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INVESTIGATION OF ALTERNATIVE DOLOMITE FILLER PROPERTIES AND THEIR APPLICATION IN CONCRETE PRODUCTION

ALTERNATĪVO DOLOMĪTA PILDVIELU ĪPAŠĪBU IZPĒTE UN TO PIELIETOŠANA BETONA RAŽOŠANĀ

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1. Introduction

Study of the cement mortar compositional material with different carbonate additives is very perspective field for investigations at the concrete material science. Nowadays, increased attention to such materials is observed owing to the large volume of waste by-product materials left 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 crushing large parent mass of rock. Thus, many secondary unwanted tiny aggregates (powders, sands) are developed with many features depending on the parent rock properties (e.g., chemical and mineralogical composition, specific gravity, hardness, strength, physical and chemical stability, pore structure and color).

In recent years, huge quantities of technological waste such as very tiny crushed dolomite sands, which need to be recycled with maximum efficiency, have accumulated in Latvia. For example, production of the crushed dolomites leaves a lot of dolomite by-product materials in the open cast mine at Plavinas. Dolomite sand by-product has been accumulating during recent decades, and its quantity has reached a million of tons. Dolomite waste quantity is increasing very rapidly as well in other open cast mines. Produced waste mostly remains unused at quarries occupying space and multiplying overall technological costs. Such situation requires the integrated approach to recycling of the produced waste [1-4].

There are many ways and possibilities of using dolomite by-product. It can be used in agriculture as lime substitute for soil treatment, as quartz sand equivalent in the building industry, etc. Herewith, we offer utilizing dolomite sand waste at the concrete production technology. This work starts continuous investigations which aim is preparation and testing of different concrete materials with dolomite by-product as filler.

This publication focuses on dolomite material usage as the perspective aggregate for concrete production, substituting traditional (quartz based) sands. The aim of the work is to develop production technology of such concrete materials with the equivalent or even enhanced set of properties. Primarily, the structure-property regularities of the produced material have been determined, as being vitally important. Considering the complicated nature of dolomite by-product, mineralogical composition of the chosen materials have been extensively investigated as well as grading analysis of the materials. All these properties have an important impact on the quality of fresh and hardened concrete. The composition of the produced concrete material was changed by modifying initial quantities of the dolomite sand additive in the composition. Compression strength, water uptake and density properties of the produced concrete material have been investigated.

2. Experimental Methods

2.1. Materials

Dolomite based sand fraction 0/4 mm was taken from the open cast mine at Plavinas and Remina, Latvia. Dolomite sand was remixed for homogeneity and dry conditioned in closed oven at 105±5 ^{0}C as preliminary preparation for the investigations. Drying conditions of the dolomite material are chosen in conformity with the preliminary grading determination and investigations by DTA-TGA analysis and X-ray diffraction method.

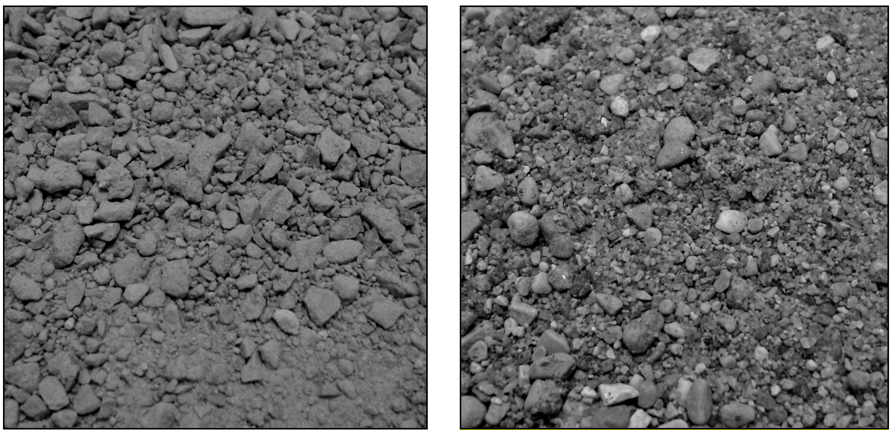

Fig. 1. Sand obtained from dolomite by-product (on left) and traditional sand (on right)

2.2. Testing of materials

The specimens of selected dolomite waste have been investigated by using several experimental methods. The particle size parameters of the materials have been investigated by grading analysis with additional washing. The grading analysis has been carried out in conformity with LVS EN 933-1:1997. Standard sieve set equipped with the mechanic vibration table has been used.

Mineralogical structure of dolomite sand specimen has been examined by the Wide Angle X-ray Diffraction analysis method (WAXD). The X-ray diffraction measurements have been carried out on the Bruker diffractometer at the temperature of 20 ^{0}C. CuK$_\alpha$ - monochromatic radiation with the wavelength of λ= 0.154 nm at the range of diffraction angles 2θ from 4 to 50 ^{0} have been used. The scanning rate was 2 deg/min.

Chemical and physical properties of the raw materials have been investigated by the differential thermal analysis (DTA-TGA). The specimens weighting about 10 mg have been heated at the rate of 10 °C/min at the temperature range from ambient to 1000 °C on the Paulig/Paulig equipment. Thermal stability of the dolomite material has been evaluated by the weight-loss curves.

2.3. Testing of samples

Various specimens of concrete filled with ether quartz or dolomite based sands were prepared. Consistency of the concrete mixes was determined by means of cone slump and cone flow [5, 6]. The mixtures of concrete have been cast into the oiled steel cube shape moulds, according to the standard LVS EN 12390-2:2002 [8]. The samples have been subjected to normal hardening conditions until complete solidification.

The specimens of concrete have been tested in accordance with LVS EN 12390-3:2002 [9]. Uniaxial compressive strength has been checked on the compression testing machine with accuracy $\pm$1%. A set of three samples was tested for each composition after the 7- and 28-day ageing period.

Water absorption has been tested in accordance with the standard ГОСТ 310.4-81 [7]. Water penetration has been measured according to LVS EN 12390-8:2002 [10]. The specimens have been placed into the experimental testing equipment and aged at the pressure of 500 kPa for 72 hours. Frost resistance test has been performed by freezing and thawing cycles in 5% NaCl solution in accordance with the standard ГОСТ 10060.2-95 [11].

3. Results and Discussion

3.1. Dolomite by-product properties

Mineralogical composition of dolomite waste has been obtained by X-ray diffraction. The pattern shown at the Fig. 2 indicates that the main components of the investigated composition are dolomite $CaCO_3 \cdot MgCO_3$ 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 $CaCO_3 \cdot MgCO_3$ 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 %.

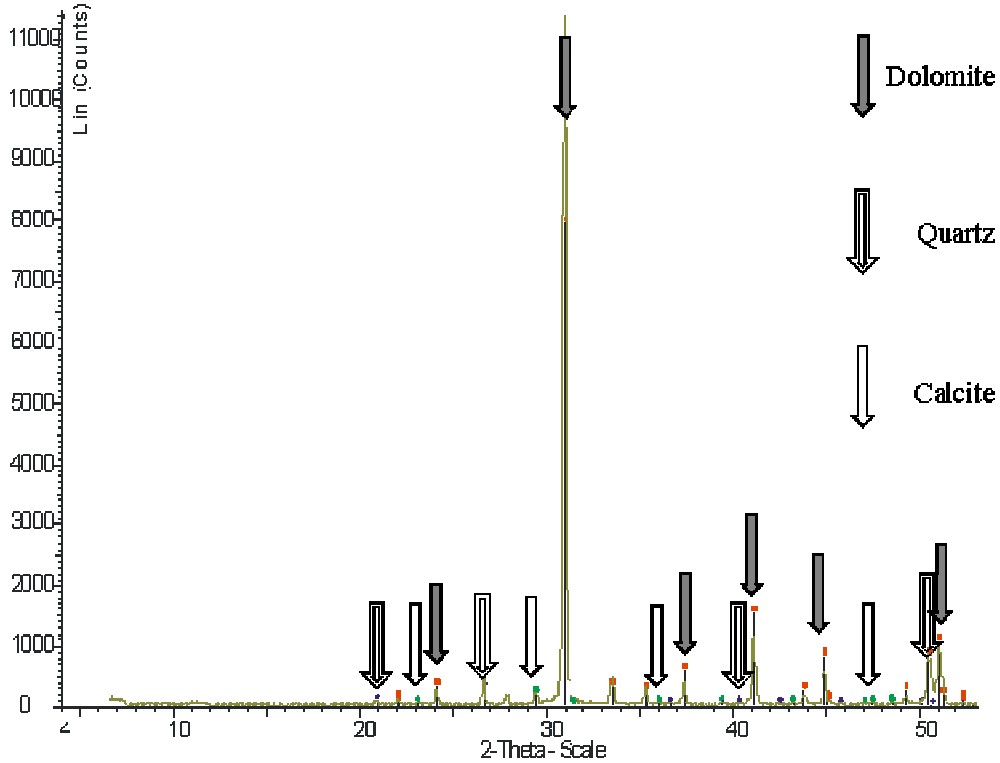

Fig 2. X-ray diffraction data of the Plavinas dolomite material

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 ^{0}C to 900 ^{0}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 [3, 4]:

$$CaCO_3{\cdot}MgCO_3 \xrightarrow{730\text{-}740^{o}C} MgO + CO_2\uparrow + CaCO_3 \xrightarrow{900^{o}C} MgO + CaO + 2CO_2$$

The X-ray diffraction analysis as well as DTA-TGA results is related to Plavinas' by-product sand. Remina's materials have the same characteristics.

3.2. The mix design

Two different types of fine-graded concrete have been developed, prepared and numbered as D1-D5, which were fine-graded concretes containing dolomite and traditional quartz sands varying from 0 to 100%, and the ordinary concretes numbered D6 and D7 with dolomite waste and traditional quartz based sand. The compositions D1-D7 of the produced concrete are shown at the Table 1. The concrete mixture components were homogenized in concrete mixer and then the necessary quantity of water was added.

The compositions D6 and D7 of the concrete mix have been developed with the help of innovative methodology using the particle size distribution diagrams for all concrete aggregates (gravel, quartz sands, and dolomite waste) as presented at Fig.3. The volume of the concrete fillers constitutes to 60-80% of its volume, and thus, granulometry of the fillers has great influence on the material final features. The resulting grading curves of the concrete compositions were calculated as resulting of the optimal grading area (fig. 3).

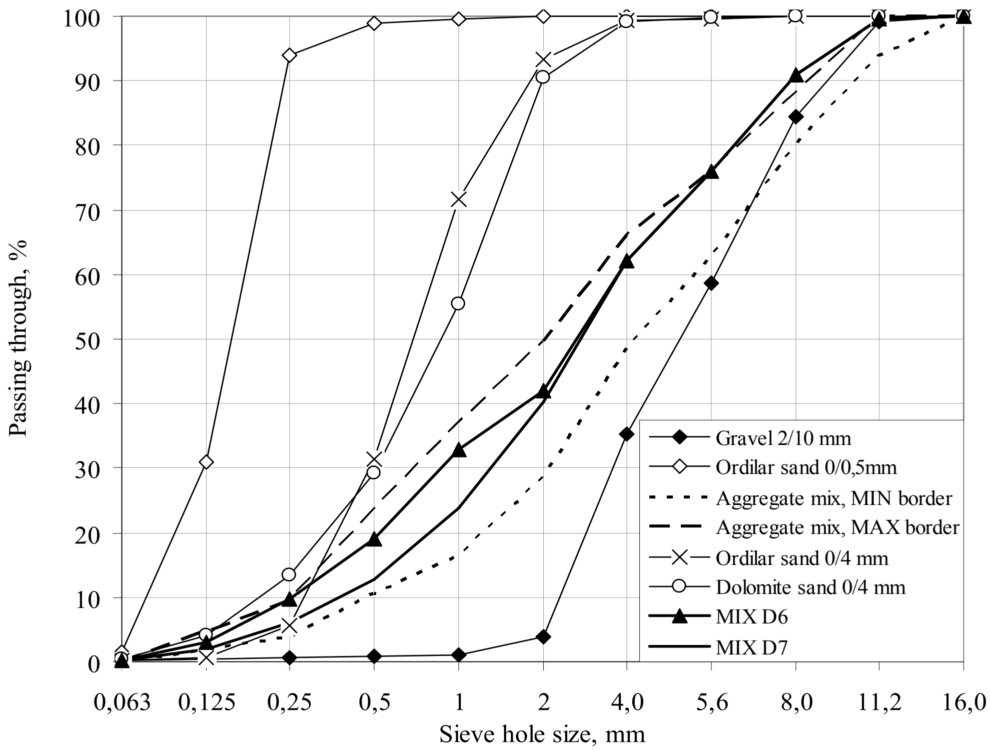

Fig.3. Particle size distribution of the concrete composition (D6 and D7)

Table 1. Concrete mixture compositions

	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/m^3							
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	–	586	–
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

3.3. Fresh and hardened concrete properties

Fresh concrete mortars properties such as water/cement ratio, cone flow and cone slump are shown at the Table 2. The analyzed data results show that concrete filled with dolomite sand has additional water content. Therefore the water/cement ratio has been changed, keeping the necessary technological parameters: mortar concrete yielding and cone slump. The water/cement ratio slightly enlarges from 0.69 to 0.76 with increasing of the dolomite content in the specimens D1-D5.

Cone flow and cone slump of the concrete are kept 170-190 mm and 70-105 mm correspondingly. Compositions of the D6 and D7 concretes are characterized by lower values of the cement/water ratio and cone slump.

Table 2. Fresh concrete mix properties

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

Physical and mechanical properties of the hardened concrete are shown at the Table 3. Density of the concrete compositions D1-D5 remains unaffected with regards to the dolomite content. Compression strength of the D1-D5 concretes remains unchanged also after 7 and 28 day aging period; it proofs that the cheaper dolomite waste can successfully replace traditional quartz sands without sacrificing the strength properties. All compositions at the range D1-D5 show that water uptake of the investigated concretes is not dependant on the composition and changes inconsiderably.

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 possible, that is featured as the semicrystalline high adhesion and the density complex epitaxial phase [13, 14]. Tension strength of the compositions D6 and D7 is 2.28 and 2.31MPa. Water penetration of D6 is 20.5mm and of D7 – 32.0mm. Experiments show that compositions filled with dolomite sand have the same frost resistance as compositions with traditional sand.

Table 3. Hardened concrete properties

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	2170	2229	2173	2229	2301	2335
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

Conclusions

On the basis of the aforesaid, we consider that the proposed dolomite sand waste can be used as the quartz sand equivalent material to produce concrete having the set of properties (cone flow, cone slump, compression strength, water uptake, density) being equal to those of the traditional concrete filled with quartz sand.

It is determined that the crushed waste produced at the Plavinas open cast mine is practically pure dolomite mineral.

The D1-D5 compositions, filled with dolomite sands Remina, require additional water quantity to maintain homogeneous fresh mortar concrete properties. The specimens with dolomite filler have equal compressions strength values with ordinary concretes: ~16-17 MPa and ~26-28 MPa after 7 and 28 days correspondingly. Water absorption of all compositions is unaffected.

The concrete composition D7, filled with dolomite sand Plavinas, has the same compression strength as the D6 composition filled with ordinary quartz sand.

Acknowledgement

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Korjakins A., Gaidukovs S., Šahmenko G., Bajare D. un Pizele D. Alternatīvo dolomīta pildvielu īpašību izpēte un to pielietošana betona ražošanā.

Mūsdienās viens no galvenajiem būvmateriālu zinātnes virzieniem Eiropā ir netradicionālu izejvielu izmantošana būvmateriālu ražošanā. Tas ir saistīts ne tikai ar tradicionālo izejvielu krājumu un ieguves apjoma

samazināšanos, bet arī ar lietderīgu tādu atkritumu apsaimniekošanu un izmantošanu, kuri radušies citos būvniecības sektoros. Darba galvenais mērķis ir aizvietot tradicionālās kvarca smilšu pildvielas betona ražošanas procesā ar alternatīvām pildvielām – dolomīta atkritumiem, kuru uzkrājumu apjomi dolomīta izstrādes karjeros ar katru gadu ievērojami palielinās. Pētījumu gaitā tika izgatavoti paraugi un veiktas pārbaudes, lai salīdzinātu tradicionāla betona un tāda betona īpašības, kur kompozīcijas izveidei kvarca smiltis daļēji vai pilnībā aizvietotas ar dolomīta izstrādes atkritumiem. Detalizēti izpētīts dolomīta smilts mineraloģiskais un ķīmiskais sastāvs. Pārbaudītas un salīdzinātas tādas materiāla īpašības kā blīvums, ūdensuzsūce, stiprība, ka arī salturība. Paraugiem noteiktas fizikāli mehāniskās īpašības (blīvums, ūdensuzsūce un spiedes pretestība, salizturība). Noskaidrots, ka dolomīta blakusproduktu smilti veiksmīgi var izmantot kā alternatīvo pildvielu betona izgatavošanai.

Korjakins A., Gaidukovs S., Šahmenko G., Bajare D. and Pizele D., Investigation of alternative dolomite filler properties and their application in concrete production.

Using unconventional raw materials for manufacturing different building products is an urgent task at present, in the light of the rapidly developing building production in Europe. The main subject of this study is usage of dolomite waste as alternative filler in production of concrete, due to the insufficient capacity of the dredged quartz sand production used in manufacturing concrete. The goal of the study is to examine mechanical and physical properties of the products containing different amount of dolomite waste and their comparison with properties of the traditional concrete. Mineralogical and chemical structure of dolomite sand has been investigated in details. It is determined, that compositions with dolomite sand require more water to provide the same mix consistency. Physical and mechanical properties, such as density, water absorption, strength, have been determined and compared. Tests have been also performed to determine frost resistance. Concluded, that alternative dolomite by-product sand can be successfully used as the quartz sand equivalent material.

Корякин А., Гайдуков С., Шахменко Г., Баяре Д. и Пизеле Д. Исследование свойств альтернативного доломитного заполнителя его применение для производства бетона.

Использование нетрадиционного сырья для производства различной строительной продукции является актуальной современной задачей в свете стремительно развивающегося строительного производства в Европе. Главным предметом этого исследования было использование доломитных отходов, как альтернативного наполнителя при производстве бетона из-за недостаточной мощности производства кварцевого песка используемого при изготовлении бетона. Целью этой работы было исследование физических и механических свойств продуктов, содержащим различное количество доломитных отходов и их сравнение со свойствами традиционного бетона. В процессе исследования были изготовлены образцы и проведены испытания с целью определить, как влияет замена традиционного песка на альтернативный доломитный песок, полученный из доломитных отходов. Детально определен минералогический и химический состав материалов. Определены и сравнены такие физические и механические свойства материала, как плотность, водопоглощение, прочность. Проведено экспериментальное определение морозостойкости бетона. Установлено, что альтернативный доломитный песок можно с успехом использовать как альтернативный заполнитель бетона.