The influence of form release agent application to the quality of concrete surfaces

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Abstract. The main aim of this article was to obtain concrete surface quality changes by the usage of different form release agent application. Secondly, to determine blemishes of concrete surfaces and divide them according to combined method provided by two documents and by using computer program: CIB Report No. 24 "Tolerances on blemishes of concrete", GOST 13015.0-83 and "ImageJ". Two different concrete compositions were made: BA1 (low fluidity, vibration is needed) and BA8 (high fluidity, vibration is not needed). Three castings with each formwork were conducted. Water emulsion based form release agent was used. Different applications (normal and excessive) of form release agent were used on the formwork.

1. Introduction

High quality surface finishes are a feature of self- compacting concrete (SCC), but by careful attention to mix design and job site workmanship, nice surfaces with the conventional concrete mixture could be achieved. The appearance of an element mainly depends on: the type of cement and addition used; the mix composition; the quality of the mould and release agent; the placing procedure.

If compared self-compacting concrete with the conventional – the color is generally more uniform also it is easier to avoid defects due to leakage spots at the location of mould joints. Blowholes, honeycombing and other blemishes can be found in all types of concrete but with more fluid concrete mixture it is possible to improve the surface finish [1-2]

International Council for Building Research has provided main guidelines how the concrete may be defined referring the surface quality [3-5]:

- ROUGH class – no special requirements for finishing;
- ORDINARY – surface finishing has a minor factor;
- ELABORATE – definite requirements for visual appearance;
- SPECIAL – highest standards for appearance.

Formworks are also very important factor for concrete surface quality. Scientist J. Sousa Coutinho [6] has made a research using two different formworks: controlled permeability (CP) and five layer wood-based formworks. The results have shown that by using CP formworks the pore diameter (nm) of concrete surface has decreased up to 50 %, porosity – up to 45 %, surface hardness (MPa) has increased up to 70 % and blow-hole ratio has decreased up to 90 % comparing with those concrete surfaces using five layer wood-based formworks.

A number of studies have been made to determine how to achieve better consolidation resulting in fewer surface blemishes [7-15]. To minimize the size and number of bug holes and all other effects, the following practices should be followed:

- Vibration period should be of sufficient duration;
- Vibrator insertions should be properly spaced and overlapped and the vibrator removed slowly;
- Each concrete layer should be consolidated from the bottom upward;
- Vibration periods should be increased on withdrawal when using impermeable forms that permit air trapped at the form surface to escape through joints as between;
- Inward sloping forms and other complex design details should be avoided;
- Vibrator should penetrate into the previous layer;

The main outcome of this research is to evaluate the usage of different form release agent application on the formwork. In addition, this paper presents a technique which provides:

A method how to evaluate the concrete surface quality using image analysis process (software – "ImageJ";

An evaluation of concrete surfaces quality by the following documents: CIB report no. 24 [4] and GOST 13015.0-83.

A combined method how to evaluate and divide concrete surfaces into special categories provided by CIB report no. 24 GOST 13015.0-83 and "ImageJ" in respect to the area of blemishes.

2. Materials and technology

JSC "Akmenes cementas" (Lithuania) Portland cement CEM II/A-LL 42.5 R was used for the test.

Kvesu quarry sand with the fraction of 0/4, bulk density of 1550 kg/m^3 and fineness module of 1.67 was used as fine aggregate for concrete mixtures. 0/1 sand fraction ($\rho = 1460$ kg/m^3, fineness module 2.37) was also used as fine aggregate. Gravel with the fraction of 4/16 and bulk density of 1327 kg/m^3 was used as the coarse aggregate. Granulometric composition of aggregates is conducted according to LST EN 12620:2003+A1:2008.

Two different concrete mixtures were prepared and their compositions are presented in Table 1.

During the research, dry aggregates were used for concrete mixtures. Cement and aggregates were dosed by weight while water and chemical admixture were dosed by volume. Chemical additives in the form of solutions were mixed with water and used in preparation of concrete mixtures. Concrete mixtures were mixed for 3 minutes in the laboratory in forced type concrete mixers.

Table 1. Concrete mixture compositions

Materials	Measurement	Concrete mixture compositions. Amount of materials for 1m^3 concrete mixture	
		BA1	BA8
Cement	kg	293	380
Water	l	158	200
Course aggregate, gravel - 4/16	kg	970	937
Fine aggregate, sand - 0/4	kg	733	487
Fine aggregate, sand - 0/1	kg	277	378
Super-plasticizer, Muraplast FK 801.1 (1.4 %)	l	4.2	–
Super-plasticizer, Glenium SKY 628 (0.9 %; 1.0 %)	l	–	3.58
Stabilizer, Rheomatrix 100 (0.26 %)	l	–	0.94
Anti – foam, Rheomix 880 (0.30 %)	l	–	1.14
Pigment, Bayferrox	kg	11.7	–
Water and cement ratio	–	0.540	0.526

Four different formworks for horizontal specimens were used for this research (figure 1): wood impregnated with polymeric oil; wood covered with rubber; sawn timber and plastic forms.

Figure 1. Formworks used for horizontal specimens

Dimensions of the different formworks were as follow:

- Wood impregnated with polymeric oil [WPO]: 550 × 300 mm for horizontal specimens;
- Wood covered with rubber [WCR]: 400 × 400 mm;
- Sawn timber formwork [ST]: 400 × 300 mm.
- Plastic formwork [P]: 400 × 400 mm;
- Wood impregnated with polymeric oil [WPOV] for vertical specimens:
  - BA1 with and without excessive release agent and BA8 with excessive release agent – 1240 × 230 mm (1 side). Total measured area – 0.57 m^2.
  - BA8 without excessive release agent – 620 × 460 mm (1 side). Total measured area – 0.57 m^2.

"PERI" formwork (wood impregnated with polymeric oil) for the casting of vertical concrete specimens.

The usage of form release agents was different. The aim was to find out the difference of concrete surfaces quality between specimens that were casted with the excessive amount of form release agent and without.

The air content of concrete mixtures was determined by LST EN 12350-7 standard. Flow table test for concrete mixtures was made according to LST EN 12350-5:2009 standard and density of concrete mixtures - LST EN 12350-6.

Vibration table was used for BA1 concrete mixtures. The parameters of vibration table were as follow: amplitude – 0.5 mm; frequency – 50 Hz. Environment conditions: 18 ^oC of temperature and 65 % of relative humidity. Vibration time was seven seconds. BA8 concrete mixture was not vibrated.

Concrete specimens were taken out from the formworks after 3 days and cured in 18 ^oC temperature dry conditions.

The evaluation of concrete surfaces was made by three methods:

- Method according to CIB Report No. 24 "Tolerances on blemishes of concrete";
- Method according to GOST 13015.0-83 standard;
- Method proposed by the authors of this article using computer program – "ImageJ".

The first method provides information about the concrete surface quality by using seven different reference photographs that illustrate the level of incidence of blowholes in surfaces.

The second method provides information about concrete surfaces according to GOST 13015.0-83 standard. The evaluation is conducted according to the diameter of blowholes.

The third method provides analytical information about the quality of concrete surfaces in respect to the ratio between area of blemishes and whole specimen. First of all, the concrete surface is pictured, that all specimens would be visible. Photos were taken around 30 cm of distance.

Methodology of an image analysis method "ImageJ":

- Image of the concrete surface is imported into the "ImageJ" program.
- Picture is set to the 8bit quality. This is done to highlight the blemishes of the surface;
- Image scale is set to the certain known dimension;
- Image colors are changed into the black and white to highlight the blemishes of the surface;

- 5 mm and bigger diameter blemishes were analyzed;
- The areas of surface blemishes are calculated.

Following statistical parameters of blemishes area were calculated: the number of blemishes (N), mean value (MV). Ratio (%) between the area of blemishes (BA) and the area of specimen (SA) is given.

3. Results and discussions

The results of statistical analysis are given at table 2. Blemishes of 5 mm^2 or bigger were evaluated. Three castings for each specimen were conducted and the average values are presented.

Table 2. Statistical analysis of the experimental results

Parameters	WPO	WCR	ST	P	WPOV
			BA1 (normal release agent application)		
N	–	–	35	–	85
MV	–	–	12.62	–	50.16
BA/SA	–	–	0.36	–	0.75
			BA1 (with excessive release agent)		
N	29	42	–	–	110
MV	7.83	7.92	–	–	28.29
BA/SA	0.14	0.21	–	–	0.55
			BA8 (normal release agent application)		
N	–	–	–	–	37
MV	–	–	–	–	27.10
BA/SA	–	–	–	–	0.18
			BA8 (with excessive release agent)		
N	–		–	–	–	74
MV	–		–	–	–	27.97
BA/SA	–		–	–	–	0.36

Technological properties of BA1 and BA8 concrete mixtures are given at table 3.

Table 3. Technological properties of BA1 and BA8 concrete mixtures

Parameter	Concrete mixtures technological properties	
	BA1	BA8
Air content, %	4.0	1.1
Concrete mixture density, kg/m^3	2374	2355
Flow table test results, mm	525	720

The evaluation of results obtained in this research was conducted according to three following methods: CIB Report No. 24 “Tolerances on blemishes of concrete”, GOST 13015.0-83 standard, “ImageJ” (table 4).

Table 3. The results of concrete mixture technological properties and the evaluation of formed concrete surfaces.

Type of formwork	Concrete mixtures	
	BA1	BA8
	CIB Report No. 24 "Tolerances on blemishes of concrete"	
	Normal release agent application	
WPO	1 [Special]	1 [Special]
WCR	1 [Special]	1 [Special]
ST	3 [Ordinary]	1 [Special]
P	1 [Special]	1 [Special]
WPOV	No requirements [Rough]	2 [Elaborate]
	With excessive release agent	
WPO	2 [Elaborate]	1 [Special]
WCR	2 [Elaborate]	1 [Special]
ST	1 [Special]	1 [Special]
P	1 [Special]	1 [Special]
WPOV	No requirements [Rough]	3 [Ordinary]
	GOST 13015.0-83	
	Normal release agent application	
WPO	A2	A2
WCR	A2	A2
ST	A4	A2
P	A2	A2
WPOV	A5	A3
	With excessive release agent	
WPO	A3	A2
WCR	A3	A2
ST	A2	A2
P	A2	A2
WPOV	A5	A3
	"ImageJ"	
	Normal release agent application	
WPO	–	–
WCR	–	–
ST	0.36 %	–
P	–	–
WPOV	0.75 %	0.18 %
	With excessive release agent	
WPO	0.14 %	–
WCR	0.21 %	–
ST	–	–
P	–	–
WPOV	0.55 %	0.36 %

On the basis of the evaluation of concrete surfaces (table 4), it was necessary to divide concrete surfaces into groups. According to these three documents all the research results were divided as follow at table 5.

Table 5. Combined concrete category classification

According to methods	Class of the concrete			
	Special	Elaborate	Ordinary	Rough
GOST 13015.0-83, categories	A1 – A2	A3	A4	A5 >
CIB Report No. 24. marks	1	2	3	No req.
"ImageJ", bugholes area, %	0 – 0.1	0.1 – 0.3	0.3 – 0.5	0.5 >

4. Conclusions

1. The quality of concrete surface was differently affected by the application of form release agent. Generally, the usage of excessive release agent resulted in more porous concrete surfaces. On the other hand, those pores became very tiny and therefore the total area of pores decreased (vertical BA1 specimens: 0.75 % to 0.55 %). The usage of excessive form release agent for vertical specimens of BA8 concrete mixture resulted in more porous concrete surfaces as well and the total area of blemishes in respect to whole specimen's surface area increased from 0.18 % to 0.36 %.
2. Generally, higher quality concrete surfaces were obtained by using more fluid concrete mixtures (BA8). Horizontal specimens that have been formed of BA8 concrete mixture were named as special, because they almost did not possess any surface blemishes (despite the different application of form release agent). The excessive form release agent application resulted in worse surface quality of horizontal specimens of BA1 concrete mixture (increased the number and area of surface blemishes).

5. References

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