Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 161 (2016) 543 – 548

Procedia Engineering

www.elsevier.com/locate/procedia

World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium 2016, WMCAUS 2016

Durability Properties of Concrete Produced by Marble Waste as Aggregate or Mineral Additives

Gulden Cagin Ulubeyli[a,]*, Turhan Bilir[a], Recep Artir[b]

[a]*Department of Civil Engineering, Bulent Ecevit University, Zonguldak, 67100, Turkey*
[b]*Department of Metallurgical and Materials Engineering, Marmara University, Istanbul, 34722, Turkey*

Abstract

In recent years, the growth in the industrial production and the consequent increase in the corresponding consumption have led to a fast decline in available natural resources. However, a high volume of the industrial production has generated a considerable amount of waste materials which have a number of adverse impacts on the environment. In this regard, the marble industry produces a huge amount of waste in the last decades and grows significantly in time. The marble waste is generally a highly polluting type of industrial wastes due to its highly alkaline nature and its manufacturing and processing techniques, all of which impose serious health threats to the surroundings. In this study, effects of waste marble on some durability properties such as water absorption and permeability, chloride penetration and carbonation, sulphate attack and abrasion resistance, and lastly performance at high temperature and freezing and thawing cycles of conventional or self-compacting concrete were investigated. As a result, it was found out that the use of waste marble in the conventional or self-compacting concrete mix as an admixture material or aggregate is suitable as it can improve durability properties of the concrete. Especially, properties of water absorption & permeability and resistance of chloride penetration & sulphate attack were improved by incorporation of waste marble in concrete.

Peer-review under responsibility of the organizing committee of WMCAUS 2016

Keywords: Concrete; marble waste; durability; admixture; aggregate; recycling;

* Corresponding author. Tel.: +90 372 291 1483; fax: +90 372 257 40 23.
E-mail address: cagin.ulubeyli@beun.edu.tr

Peer-review under responsibility of the organizing committee of WMCAUS 2016
doi:10.1016/j.proeng.2016.08.689

1. Introduction

Marble has been used as an important building material, especially for decorative purposes for centuries [1]. In processing marble such as cutting to size and polishing etc. for decorative purposes, marble dust and aggregate are created as by products [2]. During sawing, shaping, and polishing process, about 25% of the processed marble turns into dust or powder form [1]. Disposal and re-using of the waste materials of the marble industry is one of the environmental problems all over the world. As a solution to these negative effects, the literature suggests that the marble waste can be used in the construction industry as partial percent substitutes for aggregate, binder and additives in concrete. However, previous studies investigated this issue from different technical viewpoints and it seems necessary to examine the current positive, negative; and contradicting points in the use of marble waste in the concrete. By doing so, this study can have a potential to fill the above-mentioned gap in the literature. Therefore, in the present study, the effect of different usage areas of the marble waste on durability properties of concrete was investigated based on past studies. In this context, durability properties of concrete, such as (i) water absorption and permeability, (ii) chloride penetration and carbonation, (iii) sulphate attack and abrasion resistance and lastly (v) performance at high temperature and freezing and thawing cycles, were examined. Consequently, contributions of the marble waste to durability properties of concrete were presented as a whole in a detailed manner.

Fig.1. (a) Marble extraction [3]; (b) Remnants from plate cutting [3]; (c) Powder heaps [10].

2. Methodology

In this study, considering the previous studies, durability properties of concrete produced waste marble investigated in detailed manner. During the literature review, it was observed that the waste marble powder was used as mineral additives in cement or as fine/coarse aggregate in sand in producing conventional and self-compacting concrete mix. In these studies, effects of waste marble on some durability properties of concrete were investigated. In this study, these properties were grouped into (i) water absorption and permeability, (ii) chloride penetration and carbonation, (iii) sulphate attack and abrasion resistance, and lastly (v) performance at high temperature and freezing and thawing cycles. Consequently, effects of the waste marble on these properties of the concrete were evaluated in a detailed manner and reasons of results were established.

3. Results

3.1. Water Absorption and Permeability

Water absorption and permeability of results were summarized in Table 1. The most suitable replacement ratio of the waste marble was determined as 15-20% for water absorption and permeability of conventional or self-compacting concrete mix produced waste marble as binder or fine aggregate in the previous studies. This ratio has improved the water absorption and the permeability properties of conventional or self-compacting concrete. The reason for improved durability properties of the concrete was explained as filler effect. Waste marble additives fill the gaps within the concrete products, giving less porous structures. Thus, the uses of these wastes resulted in excellent durability, which in effect have positive effects on the concrete formation. Further addition of the waste marble decreased the strength and durability of concrete. This was because the addition of the waste marble beyond 15-20% makes the concrete results in a higher water demand due to its very high specific surface [4]. On the other hand, when the waste marble was used as coarse aggregate in concrete, water permeability of concrete slightly decreased with the addition of coarse marble aggregate (for the 50% replacement ratio) due to poorer adherence between the marble coarse aggregate and the cement paste compared to the conventional coarse aggregate in the literature [5].

3.2. Chloride Penetration and Carbonation

Considering the previous studies, chloride penetration and carbonation of results were summarized in Table 2. The most suitable replacement ratio of the waste marble was determined as 5-10% for chloride penetration and carbonation of conventional or self-compacting concrete mix produced waste marble as binder or fine aggregate in the previous studies. The one of reasons for decreased chloride penetration of the concrete was explained as filler effect of marble waste [1, 4]. In additionally, the low alumina percentage of the marble waste might have been the primary cause, as this compound promotes the formation of tri calcium aluminate, which favors fixation of the chloride ions [5].

Table 1. Comparison some results of water absorption and permeability.

	For Waste Marble			**Results**	
Type of Concrete	**Using Location**	**Ratio**	**Comparing Criterion**	**Water Absorption & Permeability**	**Ref.**
Conventional Concrete	As coarse aggregate	(20-50-100)%	Concrete produced by conventional primary aggregates (PA; basalt, granite and limestone) as coarse aggregate.	Water absorption by capillarity property slightly decreases with the addition of coarse marble aggregates for the mixes made with limestone and granite coarse aggregate.	[5]
Conventional Concrete	As fine aggregate	(20-50-100)%	Concrete produced by conventional primary aggregates (PA; limestone gravel, basalt sand, granite sand and siliceous river sand.) as fine aggregate.	The reduction of water absorption by capillary action is more pronounced in the 20% replacement of fine marble waste aggregate ratio because of the improved bond between aggregates and cement paste. For higher replacement ratios, the average pore size of the concrete tends to increase, negatively affecting the water absorption.	[6]
Conventional Concrete	As fine aggregate	(5-10-15)%	Concrete mix produced by sand as fine aggregate without waste marble	The penetrations of the control concretes were higher than that of the marble dust concretes. Marble dust 15% specimens were significantly more resistant to water penetration than those of other specimens.	[7]
Conventional Concrete	As fine aggregate	(25-50-100)%	Concrete mix produced by river sand as fine aggregate without waste marble	Permeability test results clearly demonstrate that the permeability of green concrete is less compared to that of conventional concrete.	[8]
Conventional Concrete	As mineral additives	(15-20-25)%	Concrete mix produced by cement as binder without waste marble	Mixes containing 5-15% marble slurry displayed better resistance to water penetration than the control, but further addition of waste marble resulted in increasing penetration depths.	[9]
Self-Compacting Concrete (SSC)	As mineral additives	(20-30-40-50)%	Concrete mix produced by cement as binder without waste marble	Considering the test results, the water absorption of SCC mixes containing 50% MP decreased by 22.6%, than mix control concrete.	[10]
Self-Compacting Concrete (SSC)	As mineral additives	(5-10-15-20)%	Concrete mix produced by cement and crushed rock dust as binder without waste marble	As a result, addition of marble powder by replacing the crushed rock dust in SCC leads to the filling phenomenon which continues only up to a 15% level of addition of marble powder. Further addition of marble powder decreases the strength and quality of concrete.	[4]

On the contrary to the other durability properties of the concrete produced waste marble, resistance to the carbonation of the mixes incorporated into marble waste as coarse aggregate or mineral additives was observed to be reducing or unchanged according to the references concrete, respectively (see in Table 3). The reason of this satiation can be explained as lower bicarbonate alkalinity of the marble waste compared to that of cement [9].

Table 2. Comparison some results of chloride penetration.

For Waste Marble			Results		
Type of Concrete	**Using Location**	**Ratio**	**Comparing Criterion**	**Chloride Ion Penetration**	**Ref.**
Conventional Concrete	As coarse aggregate	100%	Concrete produced by crushed limestone aggregates.	The resistance to chloride penetration was significantly higher for the concretes incorporating marble than for the control concretes.	[11]
Conventional Concrete	As coarse aggregate	(20-50-100)%	Concrete produced by conventional primary aggregates (PA; basalt, granite and limestone) as coarse aggregate.	They show that the chloride migration coefficient increases with the replacement ratio of PA with coarse marble aggregates.	[5]
Self-Compacting Concrete	As mineral additives	(5-10-20)%	Concrete mix produced by cement as binder without waste marble.	Chloride ion permeability of SCCs decreased dramatically. In both binary and ternary systems, marble was found to be more effective than limestone filler in reduction of the rapid chloride permeability test values, especially at 5% level of replacement.	[1]
Self-Compacting Concrete (SSC)	As mineral additives	(5-10-15-20)%	Concrete mix produced by cement and crushed rock dust as binder without waste marble	The 15% substitution of marble powder as a filler material and yields a significant reduction in the total charge passed. The mixes produce lower permeability results at 7, 28, 90 days.	[4]
Conventional Concrete	As mineral additives	(15-20-25)%	Concrete mix produced by cement as binder without waste marble	The substitution of 5-10% cement by fine grained marble slurry resulted in reduction of these capillary passages and led to reduced chloride ion migration.	[9]

3.3. Sulphate and Abrasion Resistance

These results summarized in Table 4 showed that there was an obvious increase in the sulphate resistance of the concrete with an increase in the percentage of the waste marble replacement with conventional fine or coarse aggregates and cement. These results can be explained by filler effect supported the improved bonding among the additives, cement and aggregate, which resulted in a more condensed matrix [7].

Table 3. Comparison some results of carbonation.

For Waste Marble			Results		
Type of Concrete	**Using Location**	**Ratio**	**Comparing Criterion**	**Carbonation Resistance**	**Ref.**
Conventional Concrete	As coarse aggregate	(20-50-100)%	Concrete produced by conventional primary aggregates (PA; basalt, granite and limestone) as coarse aggregate.	Concrete made with coarse marble aggregate has a similar carbonation depth to that of the reference concretes, thus supporting the microstructural similarity hypothesis between all the families.	[5]
Conventional Concrete	As mineral additives	(15-20-25)%	Concrete mix produced by cement as binder without waste marble	Increasing marble slurry content in mixes yielded in escalating carbonation depths.	[9]

Additionally, active SiO_2 in the marble powder can react with the $Ca(OH)_2$ in the concrete to form secondary calcium silicate hydrate and made it chemically stable and structurally dense, the impermeability of the concrete was enhanced as well and the marble powder can reduce the content of calcium aluminate in cementitious material, leading to increase of sulphate resistance of the concrete [8].

The abrasion values appear to be a function of the compressive strength of the concrete. In this study, abrasion resistance of the concrete produced waste marble as fine or coarse aggregate was increased (see in Table 5). It can conclude that the higher abrasion resistance of the concretes produced waste marble was resulted of a denser pore structure of the mortar [11]. Also, addition of the marble aggregate to the concrete was increased wear resistance of the concrete due to the higher hardness of the marble aggregate compared to conventional aggregate types [2].

3.4. Performance at High Temperature and Freezing and Thawing Cycles

Uysal, 2012 [12] investigated effect of high temperature on the self-compacting concrete produced waste marble, limestone and basalt powder using as filler.

Table 4. Comparison some results of sulphate resistance.

	For Waste Marble			**Results**	
Type of Concrete	**Using Location**	**Ratio**	**Comparing Criterion**	**Sulphate Resistance**	**Ref.**
Conventional Concrete	As coarse aggregate	100%	Concrete produced by crushed limestone aggregates.	The concrete sample containing marble waste showed the least effect by the action of Na_2SO_4. Marble concrete exhibited greater Na_2SO_4 resistance than all the others.	[11]
Conventional Concrete	As fine aggregate	(5-10-15)%	Concrete mix produced by sand as fine aggregate	As the amount of marble dust in concretes increased, the resistance of the concretes against sulphate attack increased. Marble dust concretes (replacement ratio of marble dust is 15%) very stable than other	[7]
Conventional Concrete	As fine aggregate	(25-50-100)%	Concrete mix produced by river sand as fine aggregate	The durability of Green concrete (mixing of marble and quarry rock dust) under sulphate is higher to that of conventional concrete.	[8]
Self-Compacting Concrete (SSC)	As mineral additives	(20-30-40-50)%	Concrete mix produced by cement as binder without waste marble	Increasing the marble or granite powder content in SCC by using of mineral additives enhances the resistance of concrete to sulphate attack, especially to sodium sulphate attack.	[10]

Table 5. Comparison some results of abrasion resistance.

	For Waste Marble			**Results**	
Type of Concrete	**Using Location**	**Ratio**	**Comparing Criterion**	**Abrasion Resistance**	**Ref.**
Conventional Concrete	As coarse aggregate	100%	Concrete produced by crushed limestone aggregates.	The lowest abrasion value observed was that for the concrete made with marble, and the highest value was for the control concrete.	[11]
Conventional Concrete	As fine aggregate	(5-10-15)%	Concrete mix produced by sand	Concretes produced marble dust (15%) had enhanced abrasion resistance compared to control specimens.	[7]
Concrete Paving Block	As fine and coarse aggregate	(10-20-30-40)%	Concrete produced by crushed sand and river sand aggregates.	Additions of marble aggregate to the concrete increases wear resistance of the paving blocks.	[2]

According to the test results, higher weight losses were observed in limestone powder series than in basalt and marble powder series. Also, as the self-compacting concrete mixtures were exposed to high temperature, limestone powder series showed higher reduction of pulse velocity when compared to basalt and marble powder series. Consequently, using of the waste marble as filler in concrete can improve the performance at high temperature of the concrete. Gencel et al., 2012 [2] studied freeze thaw durability of the concrete produced waste marble as aggregate. Freeze-thaw durability of paving blocks containing marble aggregate was higher than those of the control blocks.

4. Conclusions

In this study, effects of waste marble on some durability properties such as water absorption and permeability, chloride penetration and carbonation, sulphate attack and abrasion resistance, and lastly performance at high temperature and freezing and thawing cycles of conventional or self-compacting concrete were investigated. Considering all of the results in this study, using of the waste marble in the conventional or self-compacting concrete as mineral additives or fine/coarse aggregate was positively affected on these durability properties of concrete. However, for resistance to carbonation of the concrete mixes, no significant difference was observed compared to reference concrete mixes.

References

[1] M. Geseoglu, E. Guneyisi, M.E. Kocabag, V. Bayram, K. Mermerdas, Fresh and hardened characteristics of self-compacting concretes made with combined use of marble powder, limestone filler, and fly ash, Construction and Building Materials. 37 (2012) 160–170.

[2] O. Gencel, C. Ozel, F. Koksal, E. Erdogmus, G. Martinez-Barrera, W. Brostow, Properties of concrete paving blocks made with waste marble, Journal of Cleaner Production, 21 (2012) 62-70.

[3] E. Bacarji, R.D. Toledo Filho, E.A.B. Koenders, E.P. Figueiredo, J.L.M.P. Lopes, Sustainability perspective of marble and granite residues as concrete fillers, Construction and Building Materials, 45 (2013) 1–10.

[4] M.S. Hameed, A.A.S. Sekar, L. Balamurugan, V. Saraswathy, Self-compacting concrete using marble sludge powder and crushed rock dust, KSCE Journal of Civil Engineering, 16 (2012) 980-988.

[5] A. Andre, J. Brito, A. Rosa, D. Pedro, Durability performance of concrete incorporating coarse aggregates from marble industry waste, Journal of Cleaner Production, 65 (2014) 389-396.

[6] F. Gameiro, J. Brito, C. D. Silva, Durability performance of structural concrete containing fine aggregates from waste generated by marble quarrying industry, Engineering Structures, 59 (2014) 654–662.

[7] H. Binici, H. Kaplan, S. Yilmaz, Influence of marble and limestone dusts as additives on some mechanical properties of concrete, Scientific Research and Essay, 2 (2007) 372-379.

[8] M.S. Hameed, A.S.S. Sakar, Properties of green concrete containing quarry rock dust and marble sludge powder as fine aggregate, ARPN Journal of Engineering and Applied Sciences, 4 (2009) 83-89.

[9] A. Rana, P. Kalla, L.J. Csetenyi, Sustainable use of marble slurry in concrete, Journal of Cleaner Production, 94 (2015) 304-311.

[10] D.M. Sadek, M.M. El-Attar, H.A. Ali, Reusing of marble and granite powders in self-compacting concrete for sustainable development, Journal of Cleaner Production, 121 (2016) 19-32.

[11] H. Binici, T. Shah, O. Aksogan, H. Kaplan, Durability of concrete made with granite and marble as recycle aggregates, Journal of Materials Processing Technology, 208 (2008) 299–308.

[12] M. Uysal, Self-compacting concrete incorporating filler additives: Performance at high temperatures, Construction and Building Materials, 26 (2012) 701–706.