Mechanical degradation of normal concrete due to seawater intrusion

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Abstract. Problems that occur in concrete buildings in the coastal environment of concrete damage caused by degradation of concrete that interacted seawater. Real damage caused by seawater, consists of 3 (three) parts: submerged concrete part, concrete part affected by tidal seawater and part of the concrete affected by seawater splashing. The concrete damage discussed in this research is the mechanical degradation of concrete due to the intrusion of seawater in the submerged seawater. Damage can occur in concrete due to the reaction between aggressive seawater that is intruded into the concrete and compounds in the concrete that causes the concrete lose some of its mass, its strength, and stiffness and also accelerate the weathering process. The results of this study indicate that the reduction of compressive strength of concrete due to the intrusion of seawater tends to show a logarithmic graph. Concrete compressive strength will lose by 50% when the concrete is soaked seawater for 19,031 days. Normal quality concrete $f'c = 25$ MPa undergoes mechanical degradation due to seawater intrusion, in this case, the compressive strength of concrete is 12,063 % when soaked 28 days and 16,809 % when soaked 90 days.

Keywords: Normal Concrete, Mechanical Properties of Concrete, Sea Water

1. Introduction
The concrete for the Building structure is required to have strong properties in holding the load or working forces [1]-[3]. In addition, concrete must also have high durability so that the concrete is not easily damaged and can be used as a structure for a long time [4]-[7].

Very strong writing that is soaked with air that shows better results when compared to concrete soaked with sea air [8]-[13]. The decreasing difference for the compressive strength of sea air concrete reaches 7.187% of the strong value of fresh air concrete inspection [8]. Previous research reported that air cement factor 0.45; 0.50; and 0.55 gives some values against intense pressure and also between very strong pressure using strong water with concrete using clean water for pressures using clean water higher than drying using sea air [14]. As for the duration of curing with sea air for 1 day, 2 days, and 3 days there is a strong area. The writing is relatively small. There was a slight decrease from 1 to 3 days for the cement water factor of 0.45 and 0.5 and a slight increase from 1 to 3 days for the 0.55 cement water factor.

There is a compressive strength penetration, tensile strength, bending strength in submerged concrete sulfate [15]. The percentage decrease in seawater immersion [16] was 2.92%, 2.56%, -8.04%. The
decrease in magnesium sulfate solution 5% was 3.86%, 7.51%, -2.68% and percentage decrease in magnesium sulfate solution 5% tidal system 9.66%, 18.9% and 24.11%. With the above statement, the authors need to research seawater to degradation of seawater intrusion normal concrete materials.

2. Method

2.1. Media & water immersion
This research uses 2 media pond, where one pond in the contents of seawater and one pond again filled with fresh water. Water used for soaking concrete is seawater from Barombong Beach, Makassar, South Sulawesi, and freshwater used from PDAM Gowa, Gowa Regency, South Sulawesi Province. The model of treatment of specimens can be seen in Figure 1 and Figure 2.

![Figure 1. Concrete soaked in the seawater (BAL)](image1)
![Figure 2. Concrete soaked in the freshwater (BAT)](image2)

The amount of concrete soaked in seawater as much as 20 specimens, and soaked freshwater (PDAM) as much as 20 specimens. Illustration of the treatment of test specimens can be seen in Table 1 and Tabel 2.

| Age of Concrete | Code          | Compressive Strength Of Concrete Averages |
|-----------------|---------------|------------------------------------------|
| 14              | FcAT14_1      | f'cAT14                                  |
|                 | FcAT14_2      |                                          |
|                 | FcAT14_3      |                                          |
|                 | FcAT14_4      |                                          |
|                 | FcAT14_5      |                                          |
| 28              | FcAT28_1      | f'cAT28                                  |
|                 | FcAT28_2      |                                          |
|                 | FcAT28_3      |                                          |
|                 | FcAT28_4      |                                          |
|                 | FcAT28_5      |                                          |
| 56              | FcAT56_1      | f'cAT56                                  |
|                 | FcAT56_2      |                                          |
|                 | FcAT56_3      |                                          |
|                 | FcAT56_4      |                                          |
|                 | FcAT56_5      |                                          |
| 90              | FcAT90_1      | f'cAT90                                  |
|                 | FcAT90_2      |                                          |
|                 | FcAT90_3      |                                          |
|                 | FcAT90_4      |                                          |
|                 | FcAT90_5      |                                          |
Tabel 2. Illustration of the test specimens being soaked in seawater

| Age of Concrete | Code          | Compressive Strength of Concrete Averages |
|-----------------|---------------|------------------------------------------|
| 14              | FcAL14_1      | f'cAL14                                  |
|                 | FcAL14_2      |                                         |
|                 | FcAL14_3      |                                         |
|                 | FcAL14_4      |                                         |
|                 | FcAL14_5      |                                         |
| 28              | FcAL28_1      | f'cAL28                                  |
|                 | FcAL28_2      |                                         |
|                 | FcAL28_3      |                                         |
|                 | FcAL28_4      |                                         |
|                 | FcAL28_5      |                                         |
| 56              | FcAL56_1      | f'cAL56                                  |
|                 | FcAL56_2      |                                         |
|                 | FcAL56_3      |                                         |
|                 | FcAL56_4      |                                         |
|                 | FcAL56_5      |                                         |
| 90              | FcAL90_1      | f'cAL90                                  |
|                 | FcAL90_2      |                                         |
|                 | FcAL90_3      |                                         |
|                 | FcAL90_4      |                                         |
|                 | FcAL90_5      |                                         |

2.2. Material specification and test material

The concrete materials that will be used in this research are:

1) Cement to be used Composite Portland Cement in the market area of Makassar, South Sulawesi
2) Coarse aggregate used rubble stone originating from Bili-Bili area, Gowa regency, South Sulawesi
3) The fine aggregate used comes from the River Je'neberang, Gowa regency, South Sulawesi
4) Water mixture of concrete to be used fresh water from PDAM Makassar, South Sulawesi

Water used to soak the concrete:

1) Freshwater from PDAM Makassar, South Sulawesi
2) Seawater from Barombong, Makassar, South Sulawesi

Specification of specimen used:

1) The quality of normal concrete (f'c = 25 MPa)
2) Cylindrical concrete
3) Dimensions of concrete diameter 15 cm and height 30 cm

2.3. Variable testing

The variables studied in this research are compressive strength of concrete, duration of concrete immersion and concrete compressive strength reduction. The parameters used in this research are the normal concrete quality f'c = 25 MPa, the duration of soaking of concrete in freshwater and in the seawater that is 14 days, 28 days, 56 days and 90 days and the reduction of concrete compressive strength during the soak 14 day, 28 days, 56 days and 90 days
2.4. Research method
The methods to be used in this research are experimental research and literature study about concrete
degradation due to seawater penetration. The stages of this research are preliminary survey and research
preparation. This survey is conducted to determine the availability and feasibility of tools and materials
that will be used in research so that it can support the implementation of research

2.5. Laboratory test of specification and characteristic of a constituent material
1) Fine aggregate examination includes specific gravity and absorption, filter analysis, organic content,
mud content and weight of volume.
2) Coarse aggregate examination (rubble stone) including wear and tear, specific gravity and absorption,
filter analysis, organic content, mud content, and weight volume.
3) Freshwater examination (PDAM) includes organic content.
4) Planning of concrete mix (make mix design).
5) Mixed design (mix design) using SNI Method (SNI 03-2834-2000) by National Standardization
Agency [17].
6) Preparation of concrete test objects.

2.6. The test specimens will be made as follows
Analysis and test of mechanical degradation of concrete due to seawater intrusion. The concrete
compressive strength test (f'c) uses a 15 cm X 30 cm (15 cm x 30 cm) normal concrete mixture soaked in
20 seawater and soaked in freshwater (PDAM) 20 pieces tested on the day to 14, 28, 56 and 90

2.7. Immersion of concrete test objects
Immersion of concrete test objects is done in the following manner:
1) Normal quality concrete (f'c = 25 MPa) cylindrical 15 cm X 30 cm submerged 20 seawater for concrete
compressive strength test (f'c), concrete weight and weight of concrete volume.
2) Normal quality concrete (f'c = 25 MPa) cylindrical 15 cm X 30 cm water-soaked (PDAM) 20 samples
for concrete compressive strength test (f'c), concrete weight and weight of concrete volume.

2.8. Testing the specimens
Testing of the concrete test object is done by concrete compressive test using Universal Testing Machine
done on concrete soaked in freshwater (PDAM) [18]-[20] and seawater for 14, 28, 56 and 90 days. At
each time tested the compressive strength of concrete as much as 5 pieces of test specimens soaked in
seawater and 5 pieces of freshwater soaked specimens (PDAM water).

2.9. Analysis and data processing
The data analysis and processing were performed to determine the mechanical degradation of concrete due
to seawater intrusion by testing the compressive strength of normal quality concrete (f'c = 25 MPa) soaked
in seawater and freshwater (PDAM).

3. Result and discussion

3.1. Examination of material characteristics
The result of an examination of fine aggregate characteristic (sand) shows that it meets the requirement of
SNI specification so that fine aggregate can be used as concrete mixture. The results of the examination
can be seen in Table 3.
Tabel 3. Testing result of fine aggregate characteristics (sand)

| No | Characteristic of Fine Aggregate | SNI Specification | Interval | Testing Result | Note |
|----|----------------------------------|-------------------|----------|----------------|------|
| 1  | Clay Content                     | SNI 03-4141-1996  | max 5%   | 1.25%          | Qualify |
| 2  | Organic Content                  | SNI 03-2816-1992  | < NO. 3  | No. 1          | Qualify |
| 3  | Water Content (Wp)               | SNI 03-1971-1990  | 0.5% - 5%| 1.60%          | Qualify |
| 4  | Volume Wight                     | SNI 03-4804-1998  | 1.4 - 1.9 kg/liter | 1.42 | Qualify |
|    |                                  |                   |          | 1.65           | Qualify |
| 5  | Absorption (Rp)                  | SNI 03-1970-1990  | 0.2% - 2%| 1.42%          | Qualify |
| 6  | Specific dry weight of the surface | SNI 03-1970-1990 | 1.6 - 3.3 | 2.40 | Qualify |
| 7  | Modulus of fineness              | SNI 03-1968-1990  | 1.50 - 3.80 | 3.46 | Qualify |

The result of the examination of crude aggregate characteristic (rubble stone) indicates that it meets the requirement of SNI specification so that coarse aggregate can be used as a concrete mixture. The results of the examination can be seen in Table 4.

Tabel 4. Testing result of coarse aggregate characteristic (rubble stone)

| No | Characteristic of Coarse Aggregate | SNI Specification | Interval | Testing Result | Note |
|----|-----------------------------------|-------------------|----------|----------------|------|
| 1  | Shrinkage                         | SNI 03-2417-1991  | max 50%  | 20.38%         | Qualify |
| 2  | Clay Content                      | SNI 03-4141-1996  | max 1%   | 0.90%          | Qualify |
| 3  | Water Content (Wk)                | SNI 03-1971-1990  | 0.5% - 2%| 1.34%          | Qualify |
| 4  | Volum Weight                      | SNI 03-4804-1998  | 1.6 - 1.9 kg/liter | 1.61 | Qualify |
|    |                                    |                   |          | 1.66           | Qualify |
| 5  | Absorption (Rk)                   | SNI 03-1969-1990  | max 4%   | 2.78%          | Qualify |
| 6  | Specific dry weight of the surface| SNI 03-1969-1990  | 1.6 - 3.3 | 2.60 | Qualify |
| 7  | Modulus of fineness               | SNI 03-1968-1990  | 6.0 - 7.1 | 3.28 | Qualify |

3.2. Composition of concrete materials
The composition of the normal concrete mixture material $f'_c = 25$ MPa can be seen in Table 5.

Tabel 5. The composition of the normal concrete mixture material $f'_c = 25$

| Concrete Material | Concrete Weight (Kg/m³) | Ratio To Total Cement |
|-------------------|-------------------------|-----------------------|
| Fresh Water       | 229                     | 0.6                   |
| Cement            | 413                     | 1.0                   |
| Sand              | 530                     | 1.3                   |
| Rubble Stone      | 1058                    | 2.6                   |
3.3. Mechanical degradation of concrete due to seawater intrusion

The concrete mechanical degradation test is done by using normal concrete compressive strength test ($f'_c = 25$ MPa) by two kinds of treatment variation ie freshwater and concrete soaked concrete seawater. The result of normal concrete compressive strength ($f'_c = 25$ MPa) can be seen in Tables 6, Figure 3 and Figure 4.

### Table 6. Testing result of compressive strength normal quality concrete

| Age of Concrete (Days) | Compressive Strength Of Concrete Averages Fresh Water $f'_c$A(T) (MPa) | Compressive Strength Of Concrete Averages Sea Water $f'_c$A(L) (MPa) | Compressive Strength Of Concrete Reduction Averages (%) |
|------------------------|-------------------------------------------------|-------------------------------------------------|---------------------------------------------------|
| 14                     | 14.66                                          | 13.86                                          | 5.41                                              |
| 28                     | 17.83                                          | 15.67                                          | 12.06                                             |
| 56                     | 26.03                                          | 22.07                                          | 15.22                                             |
| 90                     | 26.60                                          | 22.13                                          | 16.81                                             |

**Figure 3.** The result of compressive strength of normal quality concrete is soaked in freshwater and seawater

**Figure 4.** Reduction of compressive strength of normal quality concrete
Figure 3 and Figure 4 show that the reduction of compressive strength of concrete due to seawater intrusion tends to show the logarithmic equation pattern. The pattern of the equations is:

\[ y = 6.0398 \times \ln(x) - 9.5152 \] (1)

Where \( y \) is the reduction of compressive strength of normal concrete post seawater intrusion (%), and \( x \) for duration of immersion (day). Equation (1) can predict that the normal compressive strength of the concrete will lose by 50% when the concrete is soaked in seawater for 19,031 days.

4. Conclusion

Normal quality concrete \( f'c = 25 \text{ MPa} \) undergoes mechanical degradation due to intrusion of seawater, in this case, the compressive strength of concrete is 12.063% when soaked 28 days and 16.809% when soaked 90 days. Result of graph of mechanical degradation due to seawater intrusion, in this case graph relation between compressive strength of normal quality concrete \( f'c = 25 \text{ MPa} \) with the length of immersion (days) yields logarithmic graph. Also, normal concrete strength of \( f'c = 25 \text{ MPa} \) will experience mechanical degradation due to seawater intrusion by 50% when soaked in seawater during 19,031 days. In a further study of the degradation of physical and mechanical properties of other concrete need to be studied further on the various quality of concrete and an application of structural components.

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