



SLUMP FLOW AND MECHANICAL PROPERTIES OF CONCRETE INCORPORATING CONCRETE WASTE SLURRY AND RUBBER POWDER

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ABSTRACT: A rapid growth in the construction industry has led to increasing by-product productions, particularly as concrete waste. Additionally, rubber wastes from used tyres pose significant environmental concerns due to its resistance against natural degradation. Due to the limited research on the combined utilization of both concrete waste slurry (CWS) and rubber powder, the novelty of this study lies in evaluating the combined effects of these two materials on the fresh and mechanical properties of concrete. Hence, the present study investigates the performance of CWS as a mortar component and rubber powder as a non-mineral filler. A testing series of mix design by volumetric proportioning comprises CWS, 10 mm coarse aggregates, and varying percentages of rubber powder (i.e., 5%, 7.5%, 10%, and 20%) were batched and tested. A total of 54 specimens, comprising 36 cubes and 18 cylinders, were prepared for compressive strength and splitting tensile strength testing, respectively. The slump flow results indicate that increasing rubber powder content reduces the workability of the concrete. Moreover, both compressive and splitting tensile strengths decreased with higher rubber powder content. Among the rubber-containing mixtures, mixture with 5% rubber powder achieved the highest compressive and splitting tensile strengths of 19.76 MPa and 2.20 MPa, respectively. Also, mixtures containing rubber powder exhibited less brittle failure. Overall, the results demonstrate the feasibility of utilizing CWS and rubber powder in concrete production.

Keywords: Concrete waste slurry, Rubber powder, Mechanical properties, Slump flow, Workability

1. INTRODUCTION

Concrete is one of the most widely used construction materials, and with the rising growth of economic and infrastructure development in Malaysia, contributing up to 5.9% of the Gross Domestic Product (GDP) in 2017, concrete production has significantly increased for construction projects [1]. The key properties of high-performance concrete include superior compressive strength, making it suitable in load-bearing structures, general resistance to weathering, and cost-effectiveness [2]. Conventional concrete is generally batched by mixing cement, coarse aggregates, fine aggregates, and water as constituent materials. A growing universal call on sustainable development goals (SDGs) requires the construction industry to increase adoption of sustainable materials to minimize concrete waste and reduce dependency on natural resources.

Wastes from the construction industry has caused a major environmental issue in Malaysia due

to improper waste management practices [1]. Construction waste is generally disposed of in landfill sites, which can contaminate the groundwater and cause soil pollution. The processing, transport, and disposal of construction waste stages require an extensive amount of used energy. Concrete waste slurry (CWS) is an example of waste from the manufacture of concrete products. For example, during the manufacturing process of spun piles, the factory generates a large amount of CWS, which requires stringent environmental disposal methods due to its high alkalinity and the presence of residual chemicals [3]. CWS is a byproduct of the concrete production industry, consisting of aggregates, minerals, and chemical admixtures. An approach to address this issue is to recycle CWS into innovative, commercially viable concrete products. However, research on the mechanical properties of concrete waste slurry, including compressive and splitting tensile strength is fairly limited.

Another waste type which is disposed of in large quantities is rubber waste from used tyres. This

waste poses significant environmental concerns due to its resistance to natural degradation from the vulcanization process [4]. Research conducted by Bušić et al. reported that a concrete mix containing 5% rubber content achieved a 28-day compressive strength of 39.04 MPa, showing a 10.7% reduction compared to 43.72 MPa in control mix counterparts, which indicates that the incorporation of rubber marginally reduces the compressive strength of concrete [5]. Li et al. reported that although rubber powder reduces the compressive strength of concrete through synergistic physical effects, rubber particles could improve the concrete impact resistance as well as abrasion resistance of concrete due to their energy-absorbing behavior [6].

Recent studies have explored the development of alternative material for sustainable engineering and environmental applications such as Nisah et al. which demonstrated that the embedment of SiO₂ into the polyurethane membrane prepared from castor oil causes higher thermal stability, mechanical strengths and chemical resistance [7]. This growing interest in innovative materials supports ongoing efforts to investigate alternative materials and for engineering applications, including the utilization of CWS and rubber powder in concrete production. Although previous studies have studied CWS and rubber powder separately, limited research has been conducted on the combined effects of the materials on concrete properties. The present study aims to investigate the mechanical properties of concrete, which incorporates CWS from a spun pile factory and varying rubber powder contents. The investigation includes fresh properties testing through slump flow test, as well as mechanical properties testing with compressive and splitting tensile strength tests.

2. RESEARCH SIGNIFICANCE

The findings from the present study provides valuable insights into the fresh and hardened properties of recycled concrete, which include flowability, compressive strength, and splitting tensile strength, by incorporating CWS and varying contents of rubber powder. The results demonstrate that with an appropriate mix design and suitable rubber powder content, CWS is effectively utilized to produce concrete with satisfactory performance. This highlights the potential of transforming industrial by-products into a useful construction material, contributing to more sustainable construction practices.

From a construction industry perspective, this study offers an alternative approach for spun pile factories to manage their concrete waste slurry more efficiently. Instead of relying on conventional

disposal methods such as landfilling, which incur additional costs and environmental burden, construction players can potentially reuse CWS to produce innovative concrete products. This not only reduces waste disposal expenses but also minimizes environmental impact by decreasing landfill sites and conserving natural resources.

In addition, adopting this approach can reduce energy emission and support compliance with increasing environmental regulations and sustainability requirements within the construction industry. The reuse of CWS and rubber powder may contribute to reducing industrial waste disposal and promoting more sustainable material utilization in the construction industry. Their incorporation into concrete production offers a potential pathway for improving resource efficiency and reducing landfill disposal of waste materials, which aligns with the objectives of Sustainable Development Goal (SDG) 12: Responsible Consumption and Production, which in this case, may help the spun pile company to reduce the area of landfill used to dispose CWS.

3. METHOD

3.1 Materials

In conventional concrete production, the composition of concrete mix consists of cement, fine aggregate, coarse aggregate and water. The cement, fine aggregate and water are combined to form a mortar, which acts as a binder to hold the coarse aggregates. In this study, the mortar was replaced with CWS generated during the fabrication of pre-stressed spun piles, as shown in Fig. 1. The CWS was obtained from the spun pile concrete casting process at the same production facility reported by Zainal et al. [3]. The chemical composition of CWS is presented in Table 1 while the density of CWS is 1808 kg/m³. The high CaO and SiO₂ content suggest that CWS possesses cementitious and filler characteristics suitable to act as mortar replacement material in concrete production. The MD1 mixture reported by Zainal et al., which consisted solely of CWS and is comparable to the CTRL-0 mixture in the present study, exhibited an initial setting time of 66 minutes and a final setting time of 105 minutes [3].

In addition, rubber powder (Fig. 2) and 10 mm granite coarse aggregates were incorporated into the concrete mixture. The rubber powder, processed from waste tyres by a recycling company, was delivered to the institutional laboratory where the concrete mixing for this study was carried out. To ensure uniform particle size, the rubber powder was filtered using a size 1.18mm sieve prior to mixing to remove any clumps.



Fig. 1 CWS generated at the spun pile factory

Table 1. Chemical composition of CWS [3]

Composition Notations (%)	CWS
SiO ₂	24.29
Al ₂ O ₃	4.95
Fe ₂ O ₃	4.94
CaO	59.04
MgO	1.54
SO ₃	3.19
K ₂ O	0.66
Na ₂ O	0.19
P ₂ O ₅	0.12
TiO ₂	0.26



Fig. 2 Rubber powder

3.2 Mix Design

Table 2. Series of concrete waste slurry mix

No	Series	Description	Cube Samples	Cylinder Samples
1	CTRL-0	CWS	6	3
2	CA-0	CWS + 30% coarse aggregates	6	3
3	ARP-5	CWS + 30% coarse aggregates + 5% rubber powder	6	3
4	ARP-7.5	CWS + 30% coarse aggregates + 7.5% rubber powder	6	3
5	ARP-10	CWS + 30% coarse aggregates + 10% rubber powder	6	3
6	ARP-20	CWS + 30% coarse aggregates + 20% rubber powder	6	3
Total			36	18

A series of six tests were conducted as shown in Table 2. Table 3 shows the material proportions for all the mix designs by mass. Due to the fluid state of the slurry, the concrete mix was proportioned using a combination of mass and volume-based measurements, based on the relationship between volume, mass and density, with the total mix fixed at 1 m³. The coarse aggregate and rubber powder were measured by mass for better accuracy, using densities of 2650 kg/m³ and 1050 kg/m³, respectively. The CWS was proportioned by volume due to its fluid nature. The absolute volume method was adopted, ensuring that the total volume of all constituents equals 1 m³ as shown in Table 4.

For example, as presented in Table 3 and Table 4 for the ARP-5 mix, 795.00 kg of coarse aggregate corresponds to approximately 0.300 m³, while 52.50 kg of rubber powder corresponds to 0.050 m³ (5%), based on densities of 2650 kg/m³ and 1050 kg/m³, respectively. The remaining volume, approximately 0.650 m³ (65%), is taken as CWS to complete the total mix volume of 1 m³. All proportions were cross-checked to ensure consistency between mass and volume measurements. The rubber powder content in kilograms (RP_{kg}), calculated based on the rubber powder percentage ($RP_{\%}$), specific gravity of rubber powder ($SGRP$) taken as 1.05 [8], and volume of concrete (VC) is expressed in Eq. (1).

$$RP_{kg} = 10 \times RP_{\%} \times SGRP \times VC \quad (1)$$

The percentages of rubber powder used in this study were 5%, 7.5%, 10%, and 20%. These percentages were selected based on findings from Mehrani et al., where they began a testing series with a minimum of 5% rubber powder content [9]. As earlier studies have shown that mechanical properties tend to decrease beyond a 10% rubber content, the mix proportion was increased up to 20% to evaluate the extent of strength reduction as the rubber powder content is doubled from 10%.

Table 3. Material compositions of mix designs by mass (per 1m³ volume)

Component	Content (kg/m ³)					
	CTRL-0	CA-0	ARP-5	ARP-7.5	ARP-10	ARP-20
CWS	1808.00	1265.60	1175.20	1130.00	1084.8	904.00
Coarse Aggregates	-	795.00	795.00	795.00	795.00	795.00
Rubber Powder	-	-	52.50	78.75	105.00	210.00

Table 4. Material composition of mix designs by volume

Component	Volume (m ³)					
	CTRL-0	CA-0	ARP-5	ARP-7.5	ARP-10	ARP-20
CWS	1.000	0.700	0.650	0.625	0.600	0.500
Coarse Aggregates	-	0.300	0.300	0.300	0.300	0.300
Rubber Powder	-	-	0.050	0.075	0.100	0.200
Total	1.000	1.000	1.000	1.000	1.000	1.000

3.3 Sample Preparation

The sample preparation was carried out in three stages, namely mixing, casting, and curing. In the mixing process, CWS was collected in a container and allowed to settle for at least 45 minutes. Subsequently, rubber powder and coarse aggregates were added based on the mix design and manually mixed to achieve a homogeneous mixture.

In the casting process, a total of 54 concrete specimens consisting of 36 cubes and 18 cylinders were prepared. The demolding process was conducted after 24 hours of casting work. Subsequently, the specimens were submerged in water for curing prior to the testing ages of 7 and 28 days.

The sample IDs were labelled according to the mixture type and rubber powder added. For example, the CTRL-0 (control mixture) mix design denotes CWS without the addition of coarse aggregates and rubber powder used to check consistency from all testing series. Meanwhile, the CA-0 mix design only uses CWS and 30% of coarse aggregates without the addition of rubber powder. This is to compare rubber and non-rubber mix designs so that the effects of rubber powder on concrete mix can be determined. Subsequently, ARP-5 represents the concrete mix consisting of CWS, 30% of 10mm coarse aggregates and rubber powder percentage of 5%.

3.4 Laboratory Testing

The slump flow test procedure was conducted in accordance with ASTM C1611 to monitor the

consistency of the fresh concrete and determine the unconfined flow potential as shown in Fig. 3 [10]. The slump flow value was calculated from the average diameter of the spread (d_1) and the perpendicular diameter (d_2).

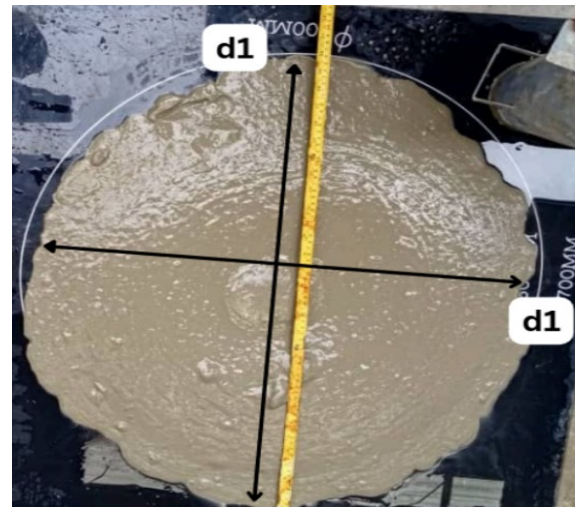


Fig. 3 Slump flow test

Prior to compressive strength testing, the weight and volume of each hardened concrete sample were measured to calculate its density [11]. The compressive strength test was conducted in accordance with BS EN 12390-3, in which the maximum load applied to 100mm cubes samples was recorded, as shown in Fig. 4 [12]. The compressive strength was calculated based on the specimen dimensions and the procedure specified in BS EN 12390-3.



Fig. 4 Compressive strength test using compression testing machine

The splitting tensile strength test was conducted in accordance with BS EN 12390-6 in which continuous load was applied on 100mm diameter and 200mm height cylindrical samples until the sample fully split as shown in Fig. 5 [13]. Subsequently, the maximum load at the point of failure was recorded and used to determine the splitting tensile strength based on the dimensions and the calculation method specified in BS EN 12390-6.



Fig. 5 Splitting tensile strength test

4. RESULTS AND DISCUSSION

4.1 Slump Flow

The slump flow test result measured the fresh properties of the concrete mix designs as shown in Table 5. As concrete workability behaves similarly to slump flow of self-consolidating concrete, the European Federation of Producers and Contractors of Specialist Products for Structures, also known as EFNARC guidelines was referenced. The slump test results show that the CTRL-0 mix (comprising only CWS) has the highest flowability of 760 mm. As

expected, the addition of coarse aggregate in the mix is prone to reduce the slump flow as seen in the CA-0 mix design, causing the slump flow to drop and be measured as 590 mm. A lower slump flow value indicated lower workability for a concrete mix design. Meanwhile, the concrete mix design with 5% rubber powder obtained slump flow of 555 mm which is within the EFNARC range [14]. However, the other mix designs with higher rubber powder content, i.e., 7.5%, 10%, and 20% had lower workability and were recorded as 480 mm, 455 mm and 410 mm, respectively. Hence these were not within the allowable limit range.

Table 5. Slump Flow Test Results

Mix Design	d ₁ (mm)	d ₂ (mm)	Slump Flow Average (mm)	EFNARC Limit Range (mm)
CTRL-0	740	780	760	550-650
CA-0	590	590	590	
ARP-5	570	540	555	
ARP-7.5	480	480	480	
ARP-10	460	450	455	
ARP-20	420	400	410	

Based on Fig. 6, the slump flow of the concrete decreases when the rubber powder content increases which aligns with the findings by Abdullah et al. [15]. The workability reduction is attributed to the higher rubber powder content, which increases the overall surface area and mixing water demand. In addition, the rough texture and elastic nature of rubber particles may contribute to higher internal friction which limits the free flow ability of the concrete [16].

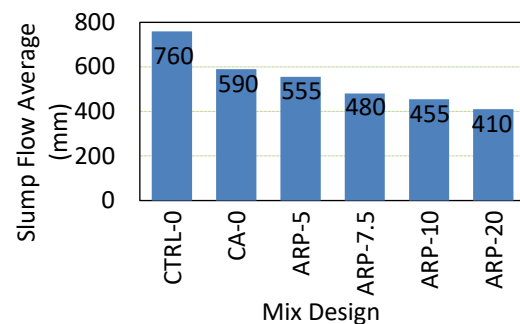


Fig. 6 Slump Flow Results

Visual stability is also a crucial characteristic of the concrete mix - as a vital indication of whether the mix can maintain uniformity during placement

without mechanical vibration. From Fig. 7, ARP-10 and ARP-20 mix designs showed clear signs of low flowability in which the concrete tends to accumulate at the center due to high viscosity. The settling of coarse aggregates in the middle of the fresh concrete suggests that higher rubber powder content disrupts the ability of the fresh concrete to maintain a uniform mix due to the lightweight and hydrophobic nature of rubber particles [16]. These could adversely impact the hardened properties of concrete, such as causing voids, and showing strength inconsistencies.

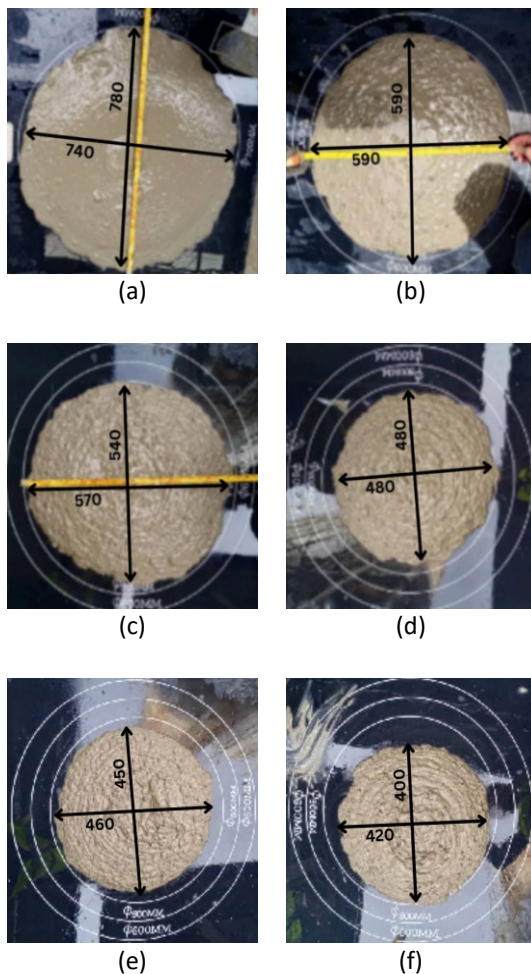


Fig. 7 Slump flow of (a) CTRL-0, (b) CA-0, (c) ARP-5, (d) ARP-7.5, (e) ARP-10 and (f) ARP-20

4.2 Mechanical Properties

Mechanical property tests are important to determine the strength of the concrete mix designs investigated. Table 6 shows the overall mechanical properties test results which include the density, compressive strength and splitting tensile strength tests while Table 7 shows the mean strength,

standard deviation (SD), and coefficient of variation (CV) of the mechanical strength results.

Compressive strength tests were conducted to determine the maximum load-carrying capacity of concrete under compression - serving as an indicator of its quality and overall performance. Based on Fig. 8, the compressive strength of concrete decreases as the rubber powder content increases. According to research by Juveria et al., this is due to the low density and hydrophobic nature of rubber, which disrupt the uniformity of the concrete mix [17]. For concrete samples incorporating CWS, 30% coarse aggregates and rubber powder, ARP-5 provided the highest compressive strength of 19.76 MPa. The strength decreased by 57.2% with 5% rubber content inclusion and gradually reduced with higher rubber content, where reductions of 69.8% (13.94 MPa), 81.4% (8.60 MPa), and 86.2% (6.35 MPa) were recorded with 7.5%, 10%, and 20% rubber content, respectively as compared to the CA-0 mixture. Although this reduction trend is in good agreement with past research, such as Amiri et al., which obtained a 17.9% compressive strength reduction as 5% rubber powder was added into a concrete mix, the strength reduction found in the present study is comparatively more abrupt. [18]. Unlike conventional concrete, the mixtures in this study utilized CWS as the mortar component, and the incorporation of hydrophobic rubber particles into the CWS-based matrix may have had a more pronounced effect on strength development due to the poor interfacial bonding between the rubber particles and the cementitious matrix. This poor bonding has been reported as one of the primary challenges associated with rubber powder incorporation, leading to the deterioration of mechanical properties [16].

However, mix designs without any rubber powder (CTRL-0 and CA-0) have higher compressive strength, which indicates that rubber powder reduces the compressive strength of the concrete. The strength reduction is likely due to the weak bonding between rubber particles and the cement matrix, as well as the increased porosity caused by the low-density nature of rubber. Moreover, the CA-0 mixes exhibited the highest average density (2113 kg/m³), which corresponded to the highest compressive strength. This is attributed to the presence of coarse aggregates, which contribute to improved packing density and overall concrete strength. This finding is aligned with research by Othman et al. which indicates that concrete samples are often correlated to their ability to withstand compressive load, where the denser concrete specimens promotes higher compressive strength [19].

Based on Table 7, most compressive strength and splitting tensile strength results show below 10% CV. However, the compressive and splitting tensile strength for ARP-20 shows a higher CV of 10.99 and 17.82 respectively. This may be due to the low density and hydrophobic nature of rubber, which disrupt the uniformity of the concrete mix. The

increased in variability may be due to the increased in interfacial transition zones (ITZ), which act as mechanical weak points within the concrete matrix, leading to specimen-dependent crack initiation and propagation paths at higher rubber content as reported by Kouno et al. [20].

Table 6. Overall Mechanical Properties Test Results

Mix Design	Average Density (kg/m ³)	Average Compressive Strength (MPa)		Average Splitting Tensile Strength (MPa)
		7 Days	28 Days	28 Days
CTRL-0	1782	32.06	36.87	2.72
CA-0	2113	40.03	46.18	2.98
ARP-5	1863	18.10	19.76	2.20
ARP-7.5	1796	13.15	13.94	1.68
ARP-10	1762	8.48	8.60	1.37
ARP-20	1648	5.49	6.35	1.15

Table 7. Mean, Standard Deviation (SD), and Coefficient of Variation (CV) of Mechanical Strength Results

Mix Design	Compressive Strength (7 days curing age)			Compressive Strength (28 days curing age)			Splitting Tensile Strength (28 days curing age)		
	Mean (MPa)	SD	CV	Mean (MPa)	SD	CV	Mean (MPa)	SD	CV
CTRL-0	32.06	0.55	1.70	36.87	3.66	9.92	2.72	0.20	7.46
CA-0	40.03	1.34	3.36	46.18	3.51	7.59	2.98	0.09	3.05
ARP-5	18.10	0.24	1.32	19.76	0.21	1.07	2.20	0.04	1.90
ARP-7.5	13.15	0.83	6.31	13.94	1.35	9.70	1.68	0.03	1.91
ARP-10	8.48	0.30	3.59	8.60	0.30	3.53	1.37	0.04	3.05
ARP-20	5.49	0.60	10.99	6.35	0.14	2.20	1.15	0.21	17.82

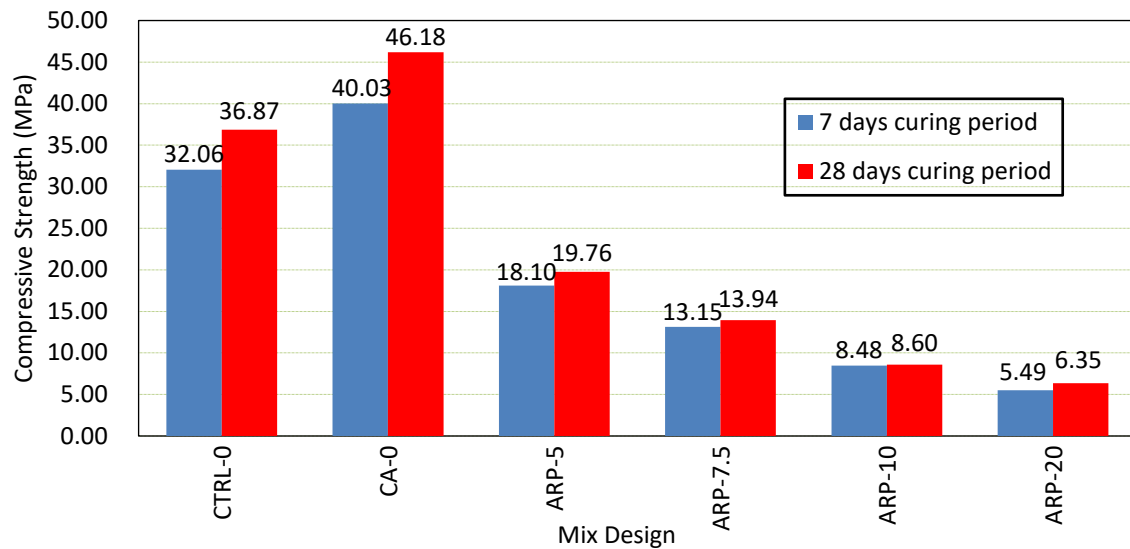


Fig. 8 Chart for Overall Compressive Strength Test Results

Another important aspect that needs to be observed is the failure mode of the hardened specimens. As seen in Fig. 9, CTRL-0 and CA-0 cube samples which contained no rubber powder, exhibited signs of brittle failure, which is consistent with the failure pattern for the MD1 mixture by Zainal et al., which consisted solely of CWS, and is comparable to the CTRL-0 mixture used in the present study [3]. In contrast, cube samples of mix designs added with rubber powder generally retained their overall shape after compressive loading, with only minor cracks observed. Similar observations were reported by Guo et al. who found that rubberized concrete specimens maintained better morphological integrity after failure due to the presence of rubber particles, which can alter crack propagation paths and reduce crack coalescence [21]. As shown in Fig. 9(c) and Fig. 9(d), the ARP-5 and ARP-7.5 cube specimens exhibited fewer and smaller cracks, which were primarily concentrated near the bottom region of the cubes. In contrast, the ARP-10 and ARP-20 specimens displayed larger cracks, as shown in Fig. 9(e) and Fig. 9(f), which were prone to propagate diagonally across the cube samples. This behaviour may be attributed to the increased rubber powder content in the mix, which may introduce more voids within the concrete matrix, thereby reducing the density and compressive strength of the concrete [22].

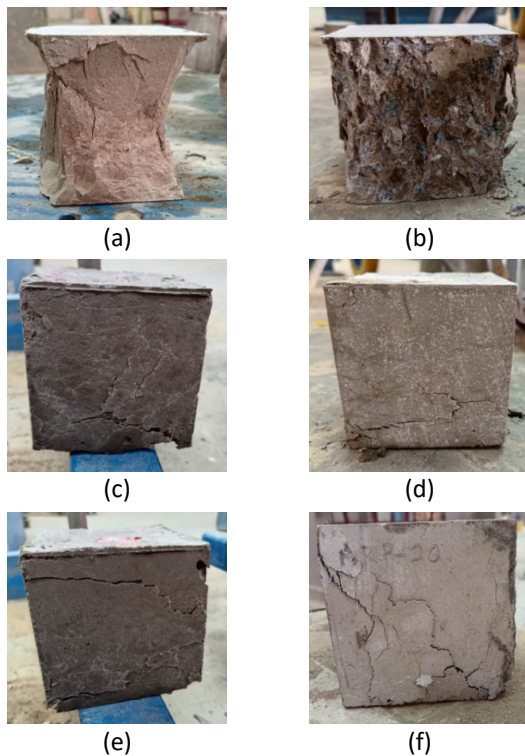


Fig. 9 Cube Samples Failure Modes of (a) CTRL-0, (b) CA-0 (c) ARP-5, (d) ARP-7.5, (e) ARP-10 and (f) ARP-20

From Fig. 10, the highest splitting tensile strength of mix design with rubber powder is ARP-5 (2.20 MPa) followed by ARP-7.5 (1.68 MPa), ARP-10 (1.37 MPa), and ARP-20 (1.15 MPa). As the percentage of rubber powder added in a concrete mix design increases, the splitting tensile strength decreases.

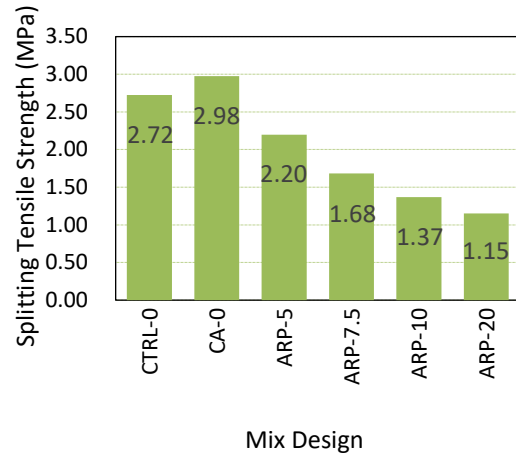


Fig. 10 Chart for Overall Splitting Tensile Strength Test Results

Among the rubber-containing concrete mixtures, ARP-5 exhibited the highest compressive strength and splitting tensile strength while maintaining acceptable fresh concrete properties. Although its compressive strength was lower than that of the CA-0 mixture, ARP-5 achieved the highest mechanical performance among all rubber-containing mixtures. Therefore, 5% rubber powder was considered the optimum replacement level within the range of rubber powder contents investigated in this study. The optimization criteria were based on achieving the best balance between fresh and hardened concrete properties while incorporating waste rubber powder for sustainable concrete production.

5. CONCLUSION

In conclusion, the findings revealed a consistent trend for both fresh and hardened concrete tests. For workability, slump flow tests showed a reduction trend in flowability as the rubber powder content increased, more readily seen to 10% and 20% additions. For rubber-containing mixtures, concrete incorporated with 5% rubber powder was the only mix design that falls within the accepted slump flow limit. The compressive strength of concrete decreased significantly by 57.2% from 46.18 MPa to 19.76 MPa as 5 % rubber powder was added compared to the concrete mixture with no rubber powder counterparts. A similar trend was seen in the splitting tensile strength test, where higher rubber

powder content in the mix design showed decline in the splitting tensile strength, indicating a weakened bonding within the concrete matrix. From the tests and results, the optimum rubber powder percentage was identified as 5% among the rubber-containing mixtures, indicating good workability and optimum measured mechanical strength. Mix designs CTRL-0 and CA-0, which contained no rubber powder, exhibited brittle failure mode while concrete specimens incorporating rubber powder retained their overall shape after compressive strength testing with minor cracking observed, possibly due to the presence of rubber particles that can alter crack propagation paths.

In supporting the feasibility of using rubber powder in concrete, recommendations are proposed to improve the present results and increase data reliability. First, future research could incorporate a microstructural analysis of concrete. Additionally, the effects of implementing different CWS setting periods can lead to deeper insights into concrete workability and inform optimum setting periods for CWS to enhance the performance of concrete

6. ACKNOWLEDGEMENT

The authors would like to express their sincere appreciation to the Ministry of Higher Education (MOHE) for the financial support provided through the FRGS-EC 2024-1 grant (Grant No: FRGS-EC/1/2024/TK01/UMS/02/1). The authors would also like to thank PMW Winabumi Sdn. Bhd. for their support and for granting permission to use their materials and factory facilities for this experimental study.

7. REFERENCES

1. Chang, T. W., & Kumar, D., Overview of Environmental Management Practice for Construction in Malaysia. *Civil and Sustainable Urban Engineering*, 1(1) 2021, pp.15-18. <https://doi.org/10.53623/csue.v1i1.33>
2. Mohajerani, A., Hui, S. Q., Mirzababaei, M., Arulrajah, A., Horpibulsuk, S., Kadir, A. A., Rahman, M. T., & Maghool, F., Amazing types, properties, and applications of fibres in construction materials. In *Materials* (Vol. 12, Issue 16) 2019, pp.1-2. <https://doi.org/10.3390/ma12162513>
3. Zainal, S. I. S., Adnan, N. M., Rizalman, A. N., Asrah, H., Chee, F. P., & Duinong, M., Effect of fiber hybridization on concrete slurry waste composite containing de-oiled bleaching earth. *Construction and Building Materials*, 464, 140127. 2025, pp.4-9. <https://doi.org/10.1016/j.conbuildmat.2025.140127>
4. Leong, S. Y., Lee, S. Y., Koh, T. Y., & Ang, D. T. C., 4R of rubber waste management: current and outlook. In *Journal of Material Cycles and Waste Management* (Vol. 25, Issue 1) 2023, pp.1-2. <https://doi.org/10.1007/s10163-022-01554-y>
5. Bušić, R., Benšić, M., Miličević, I., & Strukar, K., Prediction models for the mechanical properties of self-compacting concrete with recycled rubber and silica fume. *Materials*, 13(8), 1821. 2020, pp.11. <https://doi.org/10.3390/ma13081821>
6. Li, S., Yu, D., Jiang, C., Feng, Z., Zhao, M., & Li, Z. (2025). Influence of Waste Rubber Powder on the Mechanical and Abrasion Resistance Properties of Concrete. *Materials*, 18(22), 5157. 2025, pp.12-13. <https://doi.org/10.3390/ma18225157>
7. Nisah, K., Khairi, M., Sukandar, R., Nuzlia, C., Nasution, R. S., Ilhami, S., & Chiari, W., Fabrication and characterization of SiO₂-embedded castor oil-based membrane (*Ricinus communis* L) for aqueous Fe adsorption. *Narra X*, 2(2), e158-e158. 2024, pp.7. <https://doi.org/10.52225/narrax.v2i2.158>
8. Sofi, A., Effect of waste tyre rubber on mechanical and durability properties of concrete—A review. *Ain Shams Engineering Journal*, 9(4), 2691-2700. 2018, pp.2. <https://doi.org/10.1016/j.asej.2017.08.007>
9. Mehrani, S. A., Bhatti, I. A., Bhatti, N. B., Jhatial, A. A., & Lohar, M. A., Utilization of Rubber Powder of Waste Tyres in Foam Concrete. *Journal of Applied Engineering Sciences*, 9(1), 87–90. 2019, pp.1-2. <https://doi.org/10.2478/jaes-2019-0011>
10. ASTM., Standard Test Method for Slump Flow of Self-Consolidating Concrete 1. 2005.
11. Indrayani, I., Herius, A., Hasan, A., & Mirza, A., The Effect of Addition on Pumice and Fiber on Compressive and Flexural Strength Precast Lightweight Concrete:-. *Science and Technology Indonesia*, 5(1), 14-17. 2020, pp.16-17. <https://doi.org/10.26554/sti.2020.5.1.14-17>
12. BS EN 12390-3, Testing hardened concrete — Part 3: Compressive strength of test specimens. 2009.
13. BS EN 12390-6. Testing hardened concrete Part 6: Tensile splitting strength of test specimens. 2009.
14. EFNARC., The European guidelines for self-compacting concrete: Specification, production and use. International Bureau for Precast Concrete (BIBM). 2005, pp.44.
15. Abdullah, S. R., Riwayat, A. I., Abdul Awal, A. S. M., & Zakaria Hossain, M., Effect of rubber powder particle on the strength of foamed concrete. *International Journal of GEOMATE*, 13(38). 2017, pp.129-131. <https://doi.org/10.21660/2017.38.80292>

16. Lakhiar, M. T., Kong, S. Y., Bai, Y., Susilawati, S., Zahidi, I., Paul, S. C., & Raghunandan, M. E., Thermal and Mechanical Properties of Concrete Incorporating Silica Fume and Waste Rubber Powder. *Polymers*, 14(22). 2022, pp.9-10. <https://doi.org/10.3390/polym14224858>
17. Juveria, F., Rajeev, P., Jegatheesan, P., & Sanjayan, J., Impact of stabilisation on mechanical properties of recycled concrete aggregate mixed with waste tyre rubber as a pavement material. *Case Studies in Construction Materials*, 18. 2023, pp.2. <https://doi.org/10.1016/j.cscm.2023.e02001>
18. Amiri, M., Hatami, F., & Golafshani, E. M., Evaluating the synergic effect of waste rubber powder and recycled concrete aggregate on mechanical properties and durability of concrete. *Case Studies in Construction Materials*, 15, e00639.2021, pp.7. <https://doi.org/10.1016/j.cscm.2021.e00639>
19. Othman, R., Jaya, R. P., Muthusamy, K., Sulaiman, M., Duraisamy, Y., Abdullah, M. M. A. B., Przybył, A., Sochacki, W., Skrzypczak, T., Vizureanu, P., & Sandu, A. V., Relation between density and compressive strength of foamed concrete. *Materials*, 14(11). 2021, pp.18-19. <https://doi.org/10.3390/ma14112967>
20. Kouno, T., Qiu, Y., & Tang, R. (2026). Variability and design partial factors for rubberized concrete based on experiments and a large-scale database. *Construction and Building Materials*, 519, 145823. 2026, pp.13. <https://doi.org/10.1016/j.conbuildmat.2026.145823>
21. Guo, J., Huang, M., Huang, S., & Wang, S., An experimental study on mechanical and thermal insulation properties of rubberized concrete including its microstructure. *Applied Sciences*, 9(14), 2943. 2019, pp.9-11. <https://doi.org/10.3390/app9142943>
22. Najmi, A. M., Mariyana, A. K., Shek, P. N., & Nurizaty, Z., Hardened properties of concrete with different proportion of crumb rubber and fly ash. In *IOP Conference Series: Materials Science and Engineering* (Vol. 849, No. 1, p. 012038). IOP Publishing. 2020, pp.4-5. <https://doi.org/10.1088/1757-899X/849/1/012038>

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