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Utilization of Plastic Waste in Making Concrete Cylinders

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ABSTRACT : To overcome the problem of plastic waste accumulation in Indonesia, also based on several literature studies, and the results of research conducted by previous experts, this research is to determine how much the compressive strength of concrete cylinders use plastic waste bottles PET and glass HDPE, as material substitute for sand.
This research used 2 (two) types of plastics, namely : (a) plastic type A (PET) and ; (b) plastic type B (HDPE), made concrete cylinders measuring 10 cm in diameter x 20 cm high.
At the age of 14 days, the test results of compressive strength of concrete cylinder code A use PET type plastic compared with code B use HDPE type plastic : A1 > B1 ; A2 < B2 ; A3 < B3 ; A4 < B4.
At the age of 28 days, the test results of compressive strength of concrete cylinder code A use PET type plastic compared with code B use HDPE type plastic : A1 < B1 ; A2 > B2 ; A3 < B3 ; A4 < B4.
Cylinder type A use PET type plastic, and cylinder type B use HDPE type plastic, both at the age of 14 days and 28 days, all the same, have type drawing sketch /shape of destruction on the specimen according to type 4 = the form of shear destruction, according to SNI 1974 : 2011.[1]

KEYWORDS – plastic, waste, cylinder.

I. INTRODUCTION

In a study the Sustainable Waste Indonesia (SWI), of 100 % plastic waste produced, 69 % of it goes to landfills and only 7 % was recycled. As for 24 % polluting the environment.[2] Plastic waste that is thrown away is very diverse, ranging from everyday household goods to straws.[2] According to researcher from the University of Georgia, Dr. Jenna Jambeck, published in the journal Science on February 12, 2015, "Indonesia disposes of plastic waste as much as 3.2 million tons, and is in second place as a country that contributes plastic waste to the sea after China".[2] PET bottles can be used to build stronger and more flexible concrete structures, from sidewalks and roadblocks, to buildings and bridges, according to a new study.[3]

"There is a large amount of plastic that is stockpiled every year," said Michael Short, an assistant professor in MIT Department Nuclear Science and Engineering. "Our technology removes plastic from landfills, locks it in with concrete, and also uses less cement to make concrete, which makes less carbon dioxide emissions. This potentially pull plastic waste in landfill out of landfills becomes buildings, where exactly can help make them stronger".[3] To overcome the problem of plastic waste accumulation in Indonesia, also based on several literature studies, and the results of research conducted by previous experts, this research is to find out how much compressive strength of concrete cylinders use plastic waste PET bottles and glass HDPE, as material substitute for fine aggregate (sand).

II. LITERATURE STUDY

The results of research that have been done, use plastic waste, among them: Bagus Soebandono, As'At Pujianto, Danar Kurniawan, "Behavior of Compressive and Tensile Strength of Concrete of Mixture of HDPE Plastic Waste" : Research use HDPE plastic waste, passed sieve 19 mm and restrained sieve 4.75 mm as substitute for coarse aggregate from Yu Ping Plastics, Surakarta.[4] Concrete compressive strength value decreases along with content addition HDPE plastic waste. Average compressive strength for variation mixture of coarse aggregate of HDPE plastic waste 0 % (normal), 10 %, 15 %, and 20 %, in row equal to : 27.88 MPa ; 15.67 MPa ; 14.96 MPa ; 11.08 MPa.[4] Concrete tensile strength value decreases along with content addition HDPE plastic waste. Average tensile strength for variation mixture of coarse aggregate of HDPE plastic waste 0 % (normal), 10 %, 15 %, and 20 %, in row equal to : 2.71 MPa ; 2.34 MPa ; 2.01 MPa ; 1.72 MPa.[4]

Dantje AT Sina, Made Udiana, Bernad D Da Costa, "The Effect of Addition of Chopped Plastic Waste of High Density Polyethylene (HDPE) type at Concrete Flexural Strength" : Testing flexural strength at normal concrete blocks with 0 % plastic chopped concentrage obtained average flexural strength value of 4.12 MPa.[5]

Testing the flexural strength of concrete blocks with plastic chopped concentrage of 0.50 % obtained an average flexural strength value of 4.33 MPa, the flexural strength value of concrete blocks with plastic chopped concentrage of 0.5 % increases the flexural strength of concrete by 5.08 % of normal concrete flexural strength.[5]

Testing the flexural strength of concrete blocks with plastic chopped concentrage of 0.70 % obtained an average flexural strength value of 4.21 MPa, the flexural strength value of concrete blocks with plastic chopped concentrage of 0.7 % increases the flexural strength of concrete by 2.19 % of normal concrete flexural strength.[5]

Testing the flexural strength of concrete blocks with plastic chopped concentrage of 0.90 % obtained an average flexural strength value of 3.97 MPa, the flexural strength value of concrete blocks with plastic chopped concentrage of 0.9 % reduces the flexural strength of concrete by 3.64 % of normal concrete flexural strength.[5]

The use of HDPE type plastic bottle waste in concrete with chopped percentage of 0.50 % of the cement weight has been able to reduce the pollution of plastic waste all this time. Concrete with a quality of 25 MPa with a volume of 1 m^3 reduces plastic waste.[5]

Dwiki Pratama Putra, Sigit Tri Wicaksono, Amaliya Rasyida, Ridho Bayuaji, "Study Effect Addition of Binder Thermoplastic LDPE and PET to Mechanical Properties of Particulate Composites for Applications of Building Material" : The addition of binder thermoplastic in the form of LDPE and PET from plastic waste processing results affects mechanical and physical properties of composite materials. The addition of binder thermoplastic tends to improve mechanical and physical properties of composite materials. Composite material that has been made using binder thermoplastic in the form of LDPE and PET from plastic waste processing results meet the criteria for building materials for structural lightweight concrete applications and category C paving block for pedestrian applications and D for garden courtyard applications.[6]

Isnawati, "The Effect of Addition of Plastic Waste Aggregates to The Compressive Strength of Concrete" : The research was conducted in the concrete laboratory of PT. Cement Bosowa Maros use PET type (Polythelene Terephelate) plastic waste aggregate with test parameter concrete compressive strength. This research aims to determine the effect of adding plastic waste aggregate to the compressive strength of concrete where the mass of plastic waste is 10 x 10^{-3} kg, 20 x 10^{-3} kg, 30 x 10^{-3} kg, 40 x 10^{-3} kg, and 50 x 10^{-3} kg. The concrete samples have same volume size that is 5,298.75 cm^3. Tests and measurements of each sample were tested at the age of 3 days, 7 days and 28 days, that is parameter compressive strength. Research results obtained that the effect of adding plastic waste aggregate to its compressive strength is more plastic waste aggregate mixed in cement composition, the compressive strength is not strong enough. Where immersion period to compressive strength of concrete that is the longer the immersion period then the concrete compressive strength is getting better.[7]

Indah Handayasari, Gita Puspa Artiani, Desi Putri, "Environmentally Friendly Construction Materials by Utilization Plastic Bottle Waste of Mineral Water Packaging and Green Clamshell Waste as Paving Block Mixtures" : Use substitution material 10 % plastic bottle waste + 10 % green clamshell waste by comparison mixture 1 (cement) : 4 (sand), can increase compressive strength value at the age of 28 days, i.e 12.8 MPa which is included in quality C, the requirements are according to SNI 03-0691-1996, which one compressive strength value at quality C used for pedestrians. The compressive strength value is higher than the compressive strength value of normal paving block 7.8 MPa.[8]

The use of plastic bottle waste and clamshell waste that more and more can reduce the value of water absorption. At the age of 49 days the largest at normal paving block is 2.36 % and the smallest at the age of 49 days there is at the variation of paving block of 20 % plastic bottle waste + 20 % clamshell waste i.e 1.45 %. The percentage is included in quality A, these requirements are in accordance with SNI 03-0691-1996 where the percentage of water absorption at quality A is 3 % on average used for roads.[8]

The utilization of plastic bottle waste and clamshell waste in paving block mixture with optimum mixture variation is 10 % plastic bottle waste + 10 % clamshell waste with compressive strength value 12.8 MPa and percentage of water absorption 1.94 %.[8]

Based on the research results, the utilization of plastic bottle waste and green clamshell waste as substitute for sand and cement in paving block mixture give good results, this is showed by the increase of compressive strength value of normal paving blocks so that it can be used as one of alternative construction materials that friendly environmently.[8]

Indah Handayasari, "Alternative Study of Environmentally Friendly Construction Materials with the Utilization of Plastic Waste of Mineral Water Packaging at Concrete Mixtures" : Based on the results of calculation it was found that the highest compressive strength value was found in concrete at the age of 28 days, i.e 22.741 MPa for concrete mixture with 5 % chopped plastic waste of mineral water packaging. The compressive strength value with mixed variation 5 % chopped plastic waste of mineral water packaging is included in K-225 quality concrete requirements, where the compressive strength of required concrete (f'c) at the age of 28 days is 22.5 MPa.[9]

Based on the test results of flexural /tensile strength showed that the highest value was concrete with variation of chopped plastic waste of mineral water packaging by 5 % at the age of 28 days that is 2.666 MPa.[9]

Based on the two tests both the compressive strength test and the flexural /tensile strength test showed that variation 5 % chopped plastic waste of mineral water packaging as substitute a portion of fine aggregate at concrete mixture can give better results compared to conventional concrete.[9]

Juhana Said (1), Sungkono (2), "Processing of Plastic Waste and Water Hyacinth Plants into Alternative Building Materials that Energy-Saving" : This research use inorganic waste (plastic waste), that is used items such as tapes, VCDs, cosmetic containers, jars, etc., sourced from garbage dump, with the help of scavengers.[10]

Wall material from plastic waste is an alternative wall material that energy-saving that has high responsibility to thermal environment so it can be used as outdoor or indoor material.[10]

The material produced has interesting color variations so this material can be used as insulating material between spaces in buildings and as building outer without going through the process of painting again.[10]

This wall material from plastic waste is an alternative building material that has a very high level of strength and ductility so it is very well used as wall material, door, it can even be used as flooring and ceiling materials.[10]

Sari Utama Dewi, Rudi Purnomo, "The Effect of Additional HDPE (High Density Polyethylene) Plastic Waste on Concrete Compressive Strength on K-125 Quality": In this research the addition of plastic waste with high percentage precisely damages the properties of concrete, especially on the compressive strength produced.[11]

Based on this research, percentage additional plastic waste recommended is maximum 5 %. The maximum compressive strength that can be achieved from all mix compositions used there is at addition of plastic waste by 5 % at the age of 14 days with a compressive strength value of 10.06 MPa, from the yield value below the plan compressive strength, i.e 10.4 MPa. The plan compressive strength was not achieved due to several factors : (a) Coarse aggregate that was used did not meet the requirements or standard SK.SNI T-15-1990-03, namely at sieve analysis test. Many aggregates are too much held only in one sieve. This indicates that the aggregate used has relatively the same grain gradation. (b) The process of compacting concrete mix is done manually using vibrator manual, so that the level of density will not be reached to the maximum. (c) Compacting concrete mix that is not maximal and the uneven shape of the concrete on the top of the concrete will affect the results of concrete compressive strength test later. In order to achieve the maximum density of the concrete mixture, the compaction should be done with shaking table. (d) Uneven concrete samples in the shape pattern that is at the top of the concrete sample cause when testing concrete the distribution of load delivered to the concrete sample is uneven so the compressive strength produced is not maximal. All variations of the concrete mixture use fixed FAS that is 0.57.[11]

PETE /PET (Polyethylene Terephthalate) : Usually, at the bottom of plastic bottle packaging, there is a recycled logo with the number 1 in the middle and the words PETE or PET under the triangle. Usually used for clear /transparent /translucent plastic bottles such as mineral water bottles, juice bottles, and almost all other drinking bottles.[12]

The majority of PET plastic materials in the world are for synthetic fibers (about 60 %), in textiles PET commonly called with polyester (the base material for packaging bottles of 30 %). This PET /PETE type bottle is recommended only for single use because if it is used too often, especially if it is used to store warm or hot water, it will cause the polymer coating on the bottle will melt and release carcinogenic substances (can cause cancer).[12]

In general PET is a type that is safe for humans, the main problem lies in antimony.[13]

It is a metalloid element that contains toxins which at any time can leak from PET when it reaches a certain temperatures.[13]

According to Central Disease Center United States (CDC), antimony can cause chronic and acute diseases such as diarrhea, vomiting, and stomach ulcers.[13]

HDPE (High Density Polyethylene) : Generally, at the bottom of plastic bottle packaging, there is a recycled logo with the number 2 in the middle, and HDPE inscription under the triangle. Usually used for milk bottles that the colour white milk, gallons of drinking water, detergents, oil bottles, Tupperware, cosmetics, and others. HDPE is one of the plastic materials that is safe for use because of its ability to prevent chemical reactions between plastic packaging HDPE material with food /drink it packs.[12]

HDPE have material properties that are stronger, harder, opaque, more resistant to high temperatures, are most often recycled, and are considered one of the safest plastics to use. Same like PET, HDPE is also recommended only for one time using, because the release of antimony trioxide compounds continues to increase over time.[12] In 2011, a research stated that HDPE plastic products were the products most emit estrogenic chemical compounds.[13]

Chemicals that have active estrogenics (EA) are thought can cause health problems especially in fetuses and children.[13]

EA exposure can change the structure of human cells.[13]

EA exposure can occur when plastics are exposed to boiling water, sunlight (UV), and microwave heating.[13]

III. RESEARCH METHODOLOGY

This research use 2 (two) types of plastic, that is :

- Plastic type A (PET) : shampoo bottles, detergent bottles, oil bottles, and similar bottles, excluding drinking water bottles.
- Plastic type B (HDPE) : drinking water glass.

The plastics are chopped up to ± 5 mm in size, then washed thoroughly.

Mixture composition such as in table 1 :

Table 1. Mixture proportion of plastic and sand

Number of Specimen	Plastic Type	Plastic Percentage from Sand (%)	Plastic (kg)	Sand (kg)
N	-	0	0	8.4
A1	PET	5	0.42	7.98
A2	PET	10	0.84	7.56

Number of Specimen	Plastic Type	Plastic Percentage from Sand (%)	Plastic (kg)	Sand (kg)
A3	PET	15	1.26	7.14
A4	PET	20	1.68	6.72
B1	HDPE	5	0.42	7.98
B2	HDPE	10	0.84	7.56
B3	HDPE	15	1.26	7.14
B4	HDPE	20	1.68	6.72

N = normal /without use a mixture of PET or HDPE plastic.

The casting of mixed cylinders A were carried out on July 10, 2019, slump value was 12.3. The casting of mixed cylinders B were carried out on July 15, 2019, slump value was 17.67. The casting of mixed cylinders N were carried out on July 17, 2019, slump value was 18. The slump test refers to SNI 1972-2008.[14]

The mixture of A, B and N, were made concrete cylinders measuring diameter 10 cm x high 20 cm.

The compressive strength test of mixed concrete cylinders A, B, and N were carried out at the age of 14 days and 28 days, each three times repetition.

Calculation of concrete cylinder compressive strength test (Appendix D, SNI 1974: 2011).[1]

IV. LABORATORY TEST RESULTS

Fine aggregate /sand used is sand from Cibeureum Village, Sumedang, West Java, analyzed physically as in table 2. The results of filter analysis are included in zone 2.

Tabel 2. Physical Analysis of Sand

No	Type of Testing	Sand	Requirements
1	Water content, ……. %	2.30	SNI 03-1971-1990
2	Sludge levels, ……. %	1.10	
3	Absorption, ……. %	3.68	SNI 03-1970
4	Specific gravity, …….. gr/cc	2.55	SNI 03-1970
5	- Loose weight, ……... kg/ltr - Solid weight, ……... kg/ltr	1,524 1,704	SNI 03-4804-1998
6	Organic, ……..…. +/-	Positive	
7	Zone	2	SNI 03-2834-1992
8	Modulus of fineness	3.78	(requirements 1.5 – 3.8)
9	Hardness sand through sieve 0,3 mm	1.15	
10	Testing solidity properties of aggregate : Percentage weight part of test specimen that missing (%)	16.1	
11	Sieve analysis, cumulative : 19.2 mm, ……..…. % 9.6 mm, ……. % 4.8 mm, ……. % 2.4 mm, ……. % 1.2 mm, ……. % 0.6 mm, ……. % 0.3 mm, ……. % 0.15 mm, …….. % 0.0 mm, ……. %	 100.00 86.42 73.81 59.54 45.86 29.52 26.88 0	SNI 03-1968-1990

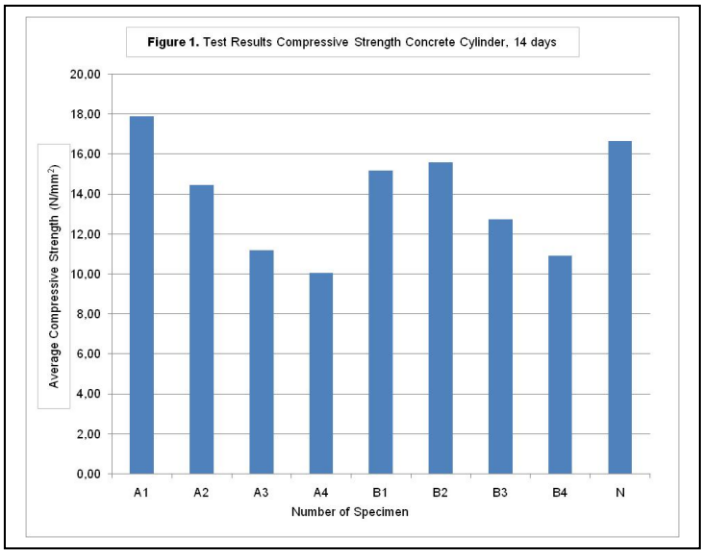
Coarse aggregate use split from Bandung, analyzed physically as in table 3.

Table 3. Physical Analysis of Split

No	Type of Testing	Split	Requirements
1	Water content, …….. %	1.84	
2	Sludge levels, ……. %	0.07	
3	Absorption, …….. %	1.23	
4	Specific gravity, …..…. gr/cc	2.75	
5	- Loose weight, ……. kg/ltr - Solid weight, ……..…. kg/ltr	1,259 1,456	
6	Modulus of fineness	1.46	
7	Sieve analysis, cumulative : 38 mm (1 1/2”), ……. % 19.2 mm (3/4”), ……. % 12.7 mm (1/2”), ……. % 9.6 mm (3/8”), ……..…. % 4 mm, ……. % 8 mm, ……. %	 100.00 100.00 94.27 51.7 8.19 0	

V. DISCUSSION

The test results of concrete cylinder compressive strength at the age of 14 days, such as at figure 1 :



Number of Specimen	A1	A2	A3	A4	B1	B2	B3	B4	N
Average Compressive Strength, 14 days	17.89	14.47	11.19	10.05	15.18	15.61	12.75	10.92	16.66

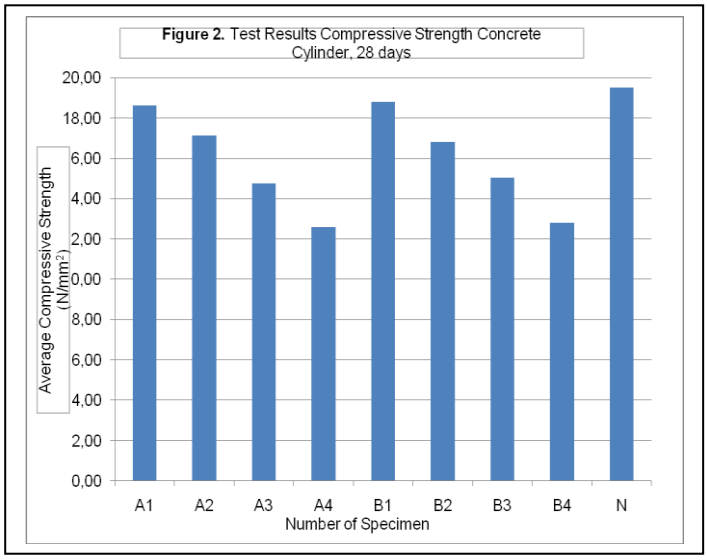
The test results of concrete cylinder compressive strength at the age of 14 days known that the highest compressive strength occurs at code A1 = 17.89 N/mm^2. Using PET type plastic /bottle as much as 5 %. The more use plastic at the sand / concrete mixture, the less compressive strength the concrete cylinder is produced. The compressive strength of concrete cylinders A1 is higher than the compressive strength of normal concrete cylinders without use plastic.

The test results of concrete cylinder compressive strength at the age of 14 days, the highest compressive strength occurs at code B2 = 15.61 N/mm^2. Using HDPE type plastic /glass as much as 10 %. Code B1 use 5 % plastic to produce less compressive strength. Besides that, the less compressive strength the concrete

cylinder is produced, by adding plastic more than 10 %. The highest compressive strength of concrete cylinder B2 is lower than the compressive strength of normal concrete cylinders without use plastic.

It is possible that in code B2 obtained amount optimal plastic that can be mixed, so obtained maximal bonding between plastic and sand and concrete, so obtained the compressive strength is higher than code B1.

The test results of concrete cylinder compressive strength at the age of 28 days, such as at figure 2 :



Number of Specimen	A1	A2	A3	A4	B1	B2	B3	B4	N
Average Compressive Strength, 28 days	18.61	17.12	14.74	12.59	18.81	16.80	15.03	12.81	19.51

The test results of concrete cylinder compressive strength at the age of 28 days, the highest compressive strength occurs at code A1 = 18.61 N/mm^2. Using PET type plastic /bottle as much as 5 %. The more use plastic in the sand /concrete mixture, the less compressive strength the concrete cylinder will produce. The compressive strength of concrete cylinder A1 is lower than the compressive strength of normal concrete cylinders without use plastic.

The test results of concrete cylinder compressive strength at the age of 28 days, the highest compressive strength occurs at code B1 = 18.81 N/mm^2. Using HDPE type plastic /glass as much as 5 %. The more use plastic in the sand /concrete mixture, the less compressive strength the concrete cylinder will produce. The compressive strength of concrete cylinder B1 is lower than the compressive strength of normal concrete cylinders without use plastic.

Fig 3. Cylinders type A at the age of 14 days have drawing sketch of type /shape of destruction on the specimen according to type 4 = shear destruction shape (SNI 1974:2011).[1]

Fig 4. Cylinders type A at the age of 28 days have drawing sketch of type /shape of destruction on the specimen according to type 4 = shear destruction shape (SNI 1974:2011).[1]

Fig 5. Cylinders type B at the age of 14 days have drawing sketch of type /shape of destruction on the specimen according to type 4 = shear destruction shape (SNI 1974:2011).[1]

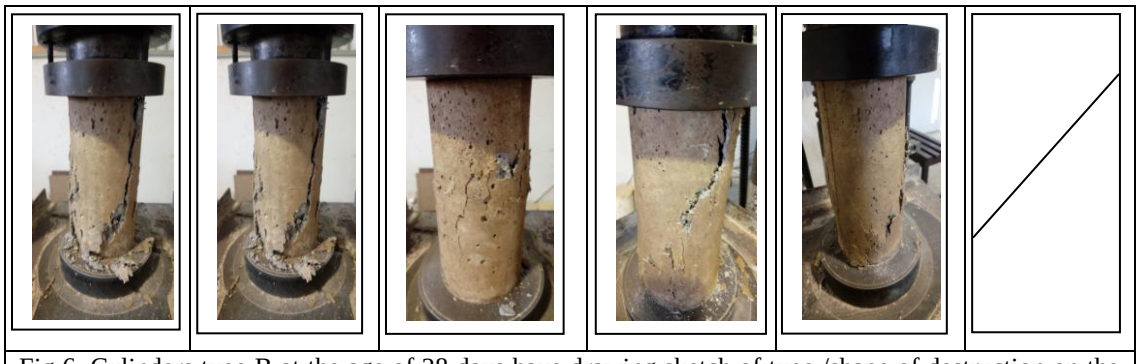


Fig 6. Cylinders type B at the age of 28 days have drawing sketch of type /shape of destruction on the specimen according to type 4 = shear destruction shape (SNI 1974:2011).[1]

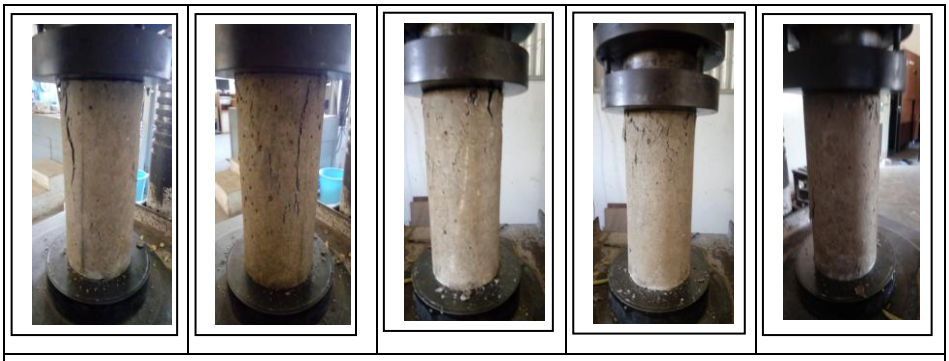


Fig 7. Cylinders type N /normal /without use bottle plastic /glass at the age of 14 days do not have drawing sketch of type /shape of destruction on the specimen according to SNI 1974:2011.[1] Only in the form of hair cracks /small cracks that do not have special pattern /irregular.

Fig 8. Cylinders type N /normal /without use bottle plastic /glass at the age of 28 days do not have drawing sketch of type /shape of destruction on the specimen according to SNI 1974:2011.[1] Cracks /breaks that occur do not have special pattern /irregular.

VI. CONCLUSION

1. Mixture A use PET type plastic, and mixture B use HDPE type plastic, both at the age of 14 days and 28 days, plastic based on its properties that solid and massive, less able to bond with concrete mixture, so that more added plastic at sand /concrete , as less as compressive strength of the concrete cylinder produced. Need to add additives to be able to bind and strengthen the bond between plastic and sand /concrete.

2. At the age of 14 days, the compressive strength test results of concrete cylinder code A using PET type plastic /bottle compared to code B using HDPE type plastic /glass : A1 > B1 ; A2 < B2 ; A3 < B3 ; A4 < B4. Only by using mixture composition 5 % PET plastic, the compressive strength exceeds mixture composition 5 % HDPE plastic. At the composition of mixture of 10 %, 15 % and 20 % PET plastic have less compressive strength than HDPE plastic mixture.

3. At the age of 28 days, the compressive strength test results of concrete cylinder code A using PET type plastic /bottle compared to code B using HDPE type plastic /glass : A1 < B1 ; A2 > B2 ; A3 < B3 ; A4 < B4. Only by using mixture composition 10 % PET plastic, the compressive strength exceeds mixture composition 10 % HDPE plastic. At the composition of mixture of 5 %, 15 % and 20 % PET plastic hve less compressive strength than HDPE plastic mixture.

4. Cylinders type A use PET type plastic, and cylinders type B use HDPE type plastic, both at the age of 14 days and 28 days, the whole is the same, have drawing sketch of type /shape of destruction on the specimen according to type 4 = shear destruction shape, according to SNI 1974:2011.[1]

5. Cylinders type N /normal /without use plastic bottles /glasses, both at the age of 14 days and 28 days, do not have drawing sketch of type /shape of destruction on the specimen according to SNI 1974:2011. Cracks /breaks that occur do not have special pattern /irregular.

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