PROPERTIES OF THIN PROTECTIVE LAYERS MADE OF SPECIAL CONCRETE

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All concrete and reinforced concrete engineering structures degrade over time when they are exposed to the surrounding environment. Adequate durability of concrete coatings must be taken into consideration. This property can be ensured by modifying the composition of the concrete mix. This can be done through the implementation of suitable admixtures and additives into cement composites, e.g. silica fume, nanosilica, polypropylene fibers or superplasticizers. This modification, called material and structural protection, can be used in the form of thin protective layers. They are intended to protect an ordinary concrete from external aggressions. Thin protective layers made of special concrete will be presented in the article. The impact of three different thicknesses of protective layers on properties of cement composites was investigated. Special concrete was modified with silica fume, crushed granite aggregate and superplasticizer based on polycarboxylate. Thin protective layers are characterized by very good water resistance and resistance to freezing and thawing. The layer of special concrete with increased durability due to the reduced water/cement ratio, high cement content and by using additives and admixtures should fully protect ordinary concrete against the negative influence of the aggressive environment.

1. Thin protective layers – ensure the construction durability

Thin protective layers (TPL) made of special concretes combine two of the three methods of securing construction. According to the Polish standards, concrete must have appropriate composition and performance to meet the requirements of durability and resistance to aggressive environments. Three ways of ensuring construction durability are shown in Fig. 1. First, construction should be shaped suitably. Another method is to use material and structural protection. It consists in obtaining optimized composition and microstructure due to applying admixtures and additives. The third method involves surface protection which includes hydrophobization, impregnation and protective coatings [1, 2].

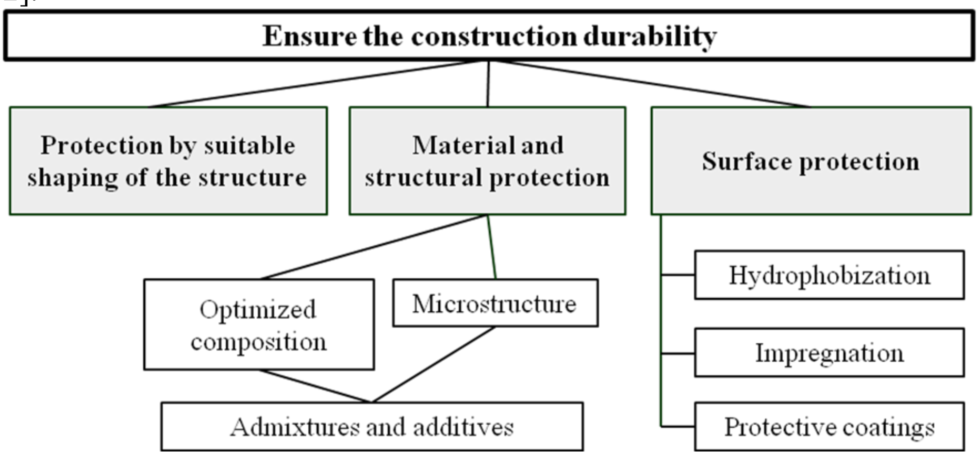

Figure 1. Methods of improving the durability

In TPL material and structural protection is in the form of special concrete. Protective layers used as a surface protection should secure structure from external influences. Special concretes are modified by using additives and admixtures, e.g. microsilica, fly ash, bitumen emulsion, various types of fibers or new materials which are obtained by nanotechnology, such as carbon nanotubes or nanosilica. It can cause the formation of the optimal microstructure or even nanostructure of concrete. To reduce water/binder ratio and improve the workability of the concrete superplasticizer based on polycarboxylate can be used. Using a thin protective layer made of special concrete, should secure structure from the adverse impact of the external environment without making an entire element with modified concrete [3].

In connection with the problem of structures protection from the effects of aggressive environments it was decided to conduct research on the use of thin protective layers made of modified concrete to protect ordinary concrete. As thin layers could be used as a pre-fabric layer, it was decided to investigate the impact of TPL changing curing time.

2. Experimental study

The study included the use of protective layers that will protect plain concrete against aggressive environments, see Fig. 2.

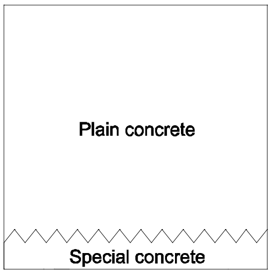

Figure 2. Diagram illustrating TPL for the plain concrete

A thin protective layer has a developed surface in the form of pyramids, which improves the contact surface with the normal concrete. Thickness of the TPL and the impact of curing time on thin protective layers properties were optimized, see Tab. 1.

Table 1. The variability ranges of considered factors

Variable factors	Code	Unit	Levels of variability		
			-1	0	1
Protective layers thickness	X_1	[mm]	15	30	45
TPL curing time	X_2	[days]	2	14	28

The minimum thickness of the protective layer of 1.5 cm was set on the basis of the minimum concrete cover for reinforcing steel, depending on the exposure classes and structures in relation to the construction element. The minimum value and the standard strength of cement composites have been taken into account in determining the curing time.

3. Materials

The experimental plan (Tab. 2) included 9 series of samples. The composition of special concrete was based on preliminary research. The cementitious material used in the tests was ordinary Portland cement CEM I 42.5 R in the amount of 500 kg/m^3. Natural and rinsed sand was used as the fine aggregate. Crushed granite aggregate with the fraction 2/4 was used as a coarse aggregate in amount of 40% of aggregate composition. Microsilica was used as microfiller and it was 5% by weight of binder. The superplasticizer was used for increasing the workability of fresh concrete and reduced water/cement ratio to 0.30. The chemical admixture was added in the amount of 1.0% by weight of cement.

Table 2. The experimental plan

Series number	Coded values		Actual values	
	X_1	X_2	X_1	X_2
1	-1	-1	15	2
7	0	-1	30	2
3	1	-1	45	2
4	-1	0	15	14
5	0	0	30	14
6	1	0	45	14
7	-1	1	15	28
8	0	1	30	28
9	1	1	45	28

Plain concrete mixture consisted of cement in an amount of 360 kg/m^3, aggregate with the fraction 0-16 and water/cement ratio 0.5.

4. Samples preparation and test methods

Concrete mixes were prepared according to the previously developed technology in laboratory mixer. After pouring the special concrete mix into oiled molds with thickness according to the test plan, a vibro-vibropressed method was used to ensure good compaction. Then, after 3 hours of curing in the molds, the samples were demolded and placed in water for a predetermined time according to the experiment plan. The next step was to place the layers back in the molds after the proper curing time and filled them with plain concrete and compact using a table vibrator. Cubic samples with a side of 10 cm after 24 hours were demolded and placed in water until testing for 28 days.

The compressive strength test [4], water resistance [5] and water absorption [6] tests were performed according to Polish standards.

5. Results

Influences of thickness and curing time of thin protective layers on selected concrete properties were investigated. Statistical analysis was performed for all the test results.

Table 3. One-dimensional significance test of compressive strength results (*significant results)

Effect	SS	Degrees of freedom	MS	F	p
Absolute term	37744.08*	1*	37744.08*	4734.449*	0.000000*
TPL thickness	124.39*	2*	62.19*	7.801*	0.003631*
TPL curing time	406.50*	2*	203.25*	25.495*	0.000006*
TPL thickness*curing time	19.28	4	4.82*	0.605*	0.664376
Measurement error	143.50	18	7.97		

For compressive strength results one-dimensional significance test was performed, shown in Table 3. Investigated variable factors have a significant influence on the compressive strength. Relevant increase in strength by an average of 12% with an increase in curing time to 14 days was noted, further elongation resulted in a decrease of 22%, see Fig. 3.

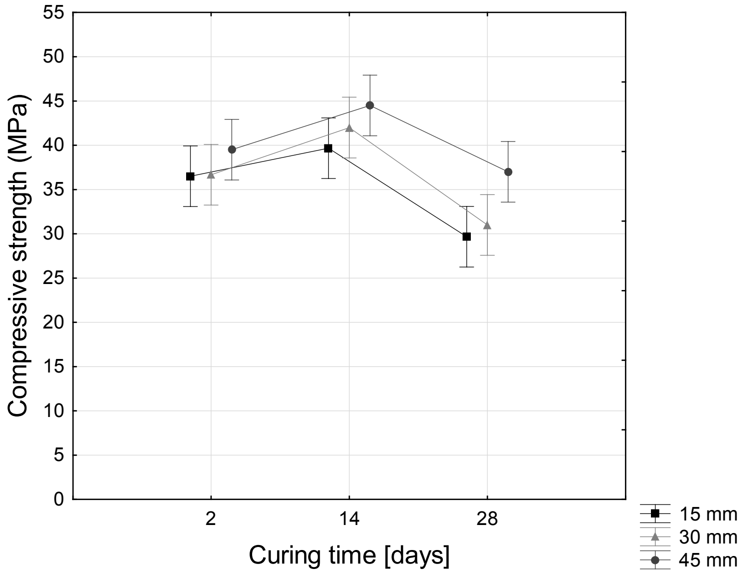

Figure 3. Expected boundary mean values for compressive strength depending on the TPL curing time

Water resistance of protective layers was complete in all samples. The maximum depth of penetration of the water, which was 15 mm, was reached in series with the 30 mm protective layer at 28-day curing time. Significant drop in water resistance was noted at 74% for 28 days of TPL curing, see Fig. 4. The worst water resistance was achieved in samples where the thickness was 30 mm.

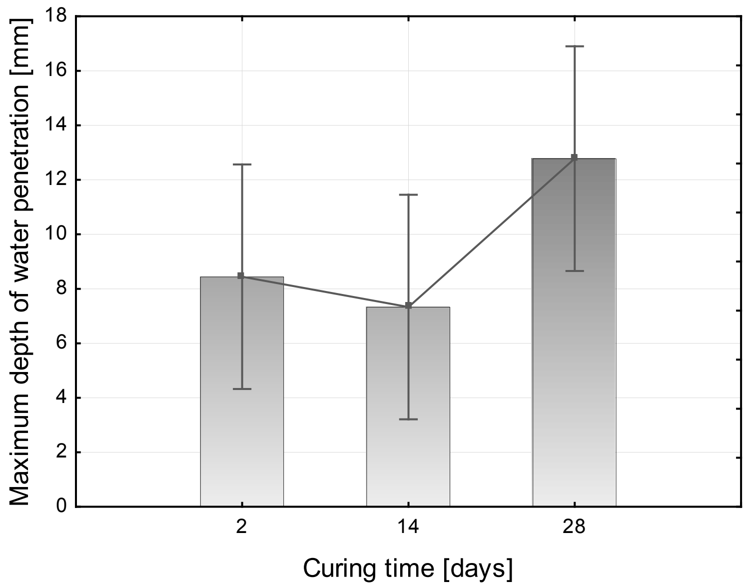

Figure 4. Expected boundary mean values for maximum depth of penetration of the water depending on the TPL curing time

Investigated variable factors have a significant influence on the water absorption. Relevant drop in absorption by 11% at 14 days of curing and a significant increase of 36% at the longest TPL curing time was noted, see Fig. 5.

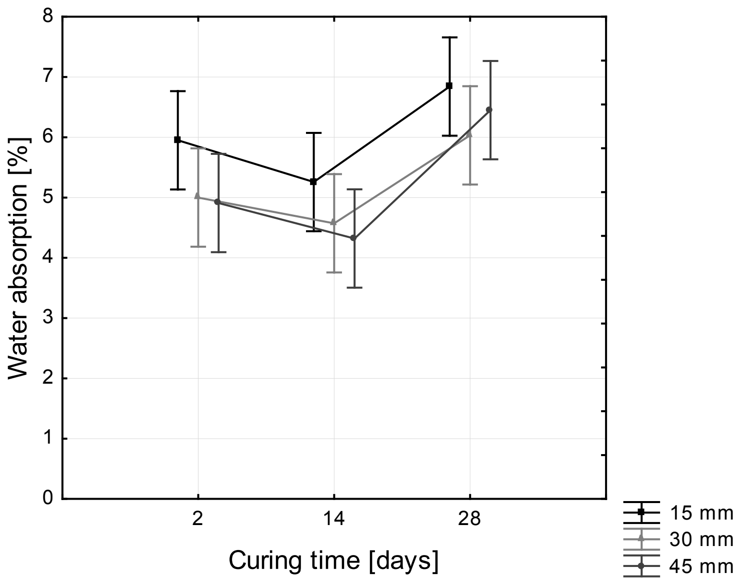

Figure 5. Expected boundary mean values for water absorption depending on the TPL curing time

With the use of variable curing time of TPL, the most beneficial properties were obtained at 14 days of curing. Based on the results it can be concluded that TPL made of special concrete protects plain concrete against the negative influence of disadvantageous conditions.

6. Conclusions

Problem of structures protection from the effects of aggressive environments is an important element of the research on the durability of concrete structures. Application of thin protective layers is a new method increasing the durability of the concrete element. TPL are characterized by low water absorption, high compressive strength and very good water resistance (Fig. 6). The depth of penetration of water under pressure in all series does not exceed 15 mm, so the TPL of this thickness fully protects the plain concrete.

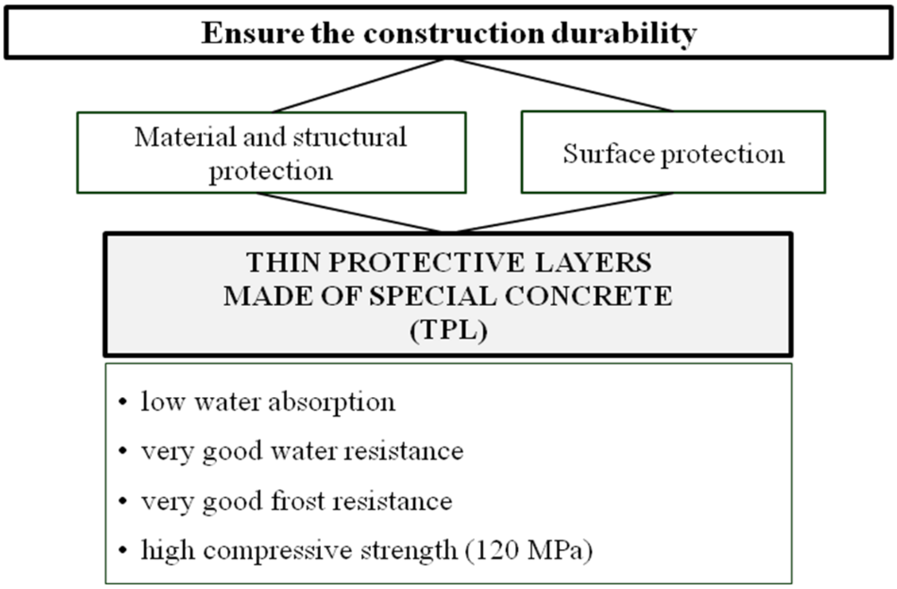

Figure 6. TPL as a means of improving the durability

The layer of special concrete with increased durability due to the reduced water/cement ratio, high cement content and by using additives and admixtures should fully protect ordinary concrete against the negative influence of the aggressive environment. The carbonation of thin protective layers in order to determine the protective properties relative to reinforcement in the concrete element should also be examined. The most important aspect is to investigate the adhesion between the thin protective layer and ordinary concrete.

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