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Mechanical Analysis of Environmentally Friendly Concrete Rubber

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***Abstract*— Tire production Indonesia has been increased by numbers from year to year along with a great amount causes the availability of abundant rubber tire waste, this waste has not been widely used and has unravel able properties leading into environmental pollution. In this research, we developed an environmentally friendly concrete innovation. This research aimed at determining the optimal value of concrete based on the rubber tire waste aggregate, compressive strength, tensile strength, modulus of elasticity and content weight of rubber concrete. This research is designed with quantitative method along with a laboratory true experimental approach. This research reviews the performance of concrete mixture incorporating 5%, 10%, 15%, 20% and 25% of discarded tire rubber as coarse aggregate replacement. The results conclude that maximum compressive strength of rubber concrete was varied 5% and 19.42 MPa of strength. Maximum split tensile strength of rubber concrete was varied 5% with a strength of 1.70 MPa, Maximum modulus of elasticity of rubber concrete was varied 5% with a strength 24204.73 MPa, The weight of the minimum content of rubber concrete is found in a variation of 25% with a weight value of 2196.27 kg / m3.**

***Keywords*— rubber concrete, compressive strength, split tensile strength, modulus of elasticity, weight of content**

I. INTRODUCTION

The developments in the building sectors trigger a abundant use of cement which consequently causes the increase on its productivity. Similarly, the highly increased on productivity causes the cost of production and continuously nature exploitation. This condition will affect the availability of raw materials in the future. A great number of rubber tires waste should increase its usability, in addition to be used as an alternative material in cement making process. Ordinary concrete consists of a unit weight of 2200 to 2500 kg/m^3 and is made of natural aggregates [1]. Concrete making was carried out on a large scale and continuously, which requires a large amount of natural resources. According to data from the Central Statistics Agency the production volume of rock quarry mining continues to increase every year, in 2011 it was 83.668,562 m^3, in 2012 it was 89.590,918 m^3, in 2013 it was 84.114,959 m^3 and in 2014 it was 104.276,218 m^3. This causes a reduction in available natural resources. Thus, the need for alternative substitute materials from nature is increasingly important.

One of the alternative materials used as a substitute for concrete constituent materials is a mere waste without reducing the concrete quality. Waste is used as a substitute for natural aggregates, which consequently may reduce environmental pollution. A typical waste that can be used is granules of used rubber tires as an aggregate substitute in manufacturing a concrete. Rubber tire waste of the unused motorized vehicles wheels, are one of the easily found waste everywhere in Indonesia, considering the numbers are increasingly greater.

Tires made of synthetic and natural rubber are mixed with black carbon and other chemical elements such as silica, resins, anti-oxidants, sulfur, paraffin, cobalt, salt, cure accelerators, actuators, and added threads and steel wire joints where the thread functions as a frame or tire reinforcing element. The yarn used is generally as polyester, rayon or nylon. Based on the main constituent materials, which is the natural and synthetic rubber, where in terms of quality, rubber is weather and water resistant, and reflects sufficient stability, highly resistant, and shows a great level of flexibility and rubber has the property of absorbing vibration which consequently provides a comfort upon riding a vehicle [2].

Rubber tires shows density of 1.08-1.27 t/m^3 and reflects an elastic modulus of 0.77-1.33 MPa. Additionally, rubber tires characteristically identical with properties such as: strong, elastic, heat insulator and waterproof so that they meet the requirements to be aggregated in concrete mixtures. The flexibility of rubber tires can prevent cracking in concrete [3]. Rubber tire aggregates are produced and classified into four types, depending on their particle size, namely shredded/chipped (about 2-20 mm), crumb (4.75–0.425 mm), ground (100% escaped 0.425 mm), and shredded fibrous [4]. Materials that have been classified as having low particle density (0.95 kg/m^3), low thermal conductivity (0.14 W / mK), high dynamic modulus and having properties as attenuation, and high resistance to weathering (non-biodegradable) [5].

In Indonesia, rubber tire waste is easily found; bearing almost each family in every society of the Indonesian people has always been riding vehicles in their daily lives. Thus, the need for tire production in Indonesia continues to increase from year to year. According to data from the Ministry of Industry in 2016, there are currently no less than 14 domestic and foreign brand tire manufacturers that produce tires in Indonesia. They have a production capacity of 77 million units for car, truck and bus tires, and 64 million units for motorcycle tires. Besides that, the utilization of rubber tire waste is still very limited, among others, it is only used for sandals, ropes, dock protectors (fenders), trash bins, and craft chairs.

Several relevant researchers have developed a lot of rubber tire waste as concrete material, including: Youssf & Elgawady [6] explained that soaking rubber in NaOH solution before mixing concrete can increase the strength of concrete. NaOH can remove zinc stearate from the rubber surface enables to increases the adhesion between rubber particles and cement paste. Ramdania et al. [7] explains that by combining glass powder and rubber aggregates, especially with a ratio of 10% and 20% rubber aggregates, the strength increases. In addition, developed rubber concrete by combining glass powder presented a higher fresh density and deformability, compared with cement rubber mixtures without glass powder. Kaloush et al. [8] further explained that the density and compressive strength of rubber concrete specimens were lower compared to control specimens, this phenomenon can be explained as follows: after vibrating, there is a coarser aggregate at the bottom while the fine aggregate rises to the top, resulting in an increase in the number of coarse-mortar contact areas at the bottom, where cracks easily start.

Li et al. [9] argues that although crumb rubber into a concrete mixture has decreased axial compressive strength and modulus elasticity of concrete, crumb rubber can increase the tenacity and energy absorption capability of concrete [10].The compressive strength values gradually decreases along with the increase on the increase of crumb rubber in the concrete mixture. On the compressive strength test, the concrete mixture with variations of 0-12.5% crumb rubber, crosses the 60 MPa boundary. Rubber concrete shows more resistance to abrasion than control concrete [11]. Rubber concrete increases energy absorption because concrete does not experience typical brittle failure but is resilient, plastic failure mode. Rubber concrete shows better resistance compared to plain concrete. This does not apply to concrete from a compressive strength below 50 MPa, which displays a consistent reduction in durability. Case Research in Construction of Rubber-coated Materials, concrete can be used efficiently. Although rubber concrete mixtures generally experience a decrease in compressive strength which can limit their use in certain structural applications, it has a number of desirable advantages, such as lowering density, higher toughness, and higher impact resistance, compared to conventional concrete. In addition to that, Bisht & Ramana [12] applied rubber waste of crumb rubber in Portland pozzolana cement concrete as a substitute of fine aggregates in varied percentages. The result concludes that 4% of fine aggregates replaceable by crumb rubber in manufacturing concrete for non-structural elements.

A concept proposed in this research is aimed at utilizing the abundant number of rubber tire waste where the presence has not been utilized properly nor does it produce anything maximal. This rubber tire waste is used as a material which is maximally used. Rubber tire wastes are used as coarse aggregate substitutes and in work processes that use variations in cement substitution. This research determines optimal value of concrete with aggregate of rubber tire waste on its compressive strength, tensile strength, elastic modulus and density of rubber concrete.

II. Review of Related Literature

A. Concrete

Concrete is a mixture of Portland cement or other hydraulic cement, fine aggregates, coarse aggregates and water, with or without additives forming a solid, strong and stable mass) [13]. Concrete is widely used as one of the building materials. Commonly, concrete consists of approximately 15% cement, 8% water, 3% air, the rest is sand and gravel [14]. Concrete is created through mixing cement, fine aggregates, coarse aggregates, water and some even using other mixtures [15]. The strength of concrete relies on many factors: the proportion of the mixture and the place temperature and humidity where the mixture is placed and hardens.

B. Rubber Tire Waste

- Physical Properties of Tires

According to the *European Committee de Normalization* CEN (2002) cited in Najib & Nadia [16], the physical properties of tires that are feasible are used for applications in civil engineering in Table I.

TABLE I. PHYSICAL PROPERTIES OF TIRES

	Physical Property		Typical Value
1	Angel of friction	14	19 º – 26º
2	Bulk density	15	~350 – 50 kg/m³
3	Compacted density	16	600 – 700 kg/m³ (*rising to* 990 kg/m³ *under* 400 kPa *vertical stress*)
4			
5	Cohesion (kPa)	17	5 -1
6	Compressibility	18	20 – 50% (at 21 – 147 kN/m³)
7	Hydraulic conductivity	19	1x10-2 – 1x10-3 m/s
8	Loose bulk density	20	3,3 – 4,8 kN/m3
9	Particle size	21	*Chips to bales*
10	Poisson's ratio	22	0,2 – 0,35
11	Resilient modulus	23	1 – 2 MPa
12	Specific gravity	24	1,1 – 1,27 t/m³
13	Thermal conductivity	25	0,15 – 0,23 W/mK

Rubber tire waste fibers, sometimes called used tire powder, technically termed "crumb tire or crumb rubber" are environmentally friendly products because they are obtained from used tires and are insoluble in soil or ground water. In addition to reducing the amount of rubber waste that is wasted into the environment, the reuse of certain rubber product waste can reduce the price of rubber as one of the important components determining the price of finished products [17]. According to Happy [17], the used tire powder engages three-dimensional network or a cross-bond product of natural rubber and synthetic rubber, reinforced with black carbon which absorbs aqueous oil from cement asphalt during the reaction period which can experience swelling and softening of the used tire powder. This increases the thickness of the modified bidder. The chopped tire is produced in a tire cutting machine. This machine cuts relatively large pieces of cutting waste. The initial cutting process can produce used tires with a length of 300-460 mm (12-18 inches) wide 100-230 mm (4-9 inches) and thick 100-150 mm (4-6 inches).

Rough shreds, tire derived aggregates, tire shredders andire chips are produced from secondary shredding, which cuts the tire down to 0.5 - 3 in.

TABLE II. TERMINOLOGY FOR RECYCLED WASTE TIRE PARTICLES [18]

Classification	Lower Limit, in (mm)	Upper Limit, in (mm)
Chopped Tire	Unspecified dimensions	
Rough Shed	1.97X1.97X1.97 (50X5050)	30X1.97X3.94 (762X50X100)
Tire Derived Aggregate	0.47 (12)	12 (305)
Tire Shreds	1.97 (50)	12 (305)
Tire Chips	0.47 (12)	1.96 (50)
Granulated Rubber	0.017 (0.425)	0.47 (12)
Ground Rubber	-	<0.017 (0.425)
Powered Rubber	-	<0.017 (0.425)

C. *Compressive Strength*

Compressive strength is one of the main performances of concrete. Compressive strength is the ability of concrete to accept a broad unity compressive force. Even though there is a small tensile stress in the concrete, it is assumed that all compressive stresses are supported by the concrete. The compressive strength was determined using a press test and cylindrical specimens with the ASTM C-39 test procedure or cube with the BS-1881 procedure [19]. The strength of a concrete is largely determined by the aggregate and binding matrix strength. Thus, the factor that can be optimized to obtain structure of concrete is the strength of the binding matrix, and is determined by the cement content in the concrete mixture. This research was carried out since rubber tire waste tends to be stronger than other mixtures of a concrete, thus, failure tends to occur on interfaces, while pumice is weaker than concrete, thus a failure is more likely occurs on aggregate. Therefore, it is perceivable that there are differences in the effect of cement mixed with rubber tire waste on normal concrete.

D. *Split Tensile Strength*

According to Nugraha and Antoni [20] tensile strength test is carried out by providing tensile stress on the concrete indirectly. The cylindrical specimens are laid down and pressed so that a tensile stress occurs on the concrete. This test is also called Splitting test or Brazilian test because this method was created in Brazil.

E. *Modulus of elasticity*

Modulus of elasticity or Young's modulus is a measure of the hardness (stiffness) of a material. This modulus in engineering applications is defined as the ratio of the voltage acting on an object to the strain produced. In more detail, this modulus is a limit number for small strains that occur in a material that is proportional to the increase in voltage. And, experimentally, this modulus can be determined from the calculation or measurement of the slope (stress) strain stress curve produced in the test of pressing a sample or specimen. The elasticity of a material is closely related to the stiffness of a material in accepting a load. Modulus of elasticity is a comparison between the pressures given by changes in the form of long unity. The greater the modulus of elasticity is the smaller the occurring deflection. Large modulus of elasticity indicates the ability of concrete to withstand large loads with small strain conditions. For normal concrete, iregularly takes modulus of elasticity between 25 KN / mm^2 to 36 KN / mm^2 [15].

Based on ASTM C 469-02, the modulus of elasticity can be calculated on the basis of below formula [21].

$$E = ((S2 - S1)) / ((2 - 0{,}000050)) \quad (1)$$

With:

E = Modulus of Elasticity (N / mm2)
S1 = Voltage at longitudinal strain 0.00005
S2 = Voltage at 40% of maximum load
2 = Strain on S2

Concrete Elasticity Modulus Tests were carried out using a Press Testing Machine and installed a longitudinal dial gauge [22]. Modulus of elasticity is the value of tension divided by concrete strain, where the stress reaches 40% of the maximum compressive strength. The weight of the concrete content can be viewed from its constituent materials so that the specific gravity of the concrete can be distinguished according to its type. Normal concrete is a material that is relatively quite heavy, with specific gravity ranging from 2.4 or weighing 2400 kg / m^3. Normal concrete is commonly used in building construction.

F. *Specific Gravity*

Based on the statement about the specific gravity of the concrete above, the weight of normal concrete contents ranges from 2.0 to 2.4 as structural concrete.

Content weight testing is done to determine the category or class of concrete that has been made. Content weight is the ratio between the weight of the test object divided by the volume. To find out the weight of concrete contents can be calculated using the following formula:

$$\rho = m / v \quad (2)$$

With:
ρ = concrete content weight (kg / m^3)
m = weight of concrete (kg)
v = concrete volume (m^3)

III. METHODOLOGY

A. *Samples*

The following sample details in Table III.

TABLE III. DETAILS OF CYLINDER TEST ITEMS

Percentage of addition of rubber tire waste	Number of Samples
0	8
5	8
10	8
15	8
20	8
25	8

B. Stages of Research

- First stage

The first stage of this research is preparation and provision of tools and materials.
The materials needed in the research are as follows:

a. Type I cement with the Holcim brand
b. Fine aggregate (sand) from the Klaten area
c. Coarse aggregates (gravel) originating from the Klaten area
d. Waste rubber tires
e. Water

- Second stage

The second stage in this research is the examination and feasibility test of the material to be used in making concrete samples. Material testing to be carried out includes:

1) Testing of fine aggregate moisture content in this research in accordance with SK-SNI 03-1971-2011.
2) Testing the levels of fine aggregate organic matter in this research in accordance with SK-SNI 03-2816-1992.
3) Testing the sludge content in this research based on SNI 4428-1997.
4) Testing of fine aggregate specific gravity in this research based on SK-SNI 1970-2008.
5) Testing of rough aggregate specific gravity in this research based on SK-SNI 1969-2008.
6) Testing of fine aggregate gradations in accordance with SK-SNI 03-1968-1990.
7) Testing of rough agergate gradation in accordance with SK-SNI 03-1968-1990.
8) Coarse aggregate abrasion tests according to SK-SNI 2417-2008.

- Third Stage

The third stage in this research was carried out planning on the composition of the mixture of concrete volumes. After knowing the results of the material test, the next step is the mixed plan stage (mix design) according to the planning method road note No. 4 on normal concrete. Mixture of concrete mixture in the form of adding rubber tire waste as a substitute for coarse aggregate with variations in addition of 0%, 5%, 10%, 15%, 20% and 25% of coarse aggregate volume.

- Fourth Stage

The fourth stage in this research is the making of test materials in accordance with the composition of the mixture of concrete volumes based on the results of the mix design calculations that have been done. Making test specimens using cylindrical molds with a diameter of 150 mm and a height of 300 mm. The stages of making test specimens are as follows:

1) Prepare the mold

Prepare a cylindrical mold with a diameter of 150mm and a height of 300mm. The mold is cleaned first then after the mold is smeared the oil on the surface in the mold so that when the concrete is dismantled it is not attached to the mold.

2) Making concrete mixes

Considering the concrete constituent according to the composition of the mix design calculation. Then the ingredients are mixed one by one and stirred until evenly mixed using molen.

3) Slump testing

Slump test is useful to check for changes in water content, if the material and aggregate gradation are uniform. Slump testing method according to SNI 03-1972-1990 is a cone set on a pedestal that has been cleaned, then fresh concrete is inserted into the cone with a small shovel, about one-third the height of the cone. By using iron rods, the concrete is pounded 25 times until the base. Add the second layer, mash 25 times with the iron bar until it touches the first layer (not the base layer). This is done identical to the third layer. After having the third layer pounding, the top surface of the cone is flattened with iron marks and the excess concrete is cleaned. Next, the ponytail is lifted upward by slowly holding the ear in 5-7 seconds. The value of slump is obtained by measuring the difference in height between the wrinkles and fresh concrete. For example the difference in height is 5 cm, then the slump value of the fresh concrete is 5 cm.

4) Casting

After testing the concrete clearance, casting is done. Casting is done as close as possible to the drop point of the mixture so that segregation does not occur. After the casted concrete in concrete molds must be compacted by sticking with an iron rod to get a good test object.

5) Demolition of the test object

After casting and let stand for + 24 hours then the mold is carefully dismantled so that the mold does not damage the test object and then the test object is marked according to the test number.

- Fifth Stage

The fifth stage in this research is the treatment of specimens. During the maintenance period the humidity must be maintained by immersing it in water up to 28 days. The test object must also be free from interference of either vibration or other disturbances that can damage the quality of the test object.

- Sixth Stage

The sixth stage in this research is the testing phase of compressive strength, split tensile strength, elastic modulus and weight to obtain the data needed in this research.

- Seventh Stage

The seventh stage in this research is the data analysis stage. Data analysis is the process of processing data obtained from the results of testing of test specimens in a laboratory. Testing the data using simple linear regression test along with the prerequisite test testing is the main requirement in making cement. To obtain results that meet established standards. Cement testing is usually carried out in a laboratory where the temperature and humidity of the room are well controlled.

- Eighth Stage

The eighth stage in this research is the stage of drawing conclusions from the research. Taking conclusions is based on data analysis carried out in the previous stage to answer the problems that have been formulated.

IV. RESULT AND THE ANALYSIS

Material inspection is carried out based on predetermined standards, the following standards used in material testing are in Table IV.

TABLE IV. STANDARDS FOR MATERIAL TESTING METHODS

Material	Testing	Code
Sand	Water content	SNI 03-1971-1990
	Levels of organic matter	SNI 03-2816-1992
	Sludge levels	
	Specific gravity and absorption,	SNI 1970-2008
	Aggregate gradation	SNI 03-1968-1990
Gravel	Specific gravity and water absorption	SNI 1969-2008
	Abrasion	SNI 2417-2008
	Aggregate gradation	SNI 03-1968-1990

1) Test results for concrete compressive strength

Compressive strength testing is carried out on concrete that has reached the age of 28 days. Cylindrical concrete compressive strength specimens with a diameter of 150 mm and a height of 300 mm. The number of compressive strength specimens was 18 pieces. The results of the compressive strength test will be presented in Table V.

TABLE V. CONCRETE STRENGTH TEST RESULTS

Code	Percentage of Waste Rubber tire	Compression Strength (MPa)	Mean (MPa)
A0-1	0%	22.63	21.87
A0-2	0%	22.06	
A0-3	0%	20.93	
A5-1	5%	20.65	19.42
A5-2	5%	18.95	
A5-3	5%	18.67	
A10-1	10%	15.84	13.76
A10-2	10%	12.44	
A10-3	10%	13.01	
A15-1	15%	12.16	11.78
A15-2	15%	11.31	
A15-3	15%	11.88	
A20-1	20%	10.75	9.90
A20-2	20%	9.62	
A20-3	20%	9.33	
A25-1	25%	5.09	6.41
A25-2	25%	6.79	
A25-3	25%	7.35	

2) Test Results of Concrete Splice Strength

Testing of split tensile strength is carried out on concrete that has reached the age of 28 days. Cylindrical tensile strength test specimens with a diameter of 150 mm and a height of 300 mm. The number of specimens of split tensile strength were 18 pieces. The results of testing the tensile strength are presented in Table VI.

TABLE VI. TEST RESULTS FOR CONCRETE TENSILE STRENGTH

Code	Percentage of Waste Rubber tire	Tensile Strength (MPa)	Mean (MPa)
B0-1	0%	1.91	1.96
B0-2	0%	1.91	
B0-3	0%	2.05	
B5-1	5%	1.70	1.70
B5-2	5%	1.77	
B5-3	5%	1.63	
B10-1	10%	1.70	1.65
B10-2	10%	1.70	
B10-3	10%	1.56	
B15-1	15%	1.20	1.27
B15-2	15%	1.34	
B15-3	15%	1.27	
B20-1	20%	0.92	1.04
B20-2	20%	1.06	
B20-3	20%	1.13	
B25-1	25%	0.85	0.82
B25-2	25%	0.85	
B25-3	25%	0.78	

3) Modulus Concrete Elasticity Test Results

The modulus of elasticity testing is done on concrete that has reached the age of 28 days. The elastic modulus is cylindrical with a diameter of 150 mm and a height of 300 mm. The number of modulus elasticity test specimens was 18. The results of testing the elastic modulus are presented in Table VII.

TABLE VII. MODULUS CONCRETE ELASTICITY TEST RESULTS

Code	Percentage of Waste Rubber tire	Modulus Elasticity (MPa)	Mean (MPa)
A0-1	0%	27222.22	25006.13
A0-2	0%	22372.04	
A0-3	0%	25424.14	
A5-1	5%	21268.69	24204.73
B5-2	5%	22236.33	
A5-3	5%	29190.18	
A10-1	10%	22123.46	20936.67
A10-2	10%	16010.40	
A10-3	10%	24676.17	
A15-1	15%	17629.63	18324.45
A15-2	15%	21333.34	
A15-3	15%	16010.40	
A20-1	20%	18172.84	16109.90
A20-2	20%	15471.47	
A20-3	20%	14685.40	
A25-1	25%	16592.59	15195.25
A25-2	25%	15363.51	
A25-3	25%	13629.63	

4) The weight of concrete

The weight of concrete content is the weight of fresh concrete contained in the mold or formwork after the concrete mixture is poured. Testing of concrete content was obtained from cylindrical concrete samples with a diameter of 150 mm and a height of 300 mm. The number of samples used was 24. The following will be presented on the results of the weight testing of concrete contents in Table VIII.

TABLE VIII. AVERAGE TEST RESULTS FOR CONCRETE CONTENT WEIGHT

Code	Percentage of Waste Rubber tire	Specific Gravity (kg/m^3)	Mean (kg/m^3)
A0-1	0%	2500.53	2474.64
A0-2	0%	2453.41	
A0-3	0%	2491.15	
A0-4	0%	2453.41	
A5-1	5%	2425.10	2418.02
A5-2	5%	2443.97	
A5-3	5%	2415.66	
A5-4	5%	2387.36	
A10-1	10%	2340.17	2347.25
A10-2	10%	2349.61	
A10-3	10%	2359.05	
A10-4	10%	2340.17	
A15-1	15%	2283.56	2318.94
A15-2	15%	2340.17	
A15-3	15%	2349.61	
A15-4	15%	2302.43	
A20-1	20%	2302.43	2276.48
A20-2	20%	2264.69	
A20-3	20%	2245.81	
A20-4	20%	2292.99	
A25-1	25%	2189.20	2196.27
A25-2	25%	2170.32	
A25-3	25%	2236.38	
A25-4	25%	2189.20	

V. DISCUSSION

A. Compressive Strength

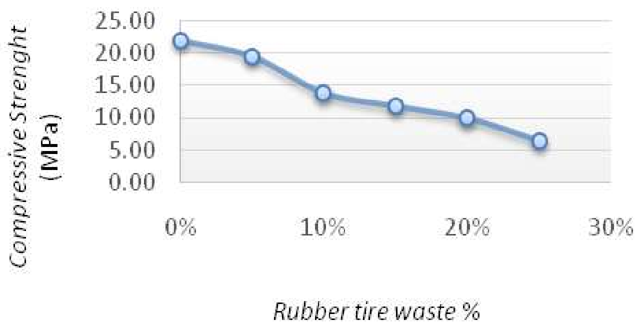

Fig. 1. Compressive Strength Testing Chart

Based on testing the greater variation in rubber tire waste, the compressive strength of the resulting concrete will decrease. In this research using replacement materials in the form of rubber tire pieces that have a smooth surface. The smooth surface properties of rubber tire pieces have an effect on the lack of bonding between rubber tires and cement. The reduction in the bond causes a decrease in the concrete compressive strength. The decrease in compressive strength in concrete by replacing rubber tire waste as coarse aggregate is also caused by the greater volume of rubber tire waste in the concrete mixture resulting in reduced workability of the concrete mixture, thus the concrete compaction is considered not good [3]. The cause of the decrease in the compressive strength of concrete is due to its mild density compared to the fine aggregate and low binding capacity.

The reduction in concrete compressive strength was caused by a lack of attachment between the rubber surface and cement paste and the rubber's flexible properties.

The maximum compressive strength of concrete with the replacement of rubber tire waste as coarse aggregate is found in variations of 5% with compressive strength of 19.42 MPa, Concrete meets structural concrete [23].

B. Split Tensile Strength

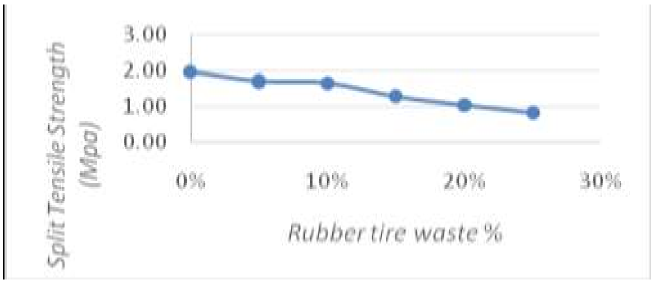

Fig. 2. Split Tensile Strenght Testing Chart

Based on the testing of the greater variation in rubber tire waste, the tensile strength of the resulting concrete decreases. The cause of the decrease in the tensile strength of the concrete is the same as the cause of the concrete compressive strength. The type of rubber tire is lighter than fine aggregate. The smooth surface properties of rubber tire pieces have an effect on the lack of bonding between rubber tires and cement. The reduction in the bond causes a decrease in the concrete compressive strength. The decrease in split tensile strength in concrete by replacing rubber tire waste as coarse aggregate is also caused by the greater volume of rubber tire waste in the concrete mixture resulting in reduced workability of the concrete mixture so that the concrete compaction is not good.

Maximum split tensile strength of concrete with replacement of rubber tire waste as coarse aggregate is found in 5% variation with compressive strength of 1.70 MPa.

C. Modulus of Elasticity

Fig. 3. Modulus of Elasticity Testing Chart

Based on testing the greater variation in rubber tire waste, the modulus of elasticity of the concrete produced decreases.

The smaller the concrete compressive strength, the concrete has a low modulus of elasticity. The smaller the modulus of elasticity, the stiffness of the material will decrease resulting in large deformation when receiving maximum force. Small stiffness results in an increase in concrete ductility itself. So that when you receive the maximum force the concrete will not be destroyed instantly, but will deform for a while until you experience total destruction [24].

D. Weight of contents

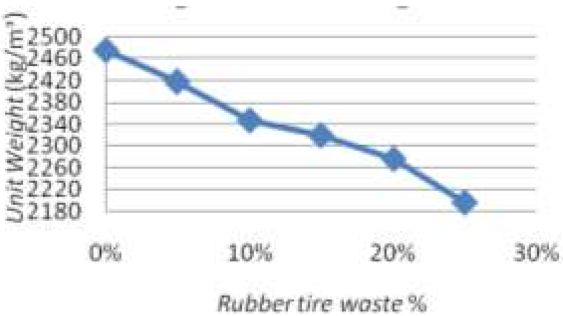

Fig. 4. Weight of Content Testing Chart

Based on the testing of the greater variation in rubber tire waste, the weight of the resulting concrete content decreases. Based on SNI 7656: 2012 [1], the weight of rubber concrete contents with variations of 0%, 5%, 10%, 15%, 20%, and 25% is classified as in the norm concrete which has a weight content of 2200 kg / m3 to 2500 kg / m^3.

VI. CONCLUSION

The optimal value of coarse aggregate replacement with rubber tire waste producing concrete with maximum compressive strength, maximum split tensile strength and maximum modulus of elasticity is found in variations of 5% with compressive strength of 19.42 MPa, split tensile strength of 1.70 MPa, modulus of elasticity of 24204.73 MPa, and the minimum content weight is in the variation of 25% with a weight value of 2196.27 kg/m^3.

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