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Review

A review on the utilisation of quarry and ornamental stone industry fine by-products in the construction sector

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HIGHLIGHTS

- Quarry and ornamental stone dust constitute a severe environmental problem.
- Limestone dust is the most commonly used by-product in the range of 10–60%.
- An addition of up to 20% of limestone dust can improve the mechanical properties.
- Durability properties should be further investigated.
- New production and mixture preparation techniques should be developed.

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ABSTRACT

Quarry dust and marble sludge, produced in large quantities from quarries, aggregates and ornamental stone plants, constitute a severe environmental problem. The use of these materials in construction applications, could lead to both economic and environmental benefits. This paper reviews the recent research studies on the production of cement-based building materials related to the use of the above by-products either as aggregates or as cement replacement materials. Studies were examined in terms of constituent materials, preparation methods, measured properties and proposed uses. Quarry dust and marble sludge were used mainly as fine aggregates or cement replacement materials in the production of concrete. Other uses included the production of building elements like load-bearing or decorative bricks and artificial stones. The on-going research must be intensified in terms of processing methods and studied properties and broadened to cover more construction applications.

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1. Introduction

Aggregate materials and ornamental stones, extracted mainly via quarrying operations, are used extensively for all construction applications and are essential for the development of any modern economy. During the production of these materials large quantities of fine by-products/wastes, such as the quarry dust and the marble sludge, are generated. The handling and disposal of these fine by-products poses severe environmental problems since they contribute to a great extent to the accumulation and harmful dispersion in air, water and soil of fine solid particles [1–3].

More specifically, during the extraction, hauling and crushing processes for the production of aggregates, large quantities of limestone fines, here on referred to as quarry dust, are generated. Particularly at the stage of crushing and screening, fine airborne material such as silt and crusher dust can be generated and emitted into the surrounding atmosphere. Silt is a material between 2 and 60 μm reduced to this size by natural processes and it is found in aggregates won from natural deposits. Crusher dust is a fine material formed mainly during the process of rock crushing and sieving. In coarse aggregates used in concrete, this fine material is present in the form of surface coating which interferes with the bond between aggregate and cement paste. Table 1 presents the chemical compositions and the size grading of the commonly used quarry and ornamental stone industry fine by-products.

Concrete regulations limit the content of fine material contained in coarse crushed aggregates for structural concrete to 1% and in crushed stone sand to 15%, so it is necessary to remove the excess dust by implementing a suitable dedusting process. Consequently, the stockpiling and disposal of this fine by-product (Fig. 1) is one of the most important problems facing the quarry industry today [3].

Table 1
Chemical composition and size grading of typical fine materials [3,25,27].

Chemical compounds (%)	Marble dust	Granite dust	Limestone dust
SiO_2	0.57	69.88	0.115
Al_2O_3	0.16	12.21	0.22
Fe_2O_3	0.11	7.73	0.23
MgO	0.2	0.07	0.97
CaO	55.26	3.17	55.44
Na_2O	0.05	3.00	–
SO_3	0.06	0.05	–
ZrO_2	0.01	–	–
P_2O_5	0.02	0.03	–
SrO	0.03	–	–
TiO_2	–	0.05	–
Cl	0.01	0.01	–
K_2O	–	3.65	–
MnO	–	0.07	–
Cr_2O_3	–	0.07	–
Loss on ignition	43.52	–	42.98
Size grading			
d_{50} (μm)	7	9	18
d_{90} (μm)	50	80	40

Although many different ways for the utilisation of limestone dust have been proposed (agricultural uses, industrial waste neutralisation, filler for paper and plastics' industry, etc.) due to several restrictions regarding mainly the geographical distribution of the quarries, quarry dust still remains an under-utilised resource. The use of quarry dust in high volume, in construction applications, through a technically and economically feasible technology, could lead to both economic and environmental benefits for the quarrying industry. Besides to additional economic benefits through reduced storage and disposal costs, the life of the primary rock source (e.g. limestone deposits) could also be extended [3].

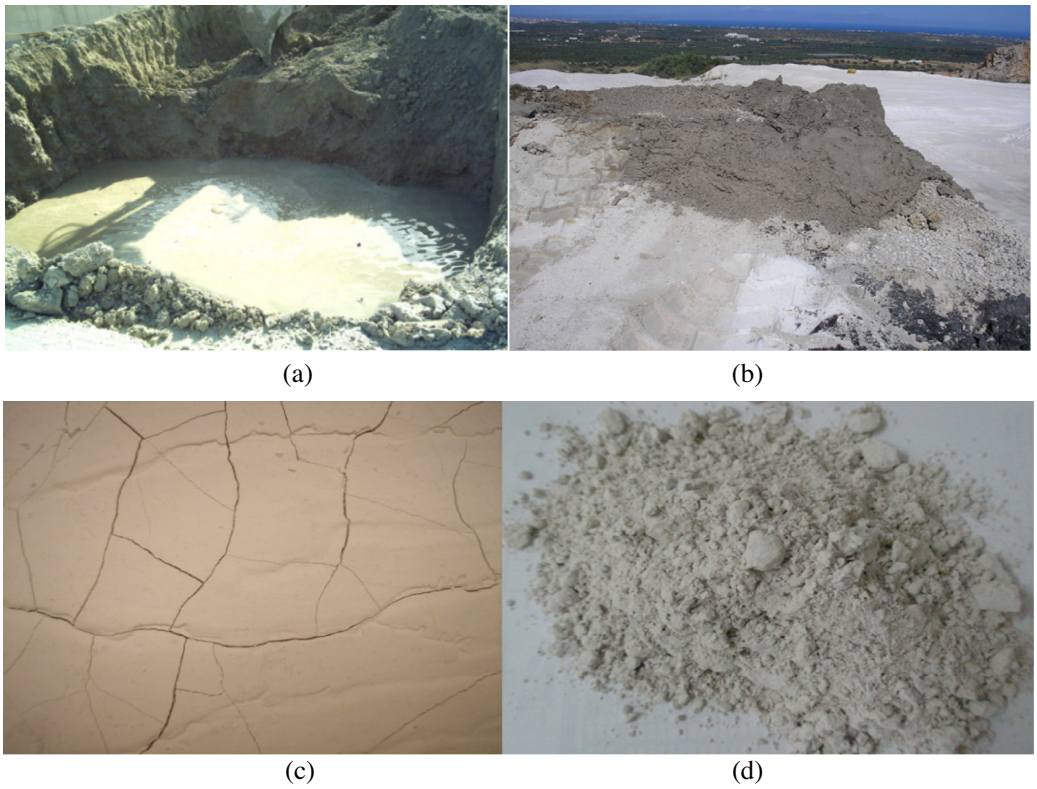

Fig. 1. (a) Deposition of quarry dust in a pond, (b) stockpiling of quarry dust in an aggregate plant yard, (c) surface of the dried ornamental stone sludge, and (d) dried quarry dust.