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Tensile Strength Behavior of Concrete Containing Seawater, Sea Sand Together With Steel Fibers

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ABSTRACT
The characteristics of concrete are that it has high compressive strength and low tensile strength. To increase the tensile strength of concrete, it is necessary to use fiber as a constituent material for concrete. This study aims to evaluate and compare the tensile strength value of concrete containing sea sand and seawater with or without steel fiber reinforcement stolen by seawater for 28 days, as well as analyze the homogeneity of the concrete mixture. The materials used are composite portland cement, gravel, sea sand and seawater and 3D 80/60 BG dramix. Determination of the volume fraction of steel fibers is 0% - 2.5% to the weight of cement. Testing the tensile strength of concrete using the split tensile strength method. The results tensile strength showed that the value of seawater concrete increased due to the reinforcement of steel fiber, with the addition of 2.5% steel fiber, which was 17.8%. The tensile strength value of seawater concrete increased due to the reinforcement of steel fiber, with the addition of 2.5% steel fiber, which is 24.2%. Overall, all test specimens showed uniformity or homogeneous amounts of gravel and steel fibers in all four cross-sectional areas.

***KeywordsL:** Sea Sand; Sea Water; Steel Fiber.*

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INTRODUCTION

Concrete has limitations or shortcomings, namely it is brittle and has a relatively low tensile capacity, which is approximately one-tenth of its compressive strength (Nawy, 1995). In addition, to overcome the problem of deficiencies in concrete, and to increase the ability of concrete to bear tensile forces, it can be done by adding fiber / fiber to the concrete mortar, hereinafter referred to as fiber concrete (fiber reinforced concrete).

This addition intends to improve he ability of concrete to bear loads, especially for parts that are interested, so that steel fiber is expected to be an option to replace the function of longitudinal reinforcement that is generally used.

Data from the United Nations and the World Meteorological Organization predict about 5 billion people will lack clean water and even drinking water (Source: Cofrence on Our World in Concrete and Structure in Singapore). Nobuaki Otsuki et al. (2011) in the conference also said that in 2025 half of humanity will live in areas that lack clean water (fresh water).

From the phenomenon mentioned above, seeing the potential of seawater sources that are so abundant, there is a thought to use seawater as a material for mixing concrete, especially in building locations that often interact with seawater.

RESEARCH METHODOLOGY

Research Design

Tensile strength is the tensile strength of concrete determined based on the compressive strength of the concrete cylinder pressed on its long side. The tensile strength of concrete is relatively low, the compressive strength and tensile strength values of concrete are not directly proportional. Every effort to improve the quality of compressive strength is only accompanied by a small increase in tensile strength value. Tensile strength is more difficult to measure compared to compressive strength due to clamping problems in the machine. Testing the tensile strength of concrete is carried out through split cylinder testing.

Horizontal mounted concrete constructions often receive loads perpendicular to the axis of the material and often undergo splitting. This happens because the carrying capacity of concrete against bending forces depends on the distance from the concrete weight line, the farther from the concrete weight line, the smaller the carrying capacity.

The test uses a concrete cylinder test specimen with a diameter of 150 mm and a length of 300 mm, placed in the longitudinal direction above the tester then the compressive load is applied evenly in the upright direction from above on the entire cylinder length. When the tensile strength is exceeded, the specimen splits into two parts from end to end. The tensile stress that arises when the specimen splits is called split cylinder strength.

Based on SNI 03-2491-2002, the value of tensile strength can be calculated by the formula:

$$f_{CT} = \frac{2P}{\pi LD}$$

Where:

fcr = *tensile strength (Kg/cm^2)*
P = *Load at split time (Kg)*
L = *Length of cylindrical test specimen (cm)*
D = *Cylindrical specimen diameter (cm)*

Research Materials

Cement

Cement is a hydraulic material which when mixed with water will turn into a material that has adhesive properties. Its use includes concrete, mortar mortar, stucco, patching materials, grout and so on. In general, there are several types of cement and types of cement on the market. Several types of cement are regulated in SNI, including: SNI 15-0302-2004 regarding portland pozolan cement (PPC = Portland pozzoland cement). Other types of cement are regulated in SNI 15-7064-2004 concerning portland composite cement (PCC = Portland Composite Cement), which is cement made from the grinding of portland cement slag and casts with inorganic materials.

Aggregate

Aggregate is the component of concrete that plays the most role in determining the amount of concrete strength. According to SNI 2847-2013 aggregates are granular materials, such as sand, gravel, crushed stone and blast-furnace slag, which are used with adhesive media to produce concrete or hydraulic cement mortar. In concrete there is usually about 60% to 80% of the aggregate volume (Edward G. Nawy, 1998: 14). Aggregate properties not only affect concrete properties, but also affect durability, resistance to quality deterioration due to the freeze-thaw cycle. Since aggregate is cheaper than cement, it is logical to use it at the highest possible percentage. Thus ordinary aggregates are stratified according to size and a mixture that is feasible to the percentage of coarse aggregate and fine aggregate (Chu-Kia Wang, 1993).

Based on SNI 03-2847-2013, aggregate is a granular material, such as sand, gravel, crushed stone, and incandescent furnace crust used together with a binding medium to form concrete or hydraulic mortar. Aggregate is very influential on the quality of concrete. In conventional concrete, aggregate occupies 70% to 75% of the total volume of concrete.

Sea Water

Seawater is forbidden to be used as water mixing for reinforced concrete, as it increases the risk of corrosion of steel bars on concrete. Nevertheless, in various cases of unavoidable circumstances, seawater can be used as water mixing, not only for ordinary concrete but also for reinforced concrete. In addition, if the utilization of seawater is allowed as a concrete material it will be very beneficial and economical in development, especially in coastal areas. In addition, it can be one solution to anticipate freshwater shortages as reported by the World Meteorological Organization (WMO), that more than half of the world's population will not be able to get enough drinking water by 2025. (Adiwijaya, 2015).

Steel fibre

Steel fibers are produced through a cold drawing process with grooves at the ends that will provide optimal bonding to concrete. With the addition of steel fiber to concrete, it provides high load bearing capacity and ductility. In addition, it will also provide fast and easy applications and provide solutions that are much more effective and economical,

The addition of steel fiber can increase the toughness of concrete, so that the structure will avoid sudden collapse due to excessive loading. The use of fibers at high volume percentages (5 to 10 percent or higher with special production techniques) can substantially increase the strength of the tensile matrix (ACI Committee 544).

Research Subjects

Aggregate characteristics

Data obtained on examination of aggregate characteristics based on SNI, ASTM and related literature are shown in table 1.

Table 1.

Test results of aggregate characteristics

No.	Aggregate characteristics	Fine Aggregate (Sea sand)	Coarse Aggregate (Crushed Stone)
1	Maximum Size	5mm	20 mm
2	Modulus of Subtlety	1.90	8.10
3	Specific Gravity *)		
	a. Real Specific Gravity	2.41	2.63
	b. Dry Base Specific Gravity	2.56	2.82
	c. Surface Specific Gravity	2.47	2.70
4	Water Absorption	2.46%	2.57%
5	Volume Weight		
	a. Release Condition	1.42	1.80
	b. Solid Conditions	1.69	1.90
6	Water Content	-	1.69%
7	Sludge content	1,50%	0.50%
8	Organic Levels	No.1 (Low)	-

Seawater Characteristics

The chemical composition contained in seawater tested in the Oceanography laboratory of the Faculty of Marine Sciences and Fisheries, Hasanuddin University, Makassar can be seen in Table 2.

Table 2.

The chemical composition of seawater

Specific Gravity (gr/cm^3)	pH	Salinity(%)	Chemical composition (mg/l)
			Cl-
1,029	8,53	18	5303,70

The maximum water-soluble Cl- (chloride) ion content in concrete based is 1% of the weight of cement.

Mix Design Composition Assignment

Determination of mix design composition by trial mix referring to SNI 03-2834-2000:

1. Determination of the composition of coarse aggregate and fine aggregate

2. Determination of free moisture content.

Estimated free moisture content (Kg/m3) required for some level of ease of concrete mortar work. Source : SNI 03–2834–2000 Procedures for making normal concrete mix plans as shown in table 3.

Table 3.

Estimated free moisture content (Kg/m3) - SNI 03–2834–2000

Slump (mm)		0-10	10-30	30-60	60-180
Maximum aggregate grain large size	Aggregate type				
10	Unbreakable stone	150	180	205	225
	Crushed stone	180	205	230	250
20	Unbreakable stone	135	160	180	195
	Crushed stone	170	190	210	225
30	Unbreakable stone	115	140	160	175
	Crushed stone	155	175	190	205

Determination of water cement ratio

In determining the water cement ratio will be influenced by aggregate conditions. To get a high strong value, try to keep the cement water factor value as small as possible while still paying attention to its workability. The smaller the value of the water cement ratio, the more difficult it is to work and can cause porous concrete but can increase the strength of concrete. The cement water factor used is 0.40 which is set in table 4.

Table 4.

Requirements for special environmental influences

Environmental conditions	Water cement ratio maksimum[1)]	*fc*'minimum[2)] (Mpa)
Concrete with low permeabilitras exposed to the influence of the water environment	0,58	28
For the protection of reinforcement against corrosion in environmentally affected concrete contains chlorides from salt or seawater	0,40	35

NOTE:

1). Calculated against weight and applicable to normal concrete.

2). For normal weight concrete and light heavy concrete.

Determination of cement content

The determination of cement content is based on consideration of the free moisture content and cement water factor.

$$Cement\ moisture\ content = \frac{Free\ moisture\ content}{Water\ cement\ ratio}$$

Determination of specific gravity of aggregate combined specification

The specific gravity of the combined specification can be calculated using the formula:

Combined Specific Gravity = a% x SG. SSD fine aggregate + b% x SG. SSD coarse aggregate

a = Best Combined Fine Aggregate Percentage

b = Best Combined coarse Aggregate Percentage

Determination of the weight of concrete volume

The volume weight of concrete is obtained based on consideration of the free moisture content and specific gravity of the combined specification, as in figure 1.

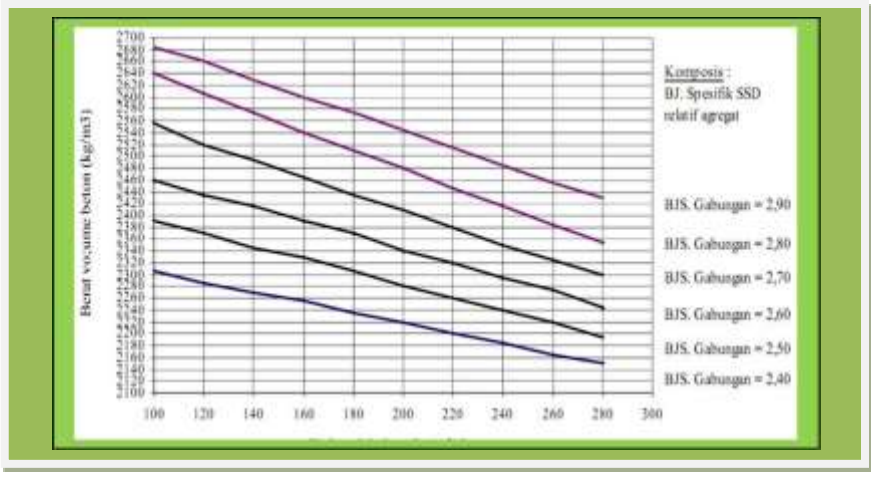

Figure 1. Volume Weight Curve of Fresh Concrete

Determination of the amount of coarse aggregate and fine aggregate

The determination of the aggregate amount used is obtained using the following formula:

A. Total aggregate weight = Volume weight of concrete - cement weight – free moisture content
B. Weight of sand aggregate = Total aggregate weight x % Sand composite
C. Coarse aggregate weight = Total aggregate weight - Weight of sand aggregate

Mix Design Concrete

Determination of mix design composition by trial mix which refers to SNI 03-2834- 2000 Design of seawater concrete mixture with volume fraction of steel fiber 0% and 2.5% of cement weight. Concrete volume fraction of 0% steel fiber is designed with a plan slump of 10 ± 2.5 cm and a compressive strength of plan of 35 ± 5 MPa. The composition of the concrete mixture for 1 m^3 can be seen in Table 5,

Table 5.
Seawater concrete mixture composition (kg/m3)

No	Materials	Type Concrete	
		0%	2,5%
		Kg	Kg
1	Sea water	204.12	204.12
2	Cement	512.50	512.50
3	Sea sand	477.30	477.30
4	Crushed stone	1099.29	1094.97
5	Steel fiber	-	12.81
	Total	2289	2285

Slump Test
The degree of abrasion is influenced by the composition of the mixture, the physical condition and the type of mixing material. The results of the slump test can be seen in Table 6.

Table 6.
Slump Test Results

Volume Fraction Steel Fiber	Slump Test Scores (cm)
0%	10
2,5%	9

Fresh concrete without steel fiber (0%) with the addition of steel fiber volume fraction meets the plan slump value of 10 ± 2.5 cm, although at steel fiber volume fraction of 2.5% the slump value decreases.

Unit Weight of Concrete
The results of the average unit weight of seawater concrete conducted when the concrete is 28 days old can be seen in Table 7.

Table 7.
Concrete Unit Weight Test Results

Steel Fiber Volume Fraction	Volume Weight of Fresh Concrete (kg/m^3)	Concrete Volume Weight Theory (kg/m^3)
0%	2346	2293
2,5%	2312	2289

With the increase in the volume fraction of steel fiber in the concrete mixture, the unit weight of concrete will decrease, but the large volume of steel fiber fraction does not change the type of concrete into lightweight concrete because the volume weight of light concrete is between 1140 – 1840 kg / m3.

Manufacture of test specimens

This research is designed for the manufacture of seawater concrete and sea sand as mixing materials with no addition of steel fibers and the addition of steel fibers 2.5% of the weight of cement, using selinder test specimens measuring 15 cm in diameter and 30 cm in height.

Test Specimen Care

For all test specimens, treatment (curing) is carried out, namely soaking curing, where the test specimens are soaked using seawater according to the test age.

Figure 2. Tensile strength tester

Cylindrical specimens measuring 15 cm in diameter and 30 cm in height. curing period 28 days, before being tested using Universal Testing Machine (Tokyo Testing Machine Inc.) capacity of 1000 kN and LVDT (Longitudinal Variable Differential Tranducer) 25 mm connected to data logger and switching box shown in figure 2.

Flowchart of research

RESULT AND DISCUSS

Tensile Strength

The results of the av % and 2.5% steel fiber volume fractions the concrete was 7 and 28 days old can be seen in Table 8.

Table 8.
Tensile Strength Test Results

Fiber Volume Fraction	Average Tensile Strength	
	7 day (MPa)	28 day (MPa)
0%	1.80	2.02
2,5%	1.98	2.38

It can be concluded that the average seawater concrete fct volume fraction of 0% steel fiber at the age of 7 days has increased due to the addition of 2.5% steel fiber, which is 10%. While the average seawater concrete fct volume fraction of 0% steel fiber at the age of 28 days has increased due to the addition of 2.5% steel fiber, which is 17.8%.

Table 9.
Recapitulation of the mean value of the relationship between load and deflection.

Fiber Volume Fraction	Load (kN)	deflection (mm)
0%	3303	0,3467
2,5%	4090	0,3827

It can be concluded that the average deflection value and maximum load increased due to the addition of steel fiber by 2.5%, namely the maximum load increased by 23.9% and deflection increased by 10.4%.

Concrete Homogeneity Testing

After testing the tensile strength and flexural strength, then the specimen is split to observe the arrangement of coarse aggregate (crushed stone) and steel fibers inside the test specimen. Figure 3. and figure 4. Shows the cross-sectional condition of the specimen after splitting. The results of concrete homogeneity testing can be seen in Table 10. and Table 11.

Table 10.
Distribution of coarse aggregate and steel fiber on cylindrical specimens 100 x 200 mm

Concrete	Coarse Aggregate		Steel Fiber		Average	
	Above	Below	Above	Below	Coarse Aggregate	Steel Fiber
0%	21	26	-	-	47	-
2,5%	20	23	21	23	43	44

Figure 3. The condition of the cylindrical specimen after splitting

Table 11.
Distribution of coarse aggregate and steel fiber on beam test specimens 100 x 100 x 400 mm

Concrete	Coarse Aggregate		Steel Fiber		Average	
	Above	Below	Above	Below	Coarse Aggregate	Steel Fiber
0%	19	20	-	-	39	-
2,5%	16	16	13	17	32	30

Figure 4. The condition of the beam specimen after splitting

The amount of distribution of coarse aggregate (crushed stone) for the top and bottom of the sample is insignificant, so it can be said that the specimens produced in this study are not homogeneous. While the distribution of steel fiber spread on test specimens that are seen visually after testing experience an even distribution distribution on concrete.

CONCLUSION

Seawater curing also affects the increase in concrete tensile strength, where the steel fiber volume fraction of 0% at the age of 28 days has increased strength by 12.2% from the age of 7 days and the volume fraction of steel fiber by 2.5% at the age of 28 days has increased strength by 20.2% from the age of 7 days. The distribution of coarse aggregate (crushed stone) in this study was not homogeneous. While the distribution of steel fiber distribution undergoes an even distribution of concrete.

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