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The Evaluation Methods of Decorative Concrete Horizontal Surfaces Quality

Albertas KLOVAS [*]**, Mindaugas DAUKŠYS**

Department of Civil Engineering Technologies, Kaunas University of Technology, Studentu str. 48, LT-51367 Kaunas, Lithuania

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The main aim of this article was to determine blemishes of concrete surfaces and divide those surfaces according to following methods provided by two documents and by authors proposed image scanning method - "ImageJ". The first method was CIB Report No. 24 "Tolerances on blemishes of concrete". This method enables to evaluate concrete surfaces according to their visual appearance by using certain reference cards. The second method was GOST 13015.0-83. This method enables to evaluate the concrete surfaces according to their biggest dimension of the blemishes. The third, authors proposed, method was "ImageJ". Latter method is based on the free source computer program. It helps to establish the quantity and the dimensions of the blemishes in the desired scale. Authors suggested to imply a ration between blemishes area and the all specimen's area as a factor for evaluation of concrete surface quality. Three different concrete compositions were made: BA1, BA7 and BA8. Also, five different formworks were used: wood impregnated with polymeric oil [WPO], wood covered with rubber [WCR], sawn timber [ST], metal [M] and plastic [P] formworks. Following parameters of the obtained results were calculated: mean value, dispersion, standard deviation and the coefficient of variation. Also maximum and minimum values of experimental results are given. Intervals of the experimental results are provided for each specimen with the biggest possibility.

Keywords: concrete surface quality, formworks, molds, form, concrete mixture compositions.

1. INTRODUCTION

In the building industry, architects and building owners generally have strict requirements for the quality of concrete surface [1]. Usually, these requirements mainly concern flatness, tint and the absence of bugholes of concrete surface. The evaluation of concrete surface flatness generally does not pose a problem on the building site. However tint and the quantity of bugholes are factors, which often are being considered by the owners, architects and building contractors.

The field of concrete surface evaluation is yet very little dealt with therefore there are only few standards or documents regarding it. One of those documents is GOST 13015.0-83 [3]. According to this Soviet standard, concrete surfaces are divided into 7 categories from A1 to A7 there A1 is the best possible and the A7 – the worst quality concrete surface. The drawback of this method is that the quantity of blemishes is not considered and there are no limits of surface blemishes area and intervals for their dimensions. The diversification is provided according to the biggest dimension of the blemishes, local rinses or indentations, the depth of cracks in concrete edge and the sum of cracks length in 1 m of concrete edge. The second document is CIB Report No. 24 "Tolerances on blemishes of concrete" [4]. This method enables to evaluate concrete surfaces according to their visual appearance by using 7 reference cards there the first card stands for the best surface quality and the 7^{th} – the worst surface quality. The method is very simple, two different reference cards must be enclosed to the concrete surface and the difference between the card's numbers gives the surface quality evaluation. Difference in the interval of 2 – 4 gives the "Special" concrete type (best surface quality), 4 – 6 – "High quality", > 6 – "Conventional" and the "Coarse concrete" is not evaluated according to this method. Although this method is simple and fast to use, but the results are usually subjective due to the different human glance at the certain concrete surface.

Researchers [2] have updated CIB Report No. 24 "Tolerances on blemishes of concrete" method by providing the quantity and bubbles area (%) for each reference card.

It must be noted that the robustness of image taking procedure haven't been yet fully researched. At the moment scientists from Norwegian university of science and technology and SINTEF enterprise are working on this.

It is not easy to achieve, that the formed concrete surfaces would be smooth, tint and bugholes free. International Council for Building Research has provided main guidelines how the concrete may be defined referring the surface quality [5]:

- ROUGH class is provided for surfaces where there is no special requirement for finish;
- ORDINARY class applies to surfaces where appearance, whilst a minor factor, is still of some importance;
- ELABORATE class applies to those with definite requirements for visual appearance;
- SPECIAL class applies to those calling for the highest standards of appearance.

To sum up, quality of concrete surface depends on various factors and their combinations. Suitable building materials and their components according to the environment conditions should be used in order to achieve the best possible concrete surface quality [6 – 11]. The right technology for concrete casting and afterwards its consolidation isn't less important factor [12 – 16, 21]. The usage of different formworks and their construction technology is crucial factor as well [17 – 20, 22 – 24].

[*] Corresponding author. Tel.: +370-619-13266; fax.: +370-37-438744.
E-mail address: *Albertas.Klovas@ktu.lt* (A. Klovas)

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 [3] and GOST 13015.0-83.
- The comparison between the "ImageJ" method (factor – ratio between the area of the blemishes and all specimen area) and CIB report No. 24 as well as GOST 13015.0-83 methods.

2. MATERIALS AND METHODOLOGY

JSC "Akmenes cementas" (Lithuania) Portland cement CEM II/A-LL 42.5 R was used. Physical and mechanical properties obtained from manufacturer of Portland cement CEM II/A-LL 42.5 R are given in Table 1. 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 and presented in Table 2.

Table 1. Physical and mechanical properties of Portland cement, CEM II/A-LL 42.5 R

Specific surface area, m^2/kg	410
Particle density, kg /m^3	3.05
Normal consistency of cement paste, %	26.5
Volume stability, mm	0.8
Initial setting time, min.	195
Compressive strength after 2 days/after 28 days, MPa	27.1/54.0
Loss on ignition, %	5.05
Insoluble materials, %	–
SO_3, %	2.48
Cl^-, %	0.015
Alkalis, calculated by Na_2O equivalent, %	<0.8

Three different compositions of concrete mixture were prepared and presented in Table 3. Plasticizing admixtures based on polycarboxylatether Muraplast FK 801.1 (MC-Bauchemie, Germany) and Glenium SKY 628 (Basf, Germany) were used with the solution density respectively of 1.05 g/ml and 1.06 g/ml. The total dosage of admixture – Muraplast FK 801.1 was 1.4 % of cement. Glenium SKY 628 – in the range of 0.9 % to 1.0 % of cement.

In addition, the pigment Bayferrox (Basf, Germany) was used for the first concrete composition (BA1). The pigment used was about 4 % in respect to the amount of cement. For the BA7 and BA8 concrete mixtures following admixtures were used: stabilizer Rheomatrix 100 (0.26 % of cement mass) and anti-foam Rheomix 880 (0.30 %).

Also form release agents were used: Ortolan SEP 711 (MC-Bauchemie, Germany) for BA1 and Rheofinish 215 (Basf, Germany) for BA7 and BA8 concrete mixtures.

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 2. Granulometric composition of aggregates

Radius of the sieve's mesh, mm	The amount of poured out material, %		
	Sand fraction 0/1	Sand fraction 0/4	Gravel fraction 4/16
16.0	100.00	100.00	98.80
8.0	100.00	100.00	42.10
4.0	100.00	95.10	4.30
2.0	99.80	81.80	1.00
1.0	99.10	54.60	0.52
0.500	77.40	12.40	0.44
0.250	2.20	0.70	0.36
0.125	0.50	0.30	0.32
0.000	0.00	0.00	0.00

Table 3. Concrete mixture compositions

Materials	Units	Concrete mixture compositions. Amount of materials for 1m^3 concrete mixture		
		BA1	BA7	BA8
Cement	kg	293	380	380
Water	l	158	198	200
Course aggregate, gravel – 4/16	kg	970	937	937
Fine aggregate, sand – 0/4	kg	733	469	487
Fine aggregate, sand – 0/1	kg	277	396	378
Super-plasticizer, Muraplast FK 801.1 (1.4 %)	l	4.2	–	–
Super-plasticizer, Glenium SKY 628 (0.9 %; 1.0 %)	l	–	3.42	3.58
Stabilizer, Rheomatrix 100 (0.26 %)	l	–	0.99	0.94
Anti-foam, Rheomix 880 (0.30 %)	l	–	1.14	1.14
Pigment, Bayferrox	kg	11.7	–	–
Water and cement ratio	–	0.540	0.520	0.526

Five different formworks were used for this research (Figure 1): wood impregnated with polymeric oil; wood covered with rubber; sawn timber; plastic and metal forms.

Dimensions of the different formworks were as follow:

- Wood impregnated with polymeric oil [WPO]: (550×300) mm for BA1 concrete composition and (400×300) mm for BA7 and BA8 concrete compositions;
- Wood covered with rubber [WCR]: (400×400) mm;
- Sawn timber formwork [ST]: (600×300) mm for BA1 concrete composition and (370×320) mm for BA7 and BA8 concrete compositions;
- Plastic formwork [P]: (400×400) mm;
- Metal formwork [M]: (400×400) mm.

a b c d e

Fig. 1. Formworks used for the concrete casting: a – wood impregnated with polymeric oil; b – wood covered with rubber; c – sawn timber; d – plastic; e – metal

Only certain concrete surface's area (300×300) mm of all different specimens was evaluated.

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 and BA7 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:

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

These methods were adjusted for blow holes evaluation only.

The first method provides information about the concrete surface's quality by using seven different reference cards (Figure 2) that illustrate the level of the incidence of blowholes in surfaces. The measure of reference cards is 10 cm of width and 10 cm of width and 10 cm of width and 30 cm of height. This method evaluates maximum allowable variation between the different zones on the scale indicated by the photographs.

Table 4 shows how the concrete surfaces with the distributed holes are evaluated by CIB Report No. 24 "Tolerances on blemishes of concrete". Blemishes are considered as maximum allowable variation between the different zones on the scale indicated by the photographs.

The second method provides information about concrete surfaces according to GOST 13015.0-83 standard. The evaluation is made in respect to the amount of the certain diameter of blowholes (Table 5).

Table 4. Consideration of the blemishes

Blemishes considered	Classes			
	Special	Elaborate	Ordinary	Rough
Distributed holes	0–2	2–4	4–6	No requirement

Table 5. Requirements for the concrete surface quality by GOST 13015.0-83

Categ. of concrete surface	Diameter or the biggest dimension of the blemish	Dimensions of the local rises and cavities	Wreckage depth of the edge	Total length of the wreckages
	Data, mm			
A1	Very smooth surface (reference)		2	20
A2	1	1	5	50
A3	4	2	5	50
A4	10	1	5	50
A5	No require.	3	10	100
A6	15	5	10	100
A7	20	No require.	20	No requir.

It must be noted that:

– for 1 m^2 of A2 concrete surface it is allowed one blowhole with the diameter or the biggest dimension of 2 mm;

– for 1 m^2 of A3 concrete surface it is allowed one blowhole with the diameter or the biggest dimension of 6 mm;

– for 1 m^2 of A4 concrete surface it is allowed one blowhole with the diameter or the biggest dimension of 15 mm;

The third method provides visual 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 the specimens would be visible. All the photographs for this research were taken by the HTC HD2 with 5 megapixels camera. Photos were taken around 30 cm of distance.

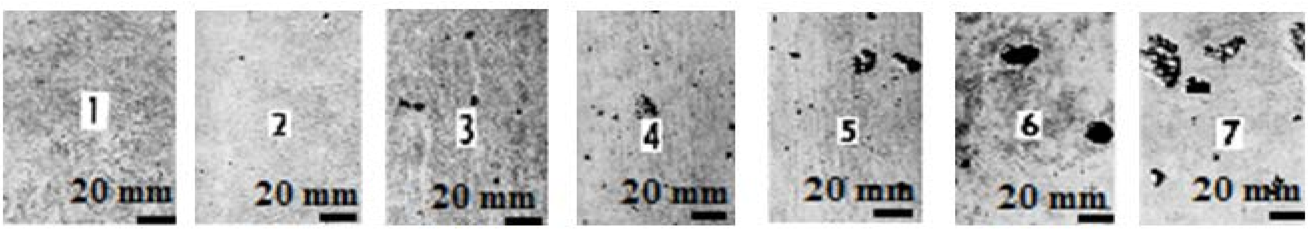
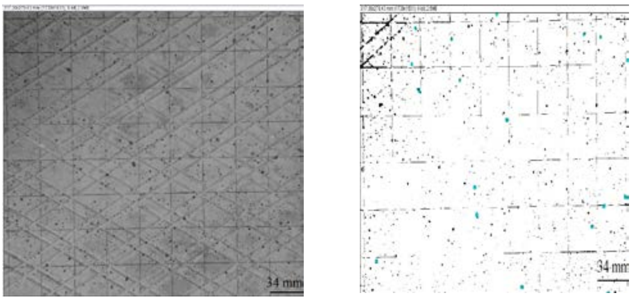


Fig. 2. Reference photographs used for evaluation of concrete surface quality

Methodology of image analysis method (Figure 3):

1. Image of the concrete surface is imported into the ImageJ program. In this research, images of around 900 cm^2 of area were analyzed. Measurements of area have varied a bit, because of the inaccuracy of the picture quality;
2. Picture is set to the 8 bit quality. This is done to highlight the blemishes of the surface;
3. Image scale is set to the certain known dimension;
4. Image colors are changed into the black and white to highlight the blemishes of the surface;
5. 1 mm and bigger diameter blemishes were analyzed;
6. The areas of surface blemishes are calculated.



Original 8bit image Black and white image

Fig. 3. Image transformation using ImageJ program

Statistical analysis of the results was made. Three castings with each formwork were performed. Computer programs “Mathcad 15” and “Excel 2010” were used. Following statistical parameters of blemishes area were calculated: mean value (MV), dispersion (D), standard deviation (SD) and the coefficient of variation (CV). Also maximum (MAX) and minimum (MIN) values of experimental results are given. The biggest relative frequency of experimental results is provided for each specimen’s surface.

3. RESULTS

The results of statistical analysis are given in Table 6. Following statistical parameters of blemishes area were calculated: mean value (MV), dispersion (D), standard deviation (SD) and the coefficient of variation (CV). Also the number of blemishes (N), minimum (MIN) and maximum (MAX) values of the experimental results are given. The biggest relative frequency with its interval (RF/I) of experimental results is provided for each specimen’s surface.

According to the information provided in Table 6, the size of surface blemishes varies between 1.033 mm^2 (formwork – metal) to 17.82 mm^2 (formwork – wood covered with rubber). The biggest standard deviation (SD) of surface blemishes area is obtained by using formworks: sawn timber (ST) (SD = 3.105 mm^2) and wood covered with rubber (WCR) (SD = 2.511 mm^2). The most porous (N = 106) concrete surface is obtained by using wood covered with rubber formwork. It must be noted, that for the specimens from BA1 concrete mixture composition, different formwork surface materials were covered with the excessive amount of form release agent without cleaning it by the soft cloth. This could be the main reason why the specimens from BA1 concrete mixture composition were the most porous compared with BA7 or BA8 compositions.

Table 6. Statistical analysis of the experimental results

Para-meters	WPO	WCR	ST	P	M
BA1					
N	59	106	12	45	70
MV	4.203	4.155	4.867	1.728	2.133
D	3.665	6.305	9.683	0.456	0.535
SD	1.914	2.511	3.105	0.675	0.732
CV	0.456	0.604	0.638	0.391	0.343
MIN	1.784	1.499	1.721	1.065	1.033
MAX	11.230	17.82	12.868	4.717	4.65
RF/I	0.322/ [3.157; 4.530)	0.557/ [1.45; 3.50)	0.500/ [3.95; 6.18)	0.556/ [1.065; 1.627)	0.314/ [1.54; 2.048)
BA7					
N	20	3	15	8	12
MV	3.665	5.908	5.899	2.934	4.144
D	3.698	0.077	12.773	1.091	2.429
SD	1.923	0.277	3.574	1.045	1.559
CV	0.525	0.047	0.606	0.356	0.376
MIN	1.392	5.651	1.570	1.625	1.213
MAX	7.793	6.202	12.351	4.379	7.277
RF/I	0.35/ [2.595; 3.798)	Not establ.	0.40/ [1.570; 3.768)	0.375/ [1.625; 2.314)	0.417/ [2.536; 3.859)

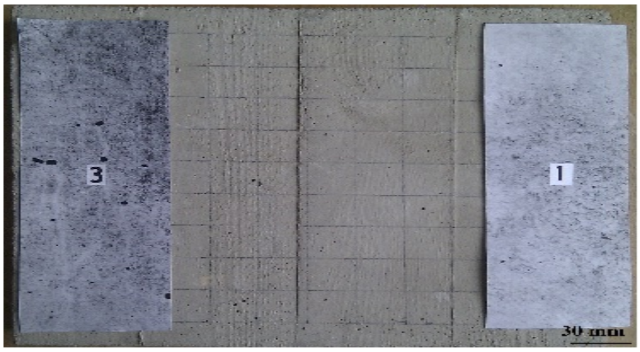


Fig. 4. Specimen’s, taken from the sawn timber formwork, surface evaluation process (BA7 concrete mixture)

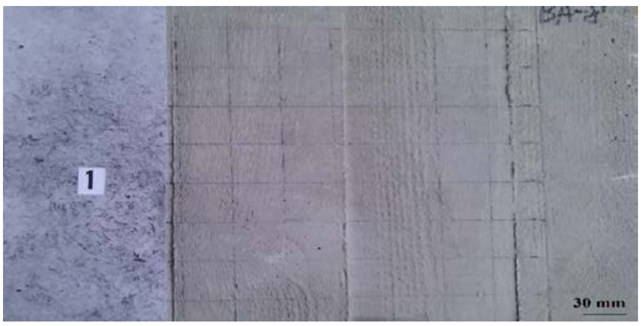


Fig. 5. Specimen’s, taken from the sawn timber formwork, surface evaluation process (BA8 concrete mixture)

On the other hand, form release agent was cleaned according to the requirements by the agent's producers. This was done for making specimens from BA7 concrete mixture composition. As it is shown in Table 6, the biggest distribution of pores (SD = 3.574) is obtained by using sawn timber formwork. This could be the result of rough surface texture of sawn timber formwork which didn't let for the air pores to get away easily during the vibration. In addition, BA1 and BA7 concrete mixtures were vibrated, while BA8 – was not.

No surface blemishes were obtained for the specimens from BA8 concrete mixture.

According to CIB Report No. 24 "Tolerances on blemishes of concrete" the quality of concrete surfaces was evaluated. Concrete surfaces, according to the concrete quality, were divided into groups provided by CIB Report No. 24. Figures 4 and 5 show the evaluation process of some specimens and the test results are given in the Table 6.

Table 7. The results of concrete mixtures technological properties and the evaluation of concrete surfaces

	BA1	BA7	BA8
Air content, %	4	1.9	1.1
Concrete mixture density, kg/m^3	2374	2335	2355
Flow table test results, mm	525	560	720
CIB Report No. 24 "Tolerances on blemishes of concrete"			
WPO	4–1=3 Elaborate	4–2=2 Special	1–1=0 Special
WCR	3–1=2 Elaborate	3–1=2 Special	1–1=0 Special
ST	3–1=2 Elaborate	3–1=2 Special	1–1=0 Special
P	3–1=2 Elaborate	3–1=2 Special	1–1=0 Special
M	3–1=2 Elaborate	2–1=1 Special	1–1=0 Special
GOST 13015.0-83			
WPO	A3	A3	A1
WCR	A3	A3	A1
ST	A3	A3	A2
P	A3	A2	A1
M	A3	A2	A1
"ImageJ"			
WPO	0.27 %	0.08 %	0 %
WCR	0.49 %	0.02 %	0 %
ST	0.065 %	0.10%	0 %
P	0.09 %	0.03 %	0 %
M	0.17 %	0.06 %	0 %

According to GOST 13015.0-83 standard, concrete surfaces were divided into groups from A1 to A7. The results are shown in Table 7.

The third method was used for evaluation of concrete surface according to the total area of blemishes. The results are shown in Table 7.

4. DISCUSSION

In order to evaluate the concrete surface quality easier, researchers [1] have simplified the usage of reference cards (see Figure 2). They have proposed the dependence of reference card number and the quantity of bubbles per 1 m^2 as well as the percentage of them.

In order to fully evaluate the quality of concrete surface, the grey scale should also be taken into consideration. Researchers [1] have analyzed this grey scale property, but they found that the biggest factor which influences the surface quality is the lightness of the environment. The robustness of image taking process should be more researched in the future.

The main distinctive feature of this article is that all concrete specimens were classified according 3 different methods. The third was authors proposed method – "ImageJ". It included one crucial factor – the ratio between blemishes and all specimen's area. Concrete specimens were divided into 4 types in respect to the surface quality. Currently in Lithuania only old standard GOST 13015.0-83 is being used and scientists haven't yet proposed the different, more up to date method. Our object was to create a more précised method which would be influenced by the human eye as less as possible. In this case the ratio factor which might be very useful for concrete surface quality evaluation was included.

Very important factor is that the evaluation according to "ImageJ" method is more objective, because the calculation part is done by the computer. Also such factors as: the quantity, size and the area ration of the blemishes are very easy to process without any ambiguity.

It is obvious that by taking photos of 1 m^2 of the certain concrete element and evaluating them according to the blemishes area by "ImageJ" method it becomes easy and objective to establish the concrete type. It is recommended to count the surface area of the blemishes in order to divide surfaces significantly more precisely.

Example of the proper usage of these methods is given below. This is done on the basis of the results obtained from this research (Table 6). According to these three documents all the research results were divided as follow:

- *Special – architectural concrete:* A1 – A2 classes according to GOST 13015.0-83; 0 – 2 marks according to CIB Report No. 24 and 0 – 0.1 % of blemishes area according to ImageJ method;
- *Elaborate – decorative concrete:* A3 – A4 classes according to GOST 13015.0-83; 2 – 4 marks according to CIB Report No. 24 and 0.1 – 2 % of blemishes area according to ImageJ method;
- *Ordinary concrete:* A5 – A6 classes according to GOST 13015.0-83; 4 – 6 marks according to CIB Report No. 24 and 2 – 4 % of blemishes area according to ImageJ method;
- *Rough concrete:* A7 and bigger classes according to GOST 13015.0-83; no requirements according to CIB Report No. 24 and more than 13 % of blemishes area according to ImageJ method.

Table 8 provides the factors for comparison of concrete surface quality according to CIB Report No. 24, GOST 13015.0-83 and ImageJ methods.

According to the information provided in Table 8, all the specimens of this research were divided into certain concrete classes in respect to their surface quality. The percentage of concrete blemishes is provided in respect to the 1 m^2 of surface area. Specimens that were formed from BA1 concrete mixture were named as elaborate concrete. BA7 concrete mixture's specimens were assigned for different concrete classes. On the basis of the results, WPO, WCR and ST specimens were classified as elaborate concrete meanwhile P and M were put as special type of concrete. The best concrete surfaces quality were obtained by using BA8 concrete mixture's composition, therefore their type was special.

Table 8. Combined concrete category diversification

According to methods	Class of the concrete			
	Special	Elaborate	Ordinary	Rough
GOST 13015.0-83, categories	A1 – A2	A3 – A4	A5 – A6	A7 >
CIB Report No. 24. marks	0 – 2	2 – 4	4 – 6	No req.
ImageJ, bugholes area, %	0 – 0.1	0.1 – 2	2 – 4	13 >

5. CONCLUSIONS

1. The main outcome of this research was to propose the concrete surface evaluation method, whereof factors would be influenced by the human eye as less as possible.
2. Very important factor, such as the ratio between the areas of the blemishes and the whole specimen was proposed.
3. The increase of concrete mixture flow was noticed while the air content was decreasing. The results have shown that the better quality of concrete surface is obtained by using concrete mixtures with higher flow parameters, but less air content.

REFERENCES

1. **Menard, J-P.** La Qualite Pour Tous Les Usages *Construction Moderne* 101 1999: p. 12.
2. **Lemaire, G., Escadeillas, G., Ringot, E.** Evaluating Concrete Surfaces Using an Image Analysis Process *Construction and Building Materials* 19 2005: pp. 604 – 611. http://dx.doi.org/10.1016/j.conbuildmat.2005.01.025
3. GOST 13015.0-83. Конструкции и изделия бетонные и железобетонные сборные (Structures and Concrete and Prefabricated Concrete) (in Russian).
4. **CIB Report No. 24, Commission W29**. Tolerances on Blemishes of Concrete, 1973.
5. **Klovas, A., Daukšys, M.** Quality and Defects of the Decorative Concrete Surface *Conference „Civil Engineering and Architecture"* Kaunas: Technology, 2011: pp. 99 – 109. (in Lithuanian).
6. **ACI 309R.** Guide of Consolidation of Concrete. ACI Committee 309, Technical Committee Document 309R-05, 2005: 35 p.
7. **ACI 116R.** Cement and Concrete Terminology. American Concrete Institute, 2000: 73 p.
8. **ACI 309.1R.** Behavior of Fresh Concrete During Vibration. ACI Committee 309, Technical Ccommittee Document 309.1R-08, 2008: 18 p.
9. **Reading, T-J.** The Bug Hole Problem *ACI Journal Proceesings* 69 (22) Nov. 1972: pp. 165 – 177.
10. **Shilstone, J-M.** Surface Blemishes in Formed Concrete. *Concrete Construction* 24 (11) Nov. 1979: pp. 719 and 765.
11. **Stamenkovic, H.** Surface Voids Can Be Controlled. *Concrete Construction* 18 (12) Dec. 1973: pp. 597 – 598.
12. **Caldarone, M-A.** High Strength Concrete. A Practical Guide *Taylor and Francis* 2009: pp. 153 – 164.
13. **Reading, T. J.** The Bug Hole Problem *ACI Journal, Proceedings* 69 (3) Mar. 1972: pp. 165 – 177.
14. **Shilstone, J. M.** Surface Blemishes in Formed Concrete *Proceedings, RILEM/ASTM/CIB Symposium on Performance Evaluation of External Vertical Surfaces of Buildings* (Otaniemi, Espoo, Aug.-Sept.), Technical Research Centre of Finland, Espoo, Finland, 1977: pp. 3 – 7.
15. **Leal da Silva, W. R., Lucena, D. S., Prudencio, L. R., Štemberk, P.** Surface Appearance of Precast Elements Fabricated Using Self – Consolidating Concrete *Concrete International* October 2011: pp. 39 – 44.
16. Information has been used from the following website: http://rsbweb.nih.gov/ij/ on 02 02 2012.
17. **Coutinho, J. S.** The Effect of Controlled Permeability Formwork (CPF) on White Concrete *ACI Materials Journal* 98 (2) 2001: pp. 148 – 171.
18. **Price, W. F.** Controlled Permeability Formwork. CIRIA Report C511, 2000: 102 p.
19. **Duggan, T.** Enhancing Concrete Durability Using Controlled Permeability Formworks *17th Conference on Our World in Concrete and Structures.* Singapore August 1992: pp. 57 – 62.
20. **Watanaba, T., Uomoto, T.** Monitoring Concrete Placing by Infrared Image Analysis *Doboku Gakkai Rombun-Hokokushu Proceedings of the Japan Society of Civil Engineers*, No. 478, Part 50 – 21, 1993: pp. 55 – 59.
21. **Harding, M. A.** Vibrating Concrete in Wall Forms *Concrete Construction* 40 (2) Feb. 1995: pp. 180 – 184.
22. Information has been used from the following website: http://www.cement.org/tech/cct_con_design_bugholes.asp on 02 02 2012.
23. **Samuelsson, P.** Voids in Concrete Surfaces *ACI Journal* November 1970: pp. 868 – 874.
24. AS 3610 Formwork for Concrete, Standards Australia, 1995: pp. 12 – 21.