratio of 0.37 for concrete I and 0.36 for concrete II. These values are close to 0.44 as given in chapter 4.2 since one has to consider that diesel and gasoline are not pure liquids but that they are rather a mixture of about 200 individual components. The theoretical value of 0.44 is only valid if the accessible pore space were the same for both liquids. However, the concretes tested contain a certain amount of water which fills the smallest pores and which may act on the two liquids differently.

5.3 Concrete composition

The main difference between concrete I and II is the water-cement ratio or even more pronounced the water-binder ratio. The water-cement ratios are 0.50 and 0.32 the water-binder ratios 0.50 and 0.29 if silica fume is supported to have the same reactivity as cement. This means that the porosity and the pore sizes are different for both concretes. Although not measured the total porosity can be assessed by assuming that cement and silica fume have hydrated to a degree of hydration of 90% of the possible maximum value. The capillary porosity which is responsible for the transport of fluids would then be [HANSEN, T.C., 1986]

$$V_{cap} = (w/c - 0.36\alpha) \cdot \text{mass of binder.} \quad (1)$$

The degree of hydration of concrete I is 0.90, and only 0.62 for concrete II because the maximum would be 0.29/0.42. Concrete I has 56.3 l capillary pores per m^3 concrete and concrete II 34.1 l/m^3. A lower water-binder ratio not only reduces pore space but also the size of the pores. Since the absorption speed is greater with larger pores concrete I should take up the liquid quicker which has been demonstrated by Fig. 1 compared to Fig. 2.

On the other hand the penetration depth of diesel is almost the same for concrete I and II. This is also acceptable because absorbed volume per area V and penetration depth e are related via porosity ε

$$V = \varepsilon \cdot e \quad (2)$$

From eq. (2) the effective porosity can be calculated, i. e. the porosity which is reached by diesel:

$$\varepsilon_{eff} = V / e \quad (3)$$

From the mean values of V from Figs. 1 and 2 which are about 0.54 l/m^2 for concrete I and 0.27 l/m^2 for concrete II after 72 h and mean values of e which are 14.4 and 14.8 mm (see chapter 4.2) it follows that ε_{eff} is equal to 3.8% and 1.8% for concrete I and II. This means that the effective porosity is less than the above assessed porosity, i.e. $\varepsilon_{eff}/\varepsilon_{ass}$ = 38/56.3 = 0.67 and 18/34.1 = 0.53. The result is at least not in contradiction to what has been stated in chapter 5.2.

5.4 Comparison between water and organic liquids

Table 2 has shown that water penetrates more into concrete which has dried for a certain period of time. The differences between concrete I and II are rather small and also the type of testing, either according to DIN of ISO, does not create a significant effect. If one compares the water penetration into a wet specimen after 28 d with the penetration of diesel into a specimen which was 70 days old at testing one can state an almost identical penetration depth. That this happened may be by chance but it has been found at least for two dense concretes which are suitable for pavings of filling stations or similar barriers for environmental protection.

6. CONCLUSION

Concrete is a useful material for environmental protection structures since it retains organic liquids in spite of its porosity. Testing of the penetration of organic liquids is rather specialized while water penetration testing follows a standard procedure. A limited series of testing has shown that diesel penetrates into a dense partly dried concrete after 72 h as much as water does in a wet concrete. Further testing is recommended in order to prove whether this result is valid for other concretes.

7. ACKNOWLEDGEMENT

The authors would like to thank Dr.-Ing. Abebe Dinku for his valuable contribution.

REFERENCES

DEUTSCHER AUSSCHUSS FÜR STAHLBETON: *Richtlinie "Betonbau beim Umgang mit wassergefährdenden Stoffen"*, Teil 1 bis 6, Beuth, Berlin, 1996

DIN 1048 Teil 5: *Prüfverfahren für Beton; Festbeton, gesondert hergestellte Probekörper*, 1991

HANSEN, T. C.: *Physical structure of hardened cement paste. A classical approach.* Materials and Structures 19, no. 114, 1986, p. 423-436

ISO/DIS 7031: *Festbeton; Bestimmung der Eindringtiefe von Wasser unter Druck,* 1963