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Performance of magnesia cements in pressed masonry units with natural aggregates: Production parameters optimisation

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Abstract

Although the manufacturing of masonry units by pressing dry concrete mixes is widespread, the information on how the process variables influence the resulting product is limited. This is partly because the process is operator controlled and partly because its details are usually confidential. The process variables are believed to be aggregates type and grading, manufacturing pressure, water to cement ratio and cement content. In this paper, the influence of the manufacturing pressure, water content and cement content on the density, porosity and strength of a number of pressed dry concrete mixes was studied. Natural aggregates and three types of binders were used: Portland cement, magnesium oxide and the combination of the two. Recently emerged magnesia cements, which are proposed as a more sustainable alternative to Portland cements, are used to assess their potential for their utilisation in the manufacturing of masonry units. Results are presented and recommendations are made to manufacturers of pressed masonry units and potential researchers conducting testing of novel materials for the utilisation of these binders in the manufacturing of construction products by pressing.

Keywords: Manufacturing pressure; Water content; Cement content; PC; Magnesium oxide; Aggregates

1. Introduction

The use of dry concrete mixes is well established in the construction sector. Applications include roller compacted concrete for the production of extensive structural elements such as dams and pavements [1] and factory consolidated dry concrete mixes for the manufacturing of masonry units (bricks, blocks, paving stones, etc.). Dry concrete mixes are characterised by low paste content, high aggregate content, and the inability to be self-consolidated [2]. Hence a compaction needs to be performed in order to densify the cement block mix. This is usually realised by a heavy weight roller in the case of roller compacted concrete or by employing pressing or vibrating devices or a combination of both in the case of masonry units. Compaction, as would be expected, results in the increase in density and therefore strength [1]. The compaction process variables are believed to be aggregates type and grading, cement content and water to cement ratio [3]. An extensive amount of data has been published on the design, production and performance of roller compacted concrete. On the other hand, although the manufacturing of masonry units by pressing dry concrete mixes is widespread, the information on how the process variables influence the resulting product is limited. The reason for this is twofold. Firstly, the factory operations often rely on the expertise of experienced stuff and some parameters (for example water content) are often estimated on site. Secondly, such information is usually considered to be confidential and is hence not publicly available. Hence if research efforts intend to simulate such a process on the laboratory scale, for example in order to test novel materials, then the information on how to optimise the variables of the procedure would be invaluable.

Portland cement (PC) has been the most widely used binder for such applications. However, the production of PC is a very energy intensive process. Due to the fact that

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almost 1.8 billion tonnes of PC are manufactured annually worldwide, this production is directly responsible for approximately 10% of all CO_2 emissions caused by anthropogenic activity. The manufacturing of this binder also causes an extensive depletion of natural resources causing irreversible detrimental changes to the landscape. Furthermore, hydration of Portland cement yields C-S-H gel, ettringite and portlandite. The last mentioned component is, however, very soluble and reactive, readily interacting with aggressive chemicals such as sulfates and chlorides. The resulting reactions are significantly expansive and are a cause of unsoundness [4]. Hence there is a need to start to utilise alternative binders whose production would have less detrimental effects on the environment and which would be less susceptible to an aggressive chemical attack.

The group of recently emerged magnesia cements seem to be a viable alternative to conventionally used binders. They are blends of reactive magnesia, a pozzolan (can be industrial by-product or waste-based) and PC. MgO in magnesia cements hydrates forming brucite replacing portlandite which is consumed by reactions with pozzolans. Due to the fact that brucite is much less soluble and much less reactive than portlandite, the aggressive chemical attack is hence substantially mitigated in magnesia cements [5]. PC is needed to achieve early strength. Magnesia cements are less detrimental to the environment as the main component of the cement, reactive MgO, is manufactured at much lower temperatures than PC. Furthermore, the CO_2 released during the production of MgO can be subsequently reabsorbed when the cement carbonates adding to strength. Despite the fact that magnesia is well known amongst cement chemists as a source of concrete unsoundness, it is dead burned MgO that is referred to here and not reactive MgO. The difference between those two materials is in the temperature of their production. As raw materials for the production of PC contain a certain amount of magnesium carbonates, this results in the magnesia formed during the calcination of PC clinker being the dead burned form as the temperature rises up to 1450 °C. Although initial data on the behaviour of reactive magnesia cements have been recently published [6], there is a lack of information on the behaviour of those cements in dry concretes.

This paper deals with the utilisation of magnesia cements in dry pressed concrete mixes, which were used for the manufacturing of masonry units namely blocks by employment of pressing. The emphasis is placed on the parameters that strongly influence the output, namely the applied manufacturing pressure, water content and cement content. Density, porosity, the evolution of compressive strength and microstructure are studied in relation of those parameters and the results are presented.

2. Materials and methods

During this experiment, magnesium oxide from Causmag XLM, Australia and PC from Lafarge, UK were used. Those components were also mixed in the ratio of 1:1 to form the third type of cement. Pulverised fuel ash (pfa) from Ratcliffe on Soar Power station, UK was used as the pozzolanic material, which is an important part of magnesia cements due to its ability to react with portlandite forming more stable C-S-H like phases [5]. The physical and chemical properties of the raw cement components are detailed in Table 2. Two types of natural aggregates were utilised in this study, builders sharp sand and gravel and they were obtained from a local supplier of building materials. The surface texture and particle shape of the aggregates were determined [7] to be angular and granular

Table 2
Properties of the raw materials used

	pfa	MgO	PC
CaO	5.8	1.2	63.6
SiO_2	42.8	1.2	13.9
Fe_2O_3	10.4	0.2	2.7
Al_2O_3	29.2	0.2	10.2
MgO	1.3	97.2	0.6
K_2O	2.6	–	0.9
Na_2O	1.1	–	–
TiO_2	2.1	–	0.1
SO_3	4	–	6.9
Specific gravity	2.03	3.23	3.15
Mean diameter (μm)	56.5	31.1	–
Specific surface area (m^2/g)	3.43	75.2	0.4
L.O.I.	11	–	–

Table 1
Solid composition of the systems studied

Denotation	Amount of binder (%)	MgO (w/w)	PC (w/w)	pfa (w/w)	Sand (w/w)	Gravel (w/w)
M	10	0.1	0	0.05	0.5	0.35
	15	0.15	0	0.075	0.46	0.32
	20	0.2	0	0.1	0.41	0.29
MP	10	0.05	0.05	0.05	0.5	0.35
	15	0.075	0.075	0.075	0.46	0.32
	20	0.1	0.1	0.1	0.41	0.29
P	10	0	0.1	0.05	0.5	0.35
	15	0	0.15	0.075	0.46	0.32
	20	0	0.2	0.1	0.41	0.29