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The Influence of Zone and Size of Sea Sand Aggregate on the Production of Self Compacting Concrete Technology

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ABSTRACT
The strength and durability that can be achieved by concrete depends on factors such as the quality of the aggregates. This study presents the effect of zone gradation and size of fine aggregates of sea sand as a mixing material for concrete production by the method of aggregate incorporation that will produce maximum compressive strength of concrete. The most important thing in the use of beach sand is the compressive strength of the concrete. If the compressive strength of the test is high, the other properties will be good. The factors that affect the compressive strength of concrete consist of the quality of materials, cement water, aggregates, working methods such as mixing, compaction and curing and the age of testing based on (SNI 03-6468-2000). The application of marine sand as a concrete mix will have a positive impact on coastal and island communities, which have difficulty obtaining sand from rivers.

Keywords: *Compressive strength, Sea sand, Zone aggregate*

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INTRODUCTION

Concrete is not free from weaknesses, the main ones being that it has a large weight, and its strength in accepting the tensile strength acting on the cross section is very low. Aggregates are very important, both to the quality of the concrete and its price. It is not less than 65-75% of the volume of concrete consists of aggregates, therefore using the maximum possible aggregate composition will result in cheaper concrete prices (Usman, 2013).

A concrete plant, also known as a batch plant or batching plant or a concrete batching plant, is equipment that combines various ingredients to form concrete. In concrete construction calculations, a high knowledge of statics and the sciences of concrete strength is not good enough if it is not accompanied by knowledge of concrete technology (Rilya Rumbayan, Seska Nicolaas, 2016). The strength and durability that can be achieved by concrete depends on factors such as the quality of aggregate, cement, the amount of mixing water, processing, compaction and others.

Concrete is a heterogeneous entity and is one of the construction materials that has been commonly used as one of the main materials or as a supporting material. It can be selected by the consumer by taking into account the advantages and disadvantages. This study examines the effect of zone gradation of fine aggregates, especially marine sand, on which zone is best for obtaining maximum compressive strength of concrete, especially with self-compacting concrete technology (Adnan, 2024).

The study of marine sand fine aggregate materials as an alternative to concrete filler materials, therefore a good composition of fine aggregate use is required The study was conducted by comparing the compressive strength values of concrete. Observations in the field have shown that coastal communities have used beach sand in concrete to build houses or other buildings. Sea sand was taken at Lumpue Beach, Parepare City. Concrete compressive strength testing was carried out at the age of 7, 14, 21 and 28 days.

(Lolo et al., 2019), the result of testing coarse and fine aggregates from Southwest Sumba has met the requirements of aggregate characteristics, but the fine aggregates in this study must be washed to remove salt content. The coarse and fine aggregates from Southwest Sumba can generally be used for concrete mixes because they meet the requirements of concrete aggregate characteristics, making them suitable for use in concrete production.

(Handayani, 2018), The fine aggregate tests obtained from the three quarries all meet the requirements for use in concrete mixes. There is a difference in the gradation of fine aggregate (sand) in the Kampung Seberang quarry in zone 4 which means very fine sand, while the Kampung Sungai quarry is in zone 3 of the fine category, in the Tanjung Wagom quarry in zone 2 in the rather coarse category. The test results of Manokwari quarry fine aggregate contain mud content of 4.8% and the fine modulus of Manokwari quarry fine aggregate is 5.025.

(Anjelica et al., 2019), the absorption and moisture content of Waihatu River fine aggregate is higher than that of Hatu Beach fine aggregate, which will affect the amount of water used in concrete mixing. The high organic content of beach sand affects the reduction of concrete strength, for more efficient use it is necessary to wash first to remove the organic content contained in the material.

(Salmonda, 2018), coastal sand on the Medan mirror beach in North Sumatra. The addition of sand is carried out to meet the demand of the community, especially the community in the coastal area. Coastal communities have used beach sand in mortar to build houses or buildings. The results showed that the use of beach sand as an alternative mortar filling material showed an average compressive strength of mortar in 14 days of 60.6 kg/cm2. The average compressive strength value of using impure (washed) beach sand was 251.51 kg/cm2 in 14 days.

(Prabowo & Sofia, 2024), identified the physical properties of sand used in the Sukabumi region along with its compressive strength. The sand used came from

Cimangkok, Cibuni, and Jebrod areas. The test specimens used were cylinders with a diameter of 15 cm and a height of 30 cm. The compressive strength value, Cimangkok Sand concrete has the highest compressive strength value that exceeds the plan compressive strength value.

(Naibaho, 2017), fine aggregates and coarse aggregates are kept in a condition close to the actual state of the field, so they are not washed but kept free of organic impurities, mud and rubbish. Concrete mix design according to ACI (American Concrete Institute): ACI 211.1-21 □ 211.1-23. suggests a way of designing mixes that shows economics, available materials, workability, durability and desired strength. The amount of water per cubic metre of mix determines the consistency/viscosity (slamp) of the concrete mix.

(Desi Lembang & Benyamin Unwakoly, 2022), with the basic material is a lightweight fine aggregate substitute with the provision that it should not exceed the maximum concrete content weight of 1900 kg/m3 (SNI 03-3449-1994). The results of fine aggregate testing from Fakfak sand for lightweight brick mixtures all meet the requirements of aggregate characteristics. The average compressive strength of CLC lightweight brick test specimens increases with the mixture/addition of additives the compressive strength value becomes very high, namely 7 days = 35.59 kN, 14 days = 40.88 kN, 21 days = 81.22 kN, and 28 days = 93.12 kN.

(Fahrizal Zulkarnain, 2023), inspection of fine aggregate and coarse aggregate, we will compare with the percentage of cement, sand, gravel and also Bond Crete to be mixed concrete mixture, concrete mixture with the addition of Bond Crete as a concrete mixture adhesive according to the age of the test plan. The added Bond Crete adhesive concrete mix was cast into a 15 cm high, 30 cm wide cylinder mould.

(Santoso Agus et al., 2017), normal concrete mix design according to SNI 03-2834-2000 and SNI 7656:2012. This study was conducted because SNI 7656: 2012 is an adoption of ACI 211 which requires a mixture by considering the economic side, the test object used is a concrete cylinder with dimensions of 150 x 300 mm. Based on the test results, the average compressive strength of concrete with SNI 2000 design for 25 MPa (BN-00-25), 30 MPa (BN-00-30), and 35 MPa (BN-00-35) plan compressive strength is 27.24 MPa, 38.99 MPa, and 44.85 MPa, respectively. While the average compressive strength of concrete with SNI 2012 design is 31.43 MPa, 36.54 MPa, and 39.76 MPa, respectively.

(Nur Selika,2023), the compressive strength test results of river sand mortar were 6.13 N/mm2 and beach sand was 5.61 N/mm2. Comparison between the compressive strength of river sand and beach sand in the coastal area of Parepare city is still difficult to compare, because in terms of characteristics it is different.

RESEARCH METHODOLOGY

Material specifications

Aggregate size affects the density of the concrete therefore aggregates are required to be well graded. The cleanliness of the aggregate greatly affects the durability and strength of the concrete, and the fineness and shape and arrangement of the grains will affect the bond between the aggregate and the cement paste. Aggregates with a good gradation will result in dense concrete, which is economically beneficial and reduces shrinkage (Connolly & Donadio, 1979).

Fine aggregate as a constituent material of concrete

Fine aggregate is an aggregate that has a grain size from 0.075 to 5 mm. The fine aggregate should not contain more than 5% mud (determined on dry weight), mud passing through a 0.063 mm sieve and if the fine aggregate exceeds 5%, the fine aggregate should be washed, while according to PBI-1971 Article 3.3 paragraph 5, the grain arrangement of fine aggregate meets the requirements that the residue above the 4 mm sieve, should be a minimum of 2% by weight, the residue above the 1 mm sieve, should be a minimum of 10% by weight, the residue above the 0.25 mm sieve, should range from 80 - 95% by weight, sea sand should not be used as fine aggregate for all concrete, unless instructed by a recognised material inspection agency (Tiwari et al., 2016).

Standard conditions or specifications of concrete mixes.

There are several concrete design methods known in the world, but in Indonesia adopted the concrete mix design method from the UK, this method is known as the DOE (Department Of-Environment) method, with this method it is expected that the difficulties encountered in the field to produce concrete strength as designed can be overcome, optimal utilisation of raw materials will be obtained, so it is expected that a mixture with the most optimal strength will still produce an economical price, because it can be known how much the most appropriate volume of cement is given to other raw materials, so that it becomes a quality concrete mixture because cement is the most expensive component when compared to the price of other raw materials (Popovics, 1992).

Effect of Zone gradation on concrete compressive strength

In concrete mixes, the zone gradation of the aggregates has a major influence on the quality of the concrete. Undersanded occurs when the available sand is unable to fill the voids between the coarse aggregates. Whereas oversanded occurs when so much sand is available that the coarse aggregate cannot be seen at all in the mix. In the practice of making concrete work, it is more common to adjust the ratio of fine aggregate to coarse aggregate, in order to compensate for the small differences in processability caused by the different gradations of sand, than to adjust the water demand (Pratama et al., 2017).

Specification of fine aggregate gradation

A well-graded aggregate is one in which the grain arrangement consists of fine to coarse grains in a regular manner. Aggregates that are well graded are ideal for use as concrete aggregates, this is because the grains fill in each other so that high density concrete will be obtained (Nurlita Pertiwi, 2014).

For ease of analysis, the amount of aggregate passing through the sieve is recorded and drawn according to the graph given The required limits to be categorised as fine aggregate are calcified zone 1 to zone 4 according to British Standard (Aswath, 2013).

Sampling

At the time of sample testing in the laboratory, the material in the sack is stirred again and put into the sample splitter by inserting it into the splitter spoon that has been placed on the tool can fall simultaneously into the shelter, then the shelter is done again as before so that the material is obtained from the shelter of the tool (Ward & Harr, 1990).

Zone distribution steps

To plan the concrete mix using the remaining fine aggregates by first separating the aggregates based on their respective zones (I, II, III, IV) with sieve numbers according to ideal specifications (Lemos et al., 2012).

Concrete mix design

The planning stages are as follows (Lydon, 1982):

a. Conduct a characterisation check of the aggregates including, gradation check, volume weight, moisture content, mud content, organic content etc.
b. Selecting the method of planning the concrete mix, there are several methods namely, road note - 4 method, D.O.E (The British Department of the Environment) method, A.C.I (The American Concrete Institute) method, Niss - Master (Japan) method, L.J Murdock (UK) method.

RESULT AND DISCUSSION

Fine aggregate gradation specification

Aggregates that are well graded are ideal for use as concrete aggregates.
In order to facilitate analysis, the amount of aggregate passing through the sieve is recorded and drawn according to the graph given The required limits to be categorised as fine aggregate are calcified zone 1 to zone 4 according to British Standard, as shown in table 1.

Table 1. Limits of fine aggregates according to British Standard (BBS 1973)

Sieve Size		Zone Aggregate			
mm	No	Zone 1	Zone 2	Zone 3	Zone 4
9,52	3/8”	100	100	100	100
4,76	4	90 - 100	90 - 100	90 - 100	95 - 100
2,38	8	60 - 95	75 - 100	85 - 100	95 – 100
1,19	16	30 – 70	55 - 90	75 - 100	90 – 100
0,60	30	15 – 34	35 – 59	60 – 79	80 – 100
0,30	50	5 – 20	5 – 30	12 – 60	5 – 50
0,15	100	0 - 10	0 - 10	0 - 10	0 - 15

Steps of zone division

Aggregate by zone (I, II, III, IV) with sieve numbers according to ideal specifications, as shown in table 2.

Tabel 2. The respective zones (I, II, III, IV) with sieve numbers according to ideal specifications

No. Sieve	Spes Zone I % Pass	Spes Ideal % Pass	
3/8”	100	-	
No. 4	90 -100	100 – 95 = 5%	5% x 71 = 3,55 kg
No. 8	60 – 95	95 – 77,5 = 17,5%	17,5% x 71 = 12,425 kg
No. 16	30 – 70	77,5 –50 = 27,5%	27,5% x 71 = 19,525 kg
No. 30	15 -34	50 – 24,5 = 25,5%	25,5% x 71 = 18,105 kg
No. 50	5 – 20	24,5 – 12,5 = 12%	12% x 71 = 8,52 kg
No. 100	0 – 10	12,5 – 5 = 7,5%	7,5% x 71 = 5,325 kg
No. 200	-	5 – 0 = 5%	5% x 71 = 3,55 kg

Aggregate coalescence

To obtain the percentage of each aggregate required for the concrete mix design, the aggregates were combined by analysing as follows:

Y1 = A1 x % cumulative sand pass + (1 - A1) cumulative gravel pass

Y2 = A2 x % cumulative sand pass + (1 - A2) cumulative gravel pass

Y1 and Y2 are taken from the gradation limit curve, maximum size of aggregate (aggregate specification limit), as shown in table 3 and table 4.

Table 3. Grain arrangement of B.S 882 aggregate

Sieve B.S 882 (mm)	% Weight passing through the sieve			
	Maximum granular weight (mm)			
	76	38	19	9,6
76	100			
38	47 – 63	100		
19	35 – 52	50 – 75	100	
9,6	26 – 42	35 – 60	45 – 75	100
4,8	20 – 35	23 – 47	29 – 49	29 – 75
2,4	17 – 29	18 – 37	23 – 42	21 – 60
1,2	13 – 24	13 – 30	15 – 35	17 – 47
0,6	8 – 17	7 – 23	9 – 28	14 – 35
0,3	4 – 9	3 – 15	2 – 13	5 – 21
0,15	-	1 – 6	1 – 2	0 – 1

Table 4. Combined aggregate using Zone I, II, III, IV

No. Sieve	Zone 1		Zone 2		Zone 3		Zone 4	
	A1	A2	A1	A2	A1	A2	A1	A2
3/4”	0	0	0	0	0	0	0	0
3/8”	19,89	63,60	19,89	63,60	19,89	63,60	19,89	63,60
No. 4			27,00	49,00	27,00	49,00	26,30	47,80
No. 8			26,30	48,00	24,86	45,00	24,20	44,20
No. 16			20,70	48,30	17,10	40,00	16,60	38,80
No. 30			18,30	57,10	12,90	40,20	11,25	35,00
No. 50			10,50	68,40	7,60	50,00	6,10	40,00
No. 100			20,00	40,00	20,00	40,00	18,00	36,36
No. 200			0	0	0	0	0	0

Aggregate is a component of concrete mix that functions as a filler material, the composition of aggregate in concrete mixes ranges from 60%-70% of the total weight of the concrete mix. Aggregate has two types that are distinguished based on their size, namely coarse aggregate and fine aggregate. A wide variety of fine aggregate options are available to you, such as free samples, paid samples.

Aggregate gradation is the distribution of aggregate grain sizes, or the grouping of aggregates of different sizes as a percentage of the total aggregate or the cumulative percentage of grains smaller or larger than each series of sieve openings. Aggregate gradation serves the purpose of obtaining compressibility/density as well as cement paste requirements, where the more varied the grain size, the better the compressibility and the less cement paste requirements where the grains are glued together and fill the space between the grains.

The combined aggregate gradation is the mixing of coarse aggregate with fine aggregate. To obtain a good combined gradation, the gradation limits adopted from B.S in SK.SNI T-15-1990-03:21 are required.

The fine aggregate gradation is prepared by separating the grain fractions based on the amount retained on the sieve. In zone 1 gradation, the grain arrangement is obtained, zone 2, zone 3, and zone 4 fine aggregate gradations are arranged with the conditions presented at the lower and upper limits of the fine aggregate gradation.

As shown in table 5, based on the test results of aggregate incorporation in size and zone gradation, the percentage of zone 2 incorporation is effective for concrete mixing.

Table 5. Combined aggregate results (a) Zone 1 (b) Zone 2 (c) Zone 3 (d) Zone 4

No. Saringan	Agregat				Agregat Gabungan	Spesifikasi
	Agregat halus		Agregat kasar			
	% lolos	Berat	% lolos	Berat		
3/4"	100	38,365	100	61,635	100	100
3/8"	100	38,365	31,34	19,320	57,685	45 – 75
No. 4	95	36,440	4,75	2,820	39,260	29 – 49
No. 8	77,5	29,730	0		29,730	23 – 42
No. 16	50	19,180			19,180	15 – 35
No. 30	25,5	9,400			9,400	9 – 28
No. 50	12,5	4,790			4,790	2 – 13
No. 100	5	1,920			1,920	1 – 2
No. 200	1,2	0,420			0,420	0

(a)

No. Saringan	Agregat				Agregat Gabungan	Spesifikasi
	Agregat halus		Agregat kasar			
	% lolos	Berat	% lolos	Berat		
3/4"	100	33,5	100	66,500	100	100
3/8"	100	33,5	31,34	20,840	54,340	45 – 75
No. 4	95	31,825	4,75	3,040	34,865	29 – 49
No. 8	87,5	29,310	0	0	29,310	23 – 42
No. 16	72,5	24,287			24,287	15 – 35
No. 30	49	16,415			16,415	9 – 28
No. 50	19	6,365			6,365	2 – 13
No. 100	5	1,675			1,675	1 – 2
No. 200	1,2	0,420			0,420	0

(b)

No. Saringan	Agregat				Agregat Gabungan	Spesifikasi
	Agregat halus		Agregat kasar			
	% lolos	Berat	% lolos	Berat		
3/4"	100	33,5	100	66,500	100	100
3/8"	100	33,5	31,34	20,800	54,340	45 – 75
No. 4	95	31,825	4,75	3,040	34,865	29 – 49
No. 8	92,5	30,581	0	0	30,987	23 – 42
No. 16	87,5	29,310			29,310	15 – 35
No. 30	69,5	23,280			23,280	9 – 28
No. 50	26	8,710			8,710	2 – 13
No. 100	5	1,675			1,675	1 – 2
No. 200	1,2	0,420			0,420	0

(c)

No. Saringan	Agregat				Agregat Gabungan	Spesifikasi
	Agregat halus		Agregat kasar			
	% lolos	Berat	% lolos	Berat		
3/4"	100	30,650	100	61,635	100	100
3/8"	100	30,650	31,34	19,320	52,380	45 – 75
No. 4	97,5	29,880	4,75	2,820	33,050	29 – 49
No. 8	95	29,120	0	0	29,120	23 – 42
No. 16	90	27,585			27,585	15 – 35
No. 30	80	24,520			24,520	9 – 28
No. 50	32,5	9,960			9,960	2 – 13
No. 100	5,5	1,685			1,685	1 – 2
No. 200	1,2	0,387			0,387	0

(d)

As shown in table 6, based on the test results of the compressive strength of aggregate incorporation on size and zone gradation, the compressive strength of aggregate incorporation of zone 2 is greater than that of zone 1, zone 3, and zone 4.

Table 6: Test results for compressive strength of aggregates (a) Zone I (b) Zone 2 (c) Zone 3 (d) Zone 4

No	Umur (hari)	Beban (Kn)	σb Kg/cm²	Koef	σb 28 hari Kg/cm²	σbm Kg/cm²	$\sigma b(28\ hari) - \sigma bm$ Kg/cm²	$\sum M$ Kg/cm²
1	3	350	158,667	0,4	396,667	382,479	201,299	375,876
2		350	158,667		396,667		201,299	
3		355	160,993		402,333		391,181	
4		355	160,993		402,333		394,181	
1	7	520	235,733	0,65	362,667		392,515	
2		525	238,000		366,641		266,506	
3		530	240,267		369,641		164,814	
4		525	238,000		366,154		266,515	
1	14	625	310,533	0,88	352,878		876,219	
2		690	312,799		355,454		730,351	
3		690	312,799		355,454		730,351	
4		690	312,799		355,454		730,351	
1	21	820	371,733	0,95	391,298		77,775	
2		810	367,200		386,526		16,378	
3		830	376,267		396,070		184,715	
4		820	371,733		391,298		77,775	
1	28	880	398,933	1,00	398,933		251,349	
2		885	401,200		401,200		391,181	
3		885	401,200		401,200		391,181	
4		880	401,200		401,200		391,181	
							$\sum$ 5817,042	

(a)

No	Umur (hari)	Beban (Kn)	σb Kg/cm²	Koef	σb 28 hari Kg/cm²	σbm Kg/cm²	$\sigma b(28\ hari) - \sigma bm$ Kg/cm²	$\sum M$ Kg/cm²
1	3	350	172,267	0,4	430,667	423,216	55,517	420,044
2		350	176,800		442		35,838	
3		355	176,800		442		352,838	
4		355	174,533		436,333		172,055	
1	7	520	273,650	0,65	421,948		1,608	
2		525	276,553		425,436		4,928	
3		530	276,533		425,436		4,928	
4		525	272,000		418,462		22,6	
1	14	625	367,200	0,88	417,273		35,319	
2		690	362,677		412,121		123,099	
3		690	364,933		414,697		72,573	
4		690	364,933		414,697		72,573	
1	21	820	401,200	0,95	422,316		0,81	
2		810	398,933		419,930		10,798	
3		830	399,667		420,702		6,320	
4		820	399,667		420,702		6,320	
1	28	880	421,600	1,00	421,600		2,611	
2		885	419,333		419,333		15,077	
3		885	419,333		419,333		15,077	
4		880	419,333		419,333		15,077	
							$\sum$ 1342,96	

(b)

No	Umur (hari)	Beban (Kn)	σb Kg/cm²	Koef	σb 28 hari Kg/cm²	σbm Kg/cm²	$\sigma b(28\ hari) - \sigma bm$ Kg/cm²	$\sum M$ Kg/cm²
1	3	375	170	0.4	425	405,902	364,744	400,48
2		370	167,333		419,333		180,392	
3		380	172,267		430,667		613,305	
4		375	170		425		364,744	
1	7	580	262,933	0.65	404,513		1,929	
2		575	260,667		401,025		23,785	
3		580	262,933		404,513		1,929	
4		580	262,933		404,513		1,929	
1	14	755	342,267	0,88	388,939		287,743	
2		755	342,267		388,939		287,743	
3		755	342,267		388,939		287,743	
4		750	340		368,364		1409,101	
1	21	850	385,333	0,95	405,614		0,083	
2		855	387,6		408		4,402	
3		855	387,6		408		4,402	
4		850	385,333		405,614		0,083	
1	28	905	410,267	1,00	410,267		19,853	
2		905	410,267		410,267		19,853	
3		900	408		408		4,402	
4		910	412,533		412,533		43,970	
							$\sum$ 3920,535	

(c)

No	Umur (hari)	Beban (Kn)	σb Kg/cm²	Koef	σb 28 hari Kg/cm²	σbm Kg/cm²	$\sigma b(28\ hari) - \sigma bm$ Kg/cm²	$\sum M$ Kg/cm²
1	3	350	158,667	0.4	396,667	365,975	941,999	358,934
2		350	158,667		395,667		941,999	
3		355	160,993		422,333		1.321,504	
4		355	160,993		402,333		1.321,504	
1	7	580	231,200	0.65	355,692		105,740	
2		585	288,933		352,205		189,613	
3		505	288,933		352,205		189,613	
4		518	231,200		355,692		105,740	
1	14	630	303,074	0.88	345,152		433,597	
2		670	303,134		345,152		433,597	
3		675	306		347,727		332,989	
4		675	306		347,727		332,989	
1	21	770	349,066	0.95	367,438		2,140	
2		765	346,800		365,053		0,850	
3		760	344,524		362,667		10,943	
4		765	346,800		365,053		0,850	
1	28	805	364,933	1,00	364,933		1,086	
2		810	367,200		367, 200		1,500	
3		825	364,933		364,933		1,006	
4		800	362,667		362,667		10,943	
							$\sum$ 6627,082	

(d)

Based on the results obtained in table 1 and table 2, the average crushing compressive strength values at 28 days for mixes using zone 2 fine aggregate incorporation are higher when compared to zone 1, zone 3, and zone 4 fine aggregate incorporation. However, the crushed compressive strength values are still below the target compressive strength but still above the characteristic compressive strength, As shown in figure 1 and figure 2.

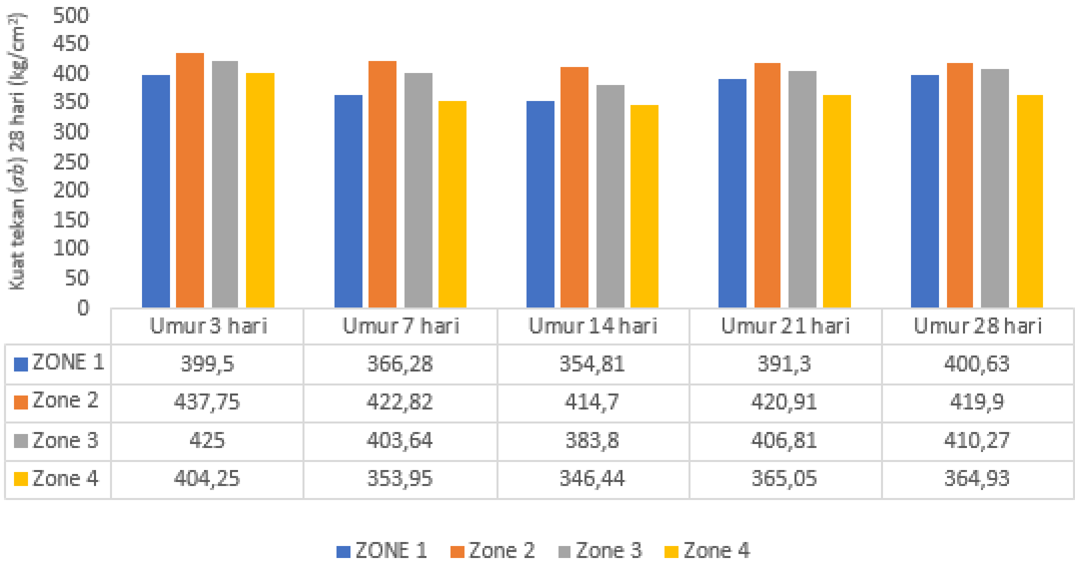

Figure 1, Relationship between compressive strength and age of concrete Zone Aggregate

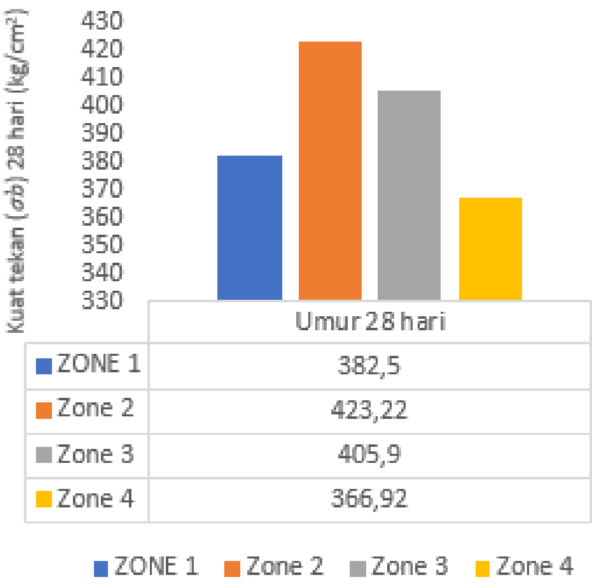

Figure 2. Relationship of 28-day average compressive strength to Aggregate Zone

CONCLUSION

The concrete mix design using zone gradation 2 fine aggregate produced maximum and average crushed compressive strength above the plan compressive strength of 42.322 MPa and standard deviation (S) of 1.928. Thus, the use of fine aggregate of sea sand by taking into account the size and zone of fine aggregate against aggregate incorporation allows it to be used as a concrete constituent material with consideration to the compressive strength characteristics of fine aggregate.

The combination of aggregates intended for concrete mixing to produce the size and zone gradation of aggregates to achieve the specified compressive strength and margin.

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