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ESTIMATION OF TYPE AND AMOUNT OF AGGREGATES IN HARDENED CONCRETE

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Sometimes happens that certificated concrete products, in which declarations of performance refer high strength and frost resistance indexes, start to deteriorate in first exploitation years. Due to aggressive environment this occurrence is frequent in concrete articles used for tiding surroundings: concrete paving blocks, slabs, curbs used for streets, parking places and pavements. Frequently, the main reason of deterioration is that concrete products are produced from the different concrete composition like samples, which have been used for certification. There are standard methods to estimate the amount of cement in concrete and to do a determination of air void characteristics in hardened concrete, but there are no methods how to estimate the amount and type of aggregates in concrete. For this reason, a new method was created. For the testing, the deteriorating paving zone, which had been built three years ago, was selected. The types of aggregates used in the production of concrete paving blocks have been estimated analyzing the cuts of the blocks. The test results show that the main aggregate, used for concrete paving block production, is gravel and it was used in higher amount as declared, while the granite breakstone and crushed gravel was used for production in lesser amount. In this case, the producer applying different amounts of aggregates reduced cost price as well as worsened the properties of concrete.

Keywords: aggregates, concrete composition, early deterioration, paving blocks.

INTRODUCTION

Concrete is a composite material. The longevity of concrete depends upon the amount and properties of components. Eighty percent of the volume of concrete is occupied by aggregate and its properties are very important to determinate the mechanisms in concrete structures. Mineral characteristics of the aggregate affect the drying shrinkage of concrete, which is attributed to pronounced moisture movement inside the aggregate (Carlos et al., 2010; Princic et al., 2013; Qian et al., 2002). Recent research states that the importance of coarse aggregate type could be even larger than the one of the W/C ratio. Namely there are: the occasional microcracks on the coarse aggregates, its porosity, rough texture and above all the physical and chemical connection between the cement past and the aggregate. In that transition zone, the cement paste could be physically and chemically badly connected to the aggregate, compromising both mechanical resistance and aggressive elements penetration resistance. Physical properties of coarse aggregates are related to the rock deterioration state (weathering) from where they come from. Stone deterioration state means the destruction of rocky connections and the transformation of rock into soil over the years (Torgal et al., 2006).

For example, limestone aggregate is an important material for concrete and also decreases production costs. After determining the properties of limestone, the optimum ratio of water–cement and aggregate mixtures were used to obtain the constant compressive strength of concrete. It is known that concrete strength is affected by changing the water–cement ratio and cement dosage. It is necessary to determine strength, texture and mineralogical characteristics, physical and chemical properties of rock and aggregate for the improvement of the concrete strength. The strength of rocks is closely related to their mineralogical composition (Yasar et al., 2004).

The granitic aggregate rich in silicate minerals, have a hard, dense and rough coarse texture and low water absorption, are more resistant and stronger than the limestone (Hussin et al., 2011).

Considering in differences of particular aggregates it is very important to test each concrete composition before using. If composition will not be tested early deterioration of concrete can occur.

Sometimes happens that certificated (tested concrete composition) concrete products, in which declarations of performance refer high strength and frost resistance indexes, started to deteriorate in first exploitation years. In Lithuania, this occurrence is frequent (due to aggressive environment) in concrete articles for used for tiding surroundings: concrete paving blocks, slabs, curbs used for streets, parking places and pavements. The defects on these buildings are visible and they reduce aesthetic view as well as buildings safety. Due to these facts the dispute starts between Builders and Contractors, who are responsible for the supply of construction products. Often the Contractor transfers the blame to the Producer or Supplier (if he exists) appealing that products were produced, for example, from the different concrete composition like samples, which were used for certification (used other concrete composition). To estimate the guilty the participants of construction often go to the court. The court reaches to estimate if the composition of the deteriorating concrete suits the declared composition. For this work the experts are employed, who must evaluate the concrete composition using standards or other methods. Using standards methods it is possible to estimate the amount of cement in concrete (LST 1428.13:1997) and to do a determination of air void characteristics in hardened concrete (LST EN 480-11:2006). Unfortunately, there are no standard methods to estimate the type and amount of aggregates water and admixture in concrete. In scientific literature, it is suggested to use special equipment, which purpose is another.

The object of this paper is to explore the amount and type of aggregates in concrete paving blocks using specially created testing method.

TEST METHODS

As mentioned before, using standard methods it is possible to estimate only the amount of cement and to do a determination of air void characteristics in hardened concrete. Meanwhile, to estimate other components in concrete there are no standard methods, but are some non-standard ones. G. Girskas (2015) offers to estimate the size and amount of pores in concrete, because the porosity of concrete is very important parameter evaluating the longevity of concrete structures. It is known that frost resistance of concrete depends upon capillary porosity and amount of air in concrete. These two parameters can be controlled during the concrete production. There are four types of pores in concrete: gel pores; capillary pores 5–5000 µm; macro pores from air; macro pores from lack of concrete compaction. The gel pores don't have any negative effect on concrete strength. Capillary and other greater pores decrease the concrete strength (Cai et al.,1998). It is known that small W/C ratio and good condition of concrete curing are important factors in getting frost resistant concrete products (Snelson et al. 2009; Gailius et al. 2009; Bai et al. 2009; Gailius et al. 2008). For estimation of the porosity of concrete, G. Girskas (2015) offered to use the polarizing microscope. Using this method the samples must be cut into 17±2 mm thickness plates. The plates must be washed with water and dried in 95° C temperature. Then the plates must be gridded by 10±1 mm. The gridline thickness must be 500 µm and length – 100 cm. During the test it's been studded how many pores are on the gridlines.

Unfortunately, for the estimation of the amount and type of aggregates in hardened concrete there is no non-standard method as well. For this reason a new method was created. The types of aggregates used in production of concrete paving blocks were estimated analyzing the cuts of blocks. Blocks were cut into two or three parts. The cut surfaces of concrete were scanned and the pictures were processed with the AUTOCAD software to sharpen the structure of concrete. The type of aggregates was evaluated visually: the oval stones were classed to gravel and angular stones to breakstone. Typically multangular stones with the darky grey or pink color classes to the granite breakstones and bright grey and bright yellow stoves classes to limestones. The diameter or side length of aggregates was estimated using loupe, milimetric ruler and AUTOCAD software (analyzing imported pictures of cut concrete paving blocks).

TEST RESULTS AND DISCUSION

As mentioned in Introduction one of the reasons, why concrete paving blocks started to deteriorate, can be that the existing composition of concrete does not suit the declared composition. The deteriorating paving zone, which had been built three years ago, was selected for the testing. The main object of the research was as follows: were all aggregates applied and appropriate amount of aggregates was applied during the production of concrete paving blocks. In some paving zone blocks structure and aggregates of concrete are visible (Fig. 1). Here dominates limestone.

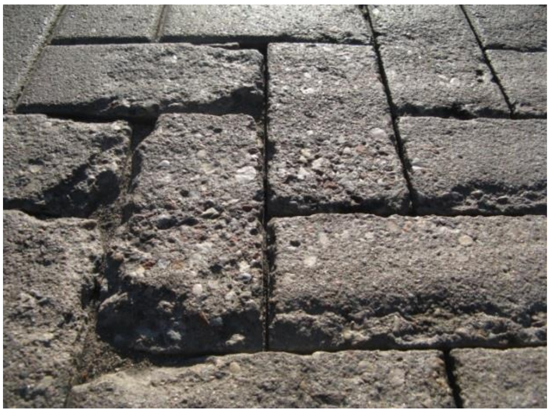

Figure 1. Visible structure and used aggregates (mostly limestone) of deteriorated concrete

According to the declaration of performance of concrete paving blocks the rated volumes of sand (fraction 0÷4 mm), gravel (fraction 2÷8 mm), granite breakstone (fraction 2÷8 mm) and crushed gravel (fraction 8÷16 mm) were calculated. The aggregates particles quantity was calculated in pieces and percent using mean values of different types of aggregates. The form of gravel particle equated to bowl and breakstone to cube.

At first, the amount of different aggregates in one concrete paving block was calculated. This calculation was made using the density of different rocks which compounds the aggregates (Table 1).

Table 1. The rated amount of different aggregates in one concrete paving block (Estimated according producer declaration of performance)

Aggregate	Sand (0÷4 mm)	Gravel (2÷8 mm)	Granite breakstone (2÷8 mm)	Crushed gravel (8÷16 mm)
Density *ρ*, kg/dm^3, g/cm^3	2.482	2.479	2.67	2.70
Mass *m*, g for one paving block	2807.89	1007.08	607.55	335.79
Volume $V = m/\rho$, cm^3	1131.3	406.2	227.5	124.4
Mean value of particle diameter *d* mm	1	5	-	-
Mean value of particle side length *a* mm	-	-	5	12
Mean value of one particle volume cm^3 (bowl shape $V_1=\pi d^3/6$; cube shape $V_1=a^3$)	0.0005233	0.065417	0.125	0.216
Number of particles $n = V/V_1$	2161857	6209.4	1820.0	575.77
Number of particles in gravel, granite breakstone and crushed gravel (6209.4+1820.0+575.8=**8605.2)**				
Amount of particles % from 8605 (8605=100 %)		72.16	21.15	6.69

The results show us, that evaluating the cuts of concrete paving blocks it is possible to estimate only the amount of large aggregates. In the cut of block must be 70.6 % of gravel (fraction 2÷8 mm), 22.3 % of granite breakstone (fraction 2÷8 mm) and 7.1 % of crushed gravel (fraction 8÷16 mm). To estimate the amount of sand particles (fraction 0÷4 mm) using visual method is hard due to very big amount of them.

Table 2. The real amount of different aggregates in one concrete paving block (Estimated according test results)

Sample No	The real amount of aggregates %		
	Gravel (2÷8 mm)	Granite breakstone (2÷8 mm)	Crushed gravel (8÷16 mm)
1	92.1	4.8	3.1
2	90.3	5.5	4.2
3	93.6	5.5	0.9
4	93.4	2.6	4.0
5	96.2	2.7	1.1
6	93.0	4.2	2.8
7	93.5	2.4	4.1
8	93.6	5.0	1.4
9	92.7	3.2	4.1
10	94.3	2.7	3.0
11	94.9	1.9	3.2
Mean value	**93.4**	**3.7**	**2.9**

The test results of real amounts of aggregates in one paving block are given in table 2 and comparison of rated and real amounts of aggregates is given in table 3.

Table 3. The comparison of rated and real amounts of aggregates

Parameter	Gravel (2÷8 mm)	Granite breakstone (2÷8 mm)	Crushed gravel (8÷16 mm)
Rated amount (*P*)	72.2	21.2	6.7
Real amount (*F*)	93.4	3.7	2.9
F/P	1.29	0.175	0.433
P/F	0.773	5.72	2.30

The test results (Table 2 and 3) show us, that main aggregate, used for concrete paving block producing, is gravel (fraction 2÷8 mm) and amount is 1.3 times higher than it was declared. While the granite breakstone (fraction 2÷8 mm) and crushed gravel (fraction 8÷16 mm) was used for production 5.7 and 2.3 times less, respectively. In this case the producer applying different amounts of aggregates (especially the most expensive and strongest aggregate granite breakstone (fraction 2÷8 mm)) reduced cost price as well as worsened the properties of concrete. This can be one of the main reasons of early concrete paving blocks deterioration.

During the test it was estimated, that the upper layer of concrete paving block was produced from other fine-graded concrete composition, while producer declared that only one concrete composition (not two like in Fig. 2) was used. In the upper layer of paving blocks the porous concrete (Fig. 2) is visible. It is known that porous concrete has higher water absorbability, lesser strength and frost resistance. Therefore, it can be the other reason of early concrete paving blocks deterioration.

Figure 2. Upper layer of concrete paving block was produced from other fine-graded concrete composition

CONCLUSIONS

Based on the obtained results the following conclusions can be drawn:

1. The structural test shows that the main early deterioration of paving blocks is the deflection from the rated concrete composition. The main aggregate, used for concrete paving block production, is gravel (fraction 2÷8 mm) and 1.3 times higher amount (than declared) of this aggregate was used. While the granite breakstone (fraction 2÷8 mm) and crushed gravel (fraction 8÷16 mm) were used for production 5.7 and 2.3 times less, respectively.
2. The producer applying different amounts of aggregates (especially the most expensive and strongest aggregate granite breakstone (fraction 2÷8 mm)) reduced cost price as well as worsened the properties of concrete. This can be one of the main reasons of early concrete paving blocks deterioration.
3. The upper layer of concrete paving block was produced from other fine-graded concrete composition, while producer declared that only one concrete composition was used. In the upper layer of paving blocks the porous concrete is visible. Therefore, it can be the other reason of early concrete paving blocks deterioration.

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