Effect of Artificial Aggregate on Mechanical Properties of Concrete

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ABSTRACT:*The need for natural aggregates is increasing along with the use of concrete in construction work. This has an impact on the exploitation of natural aggregates to become out of control and damage the environment. Artificial aggregates are an alternative to replace the use of natural aggregates. This research focuses on the use of artificial aggregates in the form of round, broken and a combination of both on the mechanical properties of concrete. Tests were carried out on compressive, tensile and flexural strength. The results of this study indicate that artificial aggregates can replace natural aggregates. The best composition in the form of a mixture of spherical and broken aggregates by 50% produced a compressive strength of 93%, 100% tensile strength and 122% flexural strength of the control concrete.*

KEYWORDS-*concrete, natural aggregate, artificial aggregate, mechanical properties*

I. INTRODUCTION

The need for concrete is increasing along with the increasing construction of buildings, infrastructure and bridges. The implication is the exploration of natural resources which can damage the environment because the content of sand and gravel in the volume of concrete is around 80% [1-2]. To reduce the use of natural materials, researchers are researching replacing coarse aggregate with artificial aggregate or with industrial waste materials [3-7]. One of the potentials to replace coarse aggregate is aggregate derived from coral waste which is quite a lot [8,9].

Some researchers state that the shape and texture of the aggregate are the determining factors in increasing the mechanical properties of the concrete mixture [10 -13]. The coarse aggregate shape affects increasing the mechanical properties of concrete compared to a round shape. Crushed aggregate increases by about 26% compressive strength, 46% flexural strength and 38% tensile strength [14-16]. Meanwhile, other researchers stated that crushed aggregates reduce the mechanical properties of concrete because the water absorption in broken aggregates is greater than in round aggregates [17]. In addition, aggregate angularity is also one of the main factors affecting workability [18, 19].

This study analyzed the mechanical properties (compressive, tensile and flexural strength) of artificial aggregates in an attempt to replace natural aggregates.

II. MATERIALS AND METHODS

2.1 Materials

The material used is an artificial stone from Kupang beach, East Nusa Tenggara, cement type I according to ASTM C 150-04 [20], coarse aggregate and fine aggregate used are from PT Adhimix. Curing (water immersion) is carried out by ASTM C192 [21]. Figure 1 shows (a) crushed artificial aggregate, (b) round artificial aggregate, and (c) natural aggregate. The proportion of the test objects is shown in Table 1.

(a) (b) (c)

Figure 1. (a) crushed artificial aggregate, (b) round artificial aggregate, (c) natural aggregate

The test object code, BK is to control concrete with the proportions namely cement, natural aggregate, and fine aggregate. Round artificial aggregate BB. BP artificial aggregate broke. BM is a mixture of round artificial aggregate and crushed artificial aggregate. BKB spherical aggregate control test object. BKP artificial aggregate control test object broken. BKM specimens with a mixture of natural aggregate, and round and broken artificial aggregate.

Table 1. Mix Design in 1m3

Code	Cement	Coarse Aggregate			Fine Aggregate	Water
		Natural aggregate	Artificial aggregate			
			Round	Broken		
BK	429.8	1158.7			680.8	150.9
BB	429.8		1158.7		680.8	150.9
BP	429.8			1158.7	680.8	150.9
BM	429.8		579.4	579.4	680.8	150.9
BKB	429.8	579.4	579.4		680.8	150.9
BKP	429.8	579.4		579.4	680.8	150.9
BKM	429.8	579.4	289.7	289.7	680.8	150.9

2.2 Methods

Make specimens according to the mix design as shown in Table 1. Then perform compressive, tensile and flexural strength tests at 7, 28 and 56 days of age. Compressive and tensile strength testing using a cylindrical test object measuring 100 x 200 mm according to ASTM C39 [22]. The tensile strength test uses the ASTM C496 standard [23]. Then p.stest the flexural strength of concrete beams according to standards(ASTM C78-94)[24].

(a) (b) (c) (d)

Figure 2. (a) Test object, (b) Compressive strength test, (c) Tensile test, (d) Flexure test

III. RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength results can be seen in Figure 3, BK aged 7 days compressive strength of 27 MPa and aged 28 33 MPa. At 7 days BP, the compressive strength was 18 MPa and 24 MPa at 28 days. BB at 7 days of compressive strength was 15 MPa and 18 MPa at 28 days. This proves that the shape of crushed stone aggregate has a higher compressive strength value compared to round-shaped aggregate according to previous researchers [25]. This is due to crushed aggregate having a rough surface, and relatively smaller cavities so that it has good adhesion between aggregates [26].

Then the compressive strength BM was 23 MPa at 7 days and 31 MPa at 28 days. BKB at the age of 7 days compressive strength of 23 MPa and 24 MPa at the age of 28 days. BKP aged 7 days had a compressive strength of 15 MPa and 19 MPa at 28 days of age. BKM at the age of 7 days was 18 MPa and at 28 days it became 23 MPa. Based on the results of mixing artificial and natural aggregates both round, broken and round broken mixture, the achievement of compressive strength is around 73% of the control concrete. The highest compressive strength in the use of mixed artificial aggregate (BM) reached 93% of the control concrete (BK).

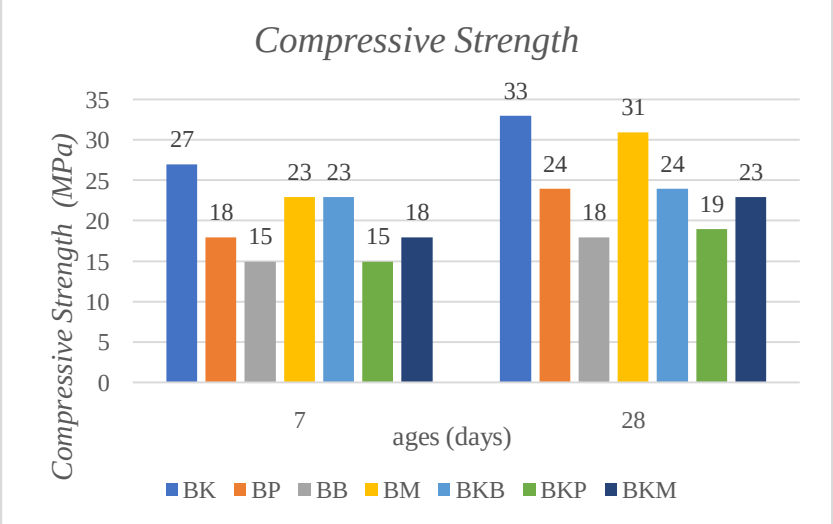

Figure 3. Compressive strength

3.2 Tensile Strength

The tensile strength results (Figure 4) show that the BK and BP samples yielded tensile strength at 7 days and 28 days of 11 MPa and 10 MPa respectively. Meanwhile, for the BB sample, it was 8 MPa. This proves that the concrete tensile strength of the BP sample (Broken Artificial Aggregate) is higher than that of the BB sample (Round Artificial Aggregate). This is because the crushed coarse aggregate has a higher tensile

strength than the round-shaped coarse aggregate. Crushed stone has a more diverse shape so it will have a high density, while the strength of round aggregate is relatively low [27,28].

Then the BM and BKB samples had the same value and increase, at 7 days of the age of 10 MPa and 28 days of 11 MPa. For the BKP and BKM samples, they have the same value at 7 days of the age of 8 MPa and 10 MPa at 28 days of age. The highest tensile strength results in BM and BKB reaching 100% of the control concrete (BK)

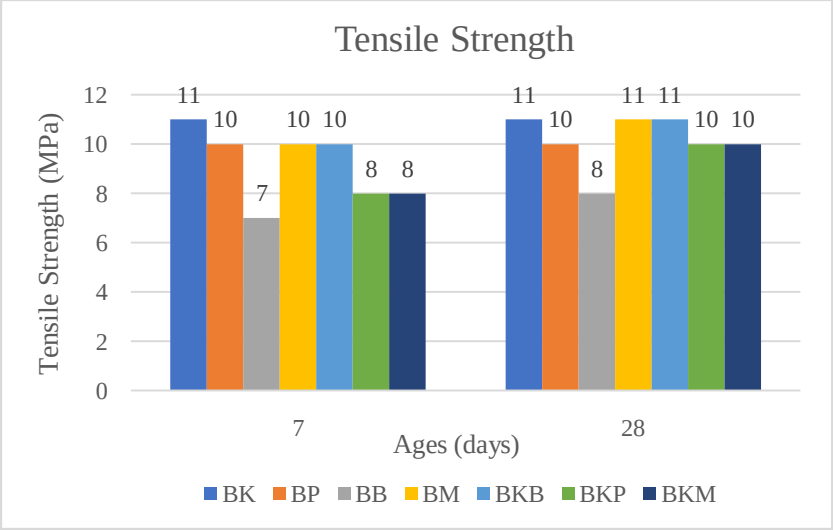

Figure 4. Tensile strength

3.3 Flexural Strength

Figure 5 shows the results of flexural strength, for the BP sample at 28 days of age it was 5.4 MPa and for the BB sample at 28 days of age, it was 4.5 MPa. It can be seen that the flexural strength of crushed aggregate is higher than that of the round aggregate because the crushed stone has an adhesive surface and adheres to the concrete paste [29,30].

The BM sample at the age of 7 days was 4.4 MPa and at the age of 28 days, it was 6.0 MPa. The BKB sample at the age of 7 days was 4.0 MPa and at the age of 28 days was 4.5 MPa. The BKP at 7 days old was 3.6 MPa and at 28 days old it was 5.0 MPa. BKM at 7 days of age was 4.7 MPa and at 28 days of age was 5.4 MPa. The highest yield of flexural strength in BM is 6.0 MPa and reaches 122% of the control concrete (BK)

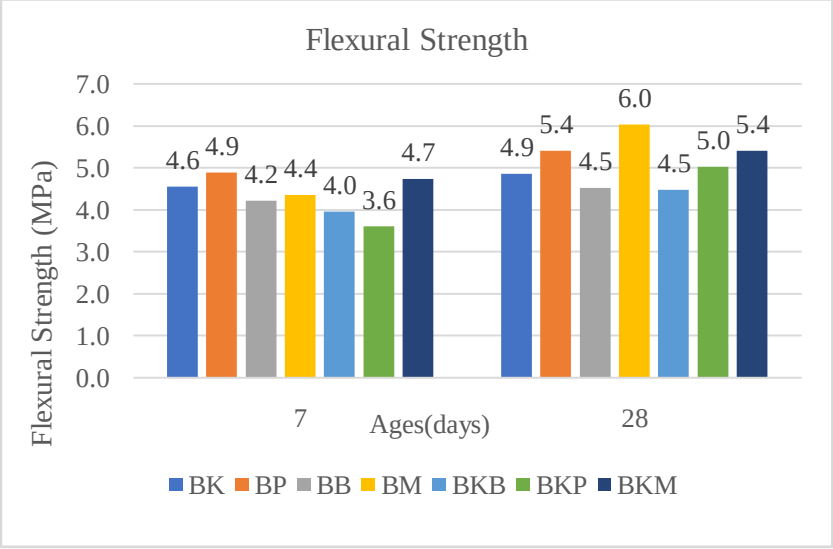

Figure 5. Flexural strength

IV. CONCLUSION

Round and broken artificial aggregates can be used as a substitute for natural aggregates, with the achievement of compressive strength reaching 93%, 100% tensile strength, and 122% flexural strength of control concrete (BK). A mixture of round and broken artificial aggregates with a percentage of 50% each is the best composition to replace natural aggregates.

REFERENCES

[1] Schneider, M.; Romer, M.; Tschudin, M.; Bolio, H. Sustainable cement production—Present and future. Cem. Concr. Res. 2011, 41, 642–650. [CrossRef
[2] Collivignarelli, MC; Cillari, G.; Ricciardi, P.; Minino, MC; Torretta, V.; Rada, EC; Abbà, A. The Production of Sustainable Concrete with the Use of Alternative Aggregates: A Review. Sustainability 2020, 12, 7903. [CrossRef]
[3] ACI 318-08. Building Code Requirements for Structural Concrete 318, American Concrete Institute.https://doi.org/10.1016/02625075(85)90032-6
[4] B. Alhayani and A. Abdallah, Manufacturing intelligent Corvus coronae module for a secured two-way image transmission under WSN. Engineering Computations Vol. 38 (2021). https://doi.org/https://doi.org/10.1108/EC-02-2020-0107
[5] L. Peng and S. Qin, Mechanical behaviour and microstructure of an artificial stone slab prepared using a SiO2 waste crucible and quartz sand. Construction and Building Materials, 171, 273–280 (2018). https://doi.org/10.1016/j.conbuildmat.2018.03.141
[6] Irka Tangke Datu, Adiwijaya Ali, Nur Aisyah Jalali and Khairil, Influence of Curing Conditions on Strength Characteristics of Sea Sand Mortar. INTEK: Research Journal, 7(2), 160 (2021). https://doi.org/10.31963/intek.v7i2.2720
[7] Chaofeng Liang, Bihao Pan, Zhiming Ma, Zhihai He dan Zhenhua Duan, Utilization of CO2 curing to enhance the properties of recycled aggregate and prepared concrete: A review. Cement and Concrete Composites, 105, 103446 (2020) https://doi.org/10.1016/j.cemconcomp.2019.103446
[8] Muhammad Humaidi and Khairil Yunuar, Alternative Use of Coral Stone For Concrete With Compressive Strength fc' 30 MPa. Intekna, Vol 14, No 1 (2014). http://ejurnal.poliban.ac.id/index.php/intekna/article/view/155
[9] Herry Yulianto and Sylvianan Dewi Sulaksono, Study of Compressive Strength of Lightweight Concrete Using Corals, Beach Sand, and Polymer Concrete Materials (Polcon). G-Smart, 4(2), 82 (2021). https://doi.org/10.24167/gsmart.v4i2.2282
[10] K Miskovsky, M Taborda Duarte, SQ Kou, PA Lindqvist, Effect of Mineralogy Composition and Texture Properties on Coarse Aggregate Quality. Journal of Materials and Performance Engineering, 144:150-13 (2004).
[11] Dong Zhang, Xiaoming Huang and Yongli Zhao, Investigation of Shape, Size, Angularity and Surface Texture Properties of Coarse Aggregate. Constr Build Mater, 330:336 34 (2012). doi:10.1016/j.conbuildmat.2012.02.096
[12] Zhiquan Zhang, Yufen Zhang, Changgen Yan dan Yunxiao Liu, Influence of crushing index on properties of recycled aggregates pervious concrete. Construction and Building Materials, 112:118–135 (2017). https://doi.org/10.1016/j.conbuildmat.2016.12.203
[13] Chen WF. (1995). Civil Engineering Handbook (CRC Press).
[14] Hachani, Mohamed Ibrahim Hachani, Abdelouahed kriker dan Mehdi Seghiri, Experimental Study and Comparison Between The Use of Natural and Artificial Coarse Aggregate in Concrete Mixture. Energy Procedia, 119, 182–191 (2017). https://doi.org/10.1016/j.egypro.2017.07.067
[15] UluçaylsayaM. (1997). New Development For Asphalt Mix Design Gyratory Shear Press. Yollar Türk Milli Committee.
[16] Rifath Sharmin, Mushtaq Ahmed, Mohiuddin Ahmed, and Forhat Afja Lubna, Strength Performance Comparison of Concrete With Uncrushed Or Crushed Coarse Aggregate. ARPN Journal of Engineering and Applied Sciences, 1, 4–1 (2006)
[17] Ali A. Aliabdo, Abd Elmoaty M. Abd Elmoaty dan Ahmed M. Fawzy, Experimental Investigation on Permeability Indices and Strength of Modified Pervious Concrete With Recycled Concrete Aggregate. Construction and Building Materials, 193, 105–127 (2018).https://doi.org/10.1016/j.conbuildmat.2018.10.182
[18] B. Aggregate, K. Coral, and P. Air, Evaluation of the compressive strength characteristics of coral coarse aggregate concrete mixed with seawater. 18–23 (2022)
[19] M.A. Aziz. Z. (1995). Engineering Materials. Dhaka, 128:129.

[20] ASTM C150– 04, Standard Specification for Portland Cement in Annual Book of ASTM Standards (2004)
[21] ASTM C192/C192M – 19, Standard Specification for Making and Curing Concrete Test Specimens in the Laboratory. United States: ASTM International (2019)
[22] ASTM C 39-05, Standard Test Method for Compressive Strength of Cylindrical Concrete
[23] ASTM C496/C496M-11, Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimen, August 2011.
[24] ASTM C 78-02, Standard Test Method For Flexural Strength of Concrete (Using Simple Beam With Third-Point Loading). ASTM International, Philadelphia 19428-2959 United States (2002)
[25] Shutong Yang, Chaohui Zang, Jinjin Xu, and Guoxi Fan, Determination of Fracture Parameters of Seawater Sea Sand Concrete Based on Maximum Fracture Load. Journal of Materials in Civil Engineering, 32, 1-11, October 2019. https://doi.org/10.1061/(ASCE)MT.1943-5533.0002981
[26] Bulgis and Rani Bastari Alkam, Utilization of Natural Aggregate and Crushed Stone Aggregate as Pavement Materials in Asphalt Concrete Mixture. 29-32 (2017). https://doi.org/10.35313/potential.v19i1.530
[27] Chunheng Zhou and Zongping Chen, Mechanical properties of recycled concrete made with various types of coarse aggregates. Construction and Building Materials. 497–506 (2017). https://doi.org/10.1016/j.conbuildmat.2016.12.163
[28] Joseph. O. Ukpata and Maurice. E. Ephraim, Flexural And Tensile Strength Properties Of Concrete Using Lateritic Sand And Quarrydust As Fine Aggregate. ARPN Journal of Engineering and Applied Sciences. 324-331 (2012)
[29] A. Gunawan, The Effect of Mixing Two Types of Coarse Aggregate on the Compressive Strength of Concrete. 59-67 (2016)
[30] Yudong Han, Jun Zhang and Yuan Gao, Effect of coarse aggregate content on fracture parameters of concrete, Engineering Mechanics. 191–205 (2013).

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