Effect of multi-adhesives on the properties of the concrete using sea sand and sea water

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Abstract. The study about the use of sea sand and sea water as a raw material in concrete production has great significance in terms of ensuring construction time and reducing costs in the exploitation and transportation stages, especially for those with coastal areas and islands. The paper presents the research results of the influences of some adhesive types on the properties of reinforced concrete using local materials such as sea sand and sea-water. From research results, it is initially showed that the effectiveness of using some types of adhesives, increasing corrosion resistance as well as quality of concrete using sea sand and sea-water.

1. Introduction
For constructions of buildings on the sea and coastal area, it is mainly used concrete and reinforced concrete. These materials need special properties to withstand the impact of the marine environment such as erosion. The use of special materials such as sulfate-resistant cement and high performance cement, sand, fresh water ... will cause difficulties for the process of transporting materials to the site; it is also the reason of increase of material costs.

Since the 1960s in the world, there have been many studies related to the use of sea sand and sea-water as materials for making concrete used for coastal areas and islands [4], [5], [6], [7], in these studies it is indicated that the use of these materials is feasible. In the marine environment of Vietnam due to the hot and humid climatic conditions containing high levels of Cl- ions, reinforced concrete structures are often corroded and destroyed quickly, especially in the condition of the changing of water level. This problem has been studies by Dr. Pham Van Khoan, Dr. Le Quang Hung, Dr. Nguyen Hong Binh, Dr. Nguyen Nam Thang researches and these studies produce significant results that contribute to the feasibility of using these materials to manufacture concrete. In addition to studying the properties of concrete used for marine area, the scientists have researched and put into concrete some mineral additives such as silica fume, thermal ash, etc. to stabilize concrete in aggressive sea water environment [1], [2], [3].

The content of the paper presents the results of the study on the effect of multi-polymers binder on the properties of concrete using local materials, sea sand and sea water. On the basis of which the development and application of suitable assortment of concrete for coastal and island climate conditions.
2. Materials and methodology

2.1. The used materials

2.1.1. Cement.

In this study cement Portland PC40 But Son is used according to national code TCVN 2682-2009.

**Table 1.** Mechanical and physical properties of PC40 But Son cement

| N/N | Criteria                              | Result | Method                        |
|-----|---------------------------------------|--------|-------------------------------|
| 1   | Fineness by Blaine method, cm²/g      | 3456   | TCVN 4030:2003                |
| 2   | Specific weight, g/cm³                | 3,05   | TCVN 4030: 2003               |
| 3   | Standard amount of water, %           | 30,5   | TCVN 6017: 1995               |
| 4   | Setting time, minutes                 |        |                               |
|     | - Start                               | 140    | TCVN 6017: 1995               |
|     | - End                                 | 190    |                               |
| 5   | Compressive strength, MPa             |        |                               |
|     | - 3 days                              | 34,86  | TCVN 6016: 2011               |
|     | - 28 days                             | 52,34  |                               |
| 6   | Stability of volume, Le Chatelier method, mm | 5,0 | TCVN 6017: 1995 |
| 7   | SO₃ content, %                        | 2,07   | TCVN 141:1998                 |

2.1.2. Sea-sand

Sand used to make concrete is sea sand taken from Quan Lan Island (Van Don District, Quang Ninh Province, Vietnam).

**Table 2.** Mechanical and physical properties of sea sand to manufacture concrete according to TCVN 7572-2006

| N/N | Criteria                              | Unit      | Result | Method                        |
|-----|---------------------------------------|-----------|--------|-------------------------------|
| 1   | Specific weight                       | g/cm³     | 2,62   | TCVN 7572 - 4:2006           |
| 2   | Volumetric mass                       | kg/m³     | 1482   | TCVN 7572 - 4:2006           |
| 3   | Finess module                         |           | 2,55   | TCVN 7572 - 2:2006           |
| 4   | Dust content, mud, clay               | %         | 0,63   | TCVN 7572 - 8:2006           |
| 5   | Organic impurity content              | With colour | Not darker | TCVN 7572 - 9:2006 |

**Table 3.** Composition of sea sand to manufacture concrete

| Sieve size, mm | Amount of accumulation retained, % | Composition of coarse sand according to TCVN 7570:2006, % |
|----------------|-----------------------------------|--------------------------------------------------------|
| 2,5            | 8,3                               | 0-20                                                   |
| 1,25           | 21,9                              | 15-45                                                  |
| 0,63           | 42,9                              | 35-70                                                  |
| 0,315          | 81,9                              | 65-90                                                  |
| 0,14           | 96,4                              | 90-100                                                 |
| Amount passing, 0,14 mm | 3,6                               | ≤10                                                    |

2.1.3. Aggregates

Crushed stone used in concrete manufacture is canxi carbonate in Phu Ly city, Ha Nam province, Vietnam, Dₜₐₛₜ=20mm.
Table 4. Mechanical properties of crushed stone

| NN | Standard name         | Unit       | Result | Method                        |
|----|-----------------------|------------|--------|-------------------------------|
| 1  | Specific weight       | g/cm³      | 2,69   | TCVN 7572 - 5:2006            |
| 2  | Volumetric mass       | kg/m³      | 1436   | TCVN 7572 - 6:2006            |
| 3  | Air content           | %          | 46,6   | TCVN 7572 - 6:2006            |
| 4  | Content of flat-lozenge grains | % | 13,32 | TCVN 7572 - 13:2006          |
| 5  | Content of clay dust  | %          | 0,78   | TCVN 7572 - 8:2006            |

Table 5. Grain composition of crushed stone

| Sieve size | Amount of accumulation | Technical requirements |
|------------|------------------------|------------------------|
| 20         | 0                      |                        |
| D_max = 20 | 9,8                    | 0-10                   |
| D_min = 5  | 91,1                   | 90-100                 |
| <5         | 100                    |                        |

2.1.4. Water
- **Fresh water**
  Fresh water used for manufacturing concrete is domestic water that satisfies the quality requirements according to Vietnamese standards TCVN 4506:2012.
- **Sea water**
  Sea water used in this study is artificial sea water made by dissolving water and some main salts in sea water, specific components as shown in Table 6.

Table 6. Chemical composition of sea water for manufacturing concrete

| Compositions | Content (g/l) | Ratio in % |
|--------------|---------------|------------|
| Cl⁻          | 19,7          | 56,3       |
| [SO₄]²⁻      | 2,2           | 6,3        |
| Mg²⁺         | 1,4           | 4,0        |
| Ca²⁺         | 0,4           | 1,1        |
| Na⁺          | 10,9          | 31,1       |
| CK           | 0,4           | 1,1        |
| Sum          | 35,0          | 100        |

2.1.5. Fly ash
Fly ash used for research is fly ash taken from Quang Ninh Thermal Power Plant (Quang Ninh T.P.P).

The results of chemical composition analysis of Quang Ninh fly ash are shown in Table 7. The properties of the fly ash were tested to classify and evaluate the ability to use as mineral additives for concrete and cement are shown in Table 8.

Table 7. Analysis results of fly ash by PCC technology in Vietnam

| Type of fly ash | L.O.I | SiO₂ | Fe₂O₃ | Al₂O₃ | CaO | MgO | SO₃ | K₂O | Na₂O | Na₂O td | TiO₂ |
|----------------|-------|------|-------|-------|-----|-----|-----|-----|------|---------|------|
| Quang Ninh T.P.P | 6,65  | 57,68| 4,97  | 22,58 | 1,48| 0,72| 0,29| 3,54| 0,12 | 2,45    | 0,2  |
Table 8. Evaluation test of fly ash properties of Quang Ninh Thermal Power Plant according to TCVN 10302:2014

| NN | Name of criteria | Unit | Results |
|----|------------------|------|---------|
| 1  | Moisture         | %    | 1.2     |
| 2  | Content of L.O.I | %    | 6.65    |
| 3  | Specific weight  | g/cm³ | 2.28    |
| 4  | Fineness on 45 micron sieve | % | 23.20 |
| 5  | Intensity activating index: at the age of 7 days | % | 79.2 |
|    | Age of 28 days   | %    | 85.4    |
| 6  | Water amount by requirement | % | 95 |

2.1.6. Finely ground slag
Furnace slag used for this research was obtained from Hoa Phat Iron and Steel Plant. Furnace slag is finely grinded by ball mill machine. The properties of furnace slag are shown in Tables 9 and 10.

Table 9. Chemical compositions of Hoa Phat slag

| L.O.I | SiO₂ | CaO  | Al₂O₃ | Fe₂O₃ | MgO | SO₃ | K₂O | Na₂O | TiO₂ |
|-------|------|------|-------|-------|-----|-----|-----|------|------|
| %     | 36.12 | 37.65 | 12.74 | 2.36  | 8.19| 0.26| 0.91| 0.30 | 0.30 |

Table 10. Mechanical and physical properties of Hoa Phat slag according to TCVN 11586-2016

| Sample type    | Specific weight g/cm³ | Specific surface, cm²/g | Amount of retained, % | Fluidity ratio, % | Active index intensity, % |
|----------------|-----------------------|-------------------------|-----------------------|-------------------|---------------------------|
| Hoa Phat slag  | 2.90                  | 4440                    | 8.0                   | 2.0               | 112                       |
|                |                       |                         |                       |                   |                           |
|                |                       |                         |                       |                   |                           |

2.1.7. Silica fume
Properties of Silica fume are evaluated according to TCVN 8827:2012 shown in table 11.

Table 11. Mechanical properties of silica fume

| NN | Name of criteria | Unit | Results | Method |
|----|------------------|------|---------|--------|
| 1  | Content of SiO₂  | %    | 91.84   | TCVN 7131:2002 |
| 2  | Moisture         | %    | 2.76    | TCVN 7572-7:2006 |
| 3  | Content of L.O.I | %    | 4.82    | TCVN 141:2008   |
| 4  | Specific weight  | g/cm³ | 2.4     | TCVN 4030:2003  |
| 5  | Intensity activity index at the age of 7 days compared to the control sample | % | 115 | TCVN 8827:2012 |

2.1.8. Chemical additives
In the study using Sikament NN chemical additives of Sika firm

2.2. Study method
In the study, the use of theoretical and experimental research methods through the evaluation of the effect of the polymers of adhesives on some properties of mixtures and concrete such as setting time, slump, intensity etc. is compared to the control sample to assess the possibility of using sea sand and sea-water in concrete fabrication for coastal and marine constructions.
3. Research results and discussion

3.1. Selection of research aggregate gradation

Table 12. Aggregate gradation of experimental concrete

| Sample group | Binder | Content of mineral additives | W/B | S/A | Binder (kg) | PC40 (kg) | GGBFS (kg) | FA (kg) | SF (kg) | River sand (kg) | Sea sand (kg) | Aggregates (kg) | C.N. (kg) | Chemical additives (kg) | Fresh water (lit) | Sea water (lit) |
|--------------|--------|-----------------------------|-----|-----|-------------|-----------|------------|---------|--------|----------------|-------------|---------------|--------|--------------------------|----------------|--------------|
| 1            | FW     | GS0                         | 0,50| 0,41| 350         | 350       | 0          | 0       | 0       | 0              | 781         | 1118          | 0,50   | 175                      | 0              |              |
| 2            | FW     | GS50                        | 0,50| 0,41| 350         | 175       | 175        | 0       | 0       | 780            | 1106        | 3,50          | 175    | 0                       |                |              |
| 3            | FW     | GS70                        | 0,50| 0,41| 350         | 165       | 245        | 0       | 0       | 777            | 1098        | 4,20          | 175    | 0                       |                |              |
| 4            | FW     | GS30SA20                    | 0,50| 0,41| 350         | 175       | 105        | 70      | 0       | 771            | 1102        | 3,78          | 175    | 0                       |                |              |
| 5            | FW     | GS40SF10                    | 0,50| 0,41| 350         | 175       | 140        | 0       | 35      | 772            | 1102        | 4,20          | 175    | 0                       |                |              |
| 6            | SW     | GS0                         | 0,47| 0,41| 350         | 350       | 0          | 0       | 0       | 781            | 1118        | 3,50          | 175    | 0                       |                |              |
| 7            | SW     | GS50                        | 0,47| 0,41| 350         | 175       | 175        | 0       | 0       | 780            | 1106        | 3,50          | 175    | 0                       |                |              |
| 8            | SW     | GS70                        | 0,47| 0,41| 350         | 165       | 245        | 0       | 0       | 770            | 1098        | 4,20          | 175    | 0                       |                |              |
| 9            | SW     | GS30SA20                    | 0,47| 0,41| 350         | 175       | 105        | 70      | 0       | 771            | 1102        | 3,78          | 175    | 0                       |                |              |
| 10           | SW     | GS40SF10                    | 0,47| 0,41| 350         | 175       | 140        | 0       | 35      | 772            | 1102        | 4,20          | 175    | 0                       |                |              |

The grades in the study are based on three main groups: 1- use fresh water (control sample), 2- use artificial sea water, 3- use sea water and Calcium Nitrite additive (4 %). Within each group is divided into coordination with the symbol GS0 - standard gradation; GS50 - graded 50% replacement of binder with finely ground slag; GS70 - graded 70% replacement of binder with finely ground slag; GS30FA20 - graded replacing 50% binder with 30% finely ground slag, 20% fly ash; GS40SF10-graded replacing 50% binder with 40% finely ground slag, 10% silica fume. Aggregate gradations are shown in Table 12.

3.2. The effect of adhesive groups on the properties of concrete mixture

Experimental results of properties of concrete mixture using sea sand and sea water are shown in Table 13.

Table 13. The effect of adhesive groups on the properties of concrete mixture

| Sample group | Symbol | Slump, cm | Time of setting, min | Volumetric mass, kg/m³ |
|--------------|--------|-----------|----------------------|------------------------|
|              |        | After 5 min. | After 30 min. | Start | End |                     |
| GS0          | C1-1   | 10,5       | 8,5                 | 375   | 490 | 2484                  |
|              | C1-2   | 6          | 4,5                 | 325   | 440 | 2484                  |
|              | C1-3   | 3,5        | 2,5                 | 255   | 325 | 2491                  |
| GS50         | C2-1   | 12,5       | 8,0                 | 405   | 570 | 2474                  |
|              | C2-2   | 8,5        | 6,5                 | 385   | 545 | 2479                  |
|              | C2-3   | 4,0        | 3,5                 | 320   | 430 | 2472                  |
| GS70         | C3-1   | 12,5       | 9,0                 | 420   | 605 | 2462                  |
|              | C3-2   | 8,5        | 6,0                 | 400   | 590 | 2460                  |
|              | C3-3   | 6,0        | 3,5                 | 320   | 475 | 2470                  |
| GS30FA20     | C4-1   | 14,5       | 11,0                | 505   | 685 | 2440                  |
|              | C4-2   | 10,0       | 6,5                 | 410   | 565 | 2445                  |
|              | C4-3   | 6,5        | 4,5                 | 320   | 440 | 2449                  |
| GS40SF10     | C5-1   | 6,5        | 5                   | 395   | 570 | 2462                  |
|              | C5-2   | 5,5        | 3,5                 | 370   | 540 | 2465                  |
|              | C5-3   | 2,5        | Slump loss          | 305   | 410 | 2471                  |
It can be seen that the workability of the concrete mixture using sea water, sea water + calcium nitrite significantly decreased in comparison with fresh water samples. The most significant changes include the GS0, GS50, GS70, GS30FA20 adhesive group; only for GS40SF10, the downward trend changes more slowly. This can be explained by the presence of Cl⁻ and Ca²⁺ ions, which promotes cement hydration leading to slump effects.

The setting time of concrete mixture when using fresh water, sea water and sea water + calcium nitrite has a marked change, especially when using sea water + calcium nitrite. Samples using sea water and sea water + calcium nitrite had a shorter setting time than fresh water samples. The time to start freezing samples using fresh water is 20 minutes to 55 minutes higher than sea samples, higher than sea samples + calcium nitrite from 80 minutes to 180 minutes. The final setting time for fresh water samples is 20 minutes to 120 minutes higher than sea samples, higher than sea samples + calcium nitrite from 115 minutes to 245 minutes. The phenomenon of shortening setting time in sea water and sea water + calcium nitrite is explained by the presence of salt, Cl⁻ and Ca²⁺ ions. When cement hydrates with water, salt concentration increases and crystalline makes concrete mixture more quickly harden faster setting time.

The volumetric mass of a concrete mixture containing an active mineral additive decreases when it is substituted for cement but does not exceed 50 kg/m³. This is explained by the density of the component materials. Compared with cement, the density of the additives is lower (cement is 3.05 g/cm³ compared to FA is 2.28 g/cm³, GGFS is 2.82 g/cm³; SF is 2.4 g/cm³) so the volumetric mass of this sample is lower than that of the sample only used cement.

3.3. The effect of adhesive on the properties of concrete

Under standard curing conditions

For each group of adhesives, the partial replacement of cement with activated mineral additives has reduced the intensity of 3-day age by 29-30%. Because of that, the mineral additives develop in strength at shorter ages than regular cement. At age 7, 28 days the disparity decreases. At the age of 91 days, the samples using mineral additives almost reached the intensity compared to the samples using conventional cement, some gradients were higher but not significant compared to concrete samples using ordinary cement.

The speed of development of strength of adhesive groups is different. With concrete samples using water mixed with fresh water, the intensity development increased steadily. Age of samples 3, 7, 28 days of fresh water are larger than the samples of the same level but using solvents are sea water or sea water + calcium nitrite.

With the concrete samples using solvents of sea water and sea water + calcium nitrite, the strength development is faster, the age of 91 and 365 days, the strength of the strength reaches the intensity of concrete samples with the same gradation with using of fresh water.

The aggregate gradations using sea water + calcium nitrite lipids at the age of 91 days and 365 days at the highest intensity were GS0 → C1-3; GS50 → C2-3; GS70 → C3-3; GS30FA20 → C4-3; GS40FS10 → C5-3; With 2 days of age, 91 days and 365 days, the concrete sample using adhesive is GS70 → C3-3 with highest strength.

Thus at the long age, the ability to develop the intensity of concrete samples with aggregate gradation used active additives is superior to concrete samples using Portland cement binder. It is consistent with the scientific basis studied.
The intensity of some gradients in the group. The use of calcium nitrite additive has an effective effect, increasing intensity as the GS0 control compound. Gradations like GS50; GS40FS10 at the age of 365 days was grades use mineral additives to replace cement from the age of 28 and 91 days reaching the same significantly compared to the control sample. However, when replacing mineral additives, the effectiveness of concrete mixture is significantly improved.

Based on the research results, some conclusions can be drawn as follows:

4. Conclusions

Table 14. The effect of adhesive on the strength of concrete

| Sample group | Symbol | 3 days (Mpa) | 7 days (Mpa) | Compressive strength at 28 days (MPa) | Compressive strength at 91 days (MPa) | Compressive strength at 365 days (MPa) |
|--------------|--------|--------------|--------------|--------------------------------------|--------------------------------------|--------------------------------------|
|              |        | Standard     | wet-dry cycle| Standard                           | wet-dry cycle                         | Standard                           |
| GS0          | C1-1   | 31,7         | 34,3         | 41,1                                | 40,8                                | 46,8                                | 42,7                                | 51                             | 53,2                            |
|              | C1-2   | 33,3         | 35,2         | 41,9                                | 41,7                                | 47,2                                | 43,9                                | 50,6                            | 56,6                            |
|              | C1-3   | 35,7         | 39           | 45,1                                | 43,5                                | 49,3                                | 45,2                                | 53,3                            | 53,9                            |
| GS50         | C2-1   | 27,6         | 30,6         | 37                                   | 37,8                                | 44,4                                | 40,4                                | 45,6                            | 49,3                            |
|              | C2-2   | 26,6         | 30,8         | 38                                   | 38,5                                | 43,7                                | 40,8                                | 51,7                            | 50,2                            |
| GS70         | C2-3   | 22,2         | 33,3         | 43,2                                | 42,3                                | 46,4                                | 43,3                                | 50,5                            | 60,6                            |
| GS30FA20     | C3-1   | 25,4         | 29,6         | 36,3                                | 34,6                                | 39,1                                | 36,5                                | 46                             | 41,9                            |
|              | C3-2   | 22,6         | 31,2         | 36,7                                | 35,5                                | 40,5                                | 37,4                                | 51,6                            | 50                               |
|              | C3-3   | 20,5         | 33,3         | 41,6                                | 39,3                                | 45,6                                | 42,8                                | 60,4                            | 47                               |
| GS40FS10     | C4-1   | 23,9         | 28,6         | 34,9                                | 32,4                                | 41,2                                | 36,3                                | 49,4                            | 45,3                            |
|              | C4-2   | 22,6         | 28,3         | 35,9                                | 34,6                                | 41,8                                | 38,2                                | 55,1                            | 49,2                            |
|              | C4-3   | 20,9         | 30,5         | 38,9                                | 37,5                                | 43,6                                | 39,4                                | 57,8                            | 46,9                            |
|              | C5-1   | 26           | 30,5         | 35,2                                | 34,5                                | 44,7                                | 38,5                                | 51,6                            | 45,8                            |
|              | C5-2   | 26,3         | 32,4         | 36,5                                | 37,6                                | 44,9                                | 39,6                                | 51,7                            | 51,6                            |
|              | C5-3   | 21           | 34,6         | 44,2                                | 43,2                                | 48,5                                | 45,5                                | 57,8                            | 56                               |

Under curing conditions in a wet-dry cycle
Concrete aggregate gradations with lower strength at different ages are lower than concrete aggregate gradations of the same aggregate graduation but cured under standard conditions.

For the gradation groups using fresh water, from table 14 it can be seen that, the GS0 control grade get highest strength at all age. The use of mineral additives to replace a part of cement does not improve the intensity. Compared with control sample, the remaining gradations rank in the lower group. Among the gradations using mineral additives in the GS50 and GS40FS10 gradation groups, there is the greatest intensity in all age days. GS70 gradation have the lowest intensity due to the low amount of cement used.

For the gradation group using sea water, from the table 14, it can be seen that the intensity of the gradations when replacing a part of cement is lower than the control sample GS0. Among gradations using mineral additives, the growth rate of intensity between gradients is different from 28-365 days old. GS40FS10 gradients have the highest growth intensity in days, and at 365 days of age, they reach the highest intensity compared to additives in the group.

For the gradation group using sea water + calcium nitrite, from table 14, it can be seen that: some grades use mineral additives to replace cement from the age of 28 and 91 days reaching the same intensity as the GS0 control compound. Gradations like GS50; GS40FS10 at the age of 365 days was more intense than the GS0 control. The use of calcium nitrite additive has an effective effect, increasing the intensity of some gradients in the group.

From the table 14, it can be seen that in harsh environment (wet-dry cycle), the mixing group uses sea water + calcium nitrite has the highest development intensity. From the intensity data at the old days and the analysis chart of gradation groups, the research team came up with the GS40FS10 and GS50 gradations which are the two gradations with the highest development intensity and optimal gradation.

4. Conclusions

Based on the research results, some conclusions can be drawn as follows:

a. The effects to concrete mixture

The research adhesives meet the requirements for construction because they are suitable to standard conditions, in which some types of adhesives that give better results than the control samples.

The workability of concrete mixture using sea water, sea water + calcium nitrite decreased significantly compared to the control sample. However, when replacing mineral additives, the effectiveness of concrete mixture is significantly improved.

The setting time of concrete mixture when using fresh water, sea water and sea water + calcium nitrite.
nitrite has marked changes. Samples using sea water and sea water + calcium nitrite have faster starting or ending times than fresh water samples.

The volume of concrete mixture increases slightly when using sea water and sea water + calcium nitrite. The volumetric mass of concrete mixture containing active mineral additives types decreased compared to the control sample.

b. The effects to compressive strength of concrete 
- Concrete is cured under standard conditions
  The concrete samples with binder replace cement by different mineral additives are for the intensity of slow development at the short age, and fast development at the long age with higher compressive strength than the control sample. The gradations used sea water + calcium nitrite solvents at the age of 91 days and 365 days at the highest strength.
- Concrete is cured on a dry, wet cycle
  In the condition of curing in the wet-dry cycle, the gradations of concrete having compressive strength are lower than the strength of the same gradation of concrete samples curing in standard conditions.

In the harsh environment (wet-dry cycle), it is found that with the gradation group using fresh water and sea water, the use of mineral additives to replace a part of concrete did not improve the compressive strength compared to the control sample. For the gradation group used water + calcium nitrite giving the highest compressive strength, compared to the control sample at 365 days of age, which had higher strength.

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