INFLUENCE OF THE GRANITE SCREENINGS TO THE PROPERTIES OF THE CONCRETE PAVING BLOCKS

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Abstract. The research deals with the granite screenings as fine aggregate influence on the technological properties of concrete mixtures and on the physical and mechanical properties and durability of concrete paving. The following several compositions of concrete mixture for the production of environment arrangements are researched: fine aggregate using only 0/2 fraction sand (B1), 10% of 0/2 fraction sand replacing with 0/2 fraction granite screenings (B2) and using only granite screenings (B3). Concrete mixtures were prepared in the laboratory, and concrete paving blocks – in the factory. The technological properties of concrete mixtures and physical and mechanical properties of concrete paving blocks (made from the mentioned concrete mixtures) were determined; the durability of the products in the cycles of frost resistance was forecasted. The research results reveal that due to the properly selected ratio between sand and granite screenings in the fine aggregate, the characteristics of concrete paving blocks are better than using only sand as fine aggregate.

Keywords: granite siftings, concrete paving blocks, tensile splitting strength, abrasion resistance, frost resistant.

1. Introduction

There is huge amount of granite screenings, which is being accumulated by producing granite rubble. One way how to utilize these production wastes is to use them as fine aggregates for producing paving blocks. This research deals with the usage of granite screenings as fine aggregates for producing those concrete elements, used for paving top layers.

Scientists Tung – Chai, Hasanan (2006) have made a research on the influence of adding wastes gained from used automobile tires (rubber fraction: 0/2, 0/3 and 0/6) to the properties of concrete paving blocks. Rubber wastes of 0/2 fraction were added (changed) accordingly, from 0 to 30% in respect of sand of 0/4 fraction as fine aggregates, rubber wastes of 0/3 and 0/6 fraction – 10% in respect to sand 0/4 as fine aggregates. The results have shown that by changing fine aggregate – sand of 0/4 fraction accordingly from 0 to 30% and putting rubber wastes of 0/2 fraction the compression strength of the concrete specimens was decreasing gradually. In order to get higher compression strength of concrete specimens it would be necessary to use chemical admixtures, which would improve the spread of rubber at concrete mixture. The least slip of concrete paving blocks is obtained by changing 10% of sand as fine aggregate of 0/4 fraction by adding rubber wastes of 0/3 and 0/6 fraction. By the increase of the amount of rubber wastes, the slip of concrete paving blocks also increases, but not exceeds the slip rate, which is obtained without addition of rubber wastes.

Scientists: Čiurlionis, Ivanauskas (2009) have made the research on the influence of shiver ashes to the properties of concrete paving blocks. This re-

search was based on changing the amount of cement accordingly from 5 to 30% by shiver ashes. Based on the results, by changing 5% of the amount of cement by shiver ashes, which density of the particles is 10% less in respect to cement particles, the mechanical and physical properties (density, water absorption, tensile strength by splitting, etc.) of formed specimens do not vary a lot, compared to the reference specimen. By evaluating the visual appearance of the concrete specimens it can be said that the surfaces are smoother, especially the corners of the specimens (cracks are not obtained). The authors also said that the increase of shiver ashes is not rational. At the moment, the price of shiver ashes is half less compared with cement, so it is obvious that the final price of the paving blocks can be decreased.

All the concrete elements including paving blocks should be durable. The resistance to freezing – thawing is one of the methods for evaluating the concrete durability. The resistance to freezing – thawing is especially important for the concrete elements, which are affected by the freezing – thawing cycles or by water with ice melting salts (Naujokaitis 2007; Skripkiūnas 2007).

Many scientists link resistance to freezing – thawing cycles to the opened porosity of the concrete (water absorption according to the mass to the specimen), but at the same time they say that this one parameter is insufficient for predicting the concrete's resistance to freezing – thawing cycles (Gurskis 1996). The big influence on the concrete's resistance to freezing – thawing cycles is being made by the density and the compression strength of the concrete (Grabiec, Piasta 2004; Tumosa *et al.* 2010). Attiogbe (1996) also says that open porosity greatly influences concrete's resistance to freezing – thawing cycles. According to Marčiukaitis (2000), test of strength of the affected concrete specimens with the same compression strength, but different water absorption rate, shows that bigger destruction is obtained by specimens with bigger water absorption rate. Scientists Gumuliauskas, Abromavičius (2001) say that the compression strength of the concrete is increasing while the certain concentration of course aggregates is reached, after that – compression strength decreases. Usually, the biggest compression strength is obtained then the concentration of the course aggregates is around 50%.

The destruction of the concrete due to the effect of freezing – thawing cycles is especially important in Lithuania, because of the contrasting weathers. The test of the concrete's resistance to freezing – thawing cycles is very sophisticated process, which requires a lot of money and time. One simpler method to know the concrete's resistance to freezing – thawing cycles is the determination by prognostication.

The concrete porosity parameters can be evaluated by measuring the kinetic of water absorption as given at this methodology (*GOST 12730.4–78*). According to this method, opened concrete porosity, as well as, total porosity (entrained air content) is evaluated. Also following parameters of pores size are determined: λ – index of concrete pore rate of medium size and α – index of uniformity rate of concrete pores. This method is widely used for determination of concrete pores structure and for resistance to freezing – thawing cycles (Shejkin, Dobshits 1989). The same method was used in USA for prognostication of concrete's durability (Attiogbe 1996).

Scientists Sodienė, Kriščiūnienė (2008) says that it is easier to calculate main components of concrete mixture by evaluating the ratio of surface areas of course and fine aggregates. It is so, because despite of the same ratio of mass of the aggregates, the surface areas can differ a lot. Also the results have shown that for the high strength concretes (C35/45 or higher) it is advisable to change fine aggregate by coarse granite rubble screenings up to 25%. By doing this, the compression strength of concrete increases up to 10 MPa. It is not recommended to add granite screenings in to the concrete mixture in order to obtain the concrete with small opened porosity.

2. Methods and materials of the research

Portland cement – CEM I 42.5 R, which was produced by AB "Akmenes cementas" was used for the research. Water consumption for normal cement paste consistency was 24.6%. Surface area of the cement particles was 360 m²/kg, density of the particles was 3110 kg m³ and bulk density was 1220 kg/m³. Sand and granite screenings were used as a fine aggregate: respectively bulk density: $\rho = 1550$ kg/m³ and $\rho = 1600$ kg/m³; fracture of the particles was the same for both – 0/2. Granite rubble was used as a course aggregate: bulk density – $\rho = 1380$ kg/m³; fracture of the particles – 5/8. The granulometry of the aggregate's particles is shown at the Table 1. As a superplasticizer REBAmix 750 (BV) was used for the research (0.9% in respect to the mass of cement).

Table 1. Granulometric composition of aggregates

Dimensions of sieve holes, mm	Sum of the passing particles, %		
	0/2 fracture sand	0/2 fracture granite screenings	5/8 fracture granite rubble
11.2	–	–	100
8	–	–	93.71
5.6	–	–	11.59
4	100	100.00	4.54
2	96.99	87.64	0.56
1	84.87	54.16	
0.71	75.49	44.83	
0.5	61.82	35.50	
0.25	25.89	18.58	0.13
0.125	2.96	5.63	
0.09	1.42	3.42	
0.063	1.06	0.96	
Content of the materials on the bottom of vessel	0.92	0.08	

Concrete mixtures were prepared in the laboratory by the forced mixing mixer. Cement and dry aggregates were dosed by mass, water and chemical admixture – by volume. Chemical admixture was mixed together with the water, which was used for the concrete mixture.

Concrete paving blocks, size of 125×125×70 mm, were formed by the vibro–pressing machine – "Compacta AB–100" in the factory. Concrete paving blocks were cured for 28 days in the water with temperature of 20±2 ºC.

Density of the concrete mixture was determined by LST EN 12350–6 methodology, Vebe rate – LST EN 12350–3, compaction rate – LST EN 12350–4. Density of the concrete – LST EN 12390–7, dimension deviations of the paving blocks, water absorption and tensile strength by splitting is determined by LST EN 1338, mass abrasion of the paving blocks – LST 1428.15, porosity parameters of the concrete are determined by the kinetic of water absorption according to GOST 12730.4–78 methodology.

This research deals with the influence of granite screenings as fine aggregates, to the technological properties of the concrete mixture. In addition, the influence of granite screenings to the physical and mechanical properties of formed paving blocks is established.

3. Results of the research

Concrete mixture with the strength class of C35/45, was designed for this study. Several types of concrete mixtures were tested: 0/2 fraction sand as a fine aggregate only (B1), changing 10% of sand by volume to the granite screenings of 0/2 fraction (B2), and the third – using granite screenings of 0/2 fraction as a fine aggregate only (B3) (see Table 2).

Table 2. The compositions of concrete mixtures

Materials	Amount of the materials for 1 m^3 of concrete mixture, kg		
	B1	B2	B3
Cement CEM I 42.5 R	443	443	453
Water	142	142	145
W/C	0.32	0.32	0.32
0/2 fraction sand	1177	1025	–
0/2 fraction granite screenings	–	152	1166
5/8 fraction granite rubble	738	738	733
REBAmix 750 (BV)	4.0	4.0	4.1
Density of the concrete mixture, kg/m^3	2504	2504	2501

3.1. Technological properties of the concrete mixtures

Compaction and Vebe rates of the concrete mixtures in respect to the mixture's composition are shown at the first figure.

As shown in Figure 1, the compaction rate of the concrete mixtures varies from 1.39 to 1.45. Following by these compaction rates, the concrete mixture's class is C1 according to the standard LST EN 12350–4. As shown in Figure 2, the Vebe rate varies from 16.3 to 13.7 s.

According to the Vebe rates, this composition of concrete mixture is assigned to V2 class with reference to LST EN 12350–3 standard. The least compaction and Vebe rates are obtained by using sand, fraction of 0/2 as fine aggregate only (B1), meanwhile the biggest rates – using granite screenings, fraction of 0/2 as fine aggregate only (B3).

Density values of concrete mixtures in respect to their compositions are given in the second figure. The second figure shows that the biggest density is obtained by using sand (fraction of 0/2) as fine aggregate only (B1), meanwhile the least values – using granite screenings (fracture of 0/2) as fine aggregate only (B3).
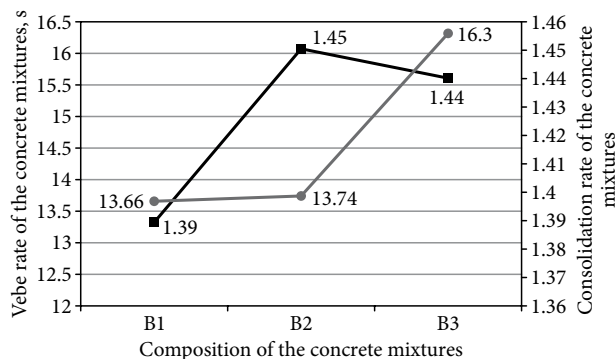
Fig. 1. The change of concrete mixtures consolidation and Vebe rates in respect to the composition of the mixture
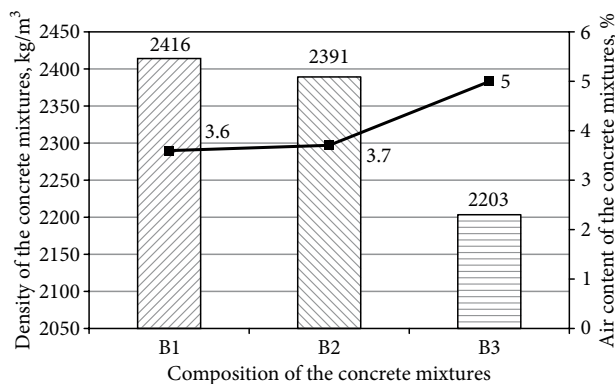

Fig. 2. The change of concrete mixtures density and air content rates in respect to the composition of the mixture

The second figure also shows that the additional air content is obtained by using granite screenings as fine aggregate. This happens, because the particles of granite screenings are finer and rougher compared with the sand particles. The biggest air content is obtained by using granite screenings as fine aggregate only (B3 composition), meanwhile the least – using only sand as fine aggregate (B1 composition).
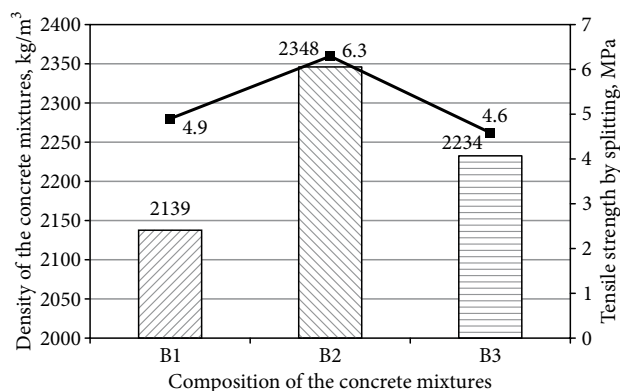
3.2. Physical and mechanical properties of the concrete paving blocks

Figure 3 shows the density and tensile strength by splitting of formed concrete paving blocks. The biggest density value is obtained by changing 10% of sand to granite screenings (as fine aggregate). The change was performed by volume (B2 composition). The least density value is obtained by using sand (fracture of 0/2) as fine aggregate only (B1 composition). Such a dispersion of density shows that the structure of paving blocks was not fully formed and it was due to the lack of vibro–pressing time.

Figure 3 also shows the tensile strength of concrete paving blocks performed by splitting. The results show that the biggest tensile strength value is obtained by using 90% of sand, fraction of 0/2, and 10% of granite screenings, fraction of 0/2, as a fine aggregate (B2 composition). On the other hand, the least value of tensile strength is obtained by using granite screenings, fraction of 0/2, as fine aggregate only (B3 composition).

Figure 4 shows the dependence of water absorption and concrete mixture composition. According to the information from the Figure 4, the least value of water absorption is obtained by changing 10% of sand to granite screenings as fine aggregate (B2 composition), meanwhile the biggest rate of water absorption is obtained by using sand as fine aggregate only (B1 composition). These results could be obtained, as mentioned above, because the structure of the concrete paving blocks was not fully formed.

Water absorption rate of concrete paving blocks, formed of concrete mixture with sand as a fine aggregate only (B1 composition) has exceeded the value of 6.27%.
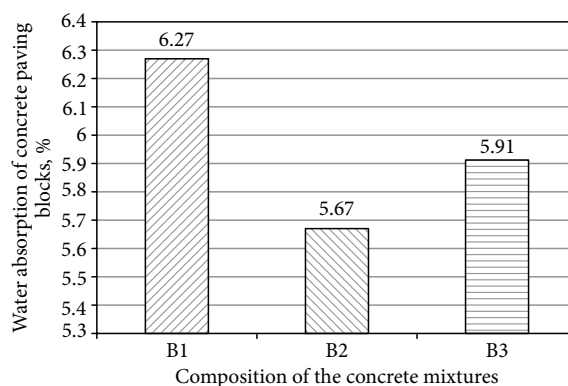

Fig. 3. The change of density and tensile strength by splitting of formed concrete paving blocks depending on the composition of the mixture

Fig. 4. The change of total water absorption of concrete paving blocks depending on the composition of the mixture

This was not allowed by the standard – LST EN 1338, which says that the rate of water absorption must not exceed the value of 6%. On the other hand, water absorption rate of concrete paving blocks, formed of concrete mixtures B2 and B3, did not exceed the value of 6%.

Concrete porosity parameters were obtained by measuring the kinetics of water absorption according to GOST 12730.4–78. By using this method opened (capillary) porosity, total porosity and closed porosity (entrained air) values were calculated. Following parameters were calculated as well: λ – index of concrete pore rate of medium size and α – index of uniformity rate of concrete pores (Table 3).

According to (Shejkin, Dobshits 1989) methodology, it is possible to forecast the resistance to freezing – thawing cycles:

$$K_{\check{s}} = \frac{P_u}{0,09 \cdot P_a},$$

where: $K_{\check{s}}$ – The criterion of concrete's freezing – thawing resistance; P_u – closed porosity of concrete (air content in the concrete), %; P_a – opened (capillary) porosity of concrete, %.

Table 3. Porosity parameters of concrete paving blocks

Composition of concrete mixtures	Water absorption, %	Porosity, %			Index of porosity	
		total	opened	closed	λ	α
B1	12.06	19.35	12.06	7.29	0.28	0.93
B2	9.91	11.25	9.91	1.34	0.10	0.52
B3	4.90	15.10	10.98	4.11	0.10	0.36

Table 3 shows that the biggest opened porosity of concrete paving blocks is obtained by using concrete mixture of B1 composition (only sand as fine aggregate). This is a clear evidence that the concrete structure was not fully formed due to the lack of vibro – pressing time. The least value of open porosity is obtained by forming the concrete paving blocks from the B2 concrete composition (fine aggregate: 10% granite screenings; 90% sand).

When $K_{\check{s}}$ – coefficient of concrete freezing –thawing is known, it is possible to predict how many cycles of freezing – thawing will the concrete withstand. As the fourth table shows, all the paving blocks made from concrete compositions: B1, B2 and B3 have more than 200 cycles of freezing – thawing (Table 4). It can be said that for paving block made from the B1 con-

Table 4. The criterion of frost resistance of concrete and forecasting frost resistance of concrete

Composition of concrete mixture	$K_{\check{s}}$	Forecasted freezing – thawing cycles
B1	6.71	>200
B2	1.50	200
B3	4.16	>200

crete composition, the calculated freezing – thawing cycles can be not very precise, because the lack of vibro – pressing time.

Figure 5 shows the abrasion of the concrete paving blocks. The biggest abrasion of concrete paving blocks is obtained by using granite screenings as fine aggregate only (concrete mixture composition B3), meanwhile the least abrasion value is obtained by using sand as fine aggregate only (concrete mixture composition B1).

Figure 6 shows how the specimens looked like after the abrasion test. Paving block formed of B1 concrete mixture composition had the smoothest surface area, meanwhile paving block made from B3 concrete composition had the most scratched surface area.
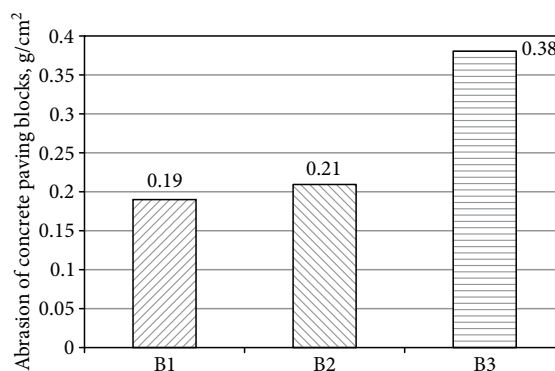
Fig. 5. The change of mass abrasion of concrete paving blocks depending on the composition of the mixture

On the basis of the results of this research, by adjusting the right ratio between granite screenings and sand as fine aggregate, it is possible to get formed concrete elements with the better properties than compared with those using only sand or granite screenings as fine aggregate.

4. Conclusions

1. Vebe rates of the concrete mixtures satisfy the class of V2, compaction rate satisfies the class of C1. All the concrete compositions were projected for the
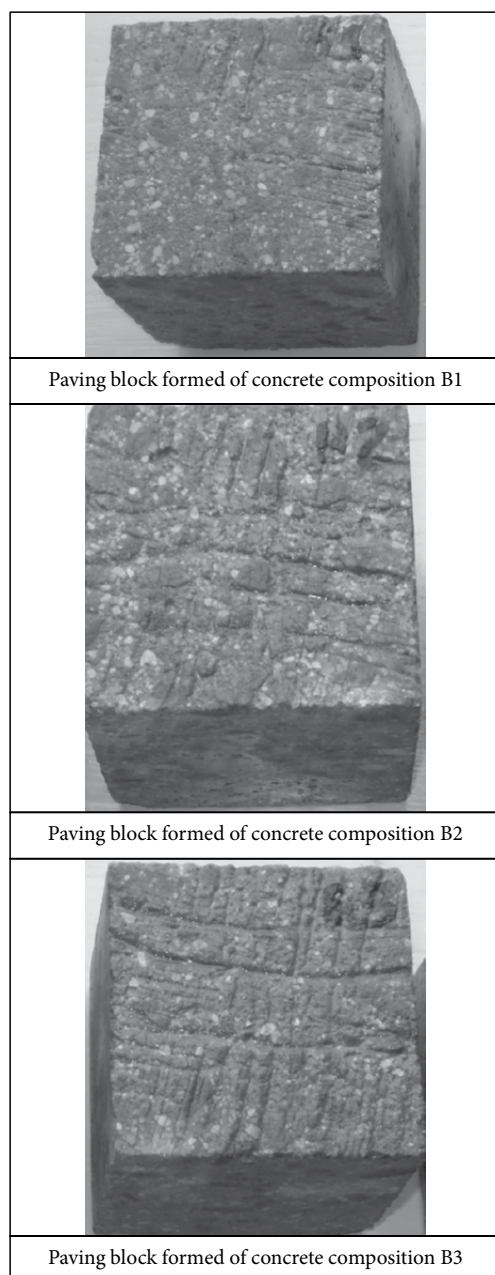
Paving block formed of concrete composition B1

Paving block formed of concrete composition B2

Paving block formed of concrete composition B3

Fig. 6. The semblance of specimens after the abrasion test

4. The value of water absorption of concrete paving block made of B1 mixture composition was obtained bigger that 6.27%. It is forbidden by the requirements of LST EN 1338 standard. According to LST EN 1338 standard, the maximum water absorption available is 6.0%. Water absorption of paving blocks made of B2 and B3 concrete mixture composition did not exceed the value of 6%.

5. The biggest open porosity of paving blocks is obtained by forming them from B1 concrete mixture composition. On the other hand, the least open porosity is obtained using B2 concrete mixture composition.

6. Forecasted cycles of freezing – thawing of concrete paving blocks exceed the value of 200 and that fits the requirements for the concrete environment elements.

References

Attiogbe, E. K. 1996. Predicting freeze–thaw durability of concrete – a new approach, *ACI Materials Journal* 93(5): 457–464.

Čiurlionis, P.; Ivanauskas, E. 2009. Skalūnų pelenų įtaka betono trinkelių savybėms, iš *Jaunimas siekia pažangos*: doktorantų mokslinės konferencijos straipsnių rinkinys. Vol. 3. LŽŪU, 181–185.

Grabiec, A. M.; Piasta, Z. 2004. Study on compatibility of cement – superplasticiser assisted by multicriteria statistical optimization, *Journal of Materials Processing Technology* 152(2): 197–203.
http://dx.doi.org/10.1016/j.jmatprotec.2004.03.020

Gumuliauskas, A.; Abromavičius, G. 2001. Užpildų įtaka betono struktūros dalių stiprumui, iš *Betonas ir gelžbetonis*: konferencijų pranešimų medžiaga. Kaunas: Technologija, 41–45.

Gurskis, V. 1996. Ryšiai tarp betono atsparumo šalčiui ir struktūros rodiklių, iš *Hidroinžinerija ir žemėtvarka*: tarptautinės mokslinės konferencijos, įvykusios Kaune, pranešimų medžiaga. Kaunas: Technologija, 54–57.

Marčiukaitis, G. 2000. Betono mišinio sudėties ir kokybės įtaka konstrukcijų standumui ir pleišėtumui, iš *Betonas ir gelžbetonis:* konferencijos pranešimų medžiaga. Kaunas: Technologija, 36–41.

Naujokaitis, A. 2007. *Statybinės medžiagos. Betonai*: mokomoji knyga. Vilnius: Technika. 356 p.

Shejkin, A. E.; Dobshits, L. M. 1989. *Tsementnye betony vysokoj morozostojkosti*. Leningrad: Strojizdat. 128 s.

Skripkiūnas, G. 2007. *Statybinių konglomeratų struktūra ir savybės*. Kauno technologijos universitetas. Kaunas: Vitae litera, 311–318.

Sodienė, V.; Kriščiūnienė, S. 2008. *Superplastikliu Muraplast FK61 modifikuoto hidrotechninio betono savybės*: Technologijos mokslo darbai vakarų Lietuvoje. Vol. 6. Klaipėdos universiteto leidykla, 131–136.

same class of consistency. It was obtained that by increasing the amount of granite screenings, fraction of 0/2, the density of concrete mixture was decreasing.

2. The tensile strength by splitting of all formed concrete granite paving blocks is bigger than the value of 3.6 MPa. That satisfies the requirements of LST EN 1338 standard.

3. The structure of concrete paving block made from B1 mixture composition was not fully formed due to the lack of vibro – pressing time.

Tumosa, M.; Daukšys, M.; Ivanauskas, E. 2010. Granito atsijų įtaka apdailinių skelto paviršiaus betono plytų savybėms, *Mokslas – Lietuvos ateitis* 2(6): 43–49. ISSN 2029–2341.

Tung – Chai, L.; Hasanan, Md. N. 2006. Granulated waste tyres in concrete paving block, in *Proc. of the 6th Asia – Pacific Structural Engineering and Construction Conference (APSEC 2006), 5–6 September 2006, Kuala Lumpur, Malaysia.*

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