Hardened Concrete Properties Manufactured by Waste Marble Powder

Suchampa Bagchi, Tarzan Naik, Nilgrib Mohanty, Nayan Kishore Giri
Department of Civil Engineering, NM Institute of Engineering and Technology, Bhubaneswar, Odisha
Department of Civil Engineering, Raajdhani Engineering College, Bhubaneswar, Odisha
Department of Civil Engineering, Aryan Institute of Engineering and Technology Bhubaneswar, Odisha

ABSTRACT: Marble is industrially processed by being cut, polished, and used for decorative purposes, and thus, economically valuable. In marble quarries, stones are cut as blocks through different methods. During the cutting process, 20-30% of a marble block becomes waste marble powder. Marble powder may be a waste generated in considerable amounts within the world. Marble waste results in a significant environmental problem further. Therefore, the utilization of waste marble within the concrete production as an admixture material or aggregate has increasingly become a crucial issue. Within the present study, effect of various usage areas of waste marble on the hardened concrete properties was investigated supported previous studies. During this context, (1) compressive, flexural, and splitting lastingness, (2) modulus of elasticity, (3) ultrasonic pulse velocity, (4) Schmidt surface hardness, and lastly (5) sorptivity coefficient/porosity of the hardened concrete, were examined. Comparing all results, the proposition “the marble waste will be employed in the assembly of concrete” was discussed during a detailed manner. As a result, the utilization of waste marble powder in (1) conventional concrete mix, (2) self-compacting concrete mix, and (3) polymer concrete mix, was revealed. Consequently, it absolutely was discovered that the employment of waste marble within the conventional concrete mix as an admixture material or aggregate is suitable because it can improve some properties of the hardened concrete. However, the utilization of waste marble within the self-compacting and polymer concrete mixes as an admixture material or aggregate isn’t affected positively in terms of hardened properties of concrete.

Keywords: Concrete, Hardened Concrete, Recycling, Waste Marble Powder

I. INTRODUCTION

Marble is a metamorphic rock resulting from the transformation of pure lime stone (Malpani, Jegarkal, Shepur, Kiran, & Adi, 2014). The rock is also one of the most important materials used in buildings since ancient times, especially for decorative purposes (Soliman, 2013). Turkey has the 40% of total marble reserve in the world. 7,000,000 tons of marble have been produced in Turkey annually and 75% of these production have been processed in nearly 5000 processing plants. It can be apparently seen that the waste materials of these plants reach millions of tons. Stocking of these waste materials is impossible (Alyamac & Ince, 2009). These type solid waste materials should be inactivated properly without polluting the environment. The most suitable inactivating method nowadays is recycling. Recycling provides with some advantages such as protecting the natural resources, energy saving, contributing to economy, decreasing the waste materials and investing for the future (Kaseva & Gupta, 1999).

Literature review in this study reveals that waste marble uses as raw or admixture material and fine or coarse aggregate in different sectors such as ceramic, brick and building materials. In this study, properties of hardened concrete produced waste marble powder used admixture or fine/coarse aggregate in the concrete were examined in detailed manner. Additionally, it was determined that possibility of usage of these waste in the concrete as admixture material or aggregate affected positively on the hardened properties of concrete. Consequently studies in the literature related hardened properties of concrete produced waste marble were examined.

II. METHODOLOGY

In this study, considering the previous studies, properties of hardened concrete produced waste marble investigated in detailed manner. All results are compared suggesting that waste marble could utilize in concrete. As a result of literature, utilization of waste marble in; (1) conventional concrete mix, (2) self-compacting concrete mix, and (3) polymer concrete mix, was revealed. Waste marble powder was used as binder in cement or as fine/coarse aggregate in sand in producing conventional concrete mix. However, the waste was utilized generally as fine aggregate in sand in self-compacting concrete mix. Waste marble was used also as aggregate with different sieve aperture in polymer concrete mix. Experiments were carried out for hardened concrete in literature were compressive, flexural, splitting, modulus of elasticity, ultrasonic pulse velocity, Schmidt surface
hardness, and lastly sorptivity coefficient/porosity tests. All results were analyzed for each study in detailed manner and these results were tabulated in twoparts.

III. RESULTS

1.1. Compressive- Flexural- Splitting Strength and Modulus of Elasticity

Compressive, flexural, splitting strength and modulus of elasticity results were summarized in Table 1. Most suitable replacement ratio of waste marble for the studies that waste marble was replaced as binder in cement in conventional concrete mix was determined as 5-10%. This ratio was improved physical and mechanical properties of conventional concrete. The reasons for improved properties of hardened concrete were explained as follows:

- The compressive strength may be due to that the active SiO₂ in waste marble powder can react with the Ca(OH)₂ in concrete to form secondary calcium silicate hydrate and make it chemically stable and structurally dense (Omar, Abd Elhameed, Sherif, & Mohamadien, 2012).
- The usage of waste marble powder in concrete shows a filler effect. The reason can be said as that the filler is an inert addition and it can be assumed as ultrafine aggregates filling voids in concrete. The usage of waste marble powder reduces the porosity in concrete matrix physically, and has an important binding property which is developed by hydration of calcite and C₃A chemically (Ergun, 2011).

Table 1. Comparison Some Results Of Compressive, Flexural, Splitting Strength And Modulus Of Elasticity.

<table>
<thead>
<tr>
<th>Type Of Concrete</th>
<th>Using Of Waste Marble In The Concrete</th>
<th>Waste Marble Ratio</th>
<th>Other Constituents Ratio</th>
<th>Cure Conditions</th>
<th>Comparing Criteria</th>
<th>Result</th>
<th>Ref</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Concrete</td>
<td>As Fine Aggregate In Sand 20-33 - 50%</td>
<td>40% (20-33-50) Quarry Stone And Sand</td>
<td>7 And 28 Days</td>
<td>Concrete Produced By Sand As Fine Aggregate Without Waste Marble</td>
<td>It Is Observed That Mix Containing 40% Sand, 40% Marble Sludge Powder, 20% Quarry Rock Dust Had The Best Compressive Strength And Mix Containing 50% Quarry Rock Dust, 50% Marble Sludge Powder And 20% Sand, 40% Quarry Rock Dust, 40% Marble Sludge Powder Had The Best Values For Spent Tensile Strength Of Concrete.</td>
<td>The 7 Days And 28 Days Compressive Strength Of Green Concrete Was 6.49% And 9.49% Higher Than Controlled Concrete Respectively. Similarly The 7 Days And 28 Days Split Tensile Strength Of Green Concrete Was 14.62 And 8.66% Which Were Higher Than Controlled Concrete Respectively.</td>
<td></td>
</tr>
</tbody>
</table>
Hardened Concrete Properties Manufactured by Waste Marble Powder

By increasing the Waste Marble Granules the Compressive Strength Values of Concrete tended to increase at each curing age. Furthermore, the mean strength of Concrete Mixes with Marble Granules was 5-10% higher than the reference Concrete. The flexural strength of Waste Marble Mix Concrete increased with the increase of the Waste Marble Ratio.

The Concrete Compressive Strength increased with the increase of Marble Dust Ratio as Sand Replacement up to 15.0% of Sand by weight. Also, the use of Marble Dust as Sand Replacement was more effective with lower W/C ratio. Generally, the 10.0% Marble Dust Content as Sand Replacement was considered the optimum content that achieving the highest Concrete Tensile Strength. This trend was the same for 0.50 and 0.40 W/C Ratio.

All specimens produced by Waste Marble Dust had higher compressive strength values than control specimens. Furthermore, compressive strength increased with increased curing age and Marble Waste Ratio.

### Mixing Ratio Of Concrete

<table>
<thead>
<tr>
<th>Type Of Concrete</th>
<th>Using Of Waste Marble In The Concrete</th>
<th>Waste Marble Ratio</th>
<th>Other Constituents Ratio</th>
<th>Cure Conditions</th>
<th>Comparing Criteria</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Concrete</td>
<td>As, Coarse Aggregate</td>
<td>100%</td>
<td></td>
<td>7 And 28 Days</td>
<td>Conventional Concrete Produced Waste Marble Aggregate Were Admixed According To IS Standards. But, Compressive Strength Of Concretes Produced Crushed Stone Aggregate Was Higher Than Conventional Produced Waste Marble Aggregate At All Curing Ages.</td>
<td>CAPLAN &amp; MASON, 2003.</td>
</tr>
<tr>
<td>Conventional Concrete</td>
<td>As Coarse Aggregate</td>
<td>100%</td>
<td>Granite Blast Furnace Slag (GBFS) And River Sand (As Fine Aggregates In This Study)</td>
<td>1.2, 28 And 90 Days</td>
<td>Concrete Produced By Crushed Limestone Stone As Coarse Aggregate.</td>
<td>The Use Of Marble And GBFS Resulted In A Significant Increase In The Compressive Strength Of The Concrete. Upon Aging The Compressive Strength Values Of All Concrete Types Increased. The Use Of Marble And Granite In Concrete Improved The Flexural- And Splitting-Tensile Strength Of Concrete. The Splitting-Tensile Strengths Of Marble And Granite Concretes Were Higher Than That Of The Conventional Concrete. The Average Values Of The Modulus Of Elasticity Of Marble And Granite Concretes Were 79% Higher Than Those Of The Conventional Concrete.</td>
</tr>
</tbody>
</table>

151
### Hardened Concrete Properties Manufactured by Waste Marble Powder

There was a slight loss of compressive strength at 28 days with an increase in the replacement ratio of PA with marble aggregate. Although results indicated a general downward trend of the mean compressive strength at 28 days with increasing incorporation ratios, this decrease may be considered almost insignificant with variations up to 10.5% (for the granite concrete mix).

Increasing the marble powder ratio replacement of cement led to the increasing as the compressive strength by about 23% and 9% for the marble powder replacement rates of 5% and 7.5%, respectively. Compared to the control mix, increasing indirect tensile strength and modulus of elasticity was recast of the by using marble powder ratios (5% and 7.5%) compared to the control mix.

#### Mixing Ratio of Concrete

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Using of Waste Marble in the Concrete</th>
<th>Waste Marble Ratio</th>
<th>Other Constituents Ratio</th>
<th>Cure Conditions</th>
<th>Comparing Criteria</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Concrete</td>
<td>As. Binder in Cement</td>
<td>(3.75-10)%</td>
<td>Diorite And Opc</td>
<td>7.28And 56Days</td>
<td>The Concrete Containing 5% Waste Marble Powder As Partial Replacement By Weight For Cement With A Super Plasticizer Admixture Had Higher Compressive Strength Than That Of The Control Concrete Specimens. Consequently, The Replacement Of Cement With Diorite And Waste Marble Powder Separately Or Together Could Be Used To Improve The Mechanical Properties Of The Conventional Concrete Mixtures.</td>
<td></td>
</tr>
<tr>
<td>Conventional Concrete</td>
<td>As. Binder in Cement</td>
<td>(5.75-10)%</td>
<td>Opc (Two Different Water:Cement (W/C) Ratios (0.40-0.50)</td>
<td>7.28And 56Days</td>
<td>The Compressive Strength Of Cement Mortar Increases By The Use Of Marble Dust As Cement Replacement. A Reduction in the Compressive Strength of Marble Dust Modified Mortar of 50% Lower Than Control Specimen Is Reported At 15.0% Marble Dust As Cement Replacement. A Significant Improvement in Concrete Tensile Strength Is Recorded Due To The Use Of Marble Dust As Cement Replacement.</td>
<td></td>
</tr>
</tbody>
</table>

---

152
## Hardened Concrete Properties Manufactured by Waste Marble Powder

Test Results Indicate That The 10% Of Marble Dust In The Cement Concrete Given The Best Compressive And Tensile Strength. And Also Increase In Curing Days Increased The Strength Of Marble Dust Concrete When Compared From 14 Days To 28 Days.

Compressive Strength Of The Concrete Has Increased With Increasing Percentages Of M.P Additions At All Curing Ages. The Highest Compressive Strength Appears When The Highest Proportion Of M.P. Specimen, Especially At Early Curing Ages. Using 50% Lwa With 15% M.P Increased The Splitting Tensile Strength Compared With Normal Concrete Mix. Modulus Of Elasticity Of Green Concrete That The Modulus Of Elasticity Increased For With Increasing The Limestone Waste With Mf In Cemel Content.

The Compressive Strength Decreases With An Increase In Mf Content.

### Mixing Ratio Of Concrete

<table>
<thead>
<tr>
<th>Type Of Concrete</th>
<th>Waste Marble In Concrete</th>
<th>Waste Marble Ratio</th>
<th>Other Constituents Ratio</th>
<th>Cure Conditions</th>
<th>Compressing Criterion</th>
<th>Result</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Compacting Concrete</td>
<td>As Binder In Cement</td>
<td>(10-20): (30%)</td>
<td>Lime Stone Powder, Barit Powder, Opc</td>
<td>7, 28, 90 And 400 Days</td>
<td>Concrete Mix Produced By Cement As Binder Without Waste Marble</td>
<td>All The Mineral Admixtures Have Shown Significant Performance Differences And The Highest Compressive Strength Obtained For Addition Of 20 % The Marble Powder Mixture When The Strength Of Specimens Increased. Dynamic Elastic Modulus Also Increased And The Highest Static Elastic Modulus And Dynamic Elastic Modulus Obtained For Addition Of 20 % And 10 % Marble Powder, Respectively.</td>
<td>Umar &amp; Yousif, 2011.</td>
</tr>
<tr>
<td>Self-Compacting Concrete</td>
<td>Mf: (50) 100-200-250-300Kg</td>
<td>Fly Ash And Opc</td>
<td>28 Days</td>
<td>Concrete Mix Produced By Cement As Binder Without Waste Marble</td>
<td>The Compressive And Flexural Strengths Decreased Because Of Increase In Marble Powder Content. But, Differences Of Compressive Strength Between Control Specimen And Specimens Containing Marble Powders (Especially, 50-100-150-200 Kg/m³ Of Marble) Were Not Too Much. Therefore, The Maximum And The Optimum Usage Amount Of Marble Powder Can Be Said As 200 Kg/m³ Content In Order To Obtain Best Performance For Both Of Fresh And Hardened Properties Of Concrete.</td>
<td>Topcu, 2010.</td>
<td></td>
</tr>
</tbody>
</table>
# Hardened Concrete Properties Manufactured by Waste Marble Powder

## Table: Mixing Ratio of Concrete

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Waste Marble Ratio</th>
<th>Other Constituents Ratio</th>
<th>Cure Conditions</th>
<th>Comparing Criteria</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Compacting Concrete</td>
<td>10% Sand</td>
<td>Polyester Was Used As Filter Material</td>
<td>3.72 And 241 Days</td>
<td>10% Replacement Of Sand With Marble Aggregate Caused About 10–20% Compressive Strength Decrease In Late Age.</td>
<td>Comianni, Misconati &amp; Mill, 2010.</td>
</tr>
<tr>
<td>Self-Compacting Concrete</td>
<td>As Fine Aggregate In Sand</td>
<td>10%</td>
<td>3, 7, 28 And 241 Days</td>
<td>10% Replacement Of Sand With Marble Aggregate Caused About 10–20% Compressive Strength Decrease In Late Age.</td>
<td>Comianni, Misconati &amp; Mill, 2010.</td>
</tr>
<tr>
<td>Polymer Concrete</td>
<td>As Aggregate With Different Sieve Aperture</td>
<td>Polyester Was Used As Filter Material</td>
<td></td>
<td>When Sieve Apertures Were Higher, Compressive And Flexural Strength Of Concretes Were Decreased.</td>
<td>Soyfian &amp; Ozi, 2012.</td>
</tr>
</tbody>
</table>
Table 2. Obtained Results Of Schmidt Surface Hardness, Ultrasonic Pulse Velocity And Porosity/Sorptivity Coefficients.

<table>
<thead>
<tr>
<th>Type Of Concrete</th>
<th>Using Location</th>
<th>Ratio</th>
<th>Comparing Criterion</th>
<th>Ultrasonic Pulse Velocity (Upv)</th>
<th>Schmidt Surface Hardness</th>
<th>Porosity / Sorptivity Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Concrete</td>
<td>As Binder As Fine Aggregate In Sand</td>
<td>52.5:10:13</td>
<td>Concrete Mix Produced By Cement As Binder Without Waste Marble / Concrete Mix Produced By Sand As Fine Aggregate Without Waste Marble</td>
<td>The Use Of Marble Dust Either As A Cement Replacement Or A Sand Replacement Has insignifican Effect On The Value Of The Ultrasonic Pulse Velocity. While Using Of Marble Dust As A Partial Replacement Of Sand Slowed An Improvement In Porosity Values, Usage Of Marble Dust As A Partial Replacement Of Cement Decreased The Porosity.</td>
<td>When Usage Of Marble Dust As A Partial Replacement Of Sand Slowed An Improvement In Porosity Values, Usage Of Marble Dust As A Partial Replacement Of Cement Decreased The Porosity.</td>
<td>Refer.</td>
</tr>
<tr>
<td>Conventional Concrete</td>
<td>As Concrete Aggregate</td>
<td>100%</td>
<td>Concrete Produced By Crushed Stone Aggregate As Coarse Aggregate 25/30 Concrete Class Properties Were Targeted According To Ts 80 Standards.</td>
<td>While Upv Value Was 4.34 Kms for Concrete Produced As Waste Marble Aggregate, This Value Was 4.48 Kms For Concrete Produced Crushed Stone Aggregate. The Obtained Results For Two Different Situations Were Suitable According To Standards Of C 25/30 Concrete Class.</td>
<td>Coplan et al., March 2013.</td>
<td>Refer.</td>
</tr>
<tr>
<td>Self-Compact EL Concrete</td>
<td>As Binder In Cement</td>
<td>(10-20-30)</td>
<td>Concrete Mix Produced By Cement As Binder Without Waste Marble</td>
<td>25/30 Concrete Class. Upv Values Compared Between 4.2 Kms And 4.3 Kms For Different Rates Of Material Waste. Upv Values Of Specimens Decreased With Increasing Marble Waste Rate In The Mix.</td>
<td>While Schmidt Surface Hardness Value Was 25 For Concrete Produced As Waste Marble Aggregate, This Value Was 23 For Concrete Produced Crushed Stone Aggregate. The Obtained Results For Two Different Situations Were Suitable According To Standards Of C 25/30 Concrete Class.</td>
<td>Refer.</td>
</tr>
<tr>
<td>Self-Compact EL Concrete</td>
<td>As Binder In Cement</td>
<td>(50-100-150-200-250-300) Kg</td>
<td>Concrete Mix Produced By Cement As Binder Without Waste Marble</td>
<td>Upv Values Compared Between 4.2 Kms And 4.5 Kms For Different Rates Of Waste Marble.</td>
<td>The Capillary Coefficient Of Concrete Decreased With The Increase In Filler Material Content Between 50 And 200 Kg/M.</td>
<td>Refer.</td>
</tr>
</tbody>
</table>
1.2. Ultrasonic Pulse Velocity, Schmidt Surface Hardness, and Sorptivity Coefficient/Porosity

Schmidt surface hardness test, ultrasonic pulse velocity test and determination of porosity/sorptivity coefficients were other carried test on the hardened concrete mixes which were summarized in Table 2. In previous studies about conventional concrete mixes produced by waste marble which was used as binder in cement and as fine/coarse aggregate in concrete.

In the study, which is based on replacement of cement or sand with waste marble powder, (Aliabdo, Abd Elmoaty, & Auda, 2014) determination of ultrasonic pulse velocity of conventional concrete was carried out. The use of marble dust either as a cement replacement or a sand replacement has insignificant effect on the value of the ultrasonic pulse velocity. Porosity of concrete also decreases with the increase of marble dust addition which act as cement revealing comparable results to control specimens in case of 0.50 and 0.40 w/p ratios. In addition, the usage of marble dust as a partial replacement of sand showed an improvement in porosity values. This improvement in porosity could be explained as a result to the filler effect of marble dust.

In some studies, waste marble was used as coarse aggregate in conventional concrete mixes. In one of these studies, ultrasonic pulse velocity and Schmidt surface hardness values were determined and C 25-30 concrete class properties was targeted according to TS 802 Standards. Results obtained in the previous study (Ceylan & Manca, 2013) for ultrasonic pulse velocity and Schmidt surface hardness tests were suitable according to TS standards.

Waste marble was also used as replaced binder in self-compacting concrete mixes. Ultrasonic pulse velocity and Sorptivity Coefficient/Porosity values were obtained in these studies. Ultrasonic pulse velocity values were determined between 4, 2 and 4, 9 km/s. While sorptivity coefficient was changed by porosity as inverse proportionality, it was changed by compressive strength as directly proportional (Topcu, Bilir, & Uygunoglu, 2009). In other study, sorptivity coefficient was decreased with increasing waste marble replacement ratio in cement (Geseoglu, Guneyisi, Kocabag, Bayram, & Mermerdas, 2012).

Lastly, waste marble had different sieve apertures were used as aggregate in polymer concrete mixes. The trend (decreasing or increasing) was not confirmed according to sieve aperture for results of ultrasonic pulse velocity and Schmidt surface hardness tests. Different results were determined for different sieve aperture. Consequently, it was concluded that grain size diameter of minerals were affected on polymer concrete technology, but, correlation coefficient between mechanical properties and grain size diameter was not high (Soykan & Ozel, 2012).

IV. CONCLUSION

Considering the all of the results in this study, using of waste marble in the conventional concrete as binder or fine/coarse aggregate was positively affected on properties of hardened concrete. Whereas in self-compacting concrete, increasing of waste marble replacement ratios in the concrete were decreased the mechanical properties of concrete. Same declining trend of hardened properties of concrete was also determined in the polymer concrete. Consequently, it was concluded that replacement of waste marble with cement or aggregate in conventional concrete was improved properties of hardened concrete. But, using of waste marble in self-compacting or polymer concrete was not affected positively on the properties of hardened concrete.
REFERENCES


