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Producing of concrete by using a dolomite waste as an alternative filler

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The object of this investigation is crushed dolomite waste that originally is mixture of sand and small size powder fractions. Investigation of physical and chemical property of material showed generally homogeneous mineralogical composition of waste: dolomite $CaMg(CO_3)_2$ content is not less than 92%. Fine-graded and ordinary concrete materials were produced substituting quartz sand with dolomite waste sands. Frost resistance and compression strength of concrete specimens filled with dolomite waste are equal to the concrete filled with traditional quartz sand. Compositions filled with dolomite sand showed higher water absorption and water penetration. Investigations have shown the possibility utilization a dolomite sand waste as substitution of traditional quartz sands.

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Introduction

Nowadays increased attention to such materials, which are storing in the large volume of waste materials staying at open dolomite stone cast mines and lime stone pits after technological production of building materials: gravel and fractioned crushed stones. Crushed stones are produced by development a large parent mass of rock. Thus, many secondary undesirable tiny aggregates (powders, sands) with features depending on the properties of the parent rock (e.g., chemical and mineralogical composition, specific gravity, hardness, strength, physical and chemical stability, pore structure and color) are considered.

Last years in Latvia remained tremendous large quantities of such technological wastes, as very tiny crushed sands, that needs to be recycled with maximum efficiency. For example, due to production of the crushed dolomites more than 10 million m^3 of waste are accumulated at one open cast mine. During decades dolomite sand waste accumulates and is quantified in million tons nowadays. Produced waste mostly remains unused on quarries occupying place and increasing overall technological costs. Such situation demands integrated approach to the produced waste recycling possibilities [1–4].

There are many ways and possibilities to use investigated dolomite fraction or sands. It can be used in agriculture as lime substitute for soil treatment, as quartz sand equivalent in building industry and other. In turn, utilization of dolomite sand wastes in production technology of concrete has been proposed. By this work the continuous investigations aiming the preparation and testing of different concrete materials using different materials and also waste materials as fillers are started.

The aim of an investigation is developing technology for production concrete materials with properties are equivalent and even enhanced of traditional concrete. The investigation was focused on the determination of structure-property regularities of the produced material, which is vitally important. Waste sands mineralogical composition is characterized using wide angle X-ray diffraction analysis (WAXD), sand size distribution is analyzed using powder grading and laser scattering analysis of its suspension. Differential thermal analysis (DTA) and thermal gravimetric analysis (TGA) of the dolomite waste are also performed. All these properties have an important influence on the quality of fresh and hardened concrete. The new compositions of produced concrete material have been created by modifying initial quantities of dolomite sand additive in the composition. Compression strength, water absorption and density properties of produced concrete material are investigated.

Experimental methods

Materials

Dolomite is supplied from the open cast mine in Latvia. Before usage and investigations dolomite sand is preliminary remixed for homogeneity and dried in closed oven at 105±5 °C. Drying conditions of the dolomite powder are chosen correspondingly to the preliminary investigations performed by DTA-TGA analysis.

Finally concrete filled with quartz and dolomite sands has been prepared. Concrete mixtures were cast into oiled steel cube shape moulds according to [5] and kept till complete solidification. Produced concrete specimens were further tested in accordance with LVS EN12390-3:2002 [6].

Testing

Specimens of the selected dolomite waste are investigated using several experimental methods. The particle size parameters of dolomite sand are found from data of the grading and laser scattering experiments, while observation of the dolomite temperature transitions during heating realized by the DTA-TGA (Fig. 1.).

The waste specimen's mineralogical structure was examined by the method of X-ray diffraction. The X-ray diffraction measurements were carried out on a Bruker diffractometer at a temperature of 20 °C. The CuK_α -monochromatic radiation with a wave length of λ= 0,154 nm in the range of diffraction angles 2θ from 4 to 50° was used. The scanning rate was 2 deg/min.

The calorimetric tests were carried out by DTA on a Paulig DTA instrument. The specimens about 10 mg in weight were heated in an inert atmosphere at a rate of 10 °C/min in the temperature range from room temperature to 1000 °C. The thermogravimetric tests by the method of TGA were performed also on a Paulig instrument. Specimens about 10 mg in weight were heated in an inert atmosphere up to 1000 °C. The dolomite powder thermal stability was evaluated from the weight-loss curves.

For identification of dolomite particle sizes we choose, firstly, sieving (also with additional washing) using sieve set equipped with mechanic vibration table and secondly, further for smaller fraction less than 63 µm laser scattering or turbidity analyses.

The compressive strength tests of concrete were performed on compression testing equipment. Testing was taken according to the standard LVS EN 12390-3:2002 for three samples of each composition after 7- and 28-day aging period.

Water penetration under pressure was performed according to LVS EN 12390-8:2002. Specimens were placed into experimental testing equipment and aged at pressure 500 kPa for 72 hours.

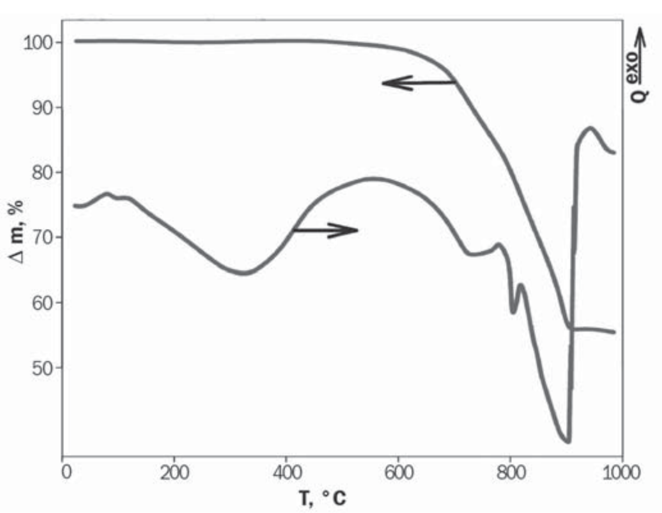

Fig. 1. DTA-TGA thermographs of dolomite waste
1. ábra Dolomit hulladék DTA-TGA görbéi

Results and discussions

Dolomite waste properties

Mineralogical composition of dolomite waste has been obtained by X-ray diffraction. The pattern indicates that the main components of the investigated composition are dolomite $CaCO_3 \times MgCO_3$ and small amounts of quartz SiO_2 – 2,5% and calcite $CaCO_3$ – 1,5%. There is no evidence of clay minerals being present in the mix. It is obvious that dolomite by nature is kind of the primary sediment mineral and has the wide spread geologic distribution [7]. The chemical formula of dolomite is $CaCO_3 \times MgCO_3$ with the averaged chemical composition. Results were obtained from the chemical analysis according to LVS EN 1744-1 which shows that dolomite is 92%, oxides – CaO ~31%, MgO ~17% and the other oxides which in total are less than 1% of the weight of the raw material – Fe_2O_3 – 0,34%, Al_2O_3 – 0,64%, Na_2O – 0,82%, K_2O – 0,76%, SO_3 – 0,05%.

The DTA-TGA analysis shows typical decomposition process of dolomite (water physical adsorption and water chemical debonding from material and separating up of the material into constituent parts) increasing the temperature. The resolving process of dolomite occurs at the temperature interval from about 590 °C to 900 °C, which is presented by the endothermic reaction peaks at DTA curve. The maximum weight loss reaches 45% what is attributed to emission of CO_2. The products of dolomite decomposition are MgO, CaO and CO_2. This process is accompanied by the following chemical reaction:

$$CaCO_3 \times MgCO_3 \xrightarrow{730\text{–}740\,°C} MgO + CO_2\uparrow + CaCO_3 \xrightarrow{900\,°C} MgO + CaO + 2CO_2$$

Two different concretes have been prepared: fine-graded concretes D1-D5 contain dolomite and traditional quartz sands varying from 0 till 100%, ordinary concretes D6 and D7 with dolomite waste and traditional quartz sand. Produced concrete compositions D1-D7 are shown in Table 1. Concrete mixture components are homogenized in concrete mixer after that necessary water quantity was added.

	Fine-graded concrete					Norm. concrete	
Mix designation	D1	D2	D3	D4	D5	D6	D7
Dolomite sand, % by total sand content	0	25	50	75	100	0	100
Concrete mixture compositions, kg/m³							
Portland cement	380	380	380	380	380	350	350
Gravel, 2–10mm	–	–	–	–	–	1038	1038
Quartz based sand of fraction 0/4 mm	1324	1000	676	331	–		
Quartz based sand of fraction 0/0,5mm	234	177	120	59	–	138	–
Remina dolomite sand	–	381	762	1169	1558	–	–
Plavinas dolomite sand	–	–	–	–	–	–	724
Water	245	256	260	264	269	212	224

Table 1. Concrete mixture compositions
1. táblázat A betonkeverékek összetétele

Optimized compositions of concretes D6 and D7 are developed by modern methodology using particle size distribution data of all concrete contaminants (gravel, quartz sands, and dolomite waste) presented in Fig. 2. Different fillers take 60–80% of concrete volume and the granulometry of the fillers has great influence on material final features. Optimal compositions of concrete are calculated. The granulometric compositions curves of produced concrete D6 and D7 are located in the region between ordinal dotted curves.

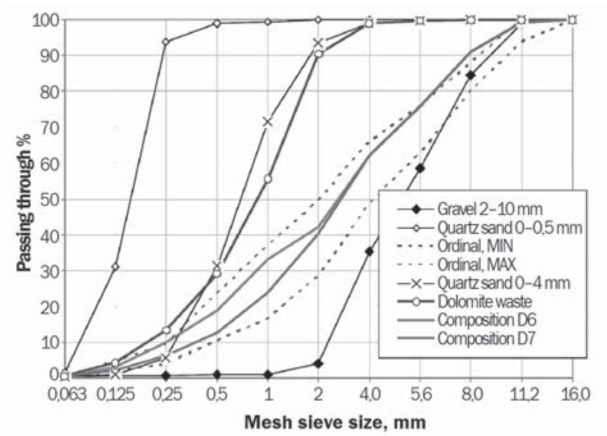

Fig. 2. Particle size distribution of concrete composition
2. ábra A beton összetételek szemcseméret eloszlása

Fresh and hardened concrete properties

Analyzing the fresh concrete mix properties such as cement/water ratio, cone flow and cone slump, can be concluded that concrete filled with dolomite sand involves additional water content. Thus the cement/water ratio has been changed for keeping necessary concrete mix consistency. Cement/water ratio slightly enlarges from 0,69 till 0,76 increasing dolomite content in the specimens D1- D5.

Cone flow and cone slump of the concrete mix are decreasing from 190 mm (D1) to 172 mm (D5) and 105 mm (D1) to 80 mm (D5) correspondingly. Concrete compositions D6 and D7 are characterized with coarse particle content and lower values of cement/water ratio. Obviously, dolomite sands, initially having semicrystalline nature particles, can quite homogeneously disperse in the volume of the growing concrete stone and develop rigid spatial interpenetrated network that causes increasing overall strength in fresh and hardened concrete. Such effect of dolomite additive to the fresh concrete mortars is owed to the changes of qualitative and quantitative characteristics of concrete stone structure formation during the intrinsic hydration reaction process. The properties of fresh concrete are shown in Table 2.

Mix designation	D1	D2	D3	D4	D5	D6	D7
Dolomite sand, % by total sand content	0	25	50	75	100	0	100
Fresh concrete mortars properties							
Cement/water ratio	0,69	0,72	0,74	0,75	0,76	0,61	0,64
Cone flow, mm	190,00	185,00	185,00	180,00	172,00	–	–
Cone slump, mm	105,00	100,00	105,00	90,00	80,00	70,00	70,00

Table 2. Fresh concrete properties
2. táblázat A frissbetonok tulajdonságai

Density of concrete compositions D1–D5 remains unaffected from the dolomite content. The compositions D1–D5 showed a little more water absorption for compositions with dolomite sand.

Compression strength of the compositions D6 and D7 remains the same after 7 and 28 days in spite of higher water/cement ratio in dolomite sand filled concrete D7, what could be an effect of the dolomite additive to the fresh concrete mortars due to changes of the qualitative and quantitative characteristics of the concrete stone structure formation during the intrinsic hydration reaction process. Some authors presuppose development of the novel hydration complex phase on the interface of the cement and dolomite particles, that is featured as the semicrystalline high adhesion and the density complex epitaxial phase [7, 8]. Tension strength of the compositions D6 and D7 is 2,28 and 2,31 MPa. Water penetration of D6 is 20,5 mm and of D7 – 32,0 mm. Physical and mechanical properties of the hardened concrete are shown in the Table 3. It was shown by the testing that compositions filled with dolomite sand have the same frost resistance as compositions with traditional sand.

Mix designation	D1	D2	D3	D4	D5	D6	D7
Dolomite sand, % from total sand content	0	25	50	75	100	0	100
Concrete properties							
Density, kg/m^3	2196,0	2170,0	2229,0	2173,0	2229,0	2301,0	2335,0
Compression strength after 7 days, MPa	16,5	16,0	16,0	16,4	17,4	19,5	20,8
Compression strength after 28 days, MPa	27,0	27,1	26,8	28,4	28,6	32,3	31,5
Water absorbtion, %	6,8	8,2	8,3	8,0	7,8	–	–
Frost resistance, cycles	F100	F100	F100	F100	F100	F150	F150

Table 3. Hardened concrete properties
3. táblázat A megszilárdult betonok tulajdonságai

Conclusions

Compositions filled with dolomite sands consume additional water quantity to maintain homogeneous fresh mortar concrete properties. Compositions filled by dolomite sand and quartz sand in different proportions have equal compressions strength values in comparison with traditional concretes: ~16–17 MPa and ~26–28 MPa after 7 and 28 days, correspondingly. Compositions with dolomite sands had higher water absorption than compositions with traditional sand.

Concrete composition filled with dolomite sand wastes has the same frost resistance as composition filled with ordinary quartz sand. In the same time, composition with dolomite sand wastes has higher water penetration under pressure.

Based on above mentioned results it is concluded that investigated dolomite sand waste can be used as quartz sand equivalent material to produce concrete with set of properties (cone flow, cone slump, compression strength, water penetration, density) very close to traditional concrete filled by quartz sand.

Acknowledgement

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Betonkészítés dolomit hulladék alternatív töltőanyagként való felhasználásával

E kutatás a homokszem nagyságú és poros frakciókból álló dolomit őrlemény vizsgálatával foglalkozik. Az anyag fizikai és kémiai tulajdonságainak vizsgálata alapján a hulladék általánosságban homogén ásványi összetételű: a dolomit – $CaMG(CO_3)_2$ – tartalom legalább 92%. Finomszemcsés és hagyományos betonokat készítettünk, amelyekben a kvarchomokot a dolomit hulladékkal helyettesítettük. A kvarchomok helyett dolomit hulladékot tartalmazó betonminták fagyállósága és nyomószilárdsága megegyezett a hagyományos, kvarchomokkal készített betonokéval. A dolomithulladék töltőanyagú betonok erősebb víz abszorpciót és vízbehatolást mutatnak. A kutatások alapján lehetőség nyílik a hagyományos kvarchomoknak hulladék dolomithomokkal való helyettesítésére a betonokban.