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Physical and Mechanical Properties of High-Strength Heavy Concrete Using Recyclable Asphalt Waste

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Abstract: *In this research the authors research of the physical and mechanical properties of high-strength heavy concrete and improve the quality of concrete constructions. High-strength heavy concrete that have a water/binder ratio between 0.500 and 0.60 are usually more durable than ordinary concrete not only because their capillarity and pore networks. So, the concrete sample specimens were tested for physical and mechanical properties which are related to durability.*

Key words: *asphalt waste, high-strength heavy concrete, Aggregate, durability, physical and mechanical properties*

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Introduction

Asphalt waste is a waste product generated during the replacement of road surfaces, which can be used, for instance, for roadside hardening. The Minister of Climate and Environment has signed a regulation to clarify the conditions for losing the waste status for asphalt waste so that it can be reused in new mineral and asphalt mixes as a partial substitute for aggregate. The change in the regulations will make it possible to manage the generated road rubble and allow savings on road upgrades, which over the next few years could amount to as much as PLN 300m.

The regulation of the Minister of Climate and Environment is the result of two years of work and cooperation with the construction industry and the General Directorate for National Roads and Motorways (GDDKiA). Thanks to the new regulation, the regulatory burden on entrepreneurs will be reduced. This, in turn, will contribute to the simplification of administrative procedures related to obtaining permits for reusing materials classified as construction waste. The new regulation takes into account the PN-EN 13108-8:2016-07 standard, which sets out the requirements for the classification and characterization of asphalt destructor as an essential material for mineral and asphalt mixtures.

Aggregate must be selected carefully for high strength mixes, as weaker aggregates may not be strong enough to resist the loads imposed on the concrete and cause failure to start in the aggregate [1, 2, 3]. It can be noted, that weaker aggregates are not a suitable component for preparing concretes with designed compressive strength higher than 30 MPa. A variety of cements were used CEM I 32.5 and CEM I 42.5.

Materials and Methods

Portland cements CEM I 42.5 and CEM I 52.5 from Jizzakh Cement Plants as per PN-EN 197 were used. As NA, mountain sand and rock of 0,16-2,5 mm and 2,5-5 mm fractions were Sangzar river and Coarse aggregate 5-70 mm from Forish places. Aggregate fulfilled requirements of RCAC II (acc. to DIN 4226-100) and type A (acc. to PN-EN-206:2014). Coarse aggregates has been sieved into fractions of: 5-10, 10-20 and 20-40 mm. Natural aggregate fractions of 0,16-2 mm and of 2,5-5 mm were used together with 5-10 mm and 10-20 mm fractions of RCA. Natural aggregate was used at air-dry condition. It had been weighted and saturated with water, in an amount of 3.6 % of its air-dry weight. Water reducer Muraplast FK 88 was used. Regular tap water was used as mixing water.

Asphalt waste collected during the renovation or construction of new roads contains around 95% aggregate. This means that it is a high-quality material that can be reused in newly laid asphalt mixtures as a partial substitute for aggregate. It can also be used to harden shoulders, road foundations and for the construction of service roads, access roads and exits. The regulations that have been in force so far, limited the possibility of recycling asphalt waste.

It is worth noting that the rehabilitation of 10 km of a two-lane motorway, during which the wearing course is replaced, generates 23 thousand tonnes of asphalt rubble of the highest quality aggregate. The rehabilitation of the wearing course for expressways is performed regularly every 12-15 years.

Table 1. Proportions of concrete mixtures [kg/m3]

Material denomination	N-1	N-2	N-3	N-4
CEM I 32.5	300	300		
CEM I 42.5			300	300
metakaolin	20	20	20	20
natural sand 0,16-2,5	260	260	260	260
natural sand 2,5-5	280	280	280	280
Coarse aggregates 10-40	600	400	600	400
Coarse aggregates 40-70	600	800	600	800
water	150	180	150	180
W/C*	0.50	0.60	0.50	0.60

Four concrete mixtures were prepared. They contained 300 kg/m^3 of CEM I 32.5 and CEM I 42.5 cement were used, together with metakaolin in an amount of 4 and 8%. Mix proportions are presented in Table 1. The workability of concrete mixtures was measured by flow table test, in accordance with PN-EN 12350-5.

Compressive and Tensile Strength Test

Specimens were prepared and cured as per PN-EN 12390-2. They were cast in steel moulds and underwent double compaction on vibrating table. After 2 days the specimens were demoulded and water-cured in the laboratory till the age of 28 days. The compressive strength tests were conducted in accordance with PN-EN 12390-3 on 100 mm cube specimens after 28 and 90 days of hardening. The tensile splitting strength tests were conducted on the same type of specimens in accordance with PN-EN 12390-6.

Results and discussion

Research results are presented in the Table 2 and 3. The results are mean values of four measurements. Only for fresh concrete mixtures, the result of flow is an average of three measured values.

Table 2.

Concrete Cubic Strength Results

Mixes	Concrete Cubic Strength, MPa					
	7 day	14 day	28 day	60 day	90 day	180 day
Control	19	24	39	45.5	56	67.1
Mix 1	22.1	25.1	40	49.9	61	67.2
Mix 2	20.5	26	48.1	49.8	64	69.87
Mix 3	20.6	28	48.9	60	65.2	69
Mix 4	25	28.9	50	58.8	65.5	72.1

Table 3.

Results of flexural strength of concrete

Составы бетонов	Flexural strength of concrete, MPa					
	7 day	14 day	28 day	60 day	90 day	180 day
Control	3.5	3.8	4.0	4.9	5.21	6.76
Mix 1	3.78	4.03	4.7	5.7	5.89	6.77
Mix 2	3.98	4.34	4.76	5.78	6.03	6.54
Mix 3	3.99	4.56	5.12	6.09	6.45	6.78
Mix 4	3.67	4.9	5.02	6.96	7.05	7.13

Compressive Strength of Concrete

The highest value of mean compressive strength 40 MPa was obtained for N-1 series containing CEM I-32.5 cement. This mixture reached also the highest compressive strength of 61 MPa after 90 days, which means a strength gain of 23 % due to post hardening. A significant gain in compressive strength from 39 MPa after 28 days to 56 MPa after 90 days. Mixtures N-1 and N-4 did not obtain surprising gain in strength between 28 and 90 days, they were 15%, and 16% respectively. The difference was mainly the result of using 2,5-5 mm fraction of natural aggregate in N-3 concrete series instead of the same fraction in N-3 concrete. This explains the requirement in EN-206 standard which exclude 0,16-5 mm fractions of aggregate from the usage in concrete production. MIX 2 and N-3 shows good results in a 64 and 65.7 MPa. At the same time if this strength decrease due to the fine aggregate is compensated, than the authors would not exclude [4, 5].

Tensile Strength of Concrete

In accordance with the compressive strength values, the highest splitting tensile strength after 28 days could be measured on the concrete out of N-1 mixture, which was 4.7 MPa. After 90 days the highest measured splitting tensile strength obtained was for concrete out of N-1 mixture, which was

5.89 MPa. The mean splitting tensile strength of the concretes is 5,89 MPa. The average value for all concrete is 5.41. These are typical values for concrete of that level of average strength.

Summary and Conclusions

In the paper it has been shown that it is possible to produce a high-strength heavy concrete with a targeted 61 MPa mean compressive strength at the age of 28 days and of more than 65 MPa after 90 days. Good durability influencing properties could be measured at the same time by the usage of coarse aggregate of an average quality. The increase in strength between 28 and 90 day of laboratory ambient conditions curing shows that test after more than 28 days period reflects better the actual properties of the tested concretes. This applies to both the mechanical properties and to those which are associated with durability. The limit of 5 % of water absorption is practically impossible to meet [6]. Replacing 2.5-5 mm fraction of natural aggregate caused slight worsening of most of the concrete durability properties.

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