TREATED SEA COMPONENTS CONCRETE

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This paper has introduced the concept of sustainable concrete. To save pure water and sand quarries, both seawater and sea sand have been used in concrete mix instead of pure water and normal sand. In addition, the cement has been partially replaced by ash from palm tree wastes to address the effect of salinity on the mechanical properties of the concrete. The workability and compressive strength of concrete were investigated for various percentages of replacement of sea-sand and palm tree waste ash. The slump and compression tests were completed, with the concrete compression test completed after 7 days and 28 days of curing with seawater. The results showed that replacing 30% of the normal sand with sea-sand and 5% of the cement with palm ash wastes in the presence of seawater as a full replacement of the tap water increased the compressive strength by 48.5% when compared to normal concrete with sea water as a mixing water.

Keywords: Sea-sand, Seawater, Workability, Compressive strength, Curing.

1 INTRODUCTION

Researchers compete to save pure water due to the shortage in the pure water. Climate change, increased human consumption, overuse, and wastage of water are the main reasons for this shortage. The concrete industry is a highly consumed industrial for pure water, so the pure water needs to be replaced. As the seas and oceans occupy the major area of the plant, so the success of using this water may lead to save pure water. However, some researchers showed that the use of the seawater decrease the concrete compressive strength. Wegian (2010) showed that the seawater mixed concrete respective compressive strength decreases after 14 days up-to 90 days of curing in seawater and he referred it to the formation of salts crystallization. In addition, Cui et al. (2014) concluded that the use of the seawater as a mixing water and marine sand as fine aggregate reduced the strength of the concrete when compared with the normal concrete. Nishida et al. (2015) indicated that adding blast furnace slag might enhance concrete performance, which increase the possibility of using seawater in mixing concrete. Lago et al. (2017) studied the effect of Sodium Chloride on the hydration of the Portland cement, they showed that 10% of sodium chloride accelerated the hydration but 20% of the sodium chloride retarded the hydration. After 28 days, they found more products of hydration products. Younis et al. (2018) compared the properties of the fresh concrete and hardened concrete of the seawater concrete and the normal concrete. They showed that the performance of the hardened concrete is slightly lower than the normal concrete also the fresh properties notably affected. Younis et al. (2020) investigated the properties of a sustainable concrete made of recycled aggregate and mixed with seawater. They showed that the use of seawater with recycled aggregate has a negative impact on the concrete properties, where the slump lowered by 25% and the compressive strength lost 33% of its value.
In addition, the sea sand can be used to replace the normal sand in the concrete mix to save sand quarries. Limeira et al. (2011) studied the durability and mechanical properties of the concrete made of the marine sand, they showed that the degraded marine sand can be used instead of normal sand. Also, they found that marine sand reduced the pores in the concrete and hence reduced the water penetration under pressure. Katano et al. (2013) developed denser and harder concrete by using seawater and sand water in the presence of the furnace slag and silica fume, fly ash. They found that this type of concrete can be used in isolated islands to reduce transportation cost. Cheng et al. (2018) investigated the use of coral sand instead of river sand in concrete fabrication, they showed that coral sand reduced the concrete strength, despite the rapid increase in early age, and increased the porosity of the concrete. Guo et al. (2020) used the sea sand and seawater as a full replacement of the normal sand and tap water, they found via statistical analysis a slight decrease in the concrete strength, concrete modulus of elasticity and concrete strain.

On the other hand, the cement industry is one of the most industries cause environmental pollution in the world. In order to reduce the pollution due to cement, researchers are seeking to reduce cement content in concrete by using fly ash. Labib (2019) investigated the use of date palm fibers in cement composites. At various percentages, the chemical and mechanical properties of date palm fibers and synthetic fibers were compared. Malkawi et al. (2019) conducted an experimental program on concrete mixed with Palm Oil Clinker (POC) aggregates. They concluded that POC concrete can be used as structural lightweight concrete at full replacement level. POC can be replaced to increase strength and durability. Nassef et al. (2021) investigated the effects of palm tree wastes on the properties of concrete in order to serve the sustainable environment by reducing cement content in the concrete mix.

2 CONCRETE MIXES

2.1 Mix Design

This study was carried out for a concrete of grad C30 that has a traditional use, the British standards (BS-EN-206 (BSI 2014), BS-8500 (BSI 2016)) were used to design the proposed mix strength. The used aggregate was crushed of maximum size 20 mm, the used cement rank is 42.5 and the slump was 60 – 180 mm, the obtained concrete components were as shown in the following Table 1.

Table 1. Mix components for concrete of grade C30.

<table>
<thead>
<tr>
<th>Component</th>
<th>Mass (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seawater</td>
<td>225</td>
</tr>
<tr>
<td>Cement</td>
<td>432.7</td>
</tr>
<tr>
<td>Sand</td>
<td>498.69</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>1163.61</td>
</tr>
<tr>
<td>Specific weight</td>
<td>2320</td>
</tr>
</tbody>
</table>

Table 2. Oman Sea salts concentrations.

<table>
<thead>
<tr>
<th>Physicochemical parameters</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>PO₄ µmole·l⁻¹</td>
<td>0.57±0.4</td>
</tr>
<tr>
<td>NO₃ µmole·l⁻¹</td>
<td>0.78±0.9</td>
</tr>
<tr>
<td>NO₂ µmole·l⁻¹</td>
<td>0.39±0.17</td>
</tr>
<tr>
<td>NH₄ µmole·l⁻¹</td>
<td>0.35±0.1</td>
</tr>
<tr>
<td>SiO₃ µmole·l⁻¹</td>
<td>6.37±5.8</td>
</tr>
<tr>
<td>Organic carbon mg·l⁻¹</td>
<td>6.37±3.7</td>
</tr>
<tr>
<td>Inorganic carbon mg·l⁻¹</td>
<td>13.62±4.6</td>
</tr>
<tr>
<td>PCO₂ µ·atm</td>
<td>211±139</td>
</tr>
</tbody>
</table>
The used seawater was collected from the Oman Sea with the following salts proportions which was investigated by Emara (2010), as shown in Table 2.

2.2 Proposed Mixes

In this study, the partial replacement of the normal sand with the sea sand was investigated with a partial replacement of the cement with the ash of the palm trees waste of 5%. Table 3 shows the codes and the replacement percentages of the proposed mixes.

<table>
<thead>
<tr>
<th>Specimen Code</th>
<th>Normal Sand Replacement Percentage With Sea Sand %</th>
<th>Percentage of Palm Trees Ash as a Partial replacement of the cement %</th>
<th>No. of Samples (Cubes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCSW000</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>PCSW500</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>PCSWSS10</td>
<td>10</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>PCSWSS30</td>
<td>30</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>PCSWSS50</td>
<td>50</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

2.3 Palm Trees Wastes Ash

Palm leaves wastes were collected in Baurimi, Sultanate of Oman, dried in the air, and then burned in the presence of air, as shown in Figure 1. 1 kg of palm leaves ash was obtained after burning 10 kg of dried palm leaves in an open oven for nearly 1 hour.

Figure 1. Palm leaves ash preparation.

3 EXPERIMENTAL PROGRAM

The experimental program of this study included the slump test for the fresh concrete and the compressive strength test after 7 and 28 days of curing in the sea water, as shown in Figure 2. 18 cubes of dimensions 150×150×150 mm were prepared for each proposed mix.

Figure 2. Curing of specimens with sea water.

4 RESULTS AND DISCUSSION

4.1 Mix Design

The slump test is the measure of the concrete workability, as shown in Figure 3, and it can indicate the quality of the produced concrete. The slump test was carried out for the proposed fresh concrete mixes; the results are shown in Figure 4.
It can be noted that all slump test results were within acceptable range of the mix design. Replacing 5% of the cement with palm leaves ash reduced the slump from 12 cm to 8 cm, where the palm leaves ash reduced the cement initial setting time. But at the same partial replacement percentage of the cement with the palm leaves ash and replacement of the normal sand with 10% of sea sand, the workability increased again due to the enhancement of the mix gradation. Raising the replacement of the normal sand to 30% of the sea sand led to decrease in the slump to 9 cm, which is referred to the fineness of the sea sand that made the sand grains occupied the voids between the particles of the coarse aggregate, and hence a reduction on the slump occurred. By increasing the replacement percentage of the normal sand with the sea sand till 50% reduced the slump to 6 cm, which can be referred to that the mix became denser due to the increase of the fine particles.

### 4.2 Concrete Compression Test

The concrete compression strength is the important indicator of the concrete quality, the proposed mixes specimens were tested after 7 days and 28 days using a compression tests machine at a loading rate of 3 kN/s, as shown in Figure 5.

Figure 6 shows the compression test results after 7 days of curing in sea water.

It can be noted that replacing 5% of the cement with palm leaves ash enhanced the concrete compressive strength by 36.5%. Replacing 10% of the normal sand with sea sand increased the strength by 14.14% compared to normal concrete. But it can be noted that replacing 10% of the
normal sand with the sea sand reduced the compressive strength in comparing this mix with the mix of the normal concrete with replacement of 5% of the cement with the palm leaves ash by 16.37%. The partial replacement of the normal sand with 30% of the sea sand increased the compressive strength by 76.86% when compared with normal concrete, and 29.56% when compared with the normal concrete with 5% replacement of the cement with palm leaves ash. Increasing the percentage of the replacement of the normal sand with sea sand to 50% reduced the compressive strength by 11.88% when compared to the replacement with 30%. But this replacement increased the compressive strength of the normal concrete and normal concrete with 5% replacement of the cement with the palm leaves ash by 58.07% and 15.8%, respectively.

Figure 7 shows the compressive strengths of the proposed mixes after 28 days of curing in the seawater. It can be noted that the same trend was obtained.

![Compressive Strength Chart](image)

**Figure 7.** Compressive strength after 28 days of curing in sea water.

When 10% of the normal sand is replaced with sea sand, the strength of the concrete increases by 5.29% when compared to normal concrete. However, replacing 10% of the normal sand with sea sand reduced the compressive strength by 16.08% when compared to the mix of normal concrete with 5% of the cement replaced with palm leaves ash. The partial replacement of normal sand with 30% sea sand increased the compressive strength by 48.55% when compared to normal concrete, and 18.37% when compared to normal concrete with 5% palm leaf ash replacement.

When the percentage of normal sand replaced with sea sand was increased to 50%, the compressive strength was reduced by 4.7% when compared to 30% replacement. However, this substitution increased the compressive strength of normal concrete and normal concrete with 5% palm leaf ash replacement by 41.86% and 13%, respectively.

5 CONCLUSION

It can be concluded that the using of the sea sand and sea water in the presence of the palm leaves ash as a treatment gave a sustainable concrete that can save both tap water and normal sand. The 30% of replacement of the normal sand with sea sand in conjunction with 5% replacement of the cement with the palm leaves ash and sea water as a mixing water gave the best mixture for this green concrete, where it gave a good and high early strength after 7 days of curing in the sea water of 27.76 MPa and it gave a good characteristic strength after 28 days of curing in the sea water where it reached to 30.66 MPa for concrete of grade C30. Moreover, the cost of the proposed mix is less than the cost of normal mix with tap water, where tap water is replaced with untreated seawater in both mixing and curing, the 5% of cement is replaced by ash of the palm waste and 30% of normal sand is replaced with untreated sea sand.

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