International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Annales de Chimie - Science des Matériaux
Vol. 49, No. 1, February, 2025, pp. 7-15
Journal homepage: http://iieta.org/journals/acsm

Study of the Characteristics of Kutai Kertanegara Local Quarry Stone for Self-Compacting Concrete Production

Muhammad Noor Asnan*, Rusandi Noor, Ni'matul Azizah Raharjanti, Eka Wahyuni, Hari S. Hartono, Vebrian

Fakultas Sains dan Teknologi, Universitas Muhammadiyah Kalimantan Timur, Samarinda 75124, Indonesia

Corresponding Author Email: mna985@umkt.ac.id

https://doi.org/10.18280/acsm.490102

Received: 1 August 2024
Revised: 16 February 2025
Accepted: 19 February 2025
Available online: 28 February 2025

Keywords:
abrasion, coarse aggregate, limestone, local stone, SCC, compressive strength

ABSTRACT

Classification, abrasion, and compressive strength conditions of rocks can affect the quality of concrete and potentially cause damage/failure of building structures. This local rock research is needed for utilization as coarse aggregate in concrete mixtures. Rocks are located in 4 quarries in Kutai Kertanegara Regency. Each quarry was identified by taking rocks in the form of boulders and coarse aggregates. Rock samples were observed visually from a geological perspective and tested for physical and mechanical properties. Rock compressive strength test with cube-shaped samples measuring 5 x 5 x 5 cm. The compressive strength value of 50 MPa was continued to make high-quality SCC concrete samples in cylinders measuring 10 x 20 cm for each age of 3, 7, 14, 21, 28, 56, and 90 days. Then, the rock classification was obtained, including limestone, and it had many cracks. The average rock abrasion value was obtained at less than 40%. The compressive strength of the rock at location KM.45 was 64.89 MPa, KM.40 obtained 42.05 MPa, while other places did not meet the minimum value. The 28-day concrete compressive strength was obtained 28.662 MPa from the KM.45 location and 23.884 MPa from the KM.40 location. The development of concrete strength according to age shows a trend that does not increase and fluctuates. Compared to concrete, it generally shows a trend that continues to increase according to age. This condition indicates that the limestone has uneven or inconsistent strength, so it is unsuitable for high-quality concrete use. This information is expected to be a guideline for using local rocks.

1. INTRODUCTION

Relating the nation's capital from Java Island to Kalimantan Island is no longer just a discourse. The issuance of Law Number 3 of 2022 concerning the National Capital (IKN Law), signed and officially enacted on February 15, 2022, is proof of the government's seriousness [1]. The law regulates the establishment of the nation's capital, Nusantara, the nation's capital and the establishment of the Nusantara Capital City (IKN) authority. The location of the New National Capital City has been determined to be part of Penajam Paser Utara Regency (PPU) and part of Kutai Kartanegara Regency, East Kalimantan Province [2]. The relocation of the New National Capital City to East Kalimantan impacts development in various fields, including development in the infrastructure sector [3]. The Nusantara Capital City's development has positive and negative direct and indirect impacts on the surrounding cities and provinces. The existence of the nation's capital city with an innovative city concept requires support from buffer areas covering the borders of Penajam Paser Utara, Kutai Kartanegara, West Kutai, Balikpapan, and Samarinda [2], so the use of materials is increasingly needed. Materials imported from outside Sulawesi, namely Palu stone and Palu sand, are available. It is also following the data submitted by the Indonesian Capital City Authority Agency and the Ministry of Public Works and Public Housing (PUPR) at the National Seminar themed "Strategy and Policy for the Implementation of IKN Development Related to the Role of Construction Service Actors in East Kalimantan Province" on October 26, 2023, that until 2024 the provision of stone material needs as a primary material for concrete is still very large. For the sustainability of development, diversification of stone quarries is required. Therefore, innovations such as utilizing the potential of local materials from quarries in East Kalimantan Province, especially materials for making concrete, need to be carried out.

The concrete mixture's main elements are cement, water, sand, and stone. Mortar is a mixture of cement, water, and sand, while the matrix is a mixture of cement and water [4]. Concrete is a heterogeneous material, and the cement paste's strength is not completely maintained when sand and aggregate are added. Concrete strength is one of the most important properties of concrete. The properties of concrete made from various mixtures are usually measured in terms of compressive strength. Aggregates added to concrete are essential elements in concrete (Coarse aggregates make up about 50-60% of the concrete volume, significantly impacting its strength and durability [5].

Rocks are a mixture of one or more different minerals, do not have a fixed composition, and are not the same as soil. Soil is a mobile, fragile material close to the earth's surface [6].

Rocks have two properties, namely physical properties and mechanical properties. The physical properties of rocks are obtained from non-destructive testing. The physical properties of rocks are specific gravity, water content, degree of saturation, porosity, and pore number. The mechanical properties of rocks are obtained by destructive testing, while mechanical properties are obtained from testing carried out in the laboratory [7-9]. Natural rocks can be classified into the history of geological formation events: igneous, sedimentary, and metamorphic rocks. These are then divided into smaller groups by breaking rocks into the desired grain size by blasting, breaking, filtering, and so on [10, 11].

Concrete, an important material in infrastructure construction, exhibits performance characteristics that are greatly influenced by the properties of its components, especially coarse aggregates. Concrete strength largely depends on coarse aggregates' strength and properties because most of the concrete volume is covered by coarse aggregates [5]. This study is a continuation of previous studies that explore the mechanical properties of concrete using equivalent mortar, which aims to explain further the factors that affect concrete performance. Previous studies have emphasized the importance of coarse aggregate characteristics, including shape, size, surface condition, and type, in determining concrete performance [12]. Concrete development has progressed very rapidly in terms of implementation methods and materials. Self-compacting concrete (SCC) is concrete that can compact itself so that it does not require a compactor [13, 14]. Its very high flowability allows the fresh concrete mixture to flow its mass, which is obtained by providing additional materials in superplasticizers with doses that can cause slump flow [15]. SCC concrete has resistance to segregation, easy filling, easy passability, high fluidity, and high deformation ability, and can maintain homogeneity during and after transportation and pouring. Due to fewer defects in the microstructure, self-compacting concrete can meet the requirements of strength, volume stability, and durability of concrete [16]. According to Prasetia and Krasna [17], the results of the examination of split stone material from Mount Katunun obtained an abrasion value of 24%, split stone from Mount Martadah of 25.8% and Awang Bangkal stone of 33.3%.

According to Safarizki et al. [18], replacing coarse aggregate from Palu with coarse aggregate from Lebak Cilong could not produce the concrete quality of fc' 30 Mpa.

According to Abdi et al. [19], the abrasion test of Muara Wahau aggregate was 14.4%, Santan aggregate was 29.05%, Senoni aggregate was 22.7%, and Batu Besaung aggregate was 26.4%. The results of this test meet the requirements for a class B foundation layer with a specification limit of 0 - 40%.

According to Surya and Purnamasari [20], Birayang split aggregate can be used in a concrete mixture of fc' 35 MPa. Its use is more efficient and economical 41% lower than the aggregate price from Palu.

According to Resti et al. [21], the use of Muara Asa aggregate and Keay sand produces a flexural strength of 3.62 MPa at the age of 28 days, and compared to aggregate and sand from Palu, the flexural strength obtained is 3.57 MPa or lower.

The elements that form the strength of concrete consist of mortar strength, rock strength and bond strength between rock and mortar [22]. This study aims to determine the effect of rock strength on the strength of concrete.

One area with the potential for rock mining is Kutai Kertanegara Regency. With such an abundance of rock mining potential in 4 locations, Kutai Kertanegara Regency has attracted researchers to examine the strength of its rocks.

This research is needed to maximize the use of the strength of local rocks that are processed into coarse aggregates in concrete mixtures.

2. RESEARCH METHODOLOGY

Problem-solving approach by conducting field surveys and laboratory testing and analyzing data related to rocks and concrete according to SNI. Direct geological survey at several research quarry locations. Sampling, processing, and rock compressive strength testing into 20 cube-shaped samples measuring 5 × 5 × 5 cm. The manufacture of test objects was carried out at the Civil Engineering Laboratory of the Muhammadiyah University of East Kalimantan. The test objects in this study were local stones in 4 locations of Kutai Kertanegara Regency from mountain stones from the Teluk Dalam Quarry, mountain stones from the Sukamaju Quarry, mountain stones from the Tenggarong-Kota Bangun KM.40 main road quarry, and mountain stones from the Tenggarong-Kota Bangun KM 45 main road Quarry. The location of the sample collection can be seen in Figure 1 and Table 1 below.

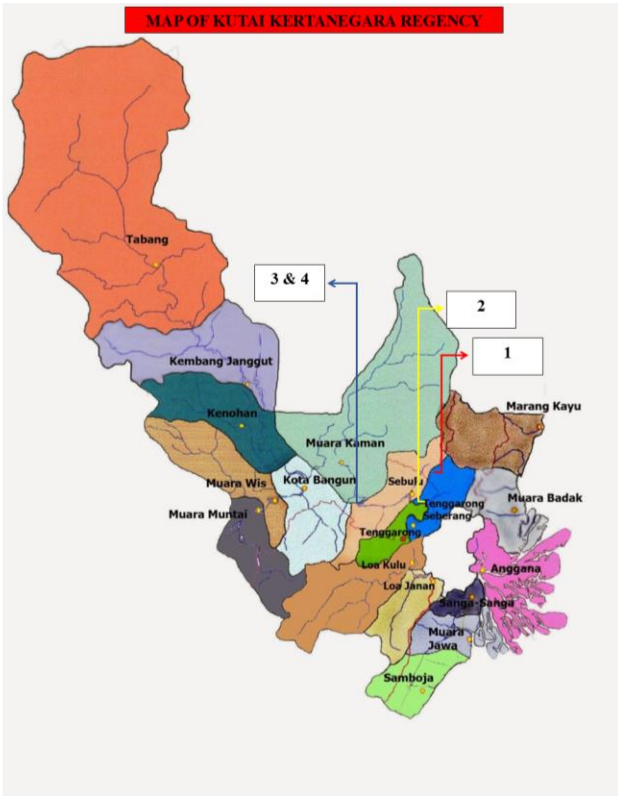


Figure 1. Rock sampling locations

Table 1. Rock sample location

Location Code	Sampling Location
Quarry 1 – TLD	Teluk Dalam Village
Quarry 2 – SKM	Sukamaju Village
Quarry 3 – BK40	Tenggarong-Kota Bangun axis road KM.40
Quarry 4 – BK45	Tenggarong-Kota Bangun axis road KM.45

Furthermore, coarse aggregate abrasion testing was carried out during the production of each quarry. Finally, SCC concrete samples with a planned mixture strength of 50 MPa and compressive strength testing at 3, 7, 14, 21, 28, 56, and 90 days.

The stages of the research can be explained as follows:

Stage 1: prepare testing equipment rock surveys and take coarse aggregate samples from the quarry location. Furthermore, visual testing of rocks and physical properties of coarse and fine aggregates (ex., Palu) includes volume weight, specific gravity, absorption, water content, mud content, aggregate sieve analysis and abrasion. Survey process indicators, equipment and physical property tests. Testing of aggregate physical properties using ASTM C127-15, ASTM C128-15, ASTM C136/C136M-14, ASTM C39/C39M-14, ASTM D4791-10, ACI Committee 211, 2008 [23-28].

Stage 2: conduct a visual inspection of rocks and coarse aggregate abrasion in the laboratory, with process indicators producing rock classification and coarse aggregate classification based on rock properties [29].

Stage 3: conduct compressive strength testing of rocks in cube samples measuring 5 × 5 × 5 cm with a minimum strength limit equal to or greater than 45 MPa. The process indicates minimal rock compressive strength to achieve high-quality concrete strength and determine the crushing/collapse pattern [30].

Stage 4: calculates the high-quality concrete material mix plan, while rocks that do not meet the minimum strength standards are made into a regular concrete mix plan. The composition of the concrete-forming material mix obtains the process indicator.

Stage 5: casting, slump testing and molding of SCC concrete and standard concrete according to the mix design results. The molding of 10 x 20 cm cylindrical concrete samples totaled 21 pieces, and 15 x 30 cm cylindrical concrete samples totaled 15. The process indicator was obtained by mixing the composition with additional materials/additives based on slump flow with a value of 550 mm and self-compacting concrete (SCC) based on SNI 6468-2000 [31], SNI 1972-2008 [32]. Stage 6 was curing and compressive strength testing of concrete samples for ages 3, 7, 14, 21, 28, 56, and 90 days. Treatment begins after 24 hours of hardening by soaking in room temperature water for concrete ages above three days. Compressive strength testing is conducted in dry conditions for 24 hours before testing [33]. Process indicators are obtained from the concrete hardening process, concrete compressive strength classification and strength development, and crushing/collapse patterns of SCC and normal concrete [34, 35]. Stage 7 analyzed the relationship between local rock strength and the maximum concrete compressive strength achieved according to the mix design, obtained strength development against concrete age, and classified concrete collapse types. Based on these characteristics, the indicators are local rock potential as a mixed material for high-quality concrete production with the SCC process [30, 31, 36]. In addition, a classification of rock strength for concrete structural output is obtained [32, 33].

3. RESULTS AND DISCUSSIONS

3.1 Physical properties of local aggregates

Based on the results of testing the physical properties of local aggregates, the specific gravity of Quarry 1 = 2.713, Quarry 2 = 2.645, Quarry 3 = 2.510 and Quarry 4 = 2.576 was obtained. The specific gravity of the four quarries has met the specifications of ASTM C 127 [18] and, according to Neville [22], is 2.50 - 2.80.

Based on the results of testing the mud content of local stone in the Quarry 3 quarry, the results were 0.867% and met ASTM C136 [25]. As shown in Table 2, Quarry 1, Quarry 2, and Quarry 4 did not meet the maximum permissible coarse aggregate mud content value of <1%.

The water content of the four quarries has met ASTM C556-89, with the permissible coarse aggregate water content value of 0 - 3%.

The aggregate absorption from 4 quarries did not meet the ASTM C127 [23] specifications, which state that the absorption value is 2% - 7%.

Table 2. Result of local aggregates physical properties

Physical Properties	Quarry 1	Quarry 2	Quarry 3	Quarry 4
Specific gravity	2.713	2.645	2.510	2.576
Volume weight (gr/cm^3)	2.600	2.643	2.576	1.328
Sludge levels (%)	5.260	4.359	0.867	8.130
Water content (%)	0.600	0.736	0.750	5.260
Absorption (%)	0.738	0.908	1.042	1.506

3.2 Classification and compressive strength of local rocks

Based on the aggregate wear test results on quarry 2 samples as shown in Table 3, a relatively large value of 34.72% was obtained, while quarry one samples had the smallest value of 29.48. The abrasion value on the aggregate is related to the compressive strength value. The greater the abrasion value produced, the lower the compressive strength value produced. The aggregate wear study from 4 quarries has met the specifications of <40%.

Table 3. Local rock abrasion

Testing	Quarry 1	Quarry 2	Quarry 3	Quarry 4
Abrasion (%)	29.48	34.72	34.14	31.75

3.2.1 Mechanical properties of stone

After testing the physical properties of the stone samples before and after they were cut into 5 cm cubes, the mechanical properties of the stone were tested by conducting a compressive strength test.

3.2.2 Mechanical properties of 5 cm stone

After the stone was cut into a cube shape measuring 5 x 5 x 5 cm, the compressive strength of the stone was tested. So that it can be written using the formula according to SNI 1974-2011 [30].

Based on Table 4 From the results of the compressive strength of the rock that can be used as coarse aggregate for structural concrete with the SCC method is the location of Quarry 4, where its strength is greater than the compressive strength of concrete 50 MPa. For Quarry 3, the rock strength is between 30 - 50 MPa, so a typical concrete sample is made. While Quarry 1 and Quarry 2 have less than 30 MPa, no concrete samples are made because they will produce nonstructural concrete (Less than 17 MPa) [37, 38].

Table 4. Compressive strength test of rock (5 cm Cube)

Sample Code	Dimensions (cm)	Compressive Strength (MPa)	Average (MPa)
	5.25	18.21	
	5.29	26.98	
Quarry 1	5.11	30.25	25.15
	5.15	24.96	
	5.23	25.34	
	5.01	26.14	
	5.23	17.04	
Quarry 2	5.09	34.74	25.97
	5.20	24.19	
	5.14	27.74	
	5.40	36.80	
	5.20	43.34	
Quarry 3	4.95	40.24	42.05
	5.10	27.76	
	4.90	62.10	
	5.50	40.23	
	5.00	91.32	
Quarry 4	5.00	67.20	64.89
	5.00	66.96	
	5.00	58.76	

3.3 Regional geological conditions of local rock samples

Based on the regional geological map of the Samarinda sheet on a scale of 1:250,000, the location of rock sampling is in Quarry 3 and Quarry 4, including the Pamaluan formation (Figure 1). The Pamaluan Formation shown in Figure 2 is composed of quartz sandstone with inserts of claystone, shale, limestone, and siltstone that are very well layered. The research location and rock samples in the research conducted are sedimentary rocks that are identified as limestone [39]. The limestone based on the regional geological map has a gray color, is solid, has medium-coarse grains, has a layered structure in some places and contains large foraminifera fossils. The Pamaluan Formation is the oldest rock exposed on the Samarinda Sheet Geological Map, and the upper part of the Pamaluan Formation has a finger-like relationship with the younger rocks above it, namely the Bebulu Formation [40]. The thickness of the rock in this formation ranges from 2000 m, and the age of the Pamaluan Formation is Oligocene to early Miocene.

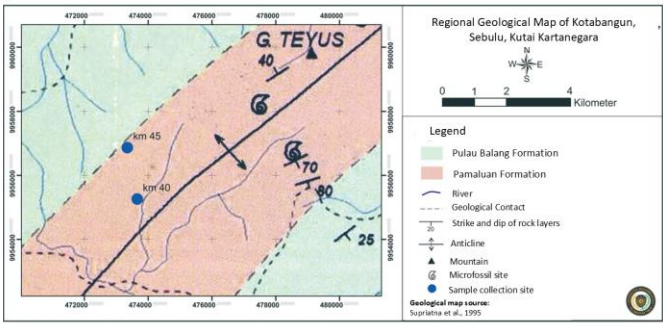
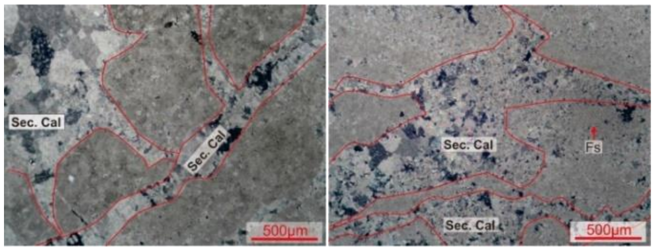


Figure 2. Regional geological map of research area

Based on macroscopic observations, the limestone in the Quarry 3 and Quarry 4 samples is gray and solid, with a grain size generally in sand. The rock reacts with HCl, which indicates that the rock is composed of calcite minerals. In the rock samples, fractures are also filled with secondary calcite minerals. Petrographic analysis was carried out on two limestone samples, namely in the Quarry 3 and Quarry 4 samples, showing that the rock is composed of calcite minerals and tends to be massive. Cracks or fractures in the rock filled with secondary calcite minerals can also be observed in microscopic appearance (Figure 3). The presence of joints or fractures as discontinuity planes in the rock can be weak planes in the rock and reduce the strength of the rock [41].



(a) (b)

Figure 3. Results of microscopic analysis of limestone in samples (a) Quarry 3 and (b) Quarry 4

3.4 Comparison with rock samples from Palu

The rocks used as construction materials originating from Palu have different characteristics. Analysis shows that the stones are included in the type of igneous rocks, which, based on the IUGS classification, are called andesite [42]. Megascopically, the stones have a slight color, aphanitic texture (minerals are so minor that they cannot be observed directly), and massive structure. In microscopic observations, the andesite is entirely composed of minerals with a mineral composition predominantly plagioclase, pyroxene, and hornblende, and quartz minerals are present in smaller amounts (Figure 4.) Microscopic results of rock samples from Palu show that the rocks are andesite igneous rocks. Mineral composition: Pl: plagioclase, Px: pyroxene, Hb: hornblende, and Qz: quartz.

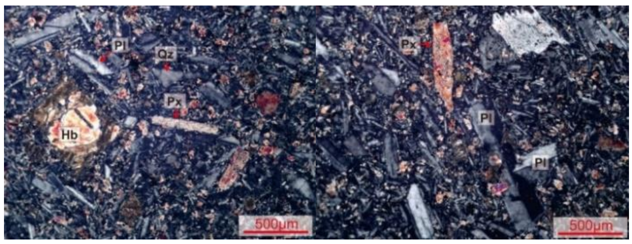


Figure 4. Microscopic results of rock samples from Palu

3.5 Slump flow result

The slab for Quarry 3 concrete is obtained at 100 - 140 mm, according to the planned standard. Meanwhile, the slump flow for quarry 4 concrete ranges from 510 - 550 mm according to the SCC concrete standard.

3.6 Compressive strength of concrete

3.6.1 Local stone quarry 3

The average compressive strength of Quarry 3 aggregate concrete is 22.838 MPa as shown in Table 5.

Table 5. Standard deviation (Quarry 3)

No.	Compressive Strength (Xi)	Xi - $\bar{X}$	(Xi - $\bar{X}$)^2
1	14.006	-8.832	78.007
2	13.067	-9.771	95.475
3	13.706	-9.132	83.392
4	15.935	-6.903	47.655
5	21.382	-1.456	2.120
6	18.254	-4.584	21.014
7	30.466	7.628	58.193
8	29.199	6.361	40.467
9	33.809	10.971	120.373
10	27.451	4.613	21.284
11	27.067	4.229	17.883
12	26.693	3.856	14.865
13	24.103	1.265	1.600
14	22.881	0.043	0.002
15	24.549	1.712	2.930
∑Xi	**342.567**		**605.260**

∑Xi = Total compressive strength of test specimens
n = Lots of data

$$\sum Xi = 342.567$$
$$n = 15$$
$$\sum (Xi - X)^2 = 605.260$$

Average compressive strength

$$\bar{X} = \frac{\sum Xi}{n}$$
$$\bar{X} = \frac{342.567}{13} = 22.838$$

Standard Deviation (s)

$$s = \sqrt{\frac{\sum(Xi - \bar{X})^2}{n-1}}$$
$$s = \sqrt{\frac{605.260}{14}} = 6.575$$

Achieved compressive strength:

$fc' = \bar{X} \pm (1.16 \text{ x s})$

Upper limit fc' $= \bar{X} + (1.16\ x\ s)$
$= 22.838 + (1.16\ x\ 6.575)$
= 30.465 MPa

Lower limit fc' $= \bar{X} - (1.16\ x\ s)$
$= 22.838 - (1.16\ x\ 6.575)$
= 15.211 MPa

The average compressive strength of concrete is 22.838 MPa while stone is 42.05 MPa, with concrete strength achieved only 54.31% of the strength.

3.6.2 Local stone quarry 4

The average compressive strength of Quarry 4 aggregate concrete is 30.852 MPa as shown in Table 6.

Table 6. Standard deviation (Quarry 4)

No.	Compressive Strength (Xi)	Xi - $\bar{X}$	(Xi - $\bar{X}$)^2
1	24.255	-6.597	43.519
2	23.936	-6.915	47.822
3	24.637	-6.215	38.623
4	29.732	-1.119	1.253
5	35.529	4.677	21.874
6	31.911	1.059	1.122
7	35.134	4.282	18.336
8	41.452	10.601	112.372
9	34.255	3.403	11.581
10	26.573	-4.278	18.305
11	25.401	-5.450	29.707
12	38.331	7.480	55.943
13	24.943	-5.909	34.916
14	31.490	0.639	0.408
15	29.554	-1.298	1.684
16	37.975	7.123	50.735
17	37.108	6.257	39.145
18	34.013	3.161	9.992
19	29.350	-1.501	2.254
20	28.318	-2.533	6.417
21	23.987	-6.864	47.120
∑Xi	**647.885**		**593.129**

Total compressive strength of test specimens ∑Xi = 647.855
Lots of data, n = 21
Amount of data, $\sum(\text{Xi} - \text{X})^2 = 593.129$
Average compressive strength ($\bar{\text{X}}$) = 30.852
Standard Deviation (s) = 5.466

Achieved compressive strength:

Upper limit fc' $= \bar{\text{X}} + (1.08 \text{ x s})$
$= 30.852 + (1.08 \text{ x } 5.466)$
= 36.733 MPa

Lower limit fc' $= \bar{\text{X}} - (1.08 \text{ x s})$
$= 30.852 - (1.08 \text{ x } 5.466)$
= 24.970 MPa

The average compressive strength of concrete is 30.852 MPa while the stone is 64.89 MPa with the concrete strength achieved only 47.55% of the stone strength.

3.7 Development of concrete strength

Based on the concrete compressive strength data according to its age from Table 4 and Table 5, it is made into a strength development graph in Figure 5. The graph shows that the concrete experiences fluctuating strength development and generally experiences decreasing strength from 14 to 28 days. Meanwhile, for high-quality SCC concrete, its strength increases from 28 days to 56 days and decreases again at 90 days. Thus, the strength of this local stone concrete shows a decrease at 28 days for standard concrete and 90 days for high-quality SCC concrete. While the strength of concrete using ex-hammer stone shows that the development of concrete strength is increasing according to the increase in concrete age [22], this indicates that the local rock used does not meet the standard of concrete strength development. This condition is greatly influenced by the strength of the stone, which is the main element that forms the strength of concrete. Quarry stones 3 and 4 are types of limestone, and there are many fracture fields, so this stone is more accessible to break or split in concrete when receiving loads. In addition, the water for the cement hydration process at the age of 21 and 28 days begins to be partially absorbed by the stone, filling the fracture field so that the stone becomes weaker in strength. The variation in the condition of this stone makes the strength of the concrete low and fluctuates after the age of the concrete is 14 days.

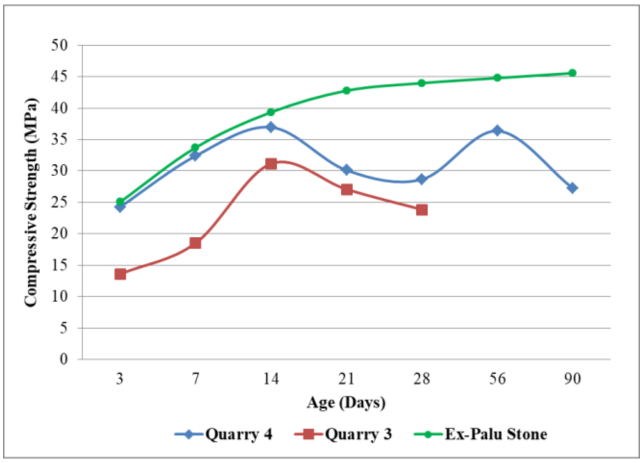


Figure 5. Concrete compressive strength development graph

3.8 Concrete collapse patterns

The collapse pattern generally forms columnar [30]. This condition is predominantly influenced by coarse aggregate and mortar. Following the sedimentary rock type with many weak areas, it first experiences destruction [41]. The development of concrete strength that decreases is influenced by rock fractures that absorb water from the concrete mixture so that over time, the fractures become weak and the weak areas become more extensive. The evidence causes 28-day-old concrete and 90-day-old high-quality SCC concrete to experience a decrease in strength, as shown in Table 7.

Figure 6 above shows that the coarse aggregate is more broken or split, which indicates the rock's lower strength compared to the strength of the mortar and the bond between the rock and the mortar. The strength of coarse aggregate is the main element that forms the strength of concrete. If the strength of the stone is low, it can significantly impact the concrete's strength and durability [22]. In addition, the strength of concrete depends on the physical properties of the coarse aggregate, where most of the concrete's volume is filled by the coarse aggregate, which can affect its performance [5].

Table 7. Concrete collapse patterns

No.	Concrete Age	Collapse Patterns
1	3 days	
2	7 days	
3	14 days	

No.	Concrete Age	Collapse Patterns
4	21 days	
5	28 days	
6	56 days	
7	90 days	

Figure 6. Concrete compression test result: Riven stone (yellow circle) & Detached stone from mortar (red circle)

4. CONCLUSIONS

Local stones from 4 quarry locations in Kutai Kertanegara Regency have a strength of between 25.15 - 64.89 MPa.

Local quarry 3 and quarry 4 stones have a strength contribution in the concrete mixture of approximately 50% of the strength of the rock. Therefore, this local stone can be recommended for constructing concrete buildings with a low risk level such as residential buildings up to 2 floors, environmental roads, and drainage cast on site (non-precast/precast).

This is evident from the observations of rock geology, where there is a non-uniform rock content in a chunk or aggregate grain and cracks in the rock that are quite dominant as weak planes so that they produce fluctuating strength in reducing the strength of the concrete.

ACKNOWLEDGMENT

Financial support is provided by Majelis Diktilitbang PP Muhammadiyah for funding this research with Contract

Number 0258.122/I.3/D/2024. The funding made this research possible, and it is greatly appreciated.

REFERENCES

[1] Pemerintah, R.I. (2022). Undang-undang nomor 3 tahun 2022 tentang ibu kota negara (UU IKN). Jakarta. https://peraturan.bpk.go.id/Details/198400/uu-no-3-tahun-2022.

[2] Prianggodo, C.A. (2023). Pembangunan ikn sebagai mercusuar strategis (kajian kritis dalam perspektif sustainable development). Jurnal Pemerintahan Dan Politik, 8(1). https://ejournal.uigm.ac.id/index.php/PDP/article/view/2898.

[3] Ain, M.I.M., Soeparlan, A.A. (2020). Pengaruh penggunaan batu laterit sebagai alternatif pengganti agregat kasar pada kekuatan beton. Journal Dynamic Saint, 4(2): 869-875. https://doi.org/10.47178/dynamicsaint.v4i2.890

[4] Asnan, M.N., Noor, R., Azzahra, R. (2019). Utilization of styrofoam-matrix for coarse aggregate to produce lightweight concrete. International Journal of Engineering & Technology, 8(1.1): 207-212. https://www.sciencepubco.com/index.php/ijet/article/view/24661

[5] Abegaz, G.T., Khan, I., Legese, A.M. (2020). Investigating the effects of coarse aggregate physical properties on strength of C-25 concrete. American Journal of Engineering and Technology Management, 5(5): 84-90. https://doi.org/10.11648/j.ajetm.20200505.12

[6] Rai, M.A., Kramadibrata, S., Wattimena, R.K. (2014). Mekanika batuan. Bandung: Penerbit ITB, 19-20. https://labgeomekanik.wordpress.com/wp-content/uploads/2020/02/buku-mekanika-batuan-made-astawa-dkk.pdf.

[7] Herastuti, K.A. (2016). Studi analisis pengaruh variasi ukuran butir batuan terhadap sifat fisik dan nilai kuat tekan. ReTII. https://journal.itny.ac.id/index.php/ReTII/article/view/516.

[8] Kaushik, S., Bhan, P.S. (2024). Chemical modifications of recycled concrete aggregate. International Journal of Emerging Science and Engineering (IJESE), 12. https://www.ijese.org/portfolio-item/G990013070624/

[9] Tam, V.W., Soomro, M., Evangelista, A.C.J. (2024). Concrete and aggregates. In Handbook of Recycling, pp. 417-428. https://doi.org/10.1016/B978-0-323-85514-3.00002-6

[10] Manasa, S., Udaybhaskar, M., Kumar, G.N. (2019). Performance of recycled aggregate concrete for M25 grade concrete. International Journal of Engineering and Advanced Technology (IJEAT), 9(2): 4694-4700. http://www.doi.org/10.35940/ijeat.B5130.129219

[11] Onyechere, I.C., Anya, C.U., Chukwu, I.J., Nwakwasi, N.L., Njoku, C.F. (2024). Influence of coarse aggregate grading types on the cost of concrete. Nigerian Journal of Technology, 43(2). https://doi.org/10.4314/njt.v43i2.4

[12] Kim, J. (2021). Construction and demolition waste management in Korea: Recycled aggregate and its application. Clean Technologies and Environmental Policy, 23(10): 2223-2234. https://doi.org/10.1007/s10098-021-02177-x

[13] Pradhan, P., Panda, S., Parhi, S.K., Panigrahi, S.K. (2022). Variation in fresh and mechanical properties of GGBFS-based self-compacting geopolymer concrete in the presence of NCA and RCA. Materials Today: Proceedings, 62: 6348-6358. https://doi.org/10.1016/j.matpr.2022.03.337

[14] Ghosh, A.H., Das, B.B. (2019). Implication of concrete with chemical admixture cured in low temperature on strength, chloride permeability and microstructure. In Sustainable Construction and Building Materials: Select Proceedings of ICSCBM 2018. Springer Singapore, pp. 287-298. https://doi.org/10.1007/978-981-13-3317-0_26

[15] Situmorang, R.N., Saelan, P. (2021). Aplikasi modified method SNI 03-2834-2000 pada campuran self compacting concrete. RekaRacana: Jurnal Teknil Sipil, 7(2): 142. https://ejurnal.itenas.ac.id/index.php/rekaracana/article/view/6621.

[16] Aljumaili, M.W., Beddu, S.B., Itam, Z., Their, J.M. (2024). Investigating the influence of recycled coarse aggregate and steel fiber on the rheological and mechanical properties of self-compacting geopolymer concrete. Annales de Chimie - Science des Matériaux, 48(2): 197-206. https://doi.org/10.18280/acsm.480206

[17] Prasetia, I., Krasna, W.A. (2020). Kajian pemanfaatan agregat lokal kalimantan selatan sebagai material perancangan beton normal. Buletin Profesi Insinyur, 3(2): 77-82. https://doi.org/10.20527/bpi.v3i2.71

[18] Safarizki, H.A., Marwahyudi, M., Pamungkas, W.A. (2021). Beton ramah lingkungan dengan abu sekam padi sebagai pengganti sebagian semen pada era new normal. Jurnal Riset Rekayasa Sipil, 4(2): 63-67. https://doi.org/10.20961/jrrs.v4i2.42978

[19] Abdi, F.N., Alkas, M.J., Setiawan, A. (2019). Uji Kelayakan Agregat Muara Wahau, Santan, Senoni, Batu Besaung sebagai Material Subbase. Seminar Nasional Rekayasa Tropis 2024, 2(1): 148-156.

[20] Surya, A., Purnamasari, E. (2018). Kajian efektifitas kuat tekan beton mutu tinggi Fc’35 mpa dengan menggunakan agregat lokal split birayang kabupaten hulu sungai tengah. Jurnal Kacapuri: Jurnal Keilmuan Teknik Sipil, 1(1): 22-31. https://doi.org/10.31602/jk.v1i1.1436

[21] Resti, A., Hidayat, M., Kamil, I., Samarinda, P.N., Timur, K., Beton, K.T., Beton, K.L. (2021). P-25 perbandingan kuat tekan dan lentur beton terhadap agregat palu comparison of concrete compressive and flexible strength using aggregate in west kutai toward palu. Prosiding Snitt Poltekba, 5: 178-184. https://jurnal.poltekba.ac.id/index.php/prosiding/article/view/1360

[22] Neville, A.M. (2011). Properties of concrete. Harlow: Pearson Education Limited. https://www.scribd.com/document/350943966/Properties-of-Concrete-by-a-m-Neville

[23] ASTM C127-15, 2015. Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate. ASTM International, United States. https://cdn.standards.iteh.ai/samples/90571/ce883b9768bd463a99ef0ff45e620ef5/ASTM-C127-15.pdf.

[24] ASTM C128-15, 2015. Standard Test Method for Density, Relative Density (Specific Gravity), and

Absorption of Fine Aggregate. ASTM International, United States. https://dl.azmanco.com/standards/ASTM-C/ASTM-C-Series-Full/C/C128.pdf.

[25] ASTM C136/C136M-14, 2014. Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. ASTM International, United States. https://cdn.standards.iteh.ai/samples/90444/6e7c97c5d16c49ed9870e7a2224821f1/ASTM-C136-C136M-14.pdf.

[26] ASTM C39/C39M-14, 2018. Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. ASTM International, United States. https://cdn.standards.iteh.ai/samples/87037/65b36479bda54b399241aa16b3c5af1a/ASTM-C39-C39M-14.pdf..

[27] ASTM D4791-10, 2010. Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate. ASTM International, United States. https://doi.org/10.1520/D4791-19.

[28] ACI Committee 211, 2008. Guide for Selecting Proportions for High-strength Concrete Using Portland Cement and Other Cementitious Materials. AmericanConcrete Institute, United States. https://www.concrete.org/portals/0/files/pdf/previews/211.4r-08web.pdf.

[29] BSN. (2008). SNI 2417-2008 Tentang Cara Uji Keausan Agregrat dengan Mesin Abrasi Los Angeles. Badan Standarisasi Nasional, Indonesia. https://imsippoliban.wordpress.com/wp-content/uploads/2016/03/5368_sni-2417_2008.pdf.

[30] BSN. (2011). SNI 1974-2011 Tentang Cara Uji Kuat Tekan Beton Dengan Benda Uji Silinder. Badan Standar Nasional Indonesia. https://spada.uns.ac.id/pluginfile.php/107120/mod_resource/content/1/sni-1974-2011%20ujinkuat%20tekan%20beton.pdf.

[31] BSN. (2000). SNI 03-6468-2000. Perencanaan Campuran Tinggi dengan Semen Portland dengan Abuterbang. Standar Nasional Indonesia. https://www.scribd.com/document/422666023/sni-03-6468-2000-pdf.

[32] BSN. (2008). SNI 1972-2008 Tentang Cara Uji Slump Beton. Badan Standar Nasional Indonesia. https://lauwtjunnji.weebly.com/uploads/1/0/1/7/10171621/sni-1972-2008_cara_uji_slump_beton.pdf.

[33] Arkis, Z. (2020). Pengaruh metode perawatan beton terhadap kuat tekan beton normal. Jurnal Teknik Sipil Institut Teknologi Padang, 7(2): 5-5. https://doi.org/10.21063/jts.2020.V702.05

[34] Allali, I., Belagraa, L., Beddar, M., dan Kessal, O. (2022). Characterization and modeling using non-destructive test (NDT) and experimental design methods of a self compacting concrete (SCC) based on mineral additions. Jurnal: Annales de Chimie: Science des Materiaux, 46(2): 85-94. https://doi.org/10.18280/acsm.460204

[35] Jebri, N., Rahmouni, Z.E.A., Djiab, N.E., dan Haffaf, E. (2022). The effect of the use of residues (metallic shavings) in the formulation of self-compacting concrete in fresh and hardened state. Jurnal: Annales de Chimie: Science des Materiaux, 46(6): 301-306. https://doi.org/10.18280/acsm.460603

[36] Li, Z., Liu, J., Xiao, J., Zhong, P. (2020). Internal curing effect of saturated recycled fine aggregates in early-age mortar. Cement and Concrete Composites, 108: 103444. https://doi.org/10.1016/j.cemconcomp.2019.103444

[37] BSN. (2019). SNI 2847-2019 Tentang Persyaratan Beton Struktural Untuk Bangunan Gedung. Badan Standar Nasional Indonesia. https://tekonsipil.sv.ugm.ac.id/wp-content/uploads/sites/938/2020/01/SNI-2847-2019-Persyaratan-Beton-Struktural-Untuk-Bangunan-Gedung-1.pdf.

[38] ACI Committee 318, 2015. Building Code Requirements for Structural Concrete (ACI 318M-14) and Commentary (ACI 318RM-14). American Concrete Institute,United States. https://www.concrete.org/Portals/0/Files/PDF/Previews/318M-14_preview.pdf.

[39] Tucker, M.E., Jones, S.J. (2023). Sedimentary petrology. Fourth edition. Wiley, Hoboken, NJ. https://www.wiley.com/en-ae/Sedimentary+Petrology%2C+4th+Edition-p-9781118786499.

[40] Supriatna, S., Sukardi, S., Rustandi, E. (1995). Peta geologi lembar samarinda kalimantan skala 1:250000. Bandung: Badan Geologi. https://opac.perpusnas.go.id/DetailOpac.aspx?id=559498#.

[41] Bewick, R.P., Kaiser, P.K., Amann, F. (2019). Strength of massive to moderately jointed hard rock masses. Journal of Rock Mechanics and Geotechnical Engineering, 11: 562-575. https://doi.org/10.1016/j.jrmge.2018.10.003

[42] Le Bas, M.J., Streckeisen, A.L. (1991). The IUGS systematics of igneous rocks. Journal of the Geological Society, 148: 825-833. https://doi.org/10.1144/gsjgs.148.5.0825

NOMENCLATURE

n	Lots of data
$\sum Xi$	Total compressive strength of test specimens, MPa
$(\bar{X})$	Average Compressive Strength, MPa
s	Standard Deviation
fc'	Compressive Strength, MPa