High-Performance Concrete Using Dolomite By-products

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INTRODUCTION

Dolomite is the widespread sedimentary rock that finds a wide application in building industry and road engineering. During the treatment of dolomite rocks, a huge amount of fine fractions (0…8 mm) are produced and classified as by-products due to the limited range of applications. For example, nowadays more than 400 000 - 450 000 t dolomite by-products are deposited in a single quarry and the annual increase of this material is 50 000 t.

There have been efforts to incorporate dolomite residues as an aggregate and micro filler component in concrete mixes [1]. There is research that reports how carbonate micro filler accelerates the rate of hydration [2]. It was proved that the positive effect of the dolomite quarry by-product takes place for self-compacting concrete (SCC). It determines the necessary paste content and provides the consistency of SCC mixes [3]. Also, dolomite by-product has been tested as filler in the lightweight concrete made of expanded clay aggregates and the incorporation of dolomite by-products improved the workability and casting of concrete [4].

The goal of this research is to elaborate effective, high-strength and durable high-performance concrete compositions with maximum content of dolomite quarry by-products.

MATERIALS AND METHODS

Experimental samples of dolomite by-product aggregate were taken from the accumulated stack in deposit quarry Birzi, one of the biggest dolomite aggregate producers in Latvia. Obtained by-products are a multi-fraction mix (range of sizes up to 8 mm) which contains a large amount of fine particles (up to 20 %). It must be noted, that dolomite deposit Birzi is characterized by high strength (more than 80 MPa), freeze-thaw resistance and low water absorption (2 %). Dolomite by-products are loose aggregate mix with bulk density 1500-1800 kg/m^3 and particle density 2640 kg/m^3. Grading analysis of dolomite by-product was done in accordance with standard EN 911-1, using the method of wet sieving due to the high content of dust particles. Granulometric composition of dolomite by-product is presented in a wide range of particle sizes up to 8 mm. The content of micro filler (particles smaller than 0.063 mm) is about 26 %. Almost half part of the material (47 %) is sand fractions (0.1 – 4.0 mm) and 30 % is the content of crushed stone (>4 mm) Samples taken from different places demonstrate quite good stability, grading deviations do not exceed 5%.

Normal type CEM I 42.5 N Portland cement (supplied by Schwenk Latvia) and also CEM I 52,5 R white Portland cement were used as binding material for sample preparation. The specific surface of CEM I 42.5 N was 3845cm^2/g, compressive strength 28.4 MPa at the age of 2 days and 55.5 MPa at the age of 28 days.

Additional aggregates were used to produce concrete mix compositions: natural washed sand 0/4 mm and gravel fractions 2/8 mm. Additionally, highly reactive pozzolana - silica fume was used for producing high strength concrete compositions. Produced mix compositions are summarized in Table 1. Mix design is based on optimal grading (Fuller's) curve of an aggregate mix and control the volume of paste and mortar phases (Figure 1).

Table 1. Mix composition of concrete with dolomite by-products

	Mix 1: Normal concrete (NC)		Mix 2: High performance SCC		Mix 3: Architectural concrete	
Compound	kg/m^3	Proportion	kg/m^3	Proportion	kg/m^3	Proportion
CEM I 42.5 N (Schwenk LV)	330		350			
CEM I 52.5 R (Aalborg)					530	
Gravel 2/11 mm	367	20%	532	29%		
Sand 0/4mm	367	20%	532	29%		
Dolomite by-product	1100	60%	734	40%	1600	100%
Silica fume (SF)			30	2%		
Effective amount of water	220		180		220	
Superplasticizer	2.3		3.5		5.3	
Effective W/C ratio	0.67		0.51		0.42	
W/(C+k*SF) (k=2 for SF – EN 206, section 5.2.5.2.)	-		0.44		-	

The first elaborated mix corresponds to economical normal strength concrete (water-cement ratio 0.73) and dolomite by-product replaces 60% of aggregate. The second mix corresponds to high-performance self-compacting concrete (water-cement ratio 0.56) and dolomite by-product replacing 40% of aggregate. Silica fume was used in this case for improving the properties of fresh and hardened concrete. The third composition corresponds to high-performance cement composite based on pure dolomite by-product and may be used for architectural exposed surfaces (mix 3).

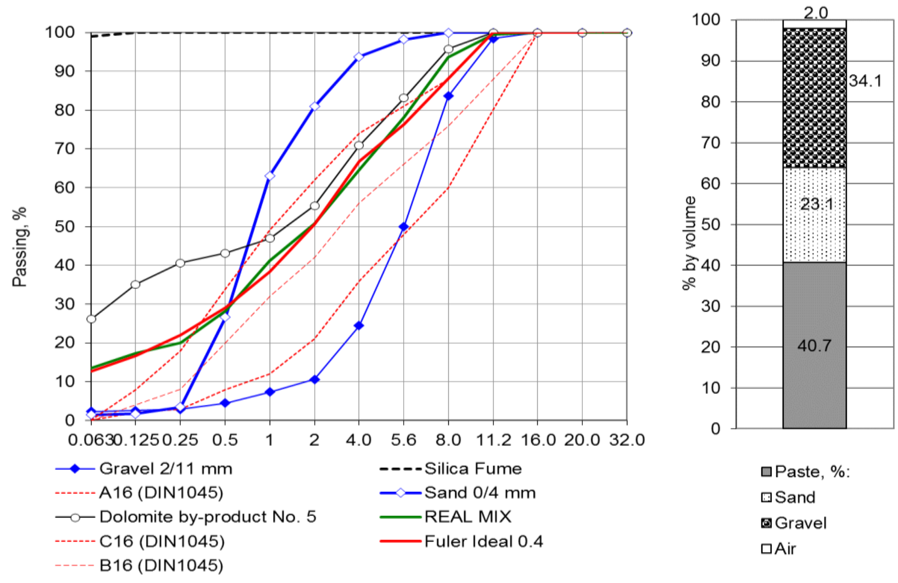

Figure 1. Aggregate mix design and phases volume content for SCC (on the right)

Samples 10x10x10 cm were produced, cured in humid conditions at 20±1 °C and tested in the ages of 7, 28 and 56 days. Compressive strength was determined in accordance with standard EN 12390-3; water permeability – EN 12390-8 by measuring the depth of water penetration under pressure. Frost resistance test was performed by freezing and thawing of partially immersed samples in 3 % NaCl solution (cycling regime -20 ºC /+ 20ºC in accordance with the CDF method). Water permeability under pressure was determined using EN 12390-8.

RESULTS

The properties of fresh and hardened concrete are summarized in Table 2.

The first elaborated concrete (mix 1) is economical normal concrete mix composition with replacing 60% traditional aggregate, this concrete could have broad commercial use of C20/25 class concrete with high workability and satisfactory water resistance and frost resistance. It had S3 workability class (cone slump 150 mm) and cone flow 450 mm.

The second one is high-performance and self-compacting concrete [5] with replacing 40% traditional aggregate by dolomite by-product. It is characterized by a cone flow of 590 mm and corresponding class SF1. Compressive strength for SCC composition has increased up to 72.1 MPa at the age of 28 days and 82,1 MPa in 56 days, which is twice more compared to normal concrete. Sufficient paste content (40.7 % in accordance with Fig. 1) and corresponding flowability are achieved by incorporation of superplasticizer, silica fume, an increased amount of cement and fine fractions as a component of dolomite by-product [6].

The third mix is high-performance architectural composite with 100 % aggregate replacing with dolomite by-product. A combination of white cement and dolomite filler makes possible to achieve light yellow color like natural dolomite rock with an architectural extra-fine surface (Fig. 2).

Table 2. Properties of hardened concrete samples

Concrete property	Normal concrete (NC)	High-performance self-compacting concrete (HP SCC)	High-performance architectural composite
Workability:			
Cone slump, mm	150	-	175
Cone flow, mm	450	590 (SF1)	-
Strength:			
28 day compressive strength, MPa	33.3	72.1	82.0
56-day compressive strength, MPa	38.6	82.1	
28-day tensile splitting strength, MPa	3.2	4.6	6.5
Durability:			
Water penetration, mm	23	15	13
Frost resistance surface scaling after 28 cycles, g/m^2	350	150-250	<150

This mix is characterized by a high flowability class (at the same time, such mix has high viscosity due to the angular shape of the particles of dolomite aggregate).

The durability such as water penetration and frost resistance indicate that the water penetration of normal concrete was 23 mm and could be reduced to 13-15 mm for HP SCC while freeze-thaw resistance was similar for both mixture compositions. Surface scaling after 28 freeze-thaw cycles was in the range 150 to 350 g/m^2, and deals with the destroying of separate weak dolomite particles (Fig. 3).

CONCLUSIONS

The study proved the possibility to utilize by-products of dolomite quarries both for conventional concrete and for high-performance self-compacting concrete which is characterized by a high degree of workability and resistance against freezing and thawing cycle.

The high content of fine particles makes possible to use it as a micro-filler component, which acts as a stabilizing agent and densifying filler. The main reason for limited flow-ability is the angular shape of dolomite aggregate particles, it may be compensated by the use of appropriate plasticizers and silica fume admixtures.

Replacing traditional aggregates and micro-fillers with dolomite by-product makes possible to obtain durable high-performance concrete with decrease environmental impact [7] and promotes rational use of local natural resources.

Figure 2. High performance architectural composite based on dolomite – white cement composition

Figure 3. HP SCC (mix 2) sample after 28 freeze-thaw cycles

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