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Analysis of durability testing of concrete landscaping units

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HIGHLIGHTS

- Freeze-thaw resistance is the one of the main characteristics evaluating durability.
- Top paving layer affects the splitting tensile strength results.
- Abrasion resistance depends significantly not only on the cement content.

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ABSTRACT

In recent years the problem of the durability of vibrocompacted concrete products (landscaping elements, paving blocks in particular) has received great attention in Europe. In Easter Europe there are rather aggressive climate conditions (temperature fluctuations, humidity, precipitation, etc.). Besides, in winter concrete paving is treated with sodium, calcium, magnesium chloride salts that accelerate the deterioration of concrete paving block structure. European standard EN 1338:2003+AC:2006 that sets forth the basic requirements and test methods for concrete paving blocks does not take into account the performance of concrete products under specific climatic conditions. Therefore, it is important to determine the basic technological factors that influence the quality of vibrocompacted concrete, in particular freeze-thaw resistance, and to optimize the composition and other technological properties of vibrocompacted concrete. The freeze-thaw resistance of concrete has to be measured by different methods. The present paper describes the testing of concrete paving blocks, the top layer of which contained different amounts of cement ranging from 527 to 385 kg/m^3. The cement content in the bottom (support) layer compositions of all specimens remained the same – 371 kg/m^3. Density, freeze-thaw resistance according to two different methods, splitting tensile strength and abrasion resistance were measured in the tests.

1. Introduction

Concrete paving blocks are made by means of automated vibrocompaction technology, which involves almost complete displacement or air and a high degree of compaction. In this process the total porosity of concrete products is reduced to the highest extent and consequently water absorption is decreased. Water absorption rate influences the deterioration of concrete products as a result cyclic freezing and thawing in the cold season. Nowadays concrete block pavements have become an attractive engineering and economical alternative for flexible and stiff pavements. The properties such as strength, durability and aesthetically pleasing surfaces have made paving blocks attractive for many commercial, municipal, industrial surroundings and places such as parking areas, pedestrian walks, traffic intersections, and roads [1]. This type of paving is evaluated for being a hard surface which is aesthetically pleasing, comfortable to walk on, trafficable, extremely durable and easy to maintain. Paving blocks are manufactured in factory conditions, ensuring consistency and accuracy. After being situated with an edge restraint over a granular bedding course, individual blocks interlock and act compositely, thus ensuring even distribution of large loads. According to the requirements, concrete paving blocks are categorized into classes that are used for labelling. According to the class of the required resistance to atmospheric effects, it is recommended to ensure the durability in the country on whose market the product will be used [2]. The control of porosity parameters and entrained air content in concrete mix is essential in the manufacturing of concrete paving blocks; besides, higher freeze-thaw resistance requirements are applied for concrete paving blocks depending on the conditions where they are used [3]. Concrete pores can be closed by means of additions supplementing the concrete mix (the number of capillary pores will reduce and the number of closed pores will increase) and thus

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the durability of concrete will increase. Fine-grained structure enables to produce paving blocs of the most intricate form. Paving blocks are usually manufactured in two stages. Firstly, the form is filled with the bottom (supporting) layer of concrete, which is compacted; afterwards a top (finishing) layer is poured onto the compacted bottom layer. The bottom layer contains coarse aggregates up to 11 mm, the top layer contains only fine aggregates up to 4 mm. These products in Northern European climate zone are often exposed to severe climate conditions and cyclic freezing and thawing; the number of freeze-thaw cycles affects the durability of concrete paving blocks. In cold winter season (3–4 months when the temperature is below 0 °C) de-icing salts and sand-salt mixtures are used to melt snow and ice on roads and walkways. These de-icing mixtures accelerate the deterioration of concrete products [4]. Durability is one of the most important concrete product quality indicators in the Northern part of Europe.

According to Kallipi, the durability indicators of hardened cement stone mainly depend on the amount of cement used and water-cement ratio (W/C); the higher is the W/C, the poorer is the quality of concrete [5]. According to Mehta & Monteiro, the porosity of concrete, water content in the mix, environmental conditions and the type of aggregate are the main factors that influence the behaviour of concrete under cyclic freezing and thawing conditions [6]. Hardened cement paste, mortar and concrete are porous materials susceptible to the penetration of gas and liquids. Pores influence the properties of a material in many different ways. Compressive strength and elasticity are mainly affected by the total pore volume, pore size and distribution in the material, the size of the biggest pores, the form and interrelation of pores. Shrinking is mainly the function of energy exchange between the surfaces of pore walls that depends on the total surface area of a porous system. Durability depends on the resistance to freezing and thawing and is controlled by the volume of air entraining pores and the distance between them [7–8]. Water absorption of cementitious systems and resistance to freezing and thawing depends on the size of pores and capillaries, their type and distribution, and the closeness of pores. Closed and small pores do not fill with water completely. The pores that are not completely filled with water are called reserve pores. During freezing, part of the water from completely filled pores can move to these reserve pores and thus make a space for the expansion of ice. Distance between pores must be not big for the freezing water to move from filled to half-filled pores [9]. The resistance of hardened cement paste to freezing and thawing is reduced by open pores and capillaries that are formed after free water evaporates from hardened cement paste. The amount of such pores and capillaries depends on W/C ratio. The more water is added to the cement mix, the more water remains unbound in hardened cement paste and the more open pores are formed after the water evaporates [10].

There are several reasons that cause the deterioration of materials in cyclic freeze-thaw conditions [10–14]:

- Increasing hydraulic pressure of freezing water and subsequent increase in volume;
- Build-up and expansion of ice crystals in capillary pores;
- Osmotic pressure building as a result of the difference of alkali and salt concentration in the liquid phase;

The main cause for the degradation, cracking, scaling and crumbling of concrete is the increasing volume of water that freezes in the pores of concrete products. The density of water is 1 g/cm^3, and the density of ice is 0.917 g/cm^3. Ice takes 9% bigger volume compared to water. Ice crystals exert pressure on the walls of pores and capillaries of hardened cement paste and by expanding can disintegrate the concrete item [15–16]. Ice is a very strong material and its adhesion to hydrophilic materials, such as hardened cement paste, is very strong. W. Micah Hale with co-authors have found that water in capillary pores does not always freeze at 0 °C temperature. The freezing temperature depends on the size and type of pores. When pores are smaller, the temperature required for the pores to freeze also drops. For instance, in pores with the diameter of 10 nm water can remain unfrozen at −5 °C, whereas in pores with the diameter of 3.5 nm water will not freeze until the temperature drops to −20 °C [17–18]. Disintegration of hardened cement paste as a result of freezing and thawing is the most common case for the destruction of concrete products. Water-saturated hardened cement paste exposed to cyclic freezing and thawing can disintegrate like any other mineral solid body [10]. Surface scaling and cracking is the main type of deterioration of concrete exposed to de-icing salts. The most widely used de-icing salts are: NaCl (sodium chloride), $MgCl_2$ (magnesium chloride), and $CaCl_2$ (potassium chloride). Hardened cement paste treated with salt solutions deteriorates faster in cyclic freeze-thaw conditions due to osmotic pressure that accelerates the destruction process 4–5 times. The effect of de-icing salts is observed in road paving concrete, concrete landscaping elements, etc. [19]. Scientists all over the world conduct tests and experiments with concrete blocks, trying to make them more durable and resistant to atmospheric effects. Most of them are directed to waste materials utilization. There are a number of investigations done on concrete paving by adding marble waste to its composition. It is a popular topic of investigations done in the countries where marble is one of the main drivers of their economy. It is used to replace up to 40% of the coarse aggregate in the mixture [20–21]. There are a number of investigations done on concrete paving resistance to atmospheric causes. Basically, scaling caused by freeze-thaw cycles is the biggest problem. Ice melting salts aggravate this process [4,22]. The effect of osmotic pressure occurs due different concentrations of alkali or salts in the liquid phase when hardened cement paste is exposed to de-icing salts under cyclic freezing and thawing conditions [23]. According to J. J. Valenza II, the osmotic pressure is not the main reason for decreasing durability of concrete subjected to NaCl solution [24]. Researchers Hudec, Kaufmann, Marchand et al. have broadly analysed cyclic freezing and thawing with the use of salt solutions and their effect on concretes and hardened cement paste [23–27]. According to J. Marchand, J. Valenza and other researchers, the biggest negative effect caused by salts under cyclic freezing and thawing conditions is when 3% salt solutions are used [24,26–28]. According to J. Šelih, $CaCl_2$ solution has the strongest destructive effect on cementitious materials [19]. According to Sutter, $MgCl_2$ and $CaCl_2$ salt solutions are the most dangerous for the durability of bridge structures [29]. Researchers believe that pozzolanic admixtures, such as silica fume, fly ash and others are suitable for reducing corrosion of hardened cement paste [30–36].

The purpose of the investigation to determine the concrete paving blocks have top layer is used for different binder content (from 527 to 385 kg/m^3) properties, broken concrete paving blocks into three different density groups (low, medium and high). Identify concrete paving top layer abrasion strength changing amount of cement content, as well as identify, absorption resistance, tensile splitting strength and durability of two different methodology (unidirectional freezing and omnidirectional freezing), and to compare them with each other.

2. Materials and compositions

The following aggregates were used for the tests: granite screening 0/2, sand 0/2, sand 0/4, gravel 2/8, granite rubble 2/8. Portland cement CEM I 42.5 R was used as the binding material. Portland cement characteristics are presented in Table 1. Chemical composition of the cement is presented in Table 2.

Table 1
Portland cement characteristics.

Properties	Portland cement CEM I 42.5 R
Specific surface, cm^2/g	3720
Particle density, kg/m^3	3190
Bulk density, kg/m^3	1220
Standard consistency paste, %	25.4
Initial setting time, min	142
Final setting time, min	189
Compressive strength after 7 days, MPa	29.2
Compressive strength after 28 days, MPa	55.1

$198 \times 98 \times 80$ mm paving blocks were formed by means of vibrocompaction to test the properties of concrete. The paving blocks were hardened in the curing chamber for 7 days. The compositions of bottom and top layers of the paving blocks are presented in Table 3.

The composition of the bottom layer of concrete paving blocks in all 6 mixes was the same: cement 371 kg, gravel 2/8 – 408 kg, sand 0/4 – 1158, granite rubble 2/8 – 403 kg, W/C – 0.32.

6 different mixes were made for the top layer of concrete paving blocks. The main difference in the mixes was cement content that was changed from 527 to 385 kg/m^3. W/C ratio ranged from 0.38 to 0.26 respectively.

3. Test specimens and selection

Paving blocks were produced in the factory by means of vibrocompaction. The dimensions of the blocks were $198 \times 98 \times 80$ mm. Concrete mixes were made in two forced mixers: one mixer for the bottom layer and another mixer for the top layer. Firstly, the concrete mix for the bottom layer was placed into the forms and compacted (15–20 s, vibration force – 70 kN). Afterwards it was covered with the top layer. The formed paving blocks were cured in the curing chamber. After 7 days of curing physical and mechanical properties of the blocks were tested.

The vibrocompaction process results in the scattering of product properties. For this reason the tested paving blocks of each composition were divided into three density levels: low density, average density, high density. The average density of paving blocks, i.e. the overall average density of all tested paving blocks is (kg/m^3); low density is the average density minus 20 kg/m^3 and less; high density is the average density plus 20 kg/m^3 and more. This classification of densities was used in order to obtain more accurate results for further testing of abrasion resistance, splitting tensile stress, total absorption and freeze-thaw resistance. The quantity of sample, including a breakdown and the standard deviations is presented in Table 4.

4. Research methods

Durability properties of concrete paving blocks were tested according to the standardised methods (Table 5).

Freeze-thaw resistance of paving blocks was tested according to two different methods. The first method (unidirectional freezing) EN 1338+AC Annex D. A 3 mm-thick salt solution proof rubber sheet was glued onto the surface of all specimens, except for the control specimen. Before the freeze-thaw test, all surfaces of the specimens, except for the test surface, were thermally insulated with 20 mm-thick polystyrene sheets. 5–2 mm-thick layer of 3% NaCl solution was poured onto the test surface. To prevent evaporation the solution was covered with a polyethylene sheet. The freeze-thaw cycle was controlled in the automated freezing chamber with adjustable freezing temperature and duration. During the freeze-thaw test temperature was measured on at least one surface of the specimens. One cycle lasted 24 h with +20 °C max temperature, and −18 °C min. temperature achieved at the 16th hour of freezing. After 7, 14, 28, 42, 56 freeze-thaw cycles the specimens were taken out of the chamber and the test surface was washed/-cleaned. The spalled material (mass loss) was dried at 80 °C temperature. The second method used was omnidirectional freezing. Paving blocks were immersed into de-icing solution (3% NaCl) for complete saturation. Prior to freezing the blocks were removed from the solution and left for 2–4 h to drain the excess freezing solution. After draining the blocks were placed into special perforated containers and moved to the freezing chamber. −18 ± 2 °C temperature must be maintained in the centre of the freezing chamber; the freezing time must be at least 3.5 h. The specimens were thawed by immersing them into −18 ± 5 °C freezing solution for at least 3 ± 0.5 h. At least one freeze-thaw cycle shall take place during 24 h. After 200 freeze-thaw cycles the specimens are tested for compressive strength.

5. Analysis of test results

All properties and design quality of concrete depend on numerous factors: binding materials, water, aggregates, quality of additions, water-cement ratio, preparation of the mix, transportation and concrete placing technologies and setting conditions, curing time, etc. The mix must be designed and composite materials must be selected so that they would meet the requirement for concrete workability, strength, durability and density.

Three curves of density (low, average and high) are presented in Fig. 1. When 527 kg of cement is used for the top layer the density of paving blocks ranges from 2240 to 2390 kg/m^3, with the average density of 2311 kg/m^3. When cement amount is reduced to 412 kg/m^3, the density of paving blocks drops to the value of 2250 kg/m^3. With 389–385 kg of cement used for the top layer the density of paving blocks remains relatively even, namely 2308–2301 kg/m^3. It should be noted that W/C ratio was different in each mix composition and ranged from 0.26 to 0.38.

Moisture (absorption) resistance of concrete depends on the compaction of concrete mass, which, in turn, depends on the used chemical additives, i.e. plasticizers. The absorption rate must be very low to prevent the saturated water turning into ice and destroying the concrete structure from inside. For this reason paving blocks are produced from fine-grained concrete with water absorption rate below 6%, irrespective of the water absorption route (from the top surface or from the ground). For laboratory testing paving blocks are immersed into water and their total absorption is measured. According to the test results, the absorption of paving blocks with 527 kg of cement used for the top layer was 3.68–4.01% (Fig. 2). Water absorption rate increases with smaller amount of cement used and the maximum absorption rate of 4.6% is reached when 412 kg of cement is used for the top layer of the blocks. When 389–385 kg cement is used, water absorption rate in high density paving blocks is 3.42–3.42%, and in low density

Table 2
Chemical composition of the cement, %.

SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	SO_3	Na_2O	H_2O	MgO	Other
20.76	6.12	3.37	63.50	1.00	0.8	0.3	–	–	4.45

Table 3
Amounts of materials used for the top and bottom layers, 1 m^3.

Materials	Compositions						Bottom layer
	1	2	3	4	5	6	
	Top layer						
Cement, kg	527	468	464	412	389	385	371
Sand 0/2, kg	1058	1068	1059	1090	1150	1136	–
Sand 0/4, kg	–	–	–	–	–	–	1158
Gravel 2/8, kg	–	–	–	–	–	–	408
Granite rubble, 2/8, kg	–	–	–	–	–	–	403
Granite grit 0/2, kg	590	596	591	608	641	634	–
Water, kg	135	136	141	139	126	145	120
Plasticizer, kg	1.58	1.40	1.39	1.24	1.17	1.15	1.13
W/C	0.26	0.29	0.30	0.34	0.32	0.38	0.32

Table 4
Quantity of sample and standard deviations.

Compositions	1			2			3			4			5			6		
The quantity of sample	105			97			102			103			122			70		
Markings	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H	L	M	H
Density	105			97			103			103			70			122		
	27	52	26	19	62	16	18	59	25	24	50	29	29	63	30	17	35	18
Standard deviation	13.64	6.38	15.16	10.63	3.48	9.65	11.67	4.37	10.08	19.72	5.16	12.03	15.01	4.83	11.42	18.33	7.55	15.22
Absorption	30			30			30			30			30			30		
	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Standard deviation	0.23	0.18	0.18	0.33	0.27	0.22	0.33	0.24	0.45	0.35	0.41	0.54	0.18	0.22	0.44	0.25	0.21	0.34
Splitting tensile	30			30			30			30			30			30		
strength	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Standard deviation	0.25	0.24	0.27	0.22	0.33	0.24	0.16	0.18	0.15	0.21	0.19	0.15	0.28	0.29	0.19	0.44	0.32	0.33
Abrasion resistance (medium)	9			9			9			9			9			9		
Standard deviation	0.10			0.12			0.20			0.19			0.20			0.16		
Freeze-thaw resistance, unidirectional freezing, (medium)	7			7			7			7			7			7		
Freeze-thaw resistance, omnidirectional freezing (medium)	7			7			7			7			7			7		
Compressive strength (medium)	14			14			14			14			14			14		
Standard deviation after freezing	1.68			2.93			2.96			2.85			3.17			1.13		
Standard deviation before freezing	3.41			2.81			3.61			4.37			2.70			3.36		

*L – low density; M – medium density; H – high density.

Table 5
Conducted tests.

Property	Standard
Density	EN 12390-7
Total absorption	EN 1338+AC Annex E
Splitting tensile strength	EN 1338+AC Annex F
Abrasion resistance	EN 1338+AC Annex G
Freeze thaw and de-icing salt durability of solid concrete paving units	EN 1338+AC Annex D
Volumetric freezing and thawing of concrete	LST L 1428.17
Compressive strength of paving blocks	LST 1551:1999

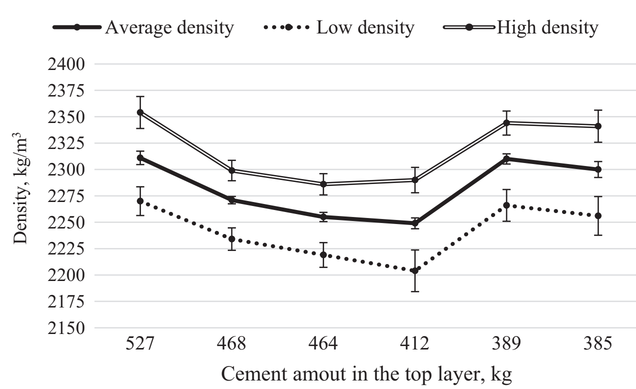

Fig. 1. Average densities of paving blocks.

paving blocks the water absorption rate is 4.05–4.22%. From the test results we may see that water absorption rate does not exceed 6% when either 527 kg or 385 kg of cement is used because the major part of a concrete block is taken by the bottom layer made of 371 kg of cement, whereas the top layer is only 6–10 mm-thick, i.e. it takes only about 10% of the thickness of the paving block. Consequently, the top layer does not have a significant influence on the total water absorption rate.

Standard EN 1338+AC, according to which the splitting tensile strength is tested, does not specify the tested specimen age in days in order to obtain the minimum splitting tensile strength of 3.6 MPa. In our case the paving blocks were cured for 7 days. The test results revealed that the minimum requirements for splitting tensile strength of more than 3.6 MPa were met by the specimens

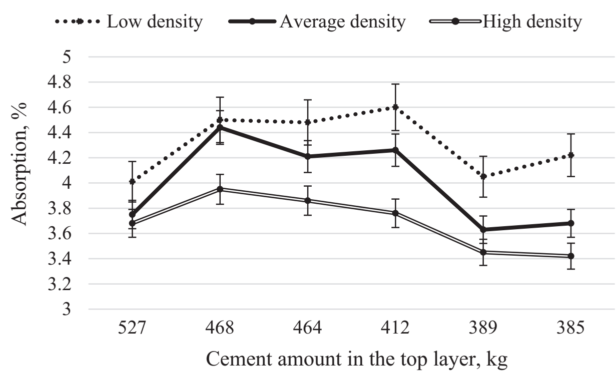

Fig. 2. Properties of paving blocks: total absorption.

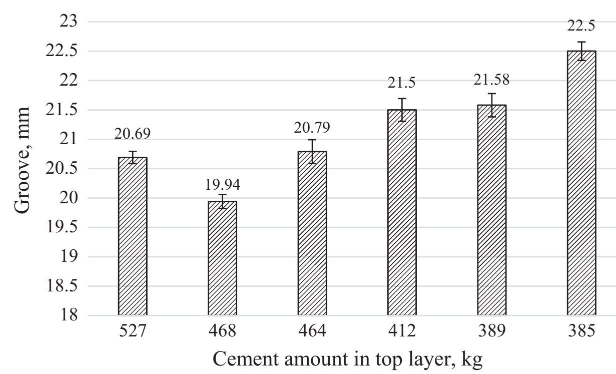

Fig. 4. Properties of paving blocks: abrasion resistance of the top layer.

where 527 kg cement was used; with lower amount of cement the splitting tensile strength dropped to 2.94 MPa; with 389–385 kg of cement used the splitting tensile strength is 3.53–3.42 MPa. In general, the splitting tensile strength changes from 3.68 to 2.94 MPa with different amounts of cement used (Fig. 3). Although the top layer takes only 10% of paving block thickness, it has an effect on the splitting tensile strength.

Abrasion resistance of paving blocks is one of durability properties. The surface layer of tested paving blocks was made of sand 0/4 and granite grit 0/2 mixed with different amounts of cement from 527 to 385 kg/m^3. Figure below shows that the groove width is 20.7 mm when the biggest amount (527 kg) of cement is used. When the amount of cement is reduced to 468 kg/m^3 the groove width slightly reduces to 19.9 mm. It may be related to slightly higher content of granite grit and sand with lower content of cement in the mix, with the same W/C ratio. When the amount of cement is reduced to 385 kg/m^3 the groove width increases up to 22.5 mm (Fig. 4). The test results showed that the best result is obtained when 468 kg/m^3 of cement is used for the top layer.

Freeze-thaw resistance is also an important property of concrete that influences the durability of concrete products and structures. Several test methods are used for freeze-thaw resistance: unidirectional (when freeze-thaw solution is poured on the top surface and all other surfaces are insulated) and omnidirectional (when the samples are subjected to freezing after being immersed in the freezing solution). The requirements for freeze-thaw resistance of concrete are applicable for those structures that are exposed to humid environment, water, recurrent positive and negative temperatures. Concrete paving blocks of exposure class XF3 and XF4 are mainly used. Freeze-thaw resistance of concrete depends most of all on water absorption (open capillary porosity). In unidirectional freeze-thaw test (EN 1338+AC Annex D), the highest mass loss was observed on the surface of specimens containing the smallest amount of cement (385 kg/m^3). A significant increase in mass loss is observed after 28 freeze-thaw cycles. After 56 freeze-thaw cycles the mass loss in specimens of this mix composition reached 0.35 kg/m^2. The least mass loss (0.05 kg/m^2 after 56 freeze-thaw cycles) was observed in the mix composition with the biggest amount of cement – 527 kg/m^2. The figure below illustrates that mass loss increases with smaller amount of cement used in the top level of paving blocks. According to LST L 1428 requirements, the test must be stopped when the drop in compressive strength becomes more than 5%. In our test the specimens were subjected to 200 freeze-thaw cycles. The compressive strength was measured before the test and after 200 freeze-thaw cycles. Prior to the freeze-thaw test the compressive strength of the specimens changed from 40.33 to 53.38 MPa. In specimens with 527 kg/m^3 of cement the compressive strength reached 45.32 MPa; in specimens with 468 kg/m^3 of cement the compressive strength reduced 5% (Fig. 5). This can be explained with increased W/C ratio up to 0.29% in the top layer of the paving blocks.

After 200 freeze-thaw cycles the compressive strength of paving blocks exposed to 3% NaCl solution in omnidirectional test was measured. The least drop in compressive strength was observed in specimens with the biggest amount of cement – 527 kg/m^3. This result was significantly influenced by W/C ratio 0.26. In specimens with 389 kg/m^3 cement the compressive strength reduced 5.6%. Although W/C ratio in these specimens was 0.32, the compressive strength dropped only 5.6% because the top layer contained the highest content of granite grits – 641 kg/m^3 and sand – 1150 kg/m^3 (Fig. 6). The compressive strength after 200 freeze-thaw cycles reduced most of all in specimens with 412 kg/m^3 of cement, and W/C ratio 0.34.

The Fig. 7 above illustrates the relationship between unidirectional and omnidirectional freeze-thaw testing in terms of mass loss (unidirectional) after 56 freeze-thaw cycles and drop in

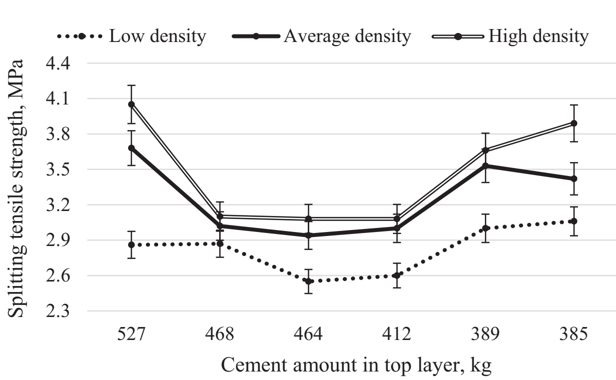

Fig. 3. Properties of paving blocks: splitting tensile strength.

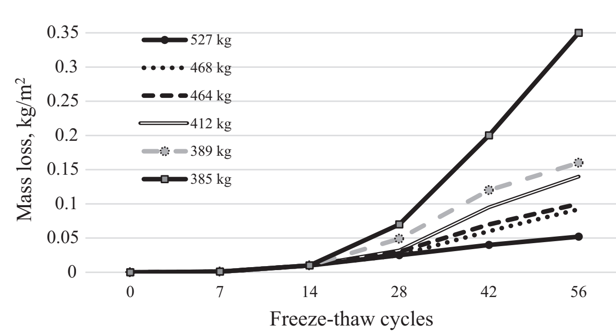

Fig. 5. Properties of paving blocks: unidirectional freeze-thaw resistance.

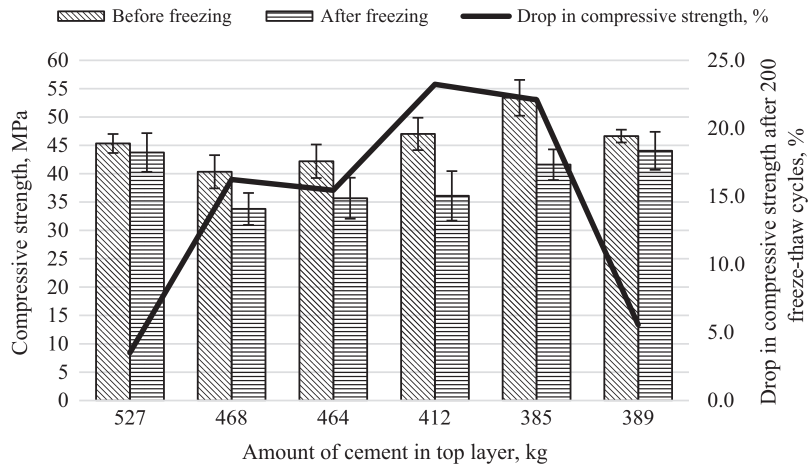

Fig. 6. Compressive strength of paving blocks.

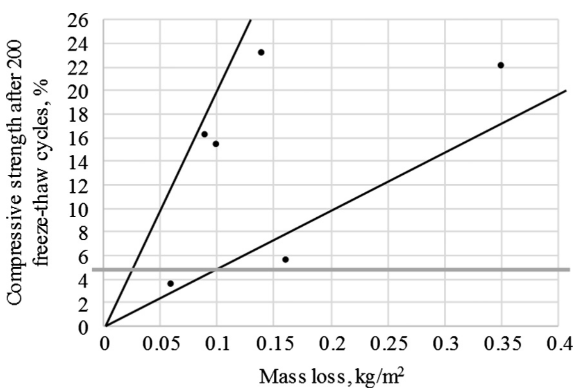

Fig. 7. Comparison of unidirectional and omnidirectional freeze-thaw testing methods.

compressive strength (omnidirectional) after 200 freeze-thaw cycles. The dotted line marks the 5% limit, above which the omnidirectional freeze-thaw testing should be discontinued. The curves in the figure show that mass loss above 0.1 kg/m^2 in unidirectional testing is equal to 5% drop in compressive strength in omnidirectional testing. According to EN 1338+AC the mass loss in paving blocks after 28 freeze-thaw cycles should not exceed 1.0 kg/m^2.

6. Conclusions

1. Paving blocks density test revealed that the highest density is achieved when 527 kg/m^3 of cement is used in the top layer of the block. Water content and W/C ratio have to be taken into consideration as they have a significant effect on the change in paving block density. The change in cement content did not have a meaningful effect on the total absorption of the top layer of the block because the top layer makes only 10% of the paving block thickness.
2. Although the top layer of the paving block is 8 mm-thick, it has an effect on the results of the splitting tensile strength test. The result of 3.6 MPa and above is reached when 527 kg of cement is used; with lower cement content the splitting tensile strength drops to 2.94 MPa. When 389–385 kg of cement is used, the splitting tensile strength is 3.53–3.42 MPa. In general, with different cement content the splitting tensile strength changes from 3.68 to 2.94 MPa.
3. It was found that abrasion resistance depends significantly not only on the cement content in the top layer but also on the aggregate content on the surface exposed to wear. With the highest content of cement, i.e. 527 kg, in the top layer the groove width was 20.7 mm; when cement content was reduced to 468 kg/m^3, the groove width slightly reduced to 19.9 mm. It can be related to the higher content of granite grit and sand with relatively the same water content in the top layer. When the amount of cement used is reduced to 385 kg/m^3, the groove width increases up to 22.5 mm.
4. Cement content is directly related to mass loss in unidirectional freeze-thaw test after 56 cycles. The least mass loss (0.05 kg/m^2) was with the highest content of cement 527 kg/m^3; when 385 kg/m^2 of cement is used the mass loss is 0.35 kg/m^2. The omnidirectional freeze-thaw test revealed that the least change in compressive strength (3.5% drop) after 200 freeze-thaw cycles occurs in the composition with the highest cement content – 527 kg/m^3. The drop in compressive strength slightly exceeded the 5% limit in the composition with 389 kg/m^3 of cement. It should be noted that the highest content of granite grits 0/2 – 641 kg/m^3 and sand 0/2 – 1150 kg/m^3 was used in this composition. The comparison of unidirectional and omnidirectional freeze-thaw testing methods leads to the conclusion that 5% drop in compressive strength (omnidirectional testing) is equal to 0.1 kg/m^2 mass loss on the specimen surface (unidirectional testing).

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