Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil
Vol. 9 No. 1 (2025) pp. 73 – 78
DOI: http://dx.doi.org/10.32832/komposit.v9i1.16456

ISSN: 2615-3513
e-ISSN: 2655-934X

The Effect of Coconut Fibre on the Compressive and Tensile Strength of Geopolymer Concrete

Irsyad Burhanudin[1], Agustinus Agus Setiawan*[2]

[1] Civil Engineering Dept., Universitas Pembangunan Jaya
Email: [1]irsyad.burhanudin@student.upj.ac.id; [2]agustinus@upj.ac.id;

ABSTRACT

This research aims to evaluate the impact of adding coconut fibre on the compressive and tensile strengths of geopolymer concrete. The study utilized geopolymer concrete composed of a mixture of fly ash and coconut coir fibre. The research variables included the percentage of coconut coir fibre in the geopolymer concrete mix, namely 0%, 0.25%, 0.50%, and 1%. Data collection involved the fabrication of geopolymer concrete, testing of coarse and fine aggregates, and aggregate sieve analysis. The results of this study are expected to provide insights into the potential of coconut fibre in enhancing the quality of geopolymer concrete. The analysis revealed that the addition of coconut fibre can increase the tensile strength of geopolymer concrete, with a peak enhancement of 32.52% observed at the optimal proportion of 0.5%. Conversely, at 1%, a decrease of 4.64% in tensile strength was noted. Furthermore, the compressive strength of geopolymer concrete experienced improvement up to a proportion of 0.5%, showing an increase of 48.79%. However, at 1%, the tensile strength decreased by 12.43%. Therefore, the 0.5% proportion of coconut fibre is considered optimal for enhancing both tensile and compressive strengths of geopolymer concrete. This research contributes to expanding the understanding of coconut fibre usage in geopolymer concrete and provides recommendations regarding the optimal proportion of coconut fibre in the geopolymer concrete mix.

Key words: *geopolymer concrete, fly ash, tensile strength, compressive strength, coconut fibre.*

Submitted:	**Reviewed:**	**Revised**	**Published:**
May 02nd 2024	June 20th 2024	June 28th 2024	February 07th 2025

INTRODUCTION

The use of geopolymer concrete as an environmentally friendly construction solution and highlights the role of coconut fibre in improving the mechanical properties of geopolymer concrete. Geopolymer concrete, which mainly consists of pozzolan, is considered an alternative that can reduce environmental impacts compared to conventional concrete that uses Portland cement (Sandya, Y., 2019). However, even though it has advantages in reducing carbon emissions, geopolymer concrete has weaknesses, especially in its tensile strength.

The background illustrates that conventional concrete, which mostly uses Portland cement, contributes significantly to global carbon dioxide emissions while geopolymer concrete can reduce carbon emissions by 56.02% (Setiawan, A., 2023). However, the main problem with geopolymer concrete is its relatively low tensile strength compared to compressive strength. To overcome this, previous research shows that adding fibre to the concrete mix can increase strength and structural integrity.

Coconut fibre is the focus of this research as a potential additional material to improve the mechanical properties of geopolymer concrete. By utilizing coconut fibre waste, this research aims to design a geopolymer concrete mixture that combines the superior properties of geopolymer concrete and additional strength from coconut fibre. This research provides a strong foundation for further exploration regarding the potential use of natural fibres in geopolymer concrete, especially in the Indonesian context.

Coconut coir fibre is an attractive alternative as an addition to geopolymer concrete because of its natural and sustainable properties. These fibres have special characteristics such as high tensile strength, the ability to resist microscopic cracks, and a rough surface. This advantage allows coconut fibre to function as a crack barrier in geopolymer concrete, preventing crack propagation, and can significantly increase the tensile strength of concrete.

The addition of coconut fibres to the concrete mixture with different percentages and fibre lengths can increase the compressive strength value of the concrete from the initial compressive strength (Ardy, R., 2017). Mechanical testing shows an increase in the compressive strength value of concrete, and coconut fibre is proven to reduce the potential for cracking. This indicates that coconut fibre can play an important role in improving the quality and performance of geopolymer concrete (Sahrudin, 2016).

Tensile strength has an important role in preventing cracks from occurring due to changes in water content and temperature. Tensile strength testing is generally carried out in the context of highway and airport construction (Murdock, 1991)

The problem formulation in this journal includes designing a geopolymer concrete mixture with coconut fibre, analyzing the influence of coconut fibre on the mechanical properties of geopolymer concrete, and determining the optimal percentage of coconut fibre in the mixture. Through three research questions, the author wants to overcome existing technical obstacles and contribute new understanding in the development of sustainable construction materials.

The research objectives include designing a geopolymer concrete mixture with coconut fibre, analyzing the effect of coconut fibre on the mechanical properties of geopolymer concrete, and determining the optimal percentage of coconut fibre. Thus, it is hoped that this research can make a significant contribution to the development of construction materials that are more environmentally friendly and sustainable.

The benefits of the research involve providing information regarding the optimal percentage of adding coconut fibre to geopolymer concrete, increasing the compressive strength of geopolymer concrete with coconut fibre, and the potential for waste processing for the benefit of Micro, Small and Medium Enterprises (UMKM in Indonesian abbreviation). Thus, the results of this research are not only useful for the academic world, but also have a positive impact on the construction industry and sustainable economy.

Meanwhile, problem limitations bind this research by focusing on concrete quality with compressive strength f'_c = 35 MPa, using cylindrical specimens of 10 × 20 cm, and emphasizing the use of alkali activators NaOH and Na_2SiO_3 with a molarity of 8. In addition, this research limiting the age of concrete work to 7, 14 and 28 days and using fly ash sourced from PLTU Lontar.

RESEARCH METHOD

All research processes are carried out in the PT Jaya Beton Indonesia laboratory which refers to the Indonesian National Standards (SNI). The planned compressive strength value of concrete test specimens is f'_c = 35 MPa with a coconut fibre percentage of 0%, 0.25%, 0.5%, and 1%. The variation code for coconut fibre as an added ingredient is BGSK 0, BGSK 0.25, BGSK 0.5, BGSK 1 as shown in Table-1. Meanwhile, the size of the test object used in this research is a concrete cylindrical test object with a diameter of 10 cm × 20 cm high. All material physical properties testing is carried out in accordance with Indonesian National Standards (SNI) including testing of fine aggregate and coarse aggregate. Table 1 shows standards for testing coarse aggregate and fine aggregate.

Table 1. Standard Testing for Aggregate

Type of test	SNI	Coarse Agg.	Fine Agg.
Specific Gravity	03-1969-2008	≥ 2.5	≥ 2.5
Unit Weight	03-4804-1998	≥ 1.4	≥ 1.4
Materials finer than 0.075 mm	03-4142-1996	≤ 1.0	≤ 1.0
Absorption	03-1996-2008	≤ 3.0	≤ 3.0
Abration	2417-2008	≤ 40	
Fineness Modulus	04-1989-F	6.0-7.1	1.5-3.8

The manufacture of test objects in this research refers to SNI-03-2834-2000 concerning procedures for selecting mixtures for normal concrete. Meanwhile, the concrete compressive strength test refers to SNI 1974-2011, and the tensile splitting test refers to SNI 03-2491-2002.

Figure 1. Coconut fiber preparation process

The L/D ratio, which is the ratio between fibre length and fibre diameter, has a significant influence on the characteristics of fibrous concrete. In this study, coconut fibre was cut to a length of 15 mm, with a fibre diameter of 0.3 mm, so that the L/D ratio = 15/0.3 = 50. The optimal length-diameter ratio for concrete coconut fibre reinforcement is 50-100. At this ratio, the fibres can spread well into the concrete cavity, resulting in a significant increase in crack resistance (Ahmad, W., 2020). The required amount of fibre weight per cylindrical mold is calculated using the equation

Jurnal Komposit: Jurnal Ilmu-ilmu Teknik Sipil
Vol. 9 No. 1 (2025) pp. 73 – 78
DOI: http://dx.doi.org/10.32832/komposit.v9i1.16456

ISSN: 2615-3513
e-ISSN: 2655-934X

$$\text{Weight} = p \times \text{vol of mold} \times \rho \qquad (1)$$

Where :

p = Percentage of coconut fibre (%)

vol. of mold = $1/4 \times \pi \times 0{,}1^2 \times 0{,}2$ (m^3)

ρ = fibre Density (= 1.150 kg/m^3)

Table-2 provide the need of fibre weight per cylindrical mold 10 cm × 20 cm, figure-2 shows the flowchart of the research project, and figur 3 shows the materials preparation stages.

Table 2. Fibre weight per cylindrical mold

Specimen code	% Fibre	Fibre Volume (m^3)	Fibre weight (gram)
BGPSK0	0		
BGPSK 0.25	0,25	$3{,}93.10^{-6}$	4,51
BGPSK 0.5	0,5	$7{,}85.10^{-6}$	9,03
BGPSK 1	1,0	$15{,}70.10^{-6}$	18,06

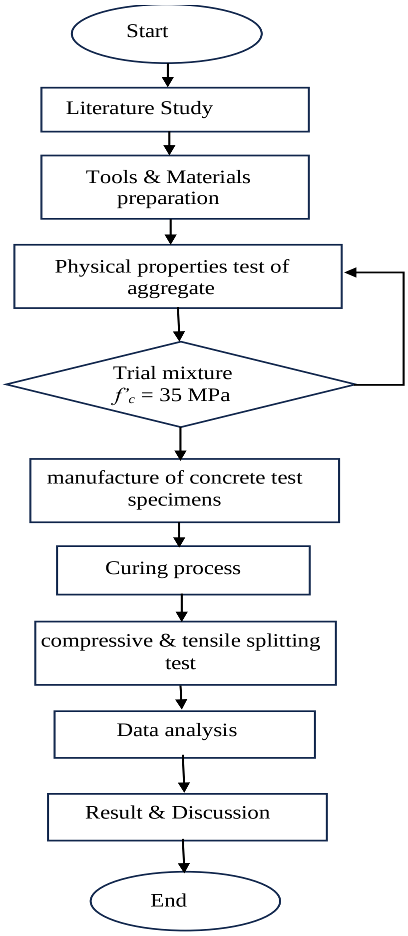

Figure 2. Research flowchart

Figure 3. Materials preparation, mixture and curing process

Table-3 shows the physical properties of fine and coarse aggregate, while Table-4 shows the mixture composition of geopolymer concrete per m^3.

Table 3. Physical properties of aggregat

Type of test	Coarse Agg.	Fine Agg.
Specific Gravity	2.54	2.52
Unit Weight	1.44	1.44
Materials finer than 0.075 mm	0.80	3.75
Absorption	2.86	2.89
Abration	20.67	-
Fineness Modulus	7.78	3.23

Table 3. Geopolymer Concrete Mixture Per 1m^3

Material	Weight	Units
Coarse Aggregate	1074,17	kg
Fine Aggregate	776,21	kg
Fly ash	386,71	kg
NaOH	48,34	kg
Na_2SiO_3	145,02	Kg
Water	36,01	Liter

RESULT AND DISCUSSION

In this research, a series of tests were carried out, including determining the specific gravity, compressive strength and tensile splitting strength of geopolymer concrete.

Unit Weight

Before carrying out a compressive strength test, the concrete must be weighed first. This weighing is carried out to obtain information regarding the weight of the concrete to be used. From the weight test results, specific gravity growth data for each coconut fibre composition was obtained, as shown in Figure 2.

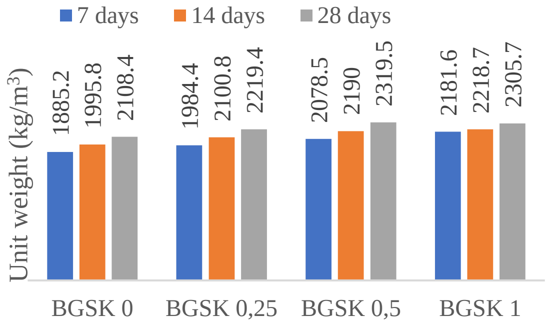

Figure 4. Unit weight of geopolymer concrete with coconut fibre

From Figure-1 it can be seen that increasing the fibre percentage in geopolymer concrete causes an increase in concrete mass in all hardening periods tested. The optimum specific gravity was recorded in 28 day old concrete with a coconut fibre content of 1%. The density of concrete after reaching 28 days of age with variations in coconut fibre of 0%, 0.25%, 0.5%, and 1% is 2180.4 kg/m^3, 2219.4 kg/m^3, 2349.95 kg/m^3, and 2319.5 kg, respectively. /m^3. Even though at BGSK 1 the specific gravity decreased by 1.29% from the highest specific gravity, namely BGSK 0.5. From these data, it can be concluded that the addition of coconut fibre from 0% to 0.5% resulted in an increase in concrete specific gravity of 7.74%.

Compressive Strength Test

From the test results shown in Figure 3, it can be seen that the compressive strength of geopolymer concrete increases along with increasing the proportion of coconut fibre. However, the target f'_c = 35 MPa was not achieved by the four types of concrete mix. The concrete mixture with the highest compressive strength was achieved by BGSK 0.5 (coconut fibre 0.5%) with a concrete age of 28 days of 29.97 MPa, a difference of 16.78% from the design compressive strength. For BGSK 0.25 (coconut fibre 0.25%) the compressive strength was achieved at 22.96 MPa, a difference of 34.4% from the design compressive strength. Meanwhile, BGSK 1 (1% coconut fibre) experienced a decrease of 10.33% from the highest compressive strength, namely BGSK 0.5. BGSK 0.5 is also the mixture proportion with the highest average, namely 25.11 MPa. Thus, it can be concluded that the optimal mixture proportion of fibre is 0.5% with a compressive strength of 29.97 MPa at 28 days, an increase of 48.79% from BGSK 0 (without fibre) which has a compressive strength of 20.21 MPa.

The increase in compressive strength of concrete is caused by the role of coconut fibre as a space filler and strengthening concrete structures. Coconut fibre can fill empty spaces in concrete, thereby increasing its density and strength. Apart from that, coconut fibre can also increase the adhesion between cement and aggregate, thereby increasing the compressive strength of concrete.

The results of this research are in line with the results of previous research which stated that the addition of coconut fibre can increase the compressive strength of concrete. For example, research conducted by (Eka, 2019) shows that the addition of coconut fibre in a proportion of 0.5% can increase the compressive strength of geopolymer concrete by 10%. Research conducted by (Hermansyah, 2023) also shows that the addition of coconut fibre in a proportion of 0.5% can increase the compressive strength of geopolymer concrete by 12%.

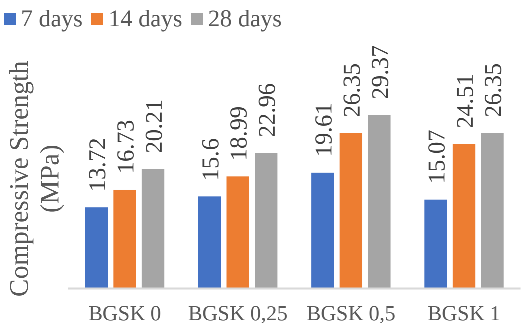

Figure 5. Compressive strength of geopolymer concrete with coconut fibre 7, 14 and 28 days

Although the compressive strength of geopolymer concrete made from fly ash and coconut fibre was not achieved according to the planned compressive strength. It turns out that coconut fibre has extraordinary potential to be used as the main ingredient in creating green concrete. With its unique characteristics, coconut fibre is able to make a positive contribution to mechanical properties. The use of coconut fibre in concrete not only allows for sustainable use of coconut waste, but can also create construction materials that are more environmentally friendly, opening up new opportunities in sustainable development innovation. Even though compressive strength is not achieved, coconut fibre can be made into green concrete.

Concrete Tensile Strength Test

One of the main advantages of concrete is its ability to withstand high compressive stress. However, concrete has a brittle nature and generally cannot withstand tensile stress well. The tensile strength of concrete is usually only about 9% to 15% of its compressive strength (Dipohusodo, 1994).

 ISSN: 2615-3513
e-ISSN: 2655-934X

The tensile test of geopolymer concrete reinforced with fibre was carried out to evaluate the concrete's ability to withstand tensile forces. This testing process involves applying a tensile load to a concrete sample until cracks occur. This test was carried out at concrete ages of 7, 14 and 28 days. The test results show that the tensile strength of geopolymer concrete reinforced with fibre increases with the increasing age of the concrete. The tensile strength of geopolymer concrete with coconut fibre increased along with increasing fibre percentage (Figure 4).

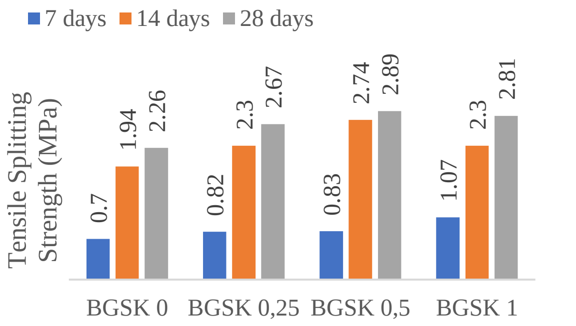

Figure6. Tensile strength of geopolymer concrete with coconut fibre 7, 14 and 28 days

The increase in fibre can also be seen from the test ages at 7 days, 14 days and 28 days. An increase in tensile splitting strength occurs with each increase in fibre percentage. At BGSK 0.25, the tensile splitting strength increased by 18.14% at a concrete age of 28 days. BGSK 0.5 also experienced an increase of up to 8.24% from BGSK 0.25. However, at BGSK 1 (1% fibre percentage), the tensile splitting strength of concrete decreased by 2.77% from a mixture proportion of 0.5%. BGSK 0.5 (0.5% fibre) is the mixture proportion with the highest increase in average tensile strength, namely 32.52% from the 0% coconut fibre mixture proportion and BGSK 0.5 is the mixture proportion closest to the design tensile strength (3.15 MPa), namely 91.86%. At age 28 days (2.89 MPa). It can be seen that the percentage of coconut fibre and the age of the concrete can influence the rate of increase in tensile splitting strength of geopolymer concrete. Apart from that, the addition of coconut fibre has been proven to be able to increase the split tensile strength value of concrete at certain mixture proportions.

The results of this research are in line with the results of previous research which also discussed the effect of adding coconut fibre on the tensile strength of geopolymer concrete. One of them is research conducted by (Setiawan, 2015). This research shows that the addition of coconut fibre in a proportion of 0.5% can increase the tensile strength of geopolymer concrete by 13%. Other research conducted by (Syahyadi, 2022) also shows that the addition of coconut fibre in a proportion of 0.5% can increase the tensile strength of geopolymer concrete by 12%.

CONCLUSSION

The addition of coconut fibre in the geopolymer concrete mixture can be done by varying the length and percentage of coconut fibre from the weight of the mixed concrete. Research shows that adding coconut fibre with a ratio of L/D = 50 and a percentage of coconut fibre of 0%, 0.25%, 0.5 %, and 1% of the weight of mixed concrete can be done with a mixture per m3 consisting of, 386.71 kg fly ash, 145.02 kg Na2SIO3, 48.34 kg NaOH, 1,076.65 kg coarse aggregate, 779.64 kg aggregate smooth and 175.91 liters of water.

The addition of coconut fibre in geopolymer concrete can improve the mechanical properties of concrete, especially compressive and tensile strength. Research shows that the addition of coconut fibre can increase the compressive strength of geopolymer concrete by up to 48.79%, while the tensile strength increases to an optimal proportion of 32.52% compared to geopolymer concrete without fibre.

A coconut fibre percentage of 0.5% can be considered a good choice. This increases the strength and durability of concrete without sacrificing environmental properties. However, these results may vary depending on specific project conditions, so further evaluation is needed according to the needs of the construction project.

REFERENCES

Ardy, R. (2017). Studi Pemanfaatan Serat Serabut Kelapa dengan Variasi Perlakuan Alkali Terhadap sifat Mekanik Beton. *Undergraduate thesis*, Universitas Atma Jaya Yogyakarta. http://e-journal.uajy.ac.id/id/eprint/13188

Ahmad, W., Farooq, S. H., Usman, M., Khan, M., Ahmad, A., Aslam, F., Yousef, R. A., Abduljabbar, H. A., & Sufian, M. (2020). Effect of Coconut Fibre Length and Content on Properties of High Strength Concrete. *Materials (Basel, Switzerland)*, *13*(5), 1075. https://doi.org/10.3390/ma13051075

Dipohusodo, I. (1994). *Struktur Beton Bertulang.* Jakarta: Gramedia. https://gpu.id/book/77873/struktur-beton-bertulang

Hermansyah, H., Sachroudi, M. R.. (2023).

Pengaruh Penambahan Sabut Kelapa Sebagai Material Serat terhadap Kuat Tekan Beton. *Jurnal Kacapuri, 6(1)*, 23 – 34. DOI: http://dx.doi.org/10.31602/jk.v6i1.10997

Murdock, & Brook. (1991). *Bahan dan Praktek Beton. (Trans: Stephanus Hindarko)*. Jakarta: Erlangga. https://perpustakaan.binadarma.ac.id/opac/detail-opac?id=3013

Rohana, E. A. (2022). Pengaruh Penambahan Abu Serabut Kelapa Sebagai Pengganti Sebagian Semen Terhadap Kuat Tekan dan Kuat Tarik Beton. *Undergraduate thesis*, Universitas Islam Riau. http://repository.uir.ac.id/id/eprint/14003

Sahrudin, & Nadia. (2016). Pengaruh Penambahan Serat Sabut Kelapa Terhadap Kuat Tekan Beton. *Jurnal Konstruksia*, 7(2), 13-20. DOI: https://doi.org/10.24853/jk.7.2.%25p

Sandya, Y., Prihantono, P. & Musalamah, S. (2019). Penggunaan Abu Sekam Padi Sebagai Pengganti Semen pada Beton Geopolimer. *Educ. Build. J. Pendidik. Tek. Bangunan dan Sipil*, 5(2), 59-63. DOI: https://doi.org/10.24114/ebjptbs.v5i2%20DES.16142

Setiawan, A., Hardjasaputra, H., Soegiarso, R. (2023). Embodied carbon dioxide of fly ash based geopolymer concrete. IOP Conference Series: Earth and Environmental Science. https://iopscience.iop.org/article/10.1088/1755-1315/1195/1/012031

Setiawan, A., Risman, A.B., Juliyatna, Fathurachman, R., Octaviani, S. (2015). Beton Geopolimer Abu Serabut Kelapa. *Jurnal Konstruksia*, 6(2), 91-97. DOI: https://doi.org/10.24853/jk.6.2.%25p

Syahyadi, R., Kurniati, Yusniyanti, E., Fitri, G., Ismail. (2021). Pengaruh Penambahan Serat Sabut Kelapa Terhadap Sifat Mekanis Mortar Geopolimer Berbasis Fly Ash Pangkalan Susu. *Prosiding Seminar Nasional Politeknik Negeri Lhokseumawe 2021*, 5(1) pp. 72-76. https://e-jurnal.pnl.ac.id/semnaspnl/article/view/2703

SNI 03-1969-2008. (2008). Metode Pengujian Berat Jenis Dan Penyerapan Air Agregat Kasar Badan Standar Nasional Indonesia. http://dwikusumadpu.wordpress.com/wp-content/uploads/2013/03/sni-1969-2008.pdf

SNI 03-4804-1998. (1998). Metode Pengujian Bobot Isi Dan Rongga Udara Dalam Agregat. Badan Standar Nasional Indonesia. http://perpus.ditbtpp.id/opac/index.php?p=show_detail&id=10113

SNI 03-4142-1996. (1996). Metode Pengujian Jumlah Bahan Dalam Agregat Yang Lolos Saringan No. 200 (0,075 Mm). Badan Standar Nasional Indonesia. https://www.scribd.com/document/626080534/SNI-03-4142-1996

SNI 1969-2016. Metode Pengujian Daya Serap Air Agregat Kasar Untuk Beton. Badan Standardisasi Nasional Indonesia. https://binamarga.pu.go.id/otomasi9/index.php?p=show_detail&id=2456&keywords=

SNI 2417-2008. (2008). Metode Pengujian Keausan Agregat Kasar. Badan Standardisasi Nasional Indonesia. https://binamarga.pu.go.id/uploads/files/687/preview_687-1-5.pdf

SK SNI-04-1989-F. (1989). Metode Pengujian Modulus Elastisitas Dinamis Campuran Aspal. Badan Standardisasi Nasional Indonesia. https://binamarga.pu.go.id/jurnal/index.php/jurnaljalanjembatan/article/download/131/52/482

SNI-03-2834-2000. (2000). Tata Cara Pemilihan Campuran Untuk Beton Normal. Badan Standardisasi Nasional Indonesia. https://binamarga.pu.go.id/uploads/files/946/pedoman-tata-cara-penentuan-campuran-beton-normal-dengan-semen-opc-ppc-dan-pcc.pdf

SNI 1974-2011. (2011). Metode Pengujian Kuat Tekan Beton. Badan Standardisasi Nasional Indonesia. https://binamarga.pu.go.id/index.php/nspk/detail/sni-19742011-tentang-cara-uji-kuat-tekan-beton-dengan-benda-uji-silinder

SNI 03-2491-2002. (2002). Metode Pengujian Kuat Tarik Belah Beton. Badan Standardisasi Nasional Indonesia. https://www.scribd.com/document/360021464/SNI-03-2491-2002-Metode-pengujian-KUAT-TARIK-BELAH-BETON-pdf