Experimental study on strength of concrete prepared by marine raw materials under different sand rates

Yan Xiaowei1

1 China Communications 2nd Navigational Bureau 3rd Engineering Co., Ltd

Abstract: The high strength concrete prepared by Marine raw materials was prepared by different coordination ratio, and its compressive strength and tensile strength were measured, and its basic mechanical properties were analyzed. The results show that the water ash ratio is 0.32, the sand rate is 37%, and the high strength concrete prepared by the Marine raw materials is the best. In water and seawater dry-wet circulation under two kinds of condition maintenance, compared with 0.28 and 0.29, the compressive strength of ocean raw materials can reach the compressive strength level of C60 concrete. Considering its economy, the water cement ratio in this paper is 0.29.

1. Introduction
In China's coastal areas, sea sand and sea stones are rich in resources and sea water resources are more abundant and easy to mine. Due to the huge reserves of these marine raw materials, they are also used in some marine projects [1], due to the fineness of sea sand. It is small, and the particle size of the sea stone is very large, and the gradation is relatively poor, which will have an adverse effect on the compressive strength of the concrete. Concrete made from marine raw materials, concrete will be not only corroded by the outside world, but also corroded by the interior of the concrete itself. As a result, various degrees of damage may occur. This damage is macroscopically reflected as damage of cement stone or cement concrete. Cracking, surface peeling, etc., can also cause the strength of cement stone or cement concrete to decrease and the steel bars in the concrete to rust. Xing Li et al. [2] found that with the increase of age, the strength of sea sand seawater concrete is equivalent to that of traditional concrete. Limeira [3] et al. conducted a large number of studies on sea sand concrete. The results show that sea sand concrete mixture properties and mechanical properties have no significant change compared with river sand. Li Yan [4] and other found that sea sand due to its mud content and mud content is significantly lower than ordinary river sand, and compressive strength is higher than river sand, but the increase is limited. Cao Weiqun [5] and other found that for higher strength coagulation, the compressive strength of sea sand coagulation is higher.

Therefore, this paper improves the strength by changing the water-cement ratio to improve the workability and self-compacting of concrete. Designed to provide technical references for concrete prepared from marine raw materials.

2. Test scheme

2.1 the raw material
1) Cement: ordinary Portland cement of zhenjiang jurong stage mud 52.5.
Table 1 P · O 52.5 the physical properties of cement

| Normal consistency (%) | Setting time (min) | Flexural strength (MPa) | Compressive strength (MPa) |
|-------------------------|-------------------|------------------------|---------------------------|
|                         | Initial setting   | Final set              | 3d                        | 28d                      |
| 28.5                    | 185               | 245                    | 7.1                       | 16.5                     |
|                         |                   |                        | 48.7                      | 66.8                     |

2) Fresh water: tap water;
3) Seawater: Artificial seawater is prepared according to the proportion of major ions in seawater. See Table 2;
4) Sea stone: the maximum particle size does not exceed 25mm, the shape of the needle is mostly, and the particle size is good.;
5) Gravel: The maximum particle size is no more than 25mm, the shape is round, and the particle size is good.;
6) River sand: The fineness modulus of sea sand is 2.65, and the water content is 0.51%.;
7) Sea sand: The fineness modulus of river sand is 2.36, and the water content is 0.29%.;
8) Admixture: polycarboxylic acid type water reducing agent, the solid content is 55%.

Table 2 main components of artificial sea water

| denomination | Molecular formula | Quality/ (g/L) |
|--------------|-------------------|----------------|
| Sodium chloride | NaCl              | 46.934         |
| Magnesium chloride | MgCl₂         | 9.962          |
| Sodium sulfate | Na₂SO₄            | 7.834          |
| Calcium chloride | CaCl₂            | 2.204          |
| Potassium chloride | KCl              | 1.328          |

2.2 Determine the water-cement ratio
According to the "General Concrete Mixing Ratio Design Regulations" (JGJ55-2011), the water-cement ratio of the prepared C60 concrete is calculated to be 0.29. According to Table 7.3.2, the water-cement ratio range selected in this test is 0.28~0.33.

2.3 Selection of sand ratio
A reasonable sand ratio gives the concrete the best workability and optimizes the strength and durability of the concrete. By carrying out different slability rates and testing the slump and strength of high-strength concrete and ordinary high-strength concrete prepared from marine raw materials, the influence of sand rate on the performance of high-strength concrete prepared from marine raw materials can be studied. According to the "General Concrete Mixing Ratio Design Regulations"(JGJ55-2011) Table 7.3.2, the sand rate selected in this test is 37%.

2.4 concrete mix design and test block size
The mixing ratio of high-strength concrete prepared by C60 marine raw materials and C60 ordinary high-strength concrete is the same. See Table 3 for details. The test block size is 150mm × 150mm × 150mm, and 6 test blocks are prepared for each mix ratio.

Table 3 Mix proportion of C60 concrete

| number | Water cement ratio | Sand rate /% | cement /kg | water/kg | Sand/kg | Stone/kg | Water reducing agent/kg |
|--------|--------------------|--------------|------------|----------|---------|----------|-------------------------|
| JS19   | 0.28               | 37           | 553.57     | 155      | 625.83  | 1065.60  | 1.77                    |
| JS20   | 0.29               | 37           | 551.72     | 160      | 624.66  | 1063.62  | 1.77                    |
| JS21   | 0.30               | 37           | 550.00     | 165      | 623.45  | 1061.55  | 1.77                    |
| JS22   | 0.31               | 37           | 548.39     | 170      | 622.20  | 1059.41  | 1.77                    |
2.5 curing conditions
The curing conditions are two kinds of curing conditions: seawater immersion and seawater dry and wet cycle. The cycle of dry and wet cycle is 4 days, seawater immersion for two days, and oven drying at (50±2) °C for two days. The strength was measured at 7d and 28d respectively.

3. Test results and analysis

3.1 Test results
The fresh concrete was placed in a slump cylinder to measure its slump, and the concrete slump was measured as shown in Tables 4-5. The compressive strength and splitting tensile strength of concrete specimens for curing 7d and 28d were measured by YAW-2000B pressure testing machine produced by Jinan Zhongluchang Testing Machine Manufacturing Co., Ltd., and the test results are shown in Tables 6-9.

Table 4 C60 ordinary high strength concrete slump value

| number | Slump value (mm) |
|--------|------------------|
| PT-JS19 | 70               |
| PT-JS20 | 73               |
| PT-JS21 | 76               |
| PT-JS22 | 81               |
| PT-JS23 | 86               |
| PT-JS24 | 93               |

Table 5 the slump value of high strength concrete prepared by C60 Marine raw materials

| number | Slump value (mm) |
|--------|------------------|
| HY-JS19 | 65               |
| HY-JS20 | 68               |
| HY-JS21 | 72               |
| HY-JS22 | 78               |
| HY-JS23 | 82               |
| HY-JS24 | 87               |

Table 6 compressive strength values of C60 normal high strength concrete (MPa)

| number | Maintenance condition |
|--------|-----------------------|
|        | Dry and wet sea water | Seawater immersion |
|        | 7d   | 28d    | 7d   | 28d    |
| PT-JS19 | 58.3 | 69.8   | 58.6 | 69.6   |
| PT-JS20 | 50.6 | 61.1   | 49.9 | 61.5   |
| PT-JS21 | 48.7 | 58.0   | 49.3 | 58.0   |
| PT-JS22 | 45.5 | 56.8   | 45.6 | 56.7   |
| PT-JS23 | 43   | 51.5   | 41.7 | 51.8   |
| PT-JS24 | 38.6 | 49.5   | 38.8 | 49.5   |

Table 7 high strength concrete compression strength value of C60 Marine raw materials (MPa)

| number | Maintenance condition |
|--------|-----------------------|
|        | Dry and wet sea water | Seawater immersion |
|        | 7d   | 28d    | 7d   | 28d    |

3
From the test data of Table 6 and Table 7, it can be concluded that the compressive strength decreases with the increase of the water-cement ratio in the water-cement ratio of 0.28~0.33, and the compressive strength increases with the increase of the age. The 7d compressive strength of high-strength concrete reached 77%~83% of 28d compressive strength. Compared with the water-cement ratio, under the same age and condition, the high-strength concrete prepared by marine raw materials has higher compressive strength than ordinary high-strength concrete.

| number   | Dry and wet sea water 7d | Dry and wet sea water 28d | Seawater immersion 7d | Seawater immersion 28d |
|----------|--------------------------|---------------------------|-----------------------|------------------------|
| PT-JS19  | 8.5                      | 10.1                      | 9.0                   | 10.2                   |
| PT-JS20  | 8.2                      | 10.1                      | 8.3                   | 10.3                   |
| PT-JS21  | 7.9                      | 9.6                       | 7.9                   | 9.5                    |
| PT-JS22  | 7.2                      | 8.9                       | 7.4                   | 9.0                    |
| PT-JS23  | 7.1                      | 8.5                       | 6.9                   | 8.5                    |
| PT-JS24  | 5.5                      | 7.9                       | 5.6                   | 7.8                    |

From the test data of Table 8 and Table 9, it can be concluded that in the water-cement ratio of 0.28~0.33, as the water-cement ratio increases, the splitting tensile strength decreases, and the compressive strength increases with the increase of age. The 7d compressive strength of high-strength concrete reached 71%~87% of 28d compressive strength. Compared with the water-cement ratio, under the same water cement ratio, the same type of mixture, the splitting tensile strength under seawater immersion curing conditions is greater than the splitting tensile strength under seawater dry and wet curing conditions.

### Table 9  high strength concrete split tensile strength value of C60 Marine raw materials (MPa)

| number   | Dry and wet sea water 7d | Dry and wet sea water 28d | Seawater immersion 7d | Seawater immersion 28d |
|----------|--------------------------|---------------------------|-----------------------|------------------------|
| PT-JS19  | 8.5                      | 10.1                      | 9.0                   | 10.2                   |
| PT-JS20  | 8.2                      | 10.1                      | 8.3                   | 10.0                   |
| PT-JS21  | 7.5                      | 9.4                       | 8.0                   | 9.5                    |
| PT-JS22  | 7.2                      | 8.4                       | 7.4                   | 9.0                    |
| PT-JS23  | 6.8                      | 8.2                       | 6.9                   | 8.5                    |
| PT-JS24  | 5.5                      | 7.7                       | 5.6                   | 7.8                    |

From the test data of Table 8 and Table 9, it can be concluded that in the water-cement ratio of 0.28~0.33, as the water-cement ratio increases, the splitting tensile strength decreases, and the compressive strength increases with the increase of age. The 7d compressive strength of high-strength concrete reached 71%~87% of 28d compressive strength. Under the same water-cement ratio, the same type of mixture, the splitting tensile strength under seawater immersion curing conditions is greater than the splitting tensile strength under seawater dry and wet curing conditions.

### 3.2 Data Analysis

The slump values of high-strength concrete and ordinary high-strength concrete prepared from marine raw materials are plotted in the same graph, as shown in Fig. 1; compressive strength and splitting of high-strength concrete and ordinary high-strength concrete prepared from marine raw materials at 28-day age. The tensile strengths are plotted in the same graph, as shown in Figures 2 and 3.

It can be seen from Fig. 1 that under the same water-cement ratio, the slump value of high-strength concrete prepared from marine raw materials is smaller than that of ordinary high-strength concrete. This is because the seawater contains chemical components, the effective water use rate is 93.6%, the real water consumption is reduced, and the real water-cement ratio is reduced, so the slump value of the concrete is smaller than the slump value of ordinary concrete.

It can be seen from Fig. 1 that for the ordinary high-strength concrete, the water-cement ratio is
0.28~0.33, the slump value of the concrete is gradually increased, and the slump value is the largest when the water-cement ratio is 0.33, and the concrete is the best. The sand ratio is reasonable. For the high-strength concrete prepared by marine raw materials, the water-cement ratio is 0.28~0.33, wherein the water-cement ratio is 0.28, the slump is the smallest, and the concrete is the worst. When the water-cement ratio is 0.33, the slump value is the largest. The workability is the best.

It can be seen from Fig. 2 that under the curing conditions of seawater immersion, the water-cement ratio is 0.28~0.33. Under the same water-cement ratio, the high-strength concrete prepared from marine raw materials has higher compressive strength than ordinary high-strength concrete. It is speculated that due to the large amount of chemical components in seawater, the effective water consumption is reduced. The true water-cement ratio of concrete prepared from marine raw materials is lower than that of ordinary high-strength concrete, and the self-compactness of ordinary high-strength concrete is relatively high, in 28d. It is difficult for Cl and SO\textsubscript{4}\textsuperscript{2-} in the seawater before the age to enter the interior of the concrete, and it is impossible to form chloride salts and sulfate early strength agents such as calcium chloride and calcium sulfate; More Cl and SO\textsubscript{4}\textsuperscript{2-}, before the 28d age of concrete, Cl and SO\textsubscript{4}\textsuperscript{2-} in coagulation produce chloride salts and sulfate early strength agents such as calcium chloride and calcium sulfate to promote cement hydration and improve concrete. Strength of. When the water-cement ratio is 0.28 and 0.29, the 28d compressive strength of high-strength concrete and ordinary high-strength concrete prepared from marine raw materials can reach the strength grade of C60 concrete respectively. Considering the economy, this paper considers that it is reasonable to choose the water-cement ratio of 0.29.

It can be seen from Fig. 2 that under the curing conditions of seawater dry-wet cycle, the 28d
The compressive strength of high-strength concrete prepared from marine raw materials is higher than that of ordinary high-strength concrete under the same water-cement ratio. The true water-cement ratio of high-strength concrete prepared from raw materials is lower than that of ordinary high-strength concrete. Even if the sulfate reacts with calcium hydroxide in cement stone to form calcium sulfate, calcium sulfate will form high sulfur with solid calcium silicate. The hydrated calcium sulfoaluminate:

\[
4\text{cao} \cdot \text{Al}_2\text{O}_3 \cdot 12\text{H}_2\text{O} + 3\text{CaSO}_4 + 20\text{H}_2\text{O} = 3\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot 3\text{CaSO}_4 \cdot 31\text{H}_2\text{O} \cdot \text{Ca(OH)}_2.
\]

The produced high-sulfur hydrated calcium aluminate contains a large amount of crystal water, and the volume is increased by 1.5 times, which will cause expansion stress. However, since the compressive strength of sea stones is higher than that of ordinary gravel, the research results show that the preparation of marine raw materials is high. The 28d compressive strength of concrete is about 1.4%~8.5% higher than that of ordinary high-strength concrete.

It can be seen from Fig. 2 that under the same water-cement ratio, the 28d compressive strength of the high-strength concrete seawater prepared under the condition of water-cement is better than that under the seawater immersion curing condition. It is speculated that before the 28-day-old concrete, whether it is seawater immersion or seawater dry-wet cycle curing conditions, the high-strength concrete prepared by marine raw materials has higher self-compactness, and the salt in the external seawater cannot migrate to the inside of the test piece. Only the salt inside the concrete forms sulfate corrosion and magnesium salt corrosion. And the corrosion effect is not obvious in the short period of 28d age. Therefore, the compressive strength of 28d under seawater immersion and seawater dry and wet cycle curing conditions is almost the same.

It can be seen from Fig. 2 that the water-cement ratio is 0.28~0.33, and the compressive strength of high-strength concrete and ordinary high-strength concrete prepared by marine raw materials under seawater dry-wet cycle curing conditions and seawater immersion curing conditions are both in water-cement ratio. When taking 0.28, the compressive strength is the largest, the water-cement ratio is 0.28~0.33, and each curve is gently sloping, indicating that the compressive strength of concrete decreases with the increase of water-cement ratio.

It can be seen from Fig. 3 that under the curing conditions of seawater immersion, the high-strength concrete prepared from marine raw materials has higher splitting tensile strength than ordinary high-strength concrete under the same water-cement ratio. It is speculated that the effective water consumption is small, the cement paste and aggregate bond strength is strengthened, and the concrete is more compact. The results show that under the same water-cement ratio, the 28d splitting tensile strength of high-strength concrete prepared by marine raw materials is about 0.99%~4.94% higher than that of ordinary high-strength concrete under the same curing conditions. Under the same curing conditions, the water-cement ratio is 0.28, and the tensile strength of high-strength concrete prepared from marine raw materials is the maximum.
It can be seen from Fig. 3 that in the water-cement ratio, the high-strength concrete prepared from marine raw materials has almost the same splitting tensile strength under seawater dry-wet cycle curing conditions and under seawater immersion curing conditions. Referring to Figure 2, under the same water-cement ratio and under the same curing conditions, the concrete tensile-compression ratio of the marine raw materials is lower than that of the ordinary high-strength concrete. The reason may be that the self-compactness of the concrete prepared by the marine raw materials is relatively high. Before the 28-day-old concrete, it is difficult to enter the interior of the concrete, whether in the seawater dry-wet cycle curing conditions or in the seawater immersion curing conditions, the external seawater \( \text{Cl}^- \) and \( \text{SO}_4^{2-} \). The concrete prepared from marine raw materials itself has enough \( \text{Cl}^- \) and \( \text{SO}_4^{2-} \) to react the sulfate with calcium hydroxide in the cement stone to form calcium sulfate, which will form with calcium silicate hydrate. High-sulfur hydrated calcium sulphoaluminate, the high-sulfur hydrated calcium sulphate produced contains a large amount of crystal water, and the volume is increased by 1.5 times, which causes expansion stress and cracks in concrete.

It can be seen from Fig. 3 that the water-cement ratio is between 0.28 and 0.33. Under the same curing conditions, the 28d splitting tensile strength of high-strength concrete prepared from marine raw materials is the maximum when the water-cement ratio is 0.28. The ash ratio is 0.28–0.33, and each curve is gently sloping, indicating that the concrete's splitting tensile strength decreases with the increase of water-cement ratio.

4. Conclusions and prospects

4.1 Conclusion

(1) When the water-cement ratio is 0.28 and 0.29, the compressive strength of high-strength concrete prepared from marine raw materials reaches the strength grade of C60 concrete. When the water-cement ratio is 0.28, the amount of cement is increased and it is not economical. This paper thinks that when the water-cement ratio is 0.29, it is more reasonable and more economical.

(2) Under the same mixing ratio, the workability of C60 ordinary high-strength concrete is better than that of high-strength concrete prepared by C60 marine raw materials.

(3) Under the same water-cement ratio, the same age, under the same curing conditions, the compressive strength of concrete prepared by C60 marine raw materials is higher than that of C60 ordinary high-strength concrete. The 28d compressive strength of high-strength concrete prepared from marine raw materials is 28d higher than ordinary high-strength concrete. The compressive strength is increased by about 1.4% to 8.5%.

(4) Under the same water-cement ratio, in the same age, under the same curing conditions, the splitting tensile strength of concrete prepared by C60 marine raw materials is higher than that of C60 ordinary high-strength concrete, and the 28d splitting tensile strength of high-strength concrete prepared by marine raw materials is higher than ordinary. The 28d splitting tensile strength of high-strength concrete increased by about 0.99%–4.94%.

(5) Due to the high self-compactness of C60 high-strength concrete, \( \text{Cl}^- \) and \( \text{SO}_4^{2-} \) in seawater are difficult to enter into the interior of concrete, which can not promote the hydration of cement in concrete, so as to improve the strength of concrete, so the ratio of water-cement to the same age, the same species. The strength of high-strength concrete before 28d in seawater immersion or seawater dry and wet conditions is almost the same.

(6) Under the same water-cement ratio, at the same age, under the same curing conditions, the concrete pulling ratio prepared by marine raw materials is lower than that of ordinary high-strength concrete.

4.2 Outlook

(1) The strength of concrete prepared from marine raw materials varies in compressive strength and
tensile strength under long-term soaking and dry-wet cycles.

(2) Study on the durability properties of concrete such as impermeability, shrinkage and concrete carbonation resistance of concrete prepared from marine raw materials.

References
[1] Chen Jian, Hu Yi. Development and countermeasures of Marine sand resources in China [J]. Marine geological dynamics, 2005, 21 (7) : 4-8.
[2] Xue Ruifeng, CAO Xi. Research on the performance of sea sand seawater concrete [journal paper]- concrete 2015(11)
[3] LIMEIRA J, AGULLOL. ETXEBERRIA M. Dredged marine sand in concrete: an experimental section of a haebon pavement[J]. Construction and Building Materials, 2010 (24) : 863-870.
[4] Li Yan, Yi Yongsheng, Gao Quan, et al. Orthogonal experimental study on mix design of high-performance sea-sand concrete [J]. Construction technology, 2010, 41 (2) : 162-164.
[5] Cao Weiqun, Su Qing, Zhao Tiejun, et al. Durability test of sea sand concrete [C] Jinan: 2010.
[6] Xu Zhongzhuan. Discussion on durability of Marine concrete [J]. Water transport engineering, 2008(11): 72-76.
[7] A dam Neville, Pierre-Claude Aitcin. High Performance Concrete-An Overview [J]. Materials and Structures, 1998(3): 25-30.
[8] Wang Shaodong, Huang Yubin, Wang Zhi. Effects of cement components on chloride ion curing ability of concrete [J]. Journal of silicate, 2000, 28(6):17-21
[9] Durability of new concrete buildings along the coast [journal paper]- coastal engineering 2002(3)
[10] Research progress on sand concrete of Liu Xiaoyan, Ming Wei, Wang Xinrui, Jiang Yaqing [journal paper]- concrete 2014(01)
[11] Liu Jun, Dong Biqin, Xing Feng, Liu Wei, Huo Yuan Simulation experiment and combination mechanism of sea sand chloride ion combined with cement colloid [journal paper]- 《Journal of the Chinese Academy of Sciences》 2009(5)
[12] OuYang Dong, Wu Tingting, Huang Huaxian, et al. Performance study of concrete mixed with sea sand [J]. Concrete 2012 (0 9) : 123-125.