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Procedia Engineering 153 (2016) 483 – 489

Procedia Engineering

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XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering"

GWT – New Testing System for „in-situ" Measurements of Concrete Water Permeability

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Abstract

The paper presents principle of a German's Water permeation Test (GWT) and results of experimental study which was carried out to assess a possibility to implement in engineering practice a new testing system (GWT) for assessment of water permeability of concrete with the respect to a new European Standard (EN 12390-8). The testing details and procedure of evaluation of the results obtained by means of GWT have been also described.

Research program consisted of laboratory tests and „in-situ" examinations of three concrete bridges situated along the national road nr 3 in Lower Silesia, Poland, close to Wrocław. Two types of concrete have been considered. Examinations carried out have shown that the results of standard water permeability measurements are with the agreement of „in-situ" NDT tests performed by means of GWT system. Obtained results confirmed that this new method is very useful for engineering practice. The „*average flux of water*" (q_m) has been proposed as an evaluation parameter. It has been shown that concrete can be considered as water permeable if $q_m \leq 0.32$ μm/sek.

Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".

Keywords: concrete; water permeability; GWT; NDT testing

1. Introduction

A new European Standard (EN 12390-8), which has been recently introduced in EU, considerably change procedures used in many European countries for evaluation of concrete ability to resist water penetration under pressure. Testing methodology proposed in this standard is basing on the determination of the depth of water penetration under pressure in hardened concrete. Standard specifies procedure of applying water under controlled

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Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".
doi:10.1016/j.proeng.2016.08.162

conditions of pressure to the surface of concrete. As an evaluation parameter the depth of penetration of the water front, which is measured after splitting the specimen, is recommended.

It is necessary to mention that new European Concrete Standard EN 206-1 does not define formal requirements concerning water permeation according to practical applications. As a result, relevant data has to be determined by designer in the technical specifications, what is not so simple because engineers are usually not enough experienced and rather expect to find such information in national standard regulations. Nevertheless, some suggestions can be found in German's national standards (DIN 1045 and DIN 1048) which were used as a base for elaboration of EN-12390-8. According to these documents it can be assumed that tests have to be performed on the at least 3 specimens coming from the same type of concrete. Concrete can be evaluated as water resist if an average of the maximum depth of penetration of the water front, measured in all tested specimens, is not higher than 50 mm.

The most important disadvantage of such measurements is their time consuming „laboratory" character what in engineering practice excludes possibility of relatively fast and „in-situ" evaluation of the actual concrete water permeability. For those reasons in several countries wide research has been performed to find a proper solution of this problem. Among other things, **G**erman's **W**ater permeability **T**est (**GWT**) seems to be one of the best concepts which were successfully implemented [1,2].

Present paper reports author's examination which were focused on the experimental verification of this testing system with respect to standard laboratory procedure specified in European Standard (EN 12390-8). The testing details and procedure of evaluation of the results obtained by means of GWT have been also described. Nevertheless, the main purpose of presented tests was to find relationship between values of the „*average water flux*" recorded by means of GWT and maximum values of water penetration obtained according to EN 12390-8.

2. Principle of the GWT

The principle of the German's Water permeation Test is to measure the amount of water penetrating the substrate under controlled pressure conditions (Fig.1). A pressure chamber (Fig.2) containing a watertight gasket is secured tightly to the surface by two anchored clamping pliers or by means of a suction plate. Alternatively, the gasket may be bonded to the surface with an adhesive. The chamber is filled with water and the filling valve is closed. The top cap of the chamber is turned until a desired water pressure is displayed on the gauge (usually 100 kPa). As water permeates into the concrete, the selected pressure is maintained by means of a micrometer gauge pushing a piston into the chamber. The piston movement compensates for the volume of penetrating into the material. The travel of the piston as a function time is used to characterize the permeation of the test surface.

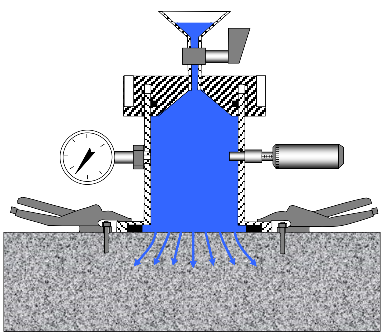

Fig. 1. Testing principle of GWT system

The gauge readings are recorded over time and used to evaluate the water permeation characteristics of the surface tested. The test may be conducted until the micrometer has no more travel. Usually a single test lasts about 5-10 minutes, depending on the concrete quality. For comparative measurements the flux „*q*", using the first mentioned procedure, may be calculated from the equation:

$$q = B\,(g_1 - g_2) / A \times t \quad \text{[mm/sec.]} \qquad (1)$$

where:

B – area of the micrometer pin being pressed into the chamber water (78.6 mm^2 for a 10 mm pin diameter)

A – water pressure surface area (3018 mm^2 for the diameter of 62 mm)

t – the time the test is performed over [sec.]

g_1, g_2 – the micrometer gauge readings in millimetres before and after the test has been performed

Fig. 2. View of GWT chamber during measurements

In practice GWT can be successfully applied for:

- evaluation of water permeation of the skin-concrete in finished structure,
- testing of the water tightness of construction joints and sealed control joints
- testing of surface before and after application of a protective water-proofing membranes to estimate an effectiveness of them.,
- evaluation of the water permeation of masonry structures.

3. Testing description

Research program consisted of laboratory tests and „in-situ" examinations of three concrete bridges situated along the national road nr 3 in Lower Silesia, Poland, close to Wrocław. For each bridge two structural elements have been selected for testing. In total six elements were examined.

Two types of concrete have been considered. Their mechanical parameters were corresponding with concrete of compressive strength representing classes C25/30 and C30/37, according to EN 206-1. Six specimens (cubes 150x150x150 mm) have been taken from each testing place and from three to four NDT measurements of GWT in each place have been performed as well. Following descriptions of examined concretes have been assumed:

CONCRETE 1

Road bridge under railway in Polkowice city (km. 357+576), concrete continuous footing designed as concrete of strength class C30/37.

series W-1 − six cube specimens (W-11, W-12, W-13, W-14, W-15 and W-16) which were tested according to EN 12390-8

series GW-1 − four GWT measurements (GW-11, GW-12, GW-13 and GW-14)

CONCRETE 2

Road bridge under railway in Polkowice city (km 357+576), concrete beam supporting bridge bearings designed as concrete of strength class C25/30.

series W-2 − six cube specimens (W-21, W-22, W-23, W-24, W-25 and W-26) which were tested according to EN 12390-8

series GW-2 − three GWT measurements (GW-21, GW-22 and GW-23)

CONCRETE 3

Road bridge under railway in Lubin city (km. 374+294), concrete beam supporting bridge bearings designed as concrete of strength class C25/30.

series W-3 − six cube specimens (W-31, W-32, W-33, W-34, W-35 and W-36) which were tested according to EN 12390-8

series GW-3 − three GWT measurements (GW-31, GW-32 and GW-33)

CONCRETE 4

Road bridge under railway in Polkowice city (357+576 km), concrete capping beam designed as concrete of strength class C30/37.

series W-4 − six cube specimens (W-41, W-42, W-43, W-44, W-45 and W-46) which were tested according to EN 12390-8

series GW-4 − three GWT measurements (GW-41, GW-42 and GW-43)

CONCRETE 5

Road bridge under Hutnicza street in Lubin city (km. 373+511), concrete beam designed as concrete of strength class C25/30.

series W-5 − six cube specimens (W-51, W-52, W-53, W-54, W-55 and W-56) which were tested according to EN 12390-8

series GW-5 − four GWT measurements (GW-51, GW-52, GW-53 and GW-54)

CONCRETE 6

Road bridge under Hutnicza street in Lubin city (km. 373+511), concrete continuous footing designed as concrete of strength class C25/30.

series W-6 − six cube specimens (W-61, W-62, W-63, W-64, W-65 and W-66) which were tested according to EN 12390-8

series GW-6 − four GWT measurements (GW-61, GW-62, GW-63 and GW-64)

Laboratory examinations were carried out according to EN 12390-8. The water pressure of 500 kPa was applied on the cube specimens placed in the standard apparatus for 72 ± 2 hours. During the tests the appearance of the surfaces of the test specimen not exposed to the water pressure has been periodically observed. After the pressure has been applied for the specified time, specimens were removed from the apparatus and split in half, perpendicularly to the face on which the water pressure was applied. As soon as the split face has dried to such an extent that the water penetration front can be clearly seen, the depth of water penetration was measured. Simultaneously, before „in-situ" NDT examination a special preliminary testing program has been carried out [3]. As a result, following testing details and technical conditions concerning GWT measurements have been defined:

- testing can be performed only if temperature of air is not less than 5^0C,
- before testing concrete surface has to be cleaned by polishing or grinding; all roughness and thin coat of cement paste have to be removed,
- particular attention should be pied on the proper tightness between concrete surface and rubber gasket sealing up pressure chamber; it is also suggested to cover gasket by silicon,
- only boiled water should be used,
- after clamping pressure chamber to the tested surface and filling it by water it is necessary to wait about 10-15 minutes; concrete surface needs some time for water absorption,

- it is recommended to do the measurements under 100 kPa pressure within the period of time about 10 minutes,
- it is also recommended to do additional GWT measurements during the test, an example one measurement in each one minute of the test,
- time of the experiment should be measured very precisely.

4. Testing results

Obtained results have shown significant differences in measured values of water penetration depth recorded for particular types of tested concretes. Detailed data of these results have been presented in Table 1. Analyzing obtained results it could be found that series number **W-2** and **W-6** does not meet the requirements assumed as a water permeability criterion. In both cases average depth of water penetration was higher than 50 mm.

Table 1. Results of the depth measurements of water penetration

Notation of tested concrete	Depth of water penetration [mm]						Average value [mm]	Average of compressive strength [MPa]
	1	2	3	4	5	6		
series W-1 (C30/37)	30	25	32	33	27	29	**29**	**57.0**
series W-2 (C25/30)	75	120	88	108	92	83	**94 > 50**	**38.5**
series W-3 (C25/30)	51	30	42	33	43	49	**41**	**43.3**
series W-4 (C30/37)	32	36	40	35	33	39	**36**	**56.4**
series W-5 (C25/30)	45	57	33	60	35	40	**45**	**45.9**
series W-6 (C25/30)	105	125	140	130	113	127	**123 > 50**	**37.9**

It is worth of mention that for tested concretes the strength influence on the ability of concrete structure to resist water pressure was not proved. An example, for concretes of similar mechanical properties obtained values of the average water penetration under pressure are varying sometimes a number of times, like we can observe in the case of series number **W-5** (45 mm) and **W-6** (123 mm). From the other hand, for some of tested series similar water penetration depth has been recorded in spite of very different strength parameters. This remark particularly refers to series **W-4** (concrete C30/37, average penetration depth – 36 mm) and **W-3** (concrete C25/30, average penetration depth – 41 mm).

Simultaneously, for all types of tested concretes, according to equation (1) the flux (q) has been determined as an evaluation parameter. The obtained results were shown in a Table 2.

Detailed discussion about the obtained results indicates that water penetration under controlled pressure is influenced by several factors. This process dependents mainly of the concrete structure itself. Influence of compacting and curing conditions is also very important. Results of GWT measurements are influenced by the same factors as well. In most cases bad quality of concrete surface is a main reason why quite significant scatter of obtained results is observed.

Taking to the account all these remarks an additional evaluation parameter characterizing dynamic of water penetration under pressure has been proposed. This factor can be considered as a „*velocity of water penetration*" defined by following equation.

$$\Delta g = g_n - g_{n+1} \quad \text{[mm/min]} \tag{2}$$

where:

Δg – velocity of water penetration [mm/min]

g_n – the micrometer gauge reading after „n" minutes of testing [mm]

g_{n+1} – the micrometer gauge reading after „n+1" minutes of testing [mm]

For better illustration, on the Fig.3 some examples of plots representing differences in the dynamics of water penetration inside concrete structure under pressure were shown. It can be seen that in the beginning of the process of applying pressure on the concrete surface quite big values of the velocity of water penetration are observed. Next, after about 2-3 minutes significant decrease of this parameter is occurring. Later this process stabilizes. Nevertheless, particular values of penetration velocity differ quite seriously. This remark concerns first of all results coded as **GW-1** and **GW-6**.

Table 2. Results obtained by means of GWT measurements

Notation of tested concrete	**Time of testing** [seconds]	**Micrometer gauge readings** ($\Delta g = g_0 - g_{10}$)	**Water flux** [μm/sek]	**Average water flux** [μm/sek]
series GW-1 (C30/37) (GW-11, GW-12, GW-13, GW-14)	600	5.33, 4.10, 2.95, 2.40	**0.231, 0.178, 0.129, 0.104**	**0.161**
series GW-2 (C25/30) (GW-21, GW-22, GW-23)	600	7.45, 8.25, 7.20	**0.323, 0.358, 0.312**	**0.331**
series GW-3 (C25/30) (GW-31, GW-32, GW-33)	600	6.75, 5.20, 4.69	**0.293, 0.225, 0.203**	**0.240**
series GW-4 (C30/37) (GW-41, GW-42, GW-43)	600	3.65, 6.55, 4.25	**0.158, 0.284, 0.184**	**0.209**
series GW-5 (C25/30) (GW-51, GW-52, GW-53, GW-54)	600	7.85, 7.70, 7.20, 6.50	**0.340, 0.334, 0.312, 0.282**	**0.317**
series GW-6 (C25/30) (GW-61, GW-62, GW-63, GW-64)	600	8.15, 8.77, 8.65, 8.40	**0.353, 0.380, 0.375, 0.364**	**0.368**

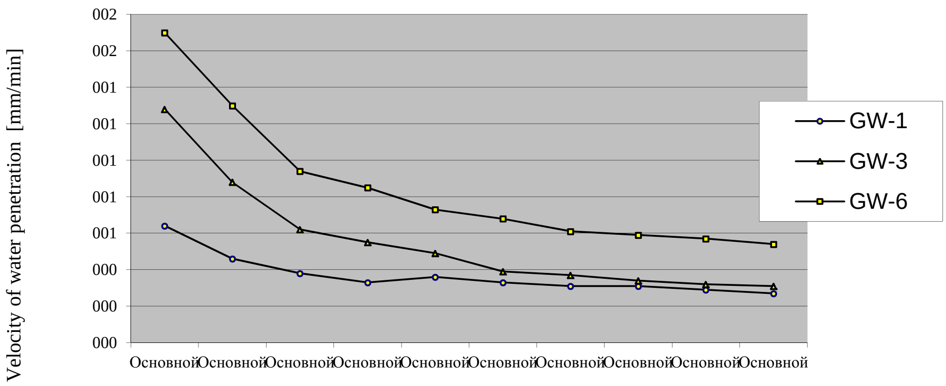

Fig. 3. Comparison of the velocity of water penetration plots obtained for different concretes

More detailed analysis of the available testing results reveals close relationship between values of water flux determined by means of GWT measurements and the depth of water penetration obtained according to standard procedure, defined by EN 12390-8. It is also visible that compressive strength of concrete is not crucial parameter for evaluation of concrete structure resistance against water penetration under pressure.

5. Conclusions

Examinations carried out have shown that the results of standard water permeability measurements are with the agreement of „in-situ" NDT tests performed by means of GWT system. Obtained results confirmed that this new method is very useful for engineering practice. According to analysis performed it could be assumed that concrete can be considered as water permeable if $q_m \leq 0.32$ μm/sec.

6. References

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