

THE USE OF WASTE BAMBOO PIECES AS A PARTIAL SUBSTITUTION OF COARSE AGGREGATES TO INCREASE THE COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT

Utilizing waste as an alternative building material is becoming an effective solution to environmental problems and is popular in developing countries. On the other hand, the concrete industry, a key component of construction, continues to innovate to improve quality and efficiency. The increasing demand for concrete is driving the development of mix designs that meet stringent quality and compressive strength standards, while taking into account environmental sustainability. Advances in concrete technology spur research initiatives to improve its quality and efficiency of use, with innovations in material selection and execution methodologies. This is aimed at meeting the increasing needs and overcoming construction challenges. Modern concrete is required to perform optimally in less time, requiring effective additives for performance enhancement. Recent research has integrated bamboo waste from the handicraft industry as a component of concrete mixes, increasing the speed of project execution and providing a sustainable solution in waste management. The authors were interested in conducting an in-depth study on improving the compressive strength of concrete by integrating waste bamboo pieces. The concrete studied had a f'_c strength of 25 MPa (K-300) and was tested at 7, 14, and 28 days to assess the effectiveness of bamboo as an additive. The test results are expected to provide significant data on the viability of bamboo waste as a partial substitution for coarse aggregate. The title of the study, "Use of Waste Bamboo Pieces as Partial Substitution for Coarse Aggregate to Increase the Compressive Strength of Concrete," reflects the objectives of the study and the utilization of sustainable materials in modern construction. Based on the results of the research that has been carried out and the discussion in the previous chapter with the variation of waste bamboo pieces 0%, 10% and 15%, the following conclusions can be drawn: the results of testing the compressive strength of normal concrete at the age of 28 days reached 452 kN (f'_c 26, 1 MPa = 104%), while variation 1 of 10% rolled bamboo cuttings waste decreased in compressive strength, reaching 305 kN (f'_c 17.60 MPa = 70%), and variation 2 of 15% rolled bamboo cuttings waste decreased, reaching 309 kN (f'_c 17.83 MPa = 71%).

Keywords: Coarse aggregate, concrete, bamboo, compressive strength, variation.

INTRODUCTION

The utilization of waste as an alternative building material has become a rapidly growing trend and is seen as an effective solution to address various environmental issues, particularly in developing countries around the world. Advances in concrete technology today have been a major driver for various research initiatives aimed at improving its quality and efficiency of use. Referring to the compositional characteristics of concrete previously described, the authors express great interest in conducting an in-depth study on the potential for

increasing the compressive strength of concrete by integrating waste bamboo pieces. The concrete considered in this study had a f'_c grade of 25 MPa, which is equivalent to K-300, and was tested at various time intervals, namely at 7 days, 14 days, and 28 days, to measure the effectiveness and performance of the bamboo additive. The results of these tests are expected to provide significant data on the viability of using bamboo waste as a partial substitution for coarse aggregate in concrete mixes.

METHODS

The method applied in this research is the experimental method, which involves the use of independent variables and dependent variables. The independent variable in this study was bamboo cuttings waste, which was used as a partial replacement of coarse aggregate in the concrete composition. The dependent variable observed in this study was the compressive strength of normal concrete having an f'_c value of 25 MPa, which is equivalent to K-300 grade concrete. The number of samples required in total in this study can be seen in table 1 below:

Table 1. Number of Research Samples

No.	Sampel Benda Uji Silinder	Jumlah Sampel			Jumlah
		Berdasarkan Umur Pengujian			
		7 hari	14 hari	28 hari	
1.	Beton normal $f'c$ 25 (MPa) atau setara dengan K-300	3	3	3	9
2.	Penambahan limbah potongan bambu sebagai pengganti sebagian agregat kasar dengan variasi 10%	3	3	3	9
3.	Penambahan limbah potongan bambu sebagai pengganti sebagian agregat kasar dengan variasi 15%	3	3	3	9
Total Benda Uji					27

Source: Processed Research Data at Pioneer Concrete Laboratory, 2024.

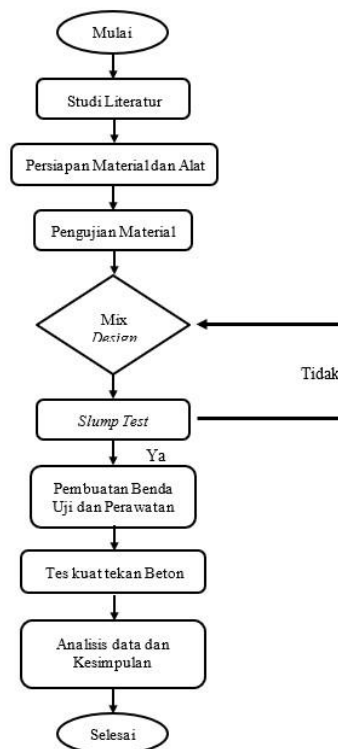
The waste bamboo cuttings used in this study as a partial substitute for coarse aggregate in concrete mixes have a size of 1 cm to 2 cm.



Source: Research documentation, 2024.

Figure 1: Waste of Wulung Bamboo Pieces

The flowchart of this research is as follows:



Source: Research Documentation, 2024.

Figure 2. Research flow diagram

RESULTS AND DISCUSSION

In the design of concrete mixes carried out based on SNI 03-2834- 2000 on “Procedures for Making Normal Concrete Mix Plans”, the design of this concrete mixture aims to determine the composition or proportion of ingredients for the preparation of concrete. The resulting test is tested at the age of 7, 14 and 28 days, as for the results of the mix design that has been done for one cylindrical test object 15cm x 30 cm. Mix Design normal quality $f'c$ 25 MPa or equivalent K-300. The provisions of the concrete plan:

- 1) Planned concrete quality = $f'c$ 25 MPa;
- 2) Cylindrical specimen = $\varnothing 15$ cm x 30 cm;
- 3) Standard deviation = 7 MPa;

- 4) Cement type = Type 1;
- 5) Slump height set = 10 ± 2 cm;
- 6) Maximum FAS value = 0.6;
- 7) Minimum cement content = 275 kg/m³;
- 8) Specific gravity of sand (SSD) = 2.54;
- 9) Split Specific gravity (SSD) = 2.56;
- 10) Maximum grain size = 40 mm;
- 11) Sand grain arrangement = No. 2 gradation area;
- 12) Planned concrete, $F_{cr} = f'_c + 1.64 \times S = 25 + 1.64 \times 5 = 33.2$ MPa;
- 13) Free cement water factor = 0.475;
- 14) Free water content;
Free water content for unbroken aggregate 175 kg/m³, free water content for broken aggregate (split stone) 205 kg/m³;
Free water content = $(2/3 \times 175) + (1/3 \times 205) = 185$ kg/m³.
- 15) Water content of cement = $185 / 0.475 = 390$ kg/m³.
- 16) Specific gravity of combined aggregates;
Percent sand = $(36 \% + 42 \%) / 2 = 39 \%$
Percent split = $100\% - 39\% = 61\%$
Specific gravity of combined aggregate = $(39 \% \times 2.54) + (61 \% \times 2.56) = 2.55$.
- 17) Concrete content weight;
The concrete content weight is found by using a graph according to the specific gravity and free water content.
Concrete content = 2360 kg/m³.
Combined aggregate content = $2360 - 390 - 185 = 1785$ kg/m³.
Sand content = $39\% \times 1785 = 696.15$ kg/m³.
Split content = $1785 - 696.15 = 1088.85$ kg/m³.
- 18) Theoretical mix proportions;
Volume:
= 3 bh x volume of concrete cylinder
= 3 x (circle area x t)
= $3 \times (1/4 \times \pi \times d^2 \times t)$
= $3 \times (1/4 \times 3.14 \times 0.152 \times 0.3)$
= 0,0159 m³

Table 2: Proportion of Test Mix 0.0159 m³

	Semen (kg)	Air (kg)	Agregat	
			Halus (kg)	Kasar (kg)
Proporsi campuran teoritis	1	0,475	2,09	3,45
Setiap m ³	390	185	696,15	1088,85
Setiap campuran uji = 0,0159 m ³	0,0159 x 390 = 5,88	0,0159 x 185 = 2,94	0,0159 x 696,15 = 11,07	0,0159 x 1088,85 = 17,31

Source: Processed Research Data, 2024.

For the experiment, the proportion of the mixture with the shrinkage rate was added. The shrinkage rate of the mixture is about 10% - 20%, 15% is taken, so that the proportion of the mixture with the shrinkage rate is obtained as follows:

Table 3. Mixture Proportion with Shrinkage Rate

	Semen (kg)	Air (kg)	Agregat	
			Halus (kg)	Kasar (kg)
Proporsi campuran teoritis	1	0,475	2,09	3,45
Setiap m ³	390	185	696,15	1088,85
Setiap campuran uji = 0,0159 m ³	0,0159 x 390 = 5,88	0,0159 x 185 = 2,94	0,0159 x 696,15 = 11,07	0,0159 x 1088,85 = 17,31
Proporsi campuran dengan angka penyusutan 7,5%	1	0,55	2,09	3,45
Setiap m ³	420	199	748	1170
Setiap campuran uji = 0,0159 m ³	0,0159 x 425,5 = 6,67	0,0159 x 212,75 = 3,38	0,0159 x 809,5 = 12,87	0,0159 x 1266,2 = 20,13

Source: Processed Research Data, 2024.

For the use of sand substitution materials using 10% and 15% of rolled bamboo pieces. The weight of the rolled bamboo pieces can be seen below,

The weight of the rolled bamboo pieces needed as a 10% sand substitute = 10% rolled bamboo pieces. weight of sand. cylinder volume = 0.34 kg.

The weight of rolled bamboo pieces needed as a 15% substitute for sand = 15% of rolled bamboo pieces. weight of sand. cylinder volume = 0.51 kg.

Slump testing is carried out when the concrete is still fresh, this experiment is carried out by means of an Abram cone or a pointed cone which has a top diameter of 10 cm, a bottom diameter of 20 cm and a height of 30 cm, equipped with a tool ear to lift the tool so that fresh concrete can come out and a 16 mm diameter slump rod with a maximum length of 60 cm (SNI 1972-2008). The test was conducted with the aim to determine the workability value of the fresh concrete mix. The lower the slump value, the harder it will be to mix, pour, transport and compact. The average slump value for 3 variations is 97 mm. The average slump value in this study is still within the initial design slump plan of 60-180 mm. The results of the slump value that has been done can be seen in Table 4 below.

Table 4. Slump Testing Result Data

Variasi Campuran	Nilai Slump	Satuan
Beton $f'c$ 25 MPa	11	cm
Beton $f'c$ 25 MPa variasi 10% limbah potongan bambu wulung	9	cm
Beton $f'c$ 25 MPa variasi 15% limbah potongan bambu wulung	8	cm

Source: Processed Research Data, 2024.



Source: Research Documentation, 2024.

The results of Slump Testing of Concrete Test Objects Variation 2

Testing the compressive strength of concrete refers to SNI 1974-2011 on the Procedure for Concrete Compressive Strength Test with cylindrical test objects. The calculation of concrete compressive strength uses the formula:

Compressive Strength = P/A (1)

P = Axial compressive force (N)

A = Cross-sectional area (mm²)

If the ratio of Length (L) to diameter (D) of the specimen is less than 1.8 correct the results obtained by multiplying by the appropriate correction factor. The correction factor applies to lightweight concrete with a weight content between 1600 kg/m³ and 1920 kg/m³ and to normal concrete. These correction factors apply to dry or wet conditions at loading. Values not contained in the table must be determined by interpolation, the correction factor applies to nominal concrete compressive strengths of 15 MPa to 45 MPa (SNI 1974-2011). Concrete compressive strength testing is carried out on test specimens at 7 days, 14 days and 28 days of age using a concrete compressive test tool (Compression Testing Machine) with readings on the tool using kN units and digital displays. The results of the concrete compressive strength test can be seen in Table 5 to Table 7 and Figure 4 and Figure 5 below.

Table 5. Cylindrical Concrete Compression Test Results at 7 Days of Age

No.	Benda Uji	Tanggal Pembuatan	Tanggal Pengujian	Umur Benda Uji (hari)
1	f'c 25	30 Nov 2024	7 Des 2024	7
2	f'c 25	30 Nov 2024	7 Des 2024	7
1	10% PBW	30 Nov 2024	7 Des 2024	7
2	10% PBW	30 Nov 2024	7 Des 2024	7
1	15% PBW	30 Nov 2024	7 Des 2024	7
2	15% PBW	30 Nov 2024	7 Des 2024	7

Berat	Aktual	Rata-rata	Prosentase
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Benda Uji (kg)	Kuat Tekan (kN)	Kuat Tekan (kN)	Rata-rata Kuat Tekan (kN)
12,268	286,3	289	66,72 %
12,27	291,8		
12,24	194	203	46,86 %
12,24	212,9		
12,24	191	175	40,40 %
12,25	159,2		

Source: Processed Research Data, 2024.

Table 6: Cylindrical Concrete Compression Test Results at the Age of 14 Days

No.	Benda Uji	Tanggal Pembuatan	Tanggal Pengujian	Umur Benda Uji (hari)
1	f'c 25	30 Nov 2024	14 Des 2024	14
2	f'c 25	30 Nov 2024	14 Des 2024	14
1	10% PBW	30 Nov 2024	14 Des 2024	14
2	10% PBW	30 Nov 2024	14 Des 2024	14
1	15% PBW	30 Nov 2024	14 Des 2024	14
2	15% PBW	30 Nov 2024	14 Des 2024	14

Berat Benda Uji (kg)	Aktual Kuat Tekan (kN)	Rata-rata Kuat Tekan (kN)	Prosentase Rata-rata Kuat Tekan (kN)
12,3	384	385	88,88 %
12,294	385,8		
12,284	245,5	252	58,18 %
12,288	257,9		
12,268	252,8	233	53,79 %
12,25	213,3		

Source: Processed Research Data, 2024.

Table 7. Cylindrical Concrete Press Test Results at 28 Days of Age

No.	Benda Uji	Tanggal Pembuatan	Tanggal Pengujian	Umur Benda Uji (hari)
1	f'c 25	30 Nov 2024	28 Des 2024	28

2	f_c 25	30 Nov 2024	28 Des 2024	28
1	10% PBW	30 Nov 2024	28 Des 2024	28
2	10% PBW	30 Nov 2024	28 Des 2024	28
1	15% PBW	30 Nov 2024	28 Des 2024	28
2	15% PBW	30 Nov 2024	28 Des 2024	28

Berat Benda Uji (kg)	Aktual Kuat Tekan (kN)	Rata-rata Kuat Tekan (kN)	Prosentase Rata-rata Kuat Tekan (kN)
12,312	456,3	452	104,35 %
12,306	447,2		
12,292	292,3	305	70,41 %
12,296	317,6		
12,302	309,9	309	71,33 %
12,298	309		

Source: Processed Research Data, 2024

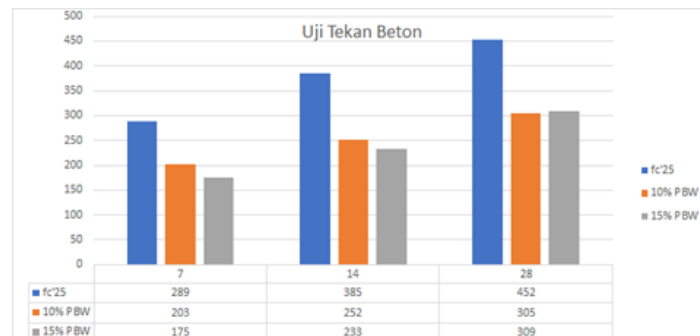


Figure 4 Bar Chart of Compressive Test of Normal Concrete, Variation 1 and Variation 2

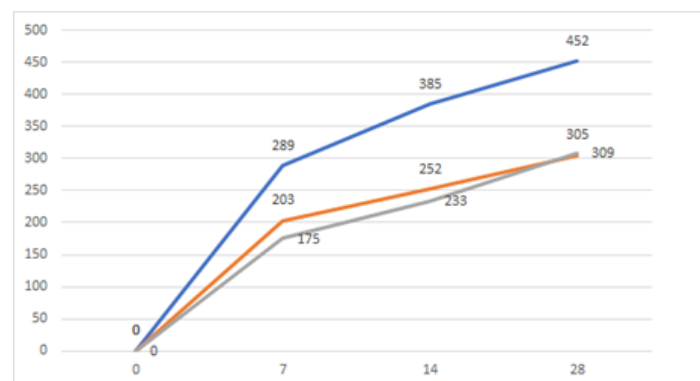


Figure 5 Compressive Test Chart of Normal Concrete, Variation 1 and Variation 2

CONCLUSIONS

Based on the results of the research that has been carried out and the discussion in the previous chapter with the variation of waste of rolled bamboo pieces 0%, 10% and 15%, the following conclusions can be drawn

The results of testing the compressive strength of normal concrete at the age of 28 days reached 452 kN (f'_c 26.1 MPa = 104%), while variation 1 of 10% rolled bamboo cuttings waste decreased in compressive strength, reaching 305 kN (f'_c 17.60 MPa = 70%), and variation 2 of 15% rolled bamboo cuttings waste decreased, reaching 309 kN (f'_c 17.83 MPa = 71%).

REFERENCES

- Taqwa, I., Rumbyarso, Y. P. A., & Darmiyanti, L. (2024). ANALYSIS OF LIGHTWEIGHT BRICK WASTE FOR PARTIAL SUBSTITUTION OF FINE AGGREGATE ON CONCRETE COMPRESSIVE STRENGTH. *INTERNATIONAL JOURNAL OF MULTI SCIENCE*, 4(02), 34-41.
- Rinjoko, N. F., Rumbyarso, Y. P. A., & Darmiyanti, L. (2024). THE EFFECT OF GRANITE WASTE AS A FINE AGGREGATE SUBSTITUTION IN ASPHALT CONCRETE BINDER COURSE. *INTERNATIONAL JOURNAL OF MULTI SCIENCE*, 4(02), 56-62.
- Darmiyanti, L., Prima, Y., & Aldianto, M. A. (2023). Analisis Borepile Menggunakan Metode Meyyerhoff dan Reese Wright. *Jurnal Sipil Krisna*, 9(1), 27-38.
- Prima, Y., & Darmiyanti, L. (2023). Analisis Kinerja Struktur Gedung Rusun TNI AU Halim Perdanakusuma Dengan Menggunakan Metode Pushover Analysis. *Jurnal Sipil Krisna*, 9(2), 26-35.
- Rumbyarso, Y. P. A., & Pribadi, G. (2023). Analisis Stabilitas Lereng dengan Metode Bishop pada Proyek Geotechnical Investigation Jalur Transportasi Pelabuhan Batubara Marangkayu Kabupaten Kutai Kartanegara. *JURNAL KRIDATAMA SAINS DAN TEKNOLOGI*, 5(02), 562-577.
- Pribadi, G., & Rumbyarso, Y. P. A. (2023). Analisis Perbandingan Daya Dukung dan Penurunan Pondasi Tiang Bor Dengan Perhitungan Manual dan Software ALLPILE. *Jurnal TESLINK: Teknik Sipil Dan Lingkungan*, 5(2), 16-20.
- Pribadi, G., & Rumbyarso, Y. P. A. (2023). Analisis Profil Atap Baja WF dengan Metode LRFD Menggunakan SAP 2000 dan Idea StatiCa. *Jurnal Teknik Industri Terintegrasi (JUTIN)*, 6(4), 1543-1559.
- Rumbyarso, Y. P. A., & Pribadi, G. (2024). Analysis of Landslide Handling With Mini Pile Reinforcement Using Plaxis Software on The "X" Toll Road Project. *Jurnal Teknik Industri Terintegrasi (JUTIN)*, 7(2), 801-810.
- Rodji, A. P., Sihombing, S. M., & Zannathahaq, F. (2023). Analisis Penerapan Sistem Satu Arah Terhadap Kemacetan Lalu Lintas Simpang Gadog, Bogor. *Konferensi Nasional Teknik Sipil (KoNTekS)*, 1(4).
- Indriasari, I. (2023). Analisis Geometrik Jalan Pada Enam Ruas Jalan Tol Dalam Kota Jakarta Seksi A Kelapa Gading-Pulo Gebang. *Analisis Geometrik Jalan Pada Enam Ruas Jalan Tol Dalam Kota Jakarta Seksi A Kelapa Gading-Pulo Gebang*, 9(1), 1-9.
- Pribadi, G., Indriasari, I., & Rahman, R. L. (2023). Analisis Substitusi Limbah Plastik (LDPE) terhadap Karakteristik Marshall Pada Campuran Laston AC-WC. *JURNAL KRIDATAMA SAINS DAN TEKNOLOGI*, 5(02), 334-347.
- ADJIE, C. P., & ARTIANI, G. P. (2024). EVALUATION OF FACTORS AFFECTING DELAY IN UJUNG MENTENG FLAT HOUSING PROJECT WORK. *INTERNATIONAL JOURNAL OF MULTI SCIENCE*, 4(02), 136-143.
- Darmiyanti, L., Pribadi, G., & Rodji, A. P. (2021). Penambahan Serbuk Kayu Kamper terhadap

- Kuat Tekan Beton. Bentang: Jurnal Teoritis dan Terapan Bidang Rekayasa Sipil, 9(2), 85-92.
- Sihombing, S. M., Rodji, A. P., & Muzamil, A. (2022). Analisis Tebal Perkerasan Runway Pada Bandara Internasional Oe-Cusse, Timor Leste. Jurnal Sipil Krisna, 8(1), 69-78.
- Sihombing, S., Rodji, A. P., & Akbar, J. A. (2019, July). Analisis Penggunaan Serbuk Batu Karang sebagai Filler pada Campuran Asphalt Concrete-Wearing Course (AC-WC). In Prosiding Seminar Nasional Teknologi Universitas Krisnadwipayana (pp. 368-375).
- Rodji, A. P., Sihombing, S. M., & Hariyanto, Q. A. (2022). Perencanaan Geometrik Jalan Tol Cibitung–Cilincing Interchange Tambelang Kabupaten Bekasi. Jurnal Sipil Krisna, 8(1), 43-49.
- Susilo, M. F. T., Rodji, A. P., & Darmiyanti, L. (2022). ANALISIS TEBAL PERKERASAN LENTUR PADA APRON PANGKALAN UDARA SAUMLAKI DI TANIMBAR MALUKU. Jurnal Sipil Krisna, 8(1), 1-10.
- Surtaryo, S., Artiani, G. P., Rodji, A. P., & Wahyono, H. (2024). Pemetaan Potensi Desa Tugu Utara sebagai Desa Wisata. Jurnal Pengabdian Masyarakat (ABDIRA), 4(4), 114-123.
- RIVANI, F., & SIHOMBING, S. M. (2024). THE EFFECT OF USING SUGAR CANE WASTE ON CONCRETE FLEXURAL STRENGTH. INTERNATIONAL JOURNAL OF MULTI SCIENCE, 4(02), 104-109.
- Simatupang, D., Sihombing, S. M., & Rodji, A. P. (2024). THE EFFECT OF GREEN SHELL POWDER WASTE AS A SUBSTITUTE FOR FINE AGGREGATE IN ASPHALT CONCRETE WEARING COURSE MIXTURE. INTERNATIONAL JOURNAL OF MULTI SCIENCE, 4(02), 70-75.
- Putri, M., Sihombing, S. M., & Pribadi, G. (2024). THE EFFECT OF CONCRETE COMPRESSIVE STRENGTH TESTING USING RUBBER SEED SUBSTITUTION AS A PARTIAL REPLACEMENT OF FINE AGGREGATE. INTERNATIONAL JOURNAL OF MULTI SCIENCE, 4(02), 49-55.
- Gita, P. (2018). Bahan konstruksi ramah lingkungan dengan pemanfaatan limbah botol plastik kemasan air mineral dan limbah kulit kerang hijau sebagai campuran paving block. Jurnal Konstruksia, 9(2), 25-30.
- Artiani, G. P. (2016, December). Analisis Faktor Penyebab Kecelakaan Lalulintas Sebagai Acuan Perencanaan Jalan Untuk Meningkatkan Keselamatan. In FORUM MEKANIKA (Vol. 5, No. 2, pp. 112-122).
- Sonhaji, M., & Indriasari, I. (2024, August). Kajian Teknis Dan Biaya Pekerjaan Facade Curtain Wall Unitized System Pada Proyek Bangunan Gedung. In FORUM MEKANIKA (Vol. 13, No. 1, pp. 1-12).
- Gita, P. (2013). ANALISIS FAKTOR PENYEBAB KECELAKAAN LALULINTAS SEBAGAI ACUAN PERENCANAAN JALAN UNTUK MENINGKATKAN KESELAMATAN LALULINTAS.(STUDI KASUS: RUAS JALAN CIASEM–PAMANUKAN KABUPATEN SUBANG, JAWA BARAT).`