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The Effect of Addition of Waste Strapping Band on Gap Graded Concrete

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***Abstract*—The study aimed to determine the effect of compressive strength and split tensile strength of gap graded concrete with the addition of strapping band waste variations of 0.5%, 1.0%, and 1.5% of the weight of cement. The study was conducted at the Materials and Concrete Laboratory of Bosowa University-Makassar. Quantitative research with experimental studies through the DoE (Design of Experiment) method conducted at the Materials and Concrete Laboratory of the Faculty of Engineering, Bosowa-Makassar University. The study design was carried out on the quality of concrete f'c 20 Mpa. Normal concrete testing has a graded grade, obtained by concrete compressive strength of an average of 23.52 MPa. Gap graded concrete with the addition of fiber strapping band as much as 0.5% of the weight of cement, obtained by compressive strength of concrete at an average of 24.06 Mpa. Compressive strength of an average of 26.04 Mpa obtained the addition of fiber strapping band waste as much as 1.0%. Concrete compressive strength of an average of 20.48 MPa gained addition of 1.5% fiber strapping band waste. The concrete tensile strength of an average of 1.463 MPa gained normal graded concrete testing. The concrete tensile strength of an average of 1.557 MPa achieved Gap graded concrete with the addition of fiber strapping band as much as 0.5% of the weight of the cement. The concrete tensile strength of an average of 2.548 MPa attained the addition of 1.0% fiber strapping band waste. Finally, the concrete tensile strength of an average of 1.982 Mpa found addition of 1.5% fiber strapping band waste.**

***Keywords*— gap graded concrete; concrete compressive strength; concrete tensile strength; waste strapping band.**

I. INTRODUCTION

The progress of concrete technology in improving quality requires creative innovation to answer the challenges of high-quality concrete needs [1].To produce quality concrete, good quality material is needed [2], in addition to other factors, such as the composition of materials and constituent materials, work methods, natural aggregate conditions [3]. Quality concrete concerns on workably, durability, strength, and economy [4]–[6].

Concrete is the material most often used in the world of construction, both building construction and road infrastructure. The nature of concrete is known to be better if the compressive strength of the concrete is higher so that the quality of concrete is based on concrete compressive strength. The greater the compressive strength of the concrete, the better the quality of the concrete [7]. Concrete is widely used because some of the constituent materials are easily available and inexpensive [8]. The concrete constituent consists of several materials that are commonly used, but with innovation and technology so that the waste can be used as an added material for forming concrete.

Waste results in environmental pollution especially plastic waste are already massive at this time. Used plastic is disposed of scattered and is a waste that cannot be broken down by soil, which can pollute the environment. In the long term, the bad consequences that are feared are the decreasing quality of land, water, air, and other natural resources [9]. A serious concern is needed in handling the problem of plastic waste in an integrated and directed manner.

Waste around our environment can be used as added material in concrete mixtures, so that it can provide an alternative to utilizing untapped wastes, such as waste plastic High-Density Polyethylene (HDPE). Optimizing the utilization of High-Density Polyethylene plastic waste is expected to reduce waste that pollutes the environment and provides added value. The advantage of using waste is that it can reduce environmental pollution and commercial value, which is certainly beneficial for the community [10].

Concrete has advantages, namely the ease of obtaining raw materials, ease of quality and durability [11], but also has weaknesses in low tensile strength, so it needs to be reinforced steel in concrete to withstand tensile strength [12]. Concrete in accepting the load that works against it requires steel reinforcement to carry the tensile load. There are several materials other than steel reinforcement to increase tensile stress and other stresses. One of them is by adding waste strapping bands to a certain amount of concrete mixture or called Concrete Fiber [13]. Concrete fiber technology is an innovation to improve concrete quality, which is a necessity in the construction industry [14].

The strapping band is a product made from PP (Polypropylene) and PET (Polyethylene) which is used in various industries, especially the packaging industry. Polypropylene fiber is a type of plastic fiber (polypropylene) which is a special production with high technology [15]. Is a polymer plastic that is easily formed when hot [16]. Fiber strapping band as added material is a material that has been used for various industrial purposes and after being discharged, it will become garbage that disrupts the environment.

The use of the strapping band is designed for compressive strength of 20 Mpa concrete which refers to the results of previous studies, obtained the value of concrete compressive strength on the addition of 0.75% polypropylene fibers of 24.31 MPa [17]. Concrete with the addition of strapping bands can reduce the weight itself so that it includes lightweight concrete. Lightweight concrete when the compressive strength of 17.24 Mpa-41.36 Mpa with a specific gravity of 1100 kg / m3 [18]. From the character and capabilities possessed, the concrete with strapping bands includes lightweight concrete for structural purposes.

Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregates, coarse aggregates and water with or without additives that form solid masses [19]. Normal concrete is concrete that gets the addition of other material with its specific gravity reaching 2200-2600 kg / m2 [20]. Cement is a type of material that has adhesive and cohesive properties that allow the attachment of other mineral fragments to a solid mass [21]. When cement is mixed with water to form a hardened mass, cement is called hydraulic cement or often called Portland cement [22]. Portland cement is a hydraulic cement produced by grinding the Portland cement slag especially consisting of calcium silicate. Cement is milled together with additional ingredients of calcium sulfate compounds and may be added with other additives [23].

Aggregates are natural mineral granules that function as fillers in concrete mixtures. The aggregate is the main component in the concrete [24] and occupies 60% -75% of the concrete volume [25]. Coarse aggregate is a material that has a size exceeding 6 mm or is stuck on filter No. 8 (2.36 mm). Coarse aggregate properties affect the final strength of hard concrete and its resistance to concrete disintegration, weather. Coarse aggregates must be clean of organic matter and must have a good bond with cement gel. Usually consists of gravel, broken stones [23].

The fine aggregate is the result of natural disintegration of rocks or sand produced by the stone-breaking industry. Fine aggregate is a space-filler between grains in the form of sand [23] and passes the No. filter. 8 (2.36 mm). The fine aggregate can increase the stability of the mixture by filling the pores or aggregate cracks.

In certain circumstances, if the availability of uniformly graded concrete material is difficult to obtain, the use of available grade graded aggregates is an alternative that can be considered. Aggregate slope gradation, which is an aggregate gradation with an incomplete size, or there are no aggregate fractions or few [26]. The distribution of aggregate grains affects the quality of concrete including the use of grading gap items if the implementation of less will produce porous and porous concrete [25].

Concrete compressive strength is the ability of hard concrete to resist compressive forces in each unit of the concrete surface area [27]. Alternatively, it can also be defined as a major mechanical characteristic of concrete, which can be identified through a laboratory test of compressive tests on specimens. The compressive strength of concrete is influenced by the proportion of the mixture, the quality of the constituent material and the quality of the work.

Normal concrete compressive strength is between 20 Mpa and 40 Mpa [28]. The composition of the mixture between cement, plastic, sand, and water, get the maximum compressive strength, specific gravity, and absorption. Tensile strength is an important trait that affects males and the size of cracks in the structure [29]. The split tensile strength of concrete is the value of the indirect tensile strength of a cylindrical concrete specimen obtained from the result of loading the specimen placed horizontally parallel to the surface of the testing machine press table. Tensile strength is an important characteristic that affects the propagation and size of cracks in the structure. The value of split tensile strength is obtained through press testing in the laboratory by overloading each cylindrical specimen laterally to its maximum strength. The formulas used in this method are as follows:

$$F_{ct} = \frac{2p}{\pi.l.d} \qquad (1)$$

Description:

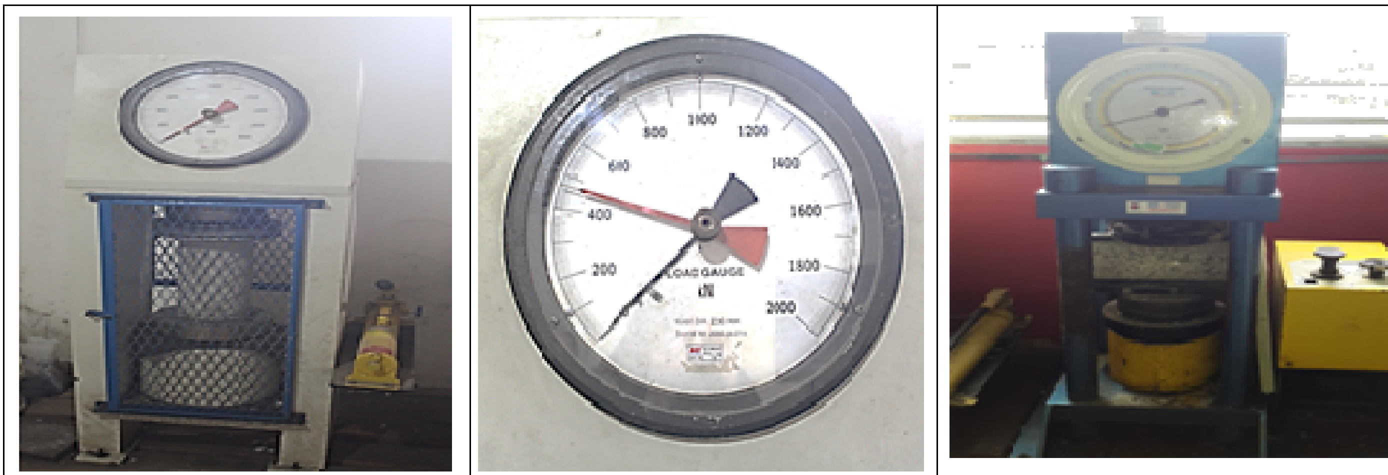
F_{ct} : Tensile Strength (Mpa)
p : load at split time (N)
d : Diameter of a cylindrical Test object
l : cylinder test object length
π : Phi

In certain circumstances, the availability of uniformly graded concrete materials is difficult to obtain so that the use of available grade graded aggregates is an alternative that can be considered. Aggregate or gap gradation study [30], which is aggregate gradation with an incomplete size or without aggregate fractions is rooted by this study. The research was conducted at the Materials and Concrete Laboratory of Bosowa University-Makassar. The study aimed to determine the effect of compressive strength and split tensile strength of gap graded concrete with the addition of strapping band waste variations of 0.5%, 1.0%, and 1.5% of the weight of cement.

II. Materials and Methods

A. Materials

This research implemented a quantitative research with experimental studies through the DoE (Design of Experiment) method. This research utilized the Materials and Concrete Laboratory provided by the Faculty of Engineering, Bosowa University-Makassar. The research design was carried out on the quality of concrete f'c 20 Mpa. The cylindrical specimen is 15 cm in diameter and 30 cm in length. The testing method of the split tensile strength of concrete is guided by the normative reference ASTM C 496 - 96, ASTM C 670: ASTM C 39, ASTM C 42, SNI 03-2493 - 1991, and SNI 03-4810 – 1998 [33] (see Figure 1).



(a) Concrete Compressive Strength Test Tool

(b) Reading Size

(c) Concrete Tensile Strength Test Tool

Fig. 1 Materials for testing method

Parameters of Fine Aggregate (Sand) and Coarse Aggregate (Broken Stone):

- Water content. Water content in the aggregate is strongly influenced by the amount of water contained in the aggregate. The greater the difference between the weight of the original aggregate and the weight of the aggregate after drying the oven, the more water contained by the aggregate and vice versa. Tolerance of water content in fine aggregates is 3% -5% and coarse aggregate is 0.5% -2%.
- Sludge level. The level of sludge is the percentage of the size that passes the filter No.200 according to ASTM and British Standard or 80 DIN (Germany) or the size of the standard filter hole = 0.075 mm. Tests in the laboratory are generally carried out by washing methods according to ASTM C-117 (2000 Sieve in Mineral Aggregates by Washing) Standard Test Method for Materials. Slurry tolerance for fine aggregates is 0.2% -6% and for coarse aggregate of 0.2% -1%.
- The volume weight is the ratio between the weight of the aggregate in the dry state and its volume. The purpose of the test is to determine the fine or coarse aggregate content weight. Volume weight tolerance for fine aggregate is 1.4 kg / ltr-1.9 kg / ltr and for coarse aggregate of 1.6 kg / ltr-1.9 kg / ltr.
- Specific gravity is the ratio between the weight of dry aggregate and the weight of distilled water whose contents are the same as the aggregate content in a saturated state at a certain temperature. Specific gravity for fine aggregate is 1.6% -3.3% and for coarse aggregate is 1.6% -3.2%.
- Absorption is the percentage of the weight of water that can be absorbed by the material against the weight of dry aggregate. The tolerance of observation for fine aggregates is 0.2% -2% and for coarse aggregate of 0.2% -4%.
- Organic content, are ingredients contained in fine aggregates, which can cause damage to concrete. Organic substances contained in fine aggregates generally come from plants that have been destroyed, especially those in the form of humus and organic mud. Harmful organic substances include sugar, oil, and fat. Sugar can inhibit cement binding and the development of concrete strength, while oil and fat can reduce the binding capacity of cement. Organic tolerance for fine aggregates is to pass the largest filter <No. 3.
- Filter analysis. The aggregate filter analysis is the distribution of aggregate gradations. The aggregate analysis provides important information about the percentage of aggregates that have passed the specified filter. Data on aggregate granular distribution is needed in concrete mortar planning. The filtering tolerance for fine aggregates is 2.2% - 3.1% and for coarse aggregates of 2.5% - 8.5%.
- Aggregate wear. Aggregate wear checks are intended to determine the resistance of coarse aggregates to wear using a Los Angeles machine. Its function is the aggregate ability to resist friction, calculated based on the destruction of the aggregate by sifting the aggregate in sieve No. 12 (1.70 mm). The wear is stated by the ratio between the weights of the wear material through the no. 10 to the original weight in percent. Aggregate wear tolerance for coarse aggregate is 15% - 50%.


Concrete Cylinder


Wear Test Equipment


Filter Analyzer


Aggregate and Scale


Strapping Band

Fig. 2 Material for experimentation

B. Method

The research procedure was carried out, as follows:

- Prepare tools and materials. The material of strapping band with a size of 2 mm x 30 mm.
- Tests for the characteristics and characteristics of fine aggregates and coarse aggregates.
- Calculation of the combination of fine and coarse aggregates to obtain the appropriate composition.
- Designing a concrete mix (mix design) with f'c 20 MPa.
- Testing of compressive strength of gradual concrete slope f'c 20 MPa
- Making the composition of mixing gradual concrete slabs with the addition of strapping band waste variations of 0.5%, 1.0%, and 1.5% of the weight of cement.
- Making gradual concrete slab specimens with various strapping bands.
- Treatment of gap gradation concrete with a variety of strapping bands for 28 days
- Testing of compressive strength and tensile strength of concrete slope with variations in a waste strapping band.
- Data analysis and conclusions.

III. RESULTS AND DISCUSSION

A. . Testing of Aggregate Characteristics

1) Fine Aggregate (Sand): There are seven types of testing for the characteristics of fine aggregates (sand) and all of them meet the requirements, as follows.

TABLE I
TEST RESULTS FOR FINE AGGREGATE (SAND)

No.	Type of Test	Interval	Result	Description
1	Water content	3% - 5%	3.59	Meets
2	Sludge levels	0.2% - 5%	1.73	Meets
3	Weight volume	1.4 kg/ltr- .9 kg/ltr	1.44	Meets
4	Specific gravity	1.6% - 3,3%	2.37	Meets
5	Absorption	0.2% - 2%	1.94	Meets
6	Organic content	< No. 3	No. 1	Meets
7	Filter analysis	2.2% - 3.1%	2.71	Meets

The results indicate that all aggregate requirements specifications meet the requirements

2) Coarse Aggregate (Broken Stone): There are seven types of tests on the characteristics of coarse aggregates (broken stones) and all of them meet the requirements, as follows.

TABLE II
TEST RESULTS OF COARSE AGGREGATES (BROKEN STONES)

No.	Type Of Test	Interval	Result	Dicriptio n
1	Water content	0.5% - 2%	1.01	Meets
2	Sludge levels	0.2% - 1%	0.83	Meets
3	Weight volume	1.6 kg/ltr – 1.9 kg/ltr	1.63	Meets
4	Specific gravity	1.6% - 3.2%	2.37	Meets
5	Absorption	0.2% - 4%	1.94	Meets
6	Filter analysis	2.5% - 8.5%	6.71	Meets
7	Aggregate wear	15% - 50%	18,83	Meets

The results indicate that all aggregate requirements specifications meet the requirements

B. Testing of Normal Concrete Compressive Strength with Graded Gradation

Tests were carried out at 28 days of concrete against 12 (twelve) specimens. The results of normal concrete compressive strength test are gradual gradation, as in the following table.

TABLE III
RESULTS OF TESTING OF NORMAL CONCRETE COMPRESSIVE STRENGTH OF GAP GRADATION

No	Test Item Code	Compressive strength , fcr P/A (MPa)	Compressive strength f'cr average (MPa)
1	NC-GG-1	25.48	23.52
2	NC-GG -2	22.08	
3	NC-GG -3	22.65	
4	NC-GG -4	24.35	
5	NC-GG -5	24.91	
6	NC-GG -6	24.63	
7	NC-GG -7	23.78	
8	NC-GG -8	23.21	
9	NC-GG -9	22.36	
10	NC-GG -10	22.93	
11	NC-GG -11	23.78	
12	NC-GG -12	22.08	

Information: - NC-GG = Normal Concrete - Gap Gradation.

Table 3 above shows that the highest compressive strength was 25.48 MPa and lowest compressive strength was 22.08 MPa. Table 2 shows the results of testing of the concrete compressive value on 12 (twelve) test objects at the age of 28 days. The test results were found to be lowest in specimens 2 and 12 at 22.08 Mpa and the largest on specimens 1 at 25.48 MPa, or an average of 23.52 Mpa. The value of compressive strength produced is all higher than the planned standard value of f'c 20 Mpa.

C. *Testing of Concrete Compressive Strength of Waste Strapping Band*

Test of concrete compressive strength was carried out on variations in waste strapping bands of 0.5%, 1% and 1.5% of cement weight with each of 3 (three) cylindrical test specimens. Based on the results of the concrete compressive strength test results are obtained as in the following table.

TABLE IV
TEST RESULTS FOR CONCRETE COMPRESSIVE STRENGTH OF STRAPPING BAND WASTE

No	Test Item Code	Compressive Strength, fcr P/A (MPa)	Compressive Strength, f'cr average (MPa)
1	SB I - 0.5 %	26.04	24.06
2	SB II - 0.5%	25.76	
3	SB III- 0.5%	20.38	
4	SB I – 1.0 %	26.89	26.04
5	SB II – 1.0 %	28.59	
6	SB III - 1,0 %	22.65	
7	SB I – 1.5 %	22.08	20.48
8	SB II – 1.5 %	18.12	
9	SB III – 1.5 %	21.23	

Information:
SB I - 0.5 % = Strapping Band, Sample 1- 0.5% Strapping Band
SB I – 1.0 % = Strapping Band, Sample 1- 1.0% Strapping Band
SB I – 1.5 % = Strapping Band, Sample 1- 1.5% Strapping Band

The results table 4 above shows the results of the variation of the concrete compressive strength test of 0.5% waste strapping band obtained 24.06 MPa. In the variation of 1.0% of 26.04 MPa and 1.5% of 20.48 MPa. there was an increase in compressive strength of concrete at 1.0% variation of 8.25%, but there was a decrease in variation of 1.5%. Also, table 2 above shows that the value of normal concrete compressive strength of 23.520 Mpa is higher than the planned standard of compressive strength of concrete, f'c 20 Mpa, so that it can be continued testing on the concrete tensile strength. The addition of strapping band waste at a variation of 0.5% was obtained from the concrete compressive strength of 24.062 Mpa, the variation of 1.00% was 26.044 Mpa and the variation of 1.5% was 20.447 Mpa.

The results of previous studies showed that the compressive strength of concrete on the addition of 0.75% polypropylene fiber was 24.31 Mpa or increased by 27.93% from fiber-free concrete [31]. When compared the two results of this study that the results of research that has been done, namely an increase of 10.73% and the results of previous studies increased by 27.93%. Both of these compressive strength tests show that there is a different percentage increase. The difference is caused, as said that to produce good quality concrete, is influenced by the composition of materials and constituent materials, how to work, natural aggregate conditions [24]. The results of the concrete compressive strength test between the research conducted and previous studies with the addition of strapping bands (polypropylene) showed that both of them had an increase. Therefore, it can be said that the results of the research carried out are reinforced by the results of previous research trials.

D. *Testing of Normal Concrete Tensile Strength, Variation of Waste Strapping Band*

Testing of the tensile strength of normal concrete as many as 3 (three) specimens and the concrete variation of waste strapping band 0.5%, 1.0% and 1.5% each of 3 (three) specimens. The test results of split tensile strength are shown in the following table.

TABLE V
TEST RESULTS OF NORMAL CONCRETE TENSILE STRENGTH, VARIATION OF WASTE STRAPPING BAND

No	Test Item Code	Tensile Strength f'ct (MPa)	Tensile Strength f'ctr average (MPa)
1	NC-GG-1	1.415	1.463
2	NC-GG -2	1.699	
3	NC-GG -3	1.274	
4	SB I - 0.5 %	1.415	1.557
5	SB II - 0.5%	1.557	
6	SB III- 0.5%	1.699	
7	SB I – 1.0 %	2.689	2.548
8	SB II – 1.0 %	2.548	
9	SB III – 1.0 %	2.406	
10	SB I – 1.5 %	1.982	1.982
11	SB II - 1,5 %	2.123	
12	SB III – 1.5 %	1.840	

Table 5 shows the results of the value of the concrete tensile strength for normal concrete obtained by an average of 1.463 MPa. The value of split tensile strength on the addition of strapping band waste variation of 0.5% obtained an average of 1.557 Mpa, a variation of 1.00% on average of 2.548 Mpa and a variation of 1.5% on average of 1.982 Mpa. In the variation of 1.00%, the greatest value is obtained or the optimum tensile strength value is 2.548 MPa.

In Table 5, it also shows that the value of normal concrete split tensile strength is 1.463 Mpa and the value of concrete split strength of strapping band variation at 1.0% is 2.548 Mpa (optimum tensile strength), indicating that there is an increase in tensile strength of 74,2%. Therefore, it can be said that there is an effect of adding waste strapping bands to the tensile strength of concrete.

The results of previous studies said that, the value of split tensile strength of lightweight concrete, on the addition of 0.75% polypropylene fiber by 4.23 Mpa or an increase of 60.38% from lightweight concrete without fiber [31]. The results of other studies said that the optimum increase in split tensile strength for FAS was 0.35, namely; 3.49 Mpa with an increase of 5.76% using variations of fiber 0.9 kg/cm [32].

The results of the next study said that the addition of polypropylene fibers to concrete mixes could increase the tensile strength of concrete. The optimum concrete tensile strength in fiber concrete with a dose of 0.65 kg/m³ at 28 days was 3.842 MPa or increased by 20.44% from normal concrete [33]. The test results of the research conducted and the results of the tests of the three previous studies on the tensile strength of the concrete have a different percentage increase. The difference is caused, as said that to produce good quality concrete, is influenced by the composition of materials and constituent materials, how to work, natural aggregate conditions [24]. The results of the concrete tensile strength test between the research conducted and previous studies with the addition of strapping bands (polypropylene fibers), showed an increase. Therefore, it can be said that the research carried out can be strengthened by the three previous studies.

E. Compressive Strength and Tensile Strength of Gap Gradation Concrete

Comparison of the compressive strength and tensile strength of the concrete variations in strapping band waste, presented in the following table 6. The test results on concrete compressive strength, through the addition of fiber strapping band waste of 0.5% each, an increase of 2.3% or to 24.06 Mpa. The addition of 1.0% waste strapping band increased by 8.3% or to 26.04 Mpa. The test results on the tensile strength of concrete, through the addition of fiber strapping band waste of 0.5% each, increased by 6.4% or to 1.557 Mpa. The addition of 1.0% waste strapping band increased by 63.7% or to 26.04 Mpa.

There was no correlation due to the addition of waste fiber strapping bands between the compressive strength of the concrete and the tensile strength of the concrete. This situation can be seen from the results of the compressive strength of the concrete, the highest increase of 8%, while the results of the split tensile strength increased significantly, namely 63.7%.

TABLE VI
.TEST RESULTS FOR THE COMPRESSIVE STRENGTH AND NORMAL CONCRETE TENSILE STRENGTH OF VARIATIONS IN WASTE STRAPPING BAND

No	Test item code	Compress. Strength, fc P/A (Mpa)	Compress. Strength, fcr average (Mpa)	Tensile strength fct (Mpa)	Tensile Strength f'ctr average (Mpa)
1	NC-GG-1	25.48	23.52	1.415	1.463
2	NC-GG-2	22.08		1.699	
3	NC-GG-3	22.65		1.274	
4	NC-GG-4	24.35			
5	NC-GG-5	24.91			
6	NC-GG-6	24.63			
7	NC-GG-7	23.78			
8	NC-GG-8	23.21			
9	NC-GG-9	22.36			
10	NC-GG-10	22.93			
11	NC-GG-11	23.78			
12	NC-GG-12	22.08			
13	SB I-0.5 %	26.04	24.06	1.415	1.557
14	SB II-0.5%	25.76		1.557	
15	SB III-0.5%	20.38		1.699	
16	SB I-1,0 %	26.89	26.04	2.689	2.548
17	SB II-1,0 %	28.59		2.548	
18	SB III-1,0 %	22.65		2.406	
19	SB I-1,5 %	22.08	20.48	1.982	1.982
20	SB II-1,5 %	18.12		2.123	
21	SB III-1,5 %	21.23		1.840	

The results of the comparison of the compressive strength and concrete tensile strength with the addition of fiber waste strapping bands are shown in the diagram. From the test, the following results are obtained. In the gap graded normal concrete the compressive strength value is 23.52 Mpa and the value of the split tensile strength is 1.46 Mpa. In gap-graded concrete added with strapping band waste, the optimal compressive strength value at 1.0% variation is 26.04 Mpa and the concrete tensile strength value is 2.548 Mpa.

Fig. 3 Concrete after compressive the strength

Fig. 4 Concrete after being given split tensile strength

IV. CONCLUSIONS

Normal concrete testing has a graded grade, obtained by concrete compressive strength of an average of 23.52 MPa. Gap graded concrete with the addition of fiber strapping band as much as 0.5% of the weight of cement, obtained by compressive strength of concrete at an average of 24.06 Mpa. Addition of fiber strapping band waste as much as 1.0%, obtained by compressive strength of an average of 26.04 Mpa. Addition of 1.5% fiber strapping band waste, obtained by concrete compressive strength of an average of 20.48 MPa.

There was an increase in concrete compressive strength towards normal concrete on the addition of waste fiber strapping bands in variations of 0.5% and 1.0%. In the variation of 1.5% waste fiber strapping band, there was a decrease in concrete compressive strength. Normal graded concrete testing is obtained by the concrete tensile strength of an average of 1.463 MPa.

Gap graded concrete with the addition of fiber strapping band as much as 0.5% of the weight of the cement, obtained by the concrete tensile strength of an average of 1.557 MPa. Addition of 1.0% fiber strapping band waste, obtained by the concrete tensile strength of an average of 2.548 MPa. Addition of 1.5% fiber strapping band waste, obtained by the concrete tensile strength of an average of 1.982 Mpa. There was an increase in the concrete tensile strength of normal concrete on the addition of waste fiber strapping bands in variations of 0.5% and 1.0%. In the variation of 1.5%, the waste fiber-strapping band decreased the concrete compressive strength.

In further research, it is recommended the study produces lightweight concrete and can be used for structural purposes. In addition, further research should conduct the testing of types of concrete other than gap-graded concrete.

REFERENCES

[1] T. R. Naik, "Sustainability of concrete construction," *Pract. Period. Struct. Des. Constr.*, vol. 13, no. 2, pp. 98–103, 2008.

[2] A. Neville and P.-C. Aitcin, "High performance concrete—an overview," *Mater. Struct.*, vol. 31, no. 2, pp. 111–117, 1998.

[3] K. K. Sagoe-Crentsil, T. Brown, and A. H. Taylor, "Performance of concrete made with commercially produced coarse recycled concrete aggregate," *Cem. Concr. Res.*, vol. 31, no. 5, pp. 707–712, 2001.

[4] G. H. Tattersall, *Workability and quality control of concrete*. CRC Press, 1991.

[5] M. Tavakoli and P. Soroushian, "Strengths of recycled aggregate concrete made using field-demolished concrete as aggregate," *Mater. J.*, vol. 93, no. 2, pp. 178–181, 1996.

[6] S. Lotfi, J. Deja, P. Rem, R. Mróz, E. van Roekel, and H. van der Stelt, "Mechanical recycling of EOL concrete into high-grade aggregates," *Resour. Conserv. Recycl.*, vol. 87, pp. 117–125, 2014.

[7] S. W. Tabsh and A. S. Abdelfatah, "Influence of recycled concrete aggregates on strength properties of concrete," *Constr. Build. Mater.*, vol. 23, no. 2, pp. 1163–1167, 2009.

[8] J. Purnomo, I. N. Saputro, and S. Sumarni, "Pengaruh Penggunaan Citric Acid sebagai Retarder pada Beton terhadap Waktu Pengikatan Semen, Kecelakaan Beton Segar dan Kuat Tekan Beton," vol. 4, no. 2, pp. 18–27, 2018.

[9] A. R. Asrib, M. N. Abduh, and G. D. Dirawan, "Environmental sustainability: The case of the Sultan Hasanuddin International airport, Makassar, South Sulawesi," *World Trans. Eng. Technol. Educ.*, vol. 14, no. 3, pp. 431–437, 2016.

[10] Z. Z. Ismail and E. A. Al-Hashmi, "Use of waste plastic in concrete mixture as aggregate replacement," *Waste Manag.*, vol. 28, no. 11, pp. 2041–2047, 2008.

[11] C. Meyer, "The greening of the concrete industry," *Cem. Concr. Compos.*, vol. 31, no. 8, pp. 601–605, 2009.

[12] W. Chen, T. M. Pham, H. Sichembe, L. Chen, and H. Hao, "Experimental study of flexural behaviour of RC beams strengthened by longitudinal and U-shaped basalt FRP sheet," *Compos. Part B Eng.*, vol. 134, pp. 114–126, 2018.

[13] S. P. Shah and B. V. Rangan, "Fiber reinforced concrete properties," in *Journal Proceedings*, 1971, vol. 68, no. 2, pp. 126–137.

[14] A. E. Naaman, "New fiber technology (cement, ceramic, and polymeric composites)," *Concr. Int.*, vol. 20, no. 7, pp. 57–62, 1998.

[15] M. Perez-Pena and B. Mobasher, "Mechanical properties of fiber reinforced lightweight concrete composites," *Cem. Concr. Res.*, vol. 24, no. 6, pp. 1121–1132, 1994.

[16] C. T. Gazda and J. M. Lalikos, "Poly-polymer plastic material and device made therefrom." Google Patents, 21-Oct-1975.

[17] P. Gunawan, W. Wibowo, and N. Suryawan, "Pengaruh Penambahan Serat Polypropylene pada Betonringan Dengan Teknologi Foam Terhadap Kuat Tekan, Kuat Tarik Belah dan Modulus Elastisitas," *Matriks Tek. Sipil*, vol. 2, no. 2, pp. 206–213, 2014.

[18] National Standardization Agency, "Indonesian National Standard SNI," 03-3449–2002, 2002.

[19] V. S. Ramachandran, *Concrete Admixtures Handbook: Properties, Science and Technology*. Elsevier Science, 1996.

[20] D. C. Teychenné, R. E. Franklin, H. C. Erntroy, D. W. Hobbs, and B. K. Marsh, *Design of Normal Concrete Mixes*. IHS BRE Press, 2005.

[21] Y.-W. Chan and V. C. Li, "Age effect on the characteristics of fibre/cement interfacial properties," *J. Mater. Sci.*, vol. 32, no. 19, pp. 5287–5292, 1997.

[22] R. H. Bogue, *The chemistry of Portland cement*, vol. 79, no. 4. LWW, 1955.

[23] National Standardization Agency, "Indonesian National Standard SNI," 15-2049–2004, 2004.

[24] B. W. H. Langer, *Natural Aggregates of the Conterminous United States*. U.S. Geological Survey bulletin, 1993.

[25] H. Widhiarto and B. Sujatimiko, "Analisis Campuran Beton Berpori Dengan Agregat Bergradasi Terpisah Ditinjau Terhadap Mutu dan Biaya," *Extrapolasi J. Tek. Sipil Untag Surabaya*, vol. 05, no. 02, pp. 24–30, 2012.

[26] R. M. Anderson and H. U. Bahia, "Evaluation and Selection of Aggregate Gradations for Asphalt Mixtures Using Superpave," *Transp. Res. Rec. J. Transp. Res. Board*, vol. 1583, no. 1, pp. 91–97, Jan. 1997.

[27] G. A. Khoury, "Compressive strength of concrete at high temperatures: a reassessment," *Mag. Concr. Res.*, vol. 44, no. 161, pp. 291–309, Dec. 1992.

[28] H. L. Malhotra, "The effect of temperature on the compressive strength of concrete," *Mag. Concr. Res.*, vol. 8, no. 23, pp. 85–94, Aug. 1956.

[29] J. M. Raphael, "Tensile Strength of Concrete," *ACI J. Proc.*, vol. 81, no. 2.

[30] D.-H. Shen, M.-F. Kuo, and J.-C. Du, "Properties of gap-aggregate gradation asphalt mixture and permanent deformation," *Constr. Build. Mater.*, vol. 19, no. 2, pp. 147–153, Mar. 2005.

[31] E. Pratama and E. S. Hisyam, "Kajian Kuat Tekan dan Kuat Tarik Belah Beton Kertas (Papercrete) dengan Bahan Tambah Serat Nylon," in *Forum Profesional Teknik Sipil*, 2016, vol. 4, no. 1.

[32] W. Kartini, "Penggunaan Serat Polypropylene Untuk Meningkatkan Kuat Tarik Belah Beton," *J. Rekayasa Perenc.*, vol. 4, no. 1, 2007.

[33] L. Rahmadianty, H. Mazaya, D. Purwanto, and R. Y. Adi, "Analisa Campuran Beton Dengan Perbandingan Volume Dan Pengamatan Karakteristik Beton Mutu Sedang," *J. KARYA Tek. SIPIL*, vol. 6, no. 2, pp. 55–69, 2017.