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The Influence of e-glass epoxy composite laminate material application on the crack pattern of cylinder concrete column cross-section

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Abstract: In order to better understand the phenomenon of applying GEC reinforcement to RCC based on the percentage of surface crack pattern (PCP), this research will use e-glass epoxy composite laminate (GEC) to obtain the damage pattern of reinforced concrete column specimens (RCC) utilizing GEC. Additionally, it will compare the splitting tensile strength (STS) and SCP. In accordance with ASTM C496 guidelines, the RCC specimens used in this investigation had a cylindrical shape and measured 150 mm in length and 50 mm in diameter. GEC material, consisting of 0–4 layers of woven e-glass fiber sheets, was applied as an extra layer on top of the RCC. In compliance with ASTM C496 guidelines, a Universal Testing Machine (UTM) was used to perform the split tensile test. With the aid of Adobe Photoshop software, the Histogram approach was used to calculate the crack pattern's proportion. The study's findings demonstrated that the specimens reinforced with four layers of GEC exhibited the highest damage pattern. This suggests that the reinforced specimens must be subjected to a sizable load in order to be damaged. Hence, the damage that occurs in the specimens can be lessened by applying GEC layers on RCC. Further information about the performance of RCC reinforced with GEC is also provided by a comparison of the splitting tensile strength and the percentage of fracture pattern.

Keywords: E-glass fiber***;*** splitting tensile strength***;*** RCC***;*** crack pattern***;*** KLG

1. INTRODUCTION

One of the most important building materials in the construction sector is concrete. Sand, gravel, and other coarse aggregates are combined with Portland cement or other hydraulic binding agents, water, and fine aggregates to create concrete. Sometimes, other ingredients, such as admixtures, are added to the mixture to give concrete particular qualities.One of the most important building materials in the construction sector is concrete. Sand, gravel, and other coarse aggregates are combined with Portland cement or other hydraulic binding agents, water, and fine aggregates to create concrete. Sometimes, other ingredients, such as admixtures, are added to the mixture to give concrete particular qualities [1]. Concrete is defined as a mixture of water, fine, and coarse aggregates, as well as Portland cement or other hydraulic cement kinds. The end product of this procedure is a dense mass that can build strong, long-lasting structural components. The concrete quality usually has a minimum compressive strength of 14.5 MPa, which is comparable to grade K-175 concrete, for structural components. The concrete's capacity to sustain the loads acting on the structure is indicated by its compressive strength [2].

Because of all of its benefits, concrete is used in construction very often. Excellent resistance to compression, moisture resistance, and shapeability in accordance with design specifications are all displayed by concrete [3]. In addition, concrete reduces sound transmission and offers fire protection. Because of these characteristics, concrete is the material of choice when building roads, bridges, buildings, and other structures [4]. In the construction sector, it is critical to have a thorough understanding of the properties of concrete and when to use it. Engineers and architects can plan and construct sturdy structures by understanding the type and quality of concrete required for different structural components [5].

Only 10% to 15% of concrete's compressive strength is accounted for by its tensile strength. Because of this characteristic, tiny fissures in the concrete can appear and cause serious harm when loads are applied to it [6]. Fibers are added to the mixture to increase its tensile strength, resulting in a composite material made of fibers and concrete. It is anticipated that the fibers in the concrete mixture will function as micro-reinforcement, containing small cracks and preventing them from growing larger as a result of applied load, thus averting the concrete's structural collapse [7].

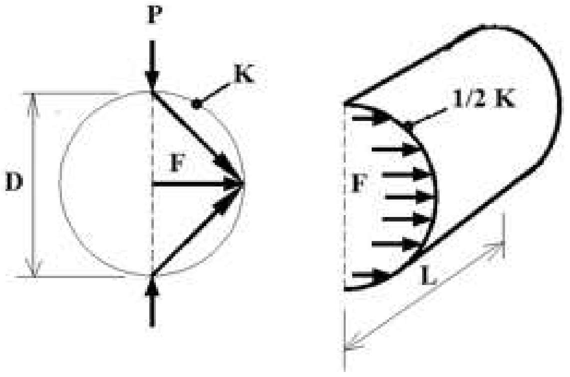
Fibers added to concrete can have a number of benefits. The resistance of the concrete mixture to tensile pressures can be increased by evenly dispersed fibers. The fibers in the concrete will stop minor cracks from getting bigger and preserve the structural integrity of the material when loads are applied. This lowers the possibility of failure and improves the concrete's resistance to applied loads [8]. One important development in the building sector is the incorporation of fibers into concrete. Using concrete-fiber composite materials has the benefit of increasing the tensile strength of concrete and reducing the possibility of cracks that could cause structural damage [9]. To guarantee that the finished concrete has sufficient tensile strength and dependable structural performance, it is crucial to take into account the unique fiber requirements and characteristics, as well as efficient fiber mixing and distribution techniques, during the planning and design of concrete structures [10].

Composite materials are multiphase systems created through the combination of two or more different types of materials. Fiber and matrix components are present in composites. The composite structure is shaped by the load-bearing framework material called fibers, which are bound together and kept in place by the matrix [11]. The matrix has characteristics that enable it to be cast or cut into the appropriate shape to meet the needs of the design. Materials that combine two or more distinct phases or elements, either chemically or physically, are called composites. These materials are built at micro, meso, or macro scales in intricate designs. In composites, the fibers and matrix combine to create a structure with certain qualities like high strength, resistance to corrosion, or favorable thermal properties [12]. Tensile strength and resistance to mechanical loads are provided by the fibers, and load transfer and damage prevention are functions of the matrix [13]. The development of stronger, lighter, and more durable materials has benefited from the use of composites in a number of industries, including construction, automotive, and aerospace. It is possible to explore creative composite development to satisfy a variety of application objectives by comprehending the characteristics of fiber and matrix materials as well as their interactions [14].

The exceptional resistance of borosilicate reinforcing fibers to chemicals and water is what makes them known as E-Glass fibers. In shipbuilding, these fibers are a popular kind of reinforcement [15]. Glass fiber reinforced polymers (GFRP), commonly referred to as E-Glass epoxy composites, are polymer matrix composites that are reinforced using E-Glass fibers. Outstanding characteristics of GFRP include a high strength-to-weight ratio and strength that is comparable to that of metals. Additionally, this composite has a number of benefits, including being colorless, translucent, lightweight, and not being constrained by the size of the object throughout the production process. As a result, GFRP is widely used in many industrial applications [16].

E-glass fibers are used as reinforcement in E-glass epoxy composites to give the required structural strength in the shipbuilding sector. These fibers can be used in harsh maritime situations because of their superior chemical and water resistance. Furthermore, GFRP's benefits—such as its high strength and light weight—make it a desirable substitute for metal in shipbuilding since it may lower weight and improve energy efficiency. Other industries, such as building construction, automotive, and aeronautics, also employ GFRP. Because of GFRP's benefits in terms of strength, sustainability, and design flexibility, it is frequently used in the creation of strong, lightweight structural components [17].

The value of indirect tensile strength derived from testing cylindrical concrete specimens is called splitting tensile strength (STS). The test specimen is positioned horizontally, parallel to the surface of the compression testing machine table, in order to perform the test [18], [19]. It is difficult to measure the tensile strength of concrete directly. Because it produces findings that accurately reflect the tensile strength, the splitting tensile strength test of concrete is therefore frequently conducted and the tensile strength value of the concrete may be ascertained. When designing concrete structural elements, splitting tensile strength is used to assess the material's shear resistance and establish the amount of time that reinforcement will take to form. Splitting tensile strength is generally less than flexural strength (modulus of rupture) but greater than direct tensile strength. Finding the cylindrical specimens' splitting tensile strength is the goal of this testing technique. Concrete cylinder specimens, 50 mm in diameter and 150 mm in height, are put through compression testing in a horizontal position in a compression testing machine in order to find out how much splitting tensile strength the specimen can tolerate. Because of the specimen's cylindrical shape, tensile forces are applied to it, which results in the crack pattern seen in the splitting tensile test [20]. Figure 1 depicts the creation of the crack pattern. The external force or load applied to the specimen through a single point of loading is represented by load P. After entering the specimen, the load reverses course and applies force F along half of the cylinder's circumference plus ½ K on the specimen walls' surface. As a result, the specimen develops tensile tensions, which cause breaking [21].



(a) (b)

Figure 1. Fundamental loading concepts in the specimen are (a) load start and (b) load direction

When determining how many colors an object has, a histogram is a graphical depiction of the frequency distribution of each color value that is present in the image or object [22]. The analysis and visualization of the amount to which various color intensities are present in an object or image is done using histograms. Most often, histograms are used to analyze digital photographs. Pixels make up digital images, and every pixel has a unique color value. The histogram helps determine the frequency with which particular color values occur in the image. A horizontal axis that represents potential color values—for example, 0 to 255 in the case of 8-bit color depth images—usually makes up a histogram. The number of pixels in the image with a specific color value is shown on the vertical axis. You can determine which color patterns are dominant in the image by looking at the histogram. For instance, if a certain color value in the histogram has a peak at that value, it means that color occurs in the image much more frequently than other colors [23].

Additionally, histograms can be used for image processing tasks like color segmentation, histogram equalization, and contrast enhancement. Understanding the distribution of colors in an image helps you make judgments about how to edit or examine it. Histograms facilitate additional analysis and processing by offering a clearer picture of the color composition inside the image or item [24].

When testing material strength, crack pattern observation is an essential phase, particularly for failure analysis and design enhancement. Crack patterns can reveal important information about the causes of failure. Materials' fracture patterns can provide information regarding the kind of failure that took place, such as tensile, flexural, or melting failure [25]. Through an understanding of the origins and features of fracture patterns, engineers can spot any problems in manufacturing or design and take the appropriate action to stop failures in the future. Additionally, the way cracks appear in materials can reveal information about their strength and quality. Engineers can determine whether a material satisfies expected standards for strength and toughness by examining the patterns of cracks present in test specimens. It may be a sign that the material does not match the required specifications if the crack patterns do not match the set standards. Furthermore, observations of crack patterns can help with design advancements. Engineers can improve the strength and durability of materials by modifying the design by comprehending the process and locations of cracks. Observations of crack patterns can also provide information that can be utilized to enhance the production procedure or choose better materials. Finally, material crack patterns can reveal details regarding anticipated lifespan or service life. Engineers can anticipate the material's lifespan under similar operating conditions by examining and comprehending the features of crack patterns in materials subjected to loads or stress [26].

The goal of this study is to examine how changing the E-Glass fiber composite laminate (CEG) layer count affects the proportion of PCP on the surface of cylindrical concrete column specimens (CCS). examining the correlation between the percentage of fracture patterns (PCP) and splitting tensile strength (STS) for every version of CEG. analyzing the trade-off in the splitting tensile tests between higher splitting tensile strength and higher crack patterns in various CEG layers.

2. METHOD

RCC samples for this study were generated in accordance with ASTM C496 guidelines. A digital scale (SF-400 type) with a maximum capacity of 10 kg and an accuracy of 1 g was used to measure the mass of the sample. A 300 kN hydraulic Universal Testing Machine (UTM), model WEW-300D, was used to evaluate the tensile strength (**Figure 2**). The material used in this study was woven E-Glass fabric (**Figure 3**), which was molded using the vacuum bagging method and acting as the structural reinforcement for RCC. The epoxy resin that was utilized included both its hardener and Bisphenol A-Epichlorohydrin kind. Composite Portland Cement was utilized, adhering to the 2014 SNI 7064 standard. According to the ACI 308R-2016 standard, the concrete aggregate composition was cement, sand, gravel, and water steeped in clean water for 28 days, followed by another 28 days of air drying.

Figure 2. Universal testing machine

Figure 3. Woven E-Glass fiberglass

The following stages are used to implement the E-Glass fabric layering technique in this study: (1) Using sandpaper and a cloth, clean the specimen's surface; (2) mix epoxy resin and hardener in a 1:1 compositional ratio (called C1); (3) coat the entire specimen with C1; (4) evenly adhere E-Glass fabric to the specimen's surface until it is completely covered; and (5) evenly reapply C1 over the E-Glass fabric. The preparation of a vacuum pump and vacuum chamber is step six. The vacuum chamber's inside is greased with oil to help separate the specimen from the chamber during the demolding process. (8) The specimen coated with E-Glass fabric is inserted into the vacuum chamber, When the vacuum condition is reached, as indicated by zero pressure on the pump's manometer, the vacuum chamber is securely sealed and the vacuum pump is disconnected. (9) The vacuum chamber is tightly sealed using insulation to create a vacuum condition. (10) The vacuum pump is activated to remove air from the vacuum chamber. Several combinations of 1, 2, 3, and 4 layers of E-Glass fabric were used in this investigation. Three RCC specimens devoid of E-Glass fabric layers were also constructed for comparison.

Opening Adobe Photoshop and the image to be examined for crack patterns is the first step in the process of utilizing the program to evaluate damage patterns. Next, crop the picture so that its crack patterns may be examined. In the Photoshop menu bar, select "Image Size" and adjust the size to get the best possible image resolution. Make a new layer and modify the colors with the eyedropper tool. Trace the pattern to be examined by clicking on the pen tool. Select "Fill Path" to see the damage pattern's color. Save the graphic or picture that was examined. Next, use the "Color Range" function to choose the color of the damage pattern. To view pixel data from the damage pattern, pick "Histogram" from the "Edit" menu. The proportion of the damage pattern is then calculated by processing the data with Microsoft Excel software

3. RESULTS AND DISCUSSION

Damage patterns were seen on the surface of the RCC for varying numbers of E-Glass epoxy layers, which were 1, 2, 3, and 4 layers (G1, G2, G3, and G4), following the splitting tensile tests on RCC specimens coated with GEC, as shown in **Figure 4**.

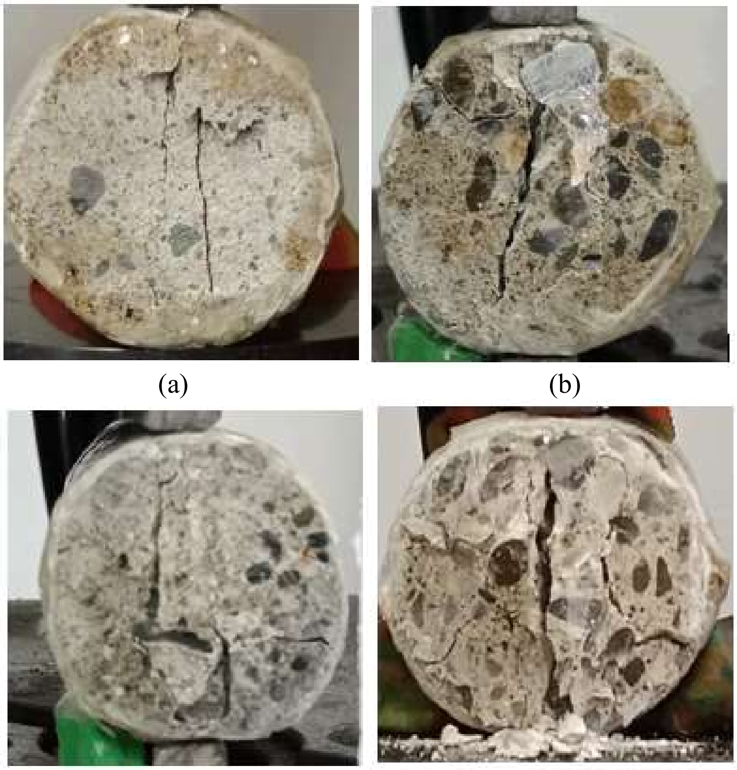

(a) (b)
(c) (d)

Figure 4. Specimen crack patterns: (a) G1, (b) G2, (c) G3, and (d) G4

After that, Adobe Photoshop was utilized to help further define the crack patterns in the images. Black denotes a damaged specimen surface, while lighter colors show an undamaged specimen surface. **Figure 5** presents the findings. **Figure 6** displays the findings of the Histogram technique computations for the percentage of damaged area on the specimen surface, or the percentage of crack patterns (PCP), with the use of Adobe Photoshop software.

For every GEC modification, data were acquired from the average percentage of PCP calculations on the surface of the RCC, as illustrated in **Figure 6**. The average PCP on the surface of the RCC for a single layer of GEC (G1) is 4.06%. 6.69% is the average PCP for the two-layer GEC variation (G2). The average PCP for the three-layer GEC variation (G3) is 6.93%. On the other hand, a notable rise in the average PCP is noted in the case of the four-layer GEC variation (G4), reaching 8.19%.

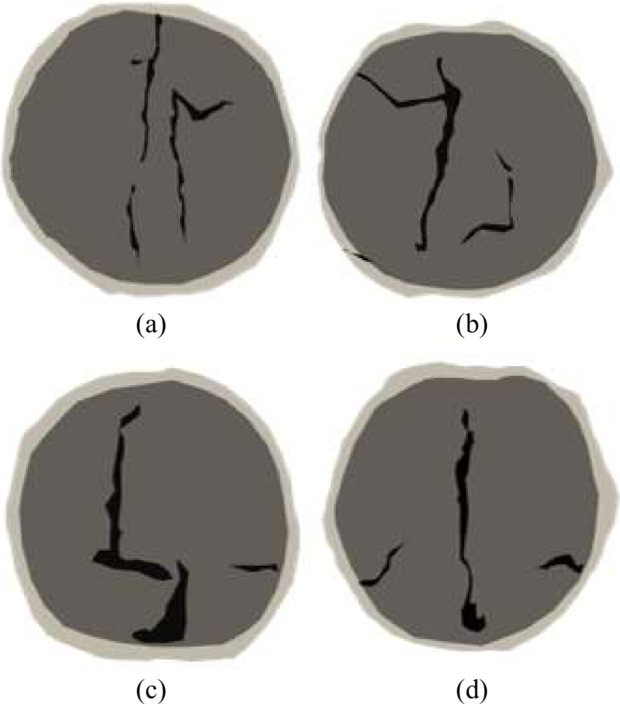

(a) (b)
(c) (d)

Figure 5. Sketch of the surface crack patterns of the specimens: (a) G1, (b) G2, (c) G3, and (d) G4

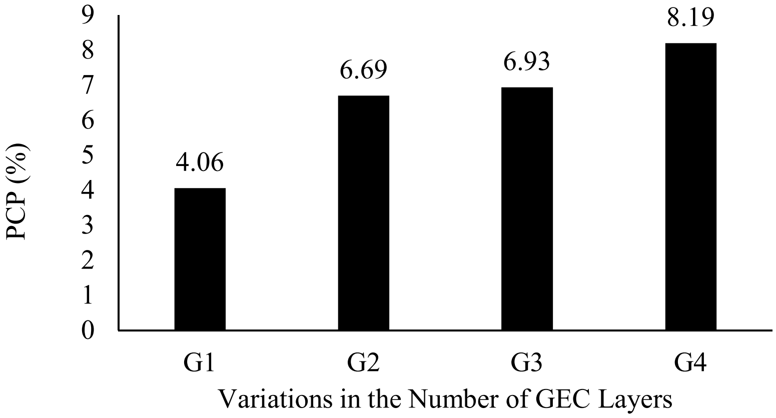


Figure 6. The results of PCP calculations on the specimen surface for each variation

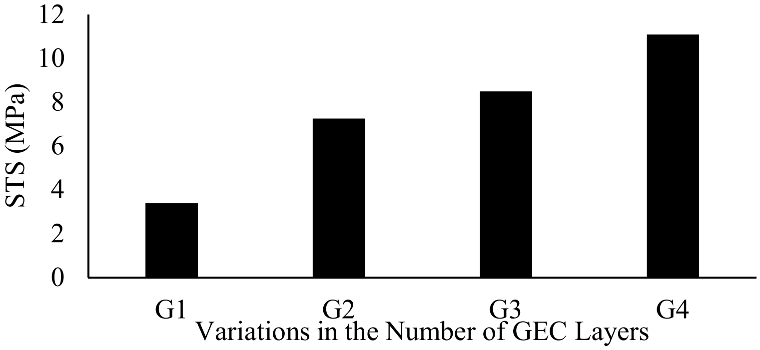


Figure 7. The STS graph of GEC specimens for each variation

Figure 7 displays the average STS of CEG specimens for each variant. In the splitting tensile tests for each CEG variation, there is a link between STS and PCP based on the STS graph and when combined with the PCP graph. This data clearly shows that STS rises as the number of CEG layers grows, suggesting that the specimens' tensile strength increases with the application of more CEG layers. But PCP also rises as the number of CEG layers increases, suggesting the development of larger fissures. Consequently, in the splitting tensile tests, there is a trade-off between the increase in tensile strength and the increase in crack patterns in the various CEG layer variants. Put another way, the PCP rises along with STS when additional CEG layers are placed. This illustrates how the quantity of CEG layers in the specimens causes cracks to become more noticeable. Tensile strength and the percentage of crack patterns are hence trade-offs. An increase in the number of CEG layers is preferable if improving tensile strength is the main goal, even though this would result in a higher PCP. On the other hand, the number of CEG layers should be carefully examined if the goal is to reduce the percentage of crack patterns in order to prevent a major drop in tensile strength.

3 CONCLUSION

The PCP on the surface of RCC specimens is greatly influenced by the amount of CEG layers. The PCP tends to rise with the number of CEG layers applied. The number of CEG layers and STS have a favorable correlation. The STS of RCC specimens rises with the application of additional CEG layers. On the other hand, PCP rises in tandem with an increase in CEG layers. This suggests that improving tensile strength and increasing damage patterns are mutually exclusive. Increasing the amount of CEG layers will result in an increase in specimen crack patterns but will also improve tensile strength. This finding implies that a comprehensive analysis is needed to choose the appropriate number of CEG layers in a design or application, taking into account both increasing tensile strength and allowing for a certain amount of damage in the form of fracture patterns.

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REFERENSI

[1] S. Arian, R. Roestaman, and S. Permana, “Pengaruh Penggunaan Agregat Kasar Kerikil Alami Terhadap Mutu Beton,” *J. Konstr.*, vol. 19, no. 1, pp. 52–59, 2021, doi: 10.33364/konstruksi/v.19-1.896.

[2] H. Manalip and S. E. Wallah, “Kuat Tekan Dan Permeabilitas Beton Porous,” *J. sipil statik*, vol. 7 No. 3, no. 3, pp. 351–358, 2019.

[3] M. Setyowati, “Perkembangan Penggunaan Beton Bertulang Di Indonesia Pada Masa Kolonial (1901-1942),” *Berk. Arkeol.*, vol. 39, no. 2, pp. 201–220, 2019, doi: 10.30883/jba.v39i2.468.

[4] P. N. Hans Handoyo, Michael Oktavianus Kurniawan, “SURVEY PERKEMBANGAN PENGGUNAAN BETON PRECAST DI SURABAYA DAN SEKITARNYA itu , diperlukan adanya survey untuk mengetahui kelebihan , dan hambatan menggunakan beton precast , serta strategi dalam meningkatkan perkembangan penggunaan beton precast , terutama,” *J. Dimens. Pratama Tek. Sipil*, pp. 108–115, 2020.

[5] F. C. Nugrahini and T. A. Permana, “Building Information Modelling (BIM) dalam Tahapan Desain dan Konstruksi di Indonesia, Peluang Dan Tantangan : Studi Kasus Perluasan T1 Bandara Juanda Surabaya,” *Agregat*, vol. 5, no. 2, pp. 459–467, 2020, doi: 10.30651/ag.v5i2.6588.

[6] N. Hidayat, A. Jusuf Zulfikar, and I. Iswandi, “Analisis Metode Split Tensile Test Komposit Laminat Jute Terhadap Kekuatan Tarik Belah Beton Kolom Silinder,” *IRA J. Tek. Mesin dan Apl.*, vol. 1, no. 2, pp. 18–26, 2022, doi: 10.56862/irajtma.v1i2.14.

[7] S. Gistyantoro, V. A. Noorhidana, T. Junaedi, and S. Sebayang, “Pengaruh Penambahan Admixture Naptha E121 Terhadap Perkembangan Kekuatan Beton Rigid Pavement,” *SINTA (Seminar Nas. Ilmu Tek. dan Apl. Ind.*, vol. 5, 2022.

[8] Y. Trianah, “Pengaruh Penambahan Serabut (Fiber) Kelapa Sawit Terhadap Porositas Beton,” *J. Tek. Sipil Cendekia*, vol. 3, no. 2, pp. 28–37, 2022, doi: 10.51988/jtsc.v3i2.49.

[9] A. J. Zulfikar, “The Flexural Strength of Artificial Laminate Composite Boards made from Banana Stems,” *Budapest Int. Res. Exact Sci. J.*, vol. 2, no. 3, pp. 334–340, 2020.

[10] D. Alamsyah, A. J. Zulfikar, M. Yusuf, and R. Siahaan, “Optimasi kekuatan tekan beton kolom silinder

diperkuat selubung komposit laminat jute dengan metode anova compressive strength optimization of cylindrical column concrete reinforced jute laminated composite wrap with anova method," *Jcebt*, vol. 6, no. 1, pp. 30–36, 2022.

[11] D. A. Siregar and A. J. Zulfikar, "Analisis Kekuatan Tekan Selubung Komposit Laminat E-glass pada Beton Kolom Silinder dengan Metode Vacuum Bagging," *J. Rekayasa Mater. Manufaktur dan Energi*, vol. 5, no. 1, pp. 20–25, 2022.

[12] M. Y. Yuhazri, A. J. Zulfikar, and A. Ginting, "Fiber Reinforced Polymer Composite as a Strengthening of Concrete Structures: A Review," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1003, no. 1, 2020, doi: 10.1088/1757-899X/1003/1/012135.

[13] M. Amirhafizan, M. Yuhazri, H. Umarfaruq, S. Lau, A. Kamarul, and A. Zulfikar, "Laminated Jute and Glass Fibre Reinforced Composite for Repairing Concrete Through Wrapping Technique," *Int. J. Integr. Eng.*, vol. 15, no. 1, pp. 1–8, 2023.

[14] F. A. Achmad Jusuf Zulfikar, Din Aswan A. Ritonga, Siswo Pranoto and J. Kurniawan Nasution, Zainal Arif, "Analisis Kekuatan Mekanik Komposit Polimer Diperkuat Serbuk Kulit Kerang," *J. Rekayasa Mater. Manufaktur dan Energi*, vol. 6, no. 1, pp. 30–40, 2023, doi: https://doi.org/10.30596/rmme.v6i1.13599.

[15] & R. B. S. Achmad Jusuf Zulfikar, Muhammad Yusuf R. Siahaan, "Analisis Signifikansi Roda Skateboard Berbahan Komposit Serbuk Batang Pisang Terhadap Perfoma Kecepatan Dengan Metode Anova," *J. Rekayasa Mater. Manufaktur dan Energi*, vol. 4, no. 2, pp. 83–90, 2021, doi: 10.30596/rmme.v4i2.8068.

[16] I. R. A. Jurnal, T. Mesin, P. A. T. Lubis, and A. J. Zulfikar, "Analisis Kekuatan Tarik Belah Komposit Laminat Jute sebagai Penguat Beton Kolom Silinder Berdasarkan Metode Penyerapan Energi Bahan," vol. 1, no. 2, pp. 55–64, 2022.

[17] M. Al Rasid and A. J. Zulfikar, "Analysis Tensile Strength of Laminate Jute Composites Based on Damage Patterns of Cylinder Columns Split Tensile Test Method," *J. Ilm. Tek. Sipil dan Arsit.*, vol. 1, no. 2, pp. 97–103, 2022, doi: 10.31289/jitas.v1i2.1454.

[18] R. A. Purba, A. J. Zulfikar, and I. Iswandi, "Analisis Kekuatan Komposit Laminat Hybrid Jute E-Glass Berdasarkan Pola Kerusakan dengan Metode Split Tensile Test," *IRA J. Tek. Mesin dan Apl.*, vol. 1, no. 3, pp. 83–91, 2023, doi: 10.56862/irajtma.v1i3.37.

[19] D. Wang *et al.*, "Tuning layer thickness and layer arrangement in a GdMnO3 and GdMnO3-MoSe2 bi-layer absorber to cover the S, C, and X band frequency range," *Surfaces and Interfaces*, vol. 36, p. 102507, 2023, doi: 10.1016/j.surfin.2022.102507.

[20] A. J. Zulfikar, Y. Yaakob, H. M. Umarfaruq, and R. Syah, "Natural Jute Laminate for the Improvementof Strength Properties of Concrete Specimen," *Eng. Trans.*, vol. 17, no. 1, pp. 30–42, 2023, doi: 10.24423/EngTrans.3120.20231017.

[21] R. Armidion and T. Rahayu, "Peningkatan nilai kuat tarik belah beton dengan campuran limbah botol plastik polyetylene terephthalate (pet)," *J. Konstr.*, vol. 10, no. 1, pp. 117–126, 2018, [Online]. Available: https://jurnal.umj.ac.id/index.php/konstruksia/article/view/3877

[22] G. Winarno, M. Irsal, C. A. Karenina, G. Sari, and R. N. Hidayati, "Metode Histogram Equalization untuk Peningkatan Kualitas Citra dengan Menggunakan Studi Phantom Lumbosacral," *J. Kesehat. Vokasional*, vol. 7, no. 2, p. 104, 2022, doi: 10.22146/jkesvo.71469.

[23] D. Derlini and A. Jusuf Zulfikar, "Penyelidikan Kegagalan pada Alat Pemisah Karet Alam Jenis LRH 410," *IRA J. Tek. Mesin dan Apl.*, vol. 1, no. 3, pp. 51–61, 2023, doi: 10.56862/irajtma.v1i3.34.

[24] S. Ratna, "Pengolahan Citra Digital Dan Histogram Dengan Phyton Dan Text Editor Phycharm," *Technol. J. Ilm.*, vol. 11, no. 3, p. 181, 2020, doi: 10.31602/tji.v11i3.3294.

[25] N. Rasidi, "Perbandingan Pola Retak dan Lendutan pada Pelat Beton Menggunakan Tulangan Konvensional dan Wiremesh," *J. Tek. Ilmu dan Apl.*, vol. 9, no. 2, pp. 72–75, 2020.

[26] A. Amir, A. Rahman, Y. Rahmi, D. Purnamasari, and Veranita, "Pola Kegagalan Balok Beton Bertulang Spiral Tanpa Beton Pada Penampang Tarik," *J. Tek. Sipil dan Teknol. Konstr.*, vol. 9, no. 1, pp. 55–64, 2023.