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Investigation of Wall Panel Performance Using Recycled Concrete Aggregate and Perlite as Partial Replacement for Natural Fine Aggregate Under Uniformly Distributed Load

(Penyiasatan Prestasi Panel Dinding Menggunakan Agregat Konkrit Kitar Semula dan Perlit sebagai Penggantian Separa bagi Agregat Halus Asli Di Bawah Beban Teragih Seragam)

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ABSTRACT

The increasing depletion of natural resources and the environmental impact of conventional construction practices necessitate the exploration of sustainable alternatives in the construction industry. One promising approach is the use of recycled concrete aggregate (RCA) as a partial replacement for natural fine aggregates in concrete production. However, the performance of RCA in structural applications remains a critical concern, particularly regarding its impact on the mechanical properties of concrete. This study investigates the effects of RCA on the structural performance of wall panels subjected to uniformly distributed loads, with a focus on fresh and hardened properties. Wall panels with dimensions of 1000 mm x 480 mm x 120 mm were produced with RCA replacing 0% and 50% of the natural fine aggregate. The samples were labelled as control (SW120UC) and RCA (SW120U) samples, respectively. In terms of fresh properties, the workability of the control mortar (SW120UC) with 0% RCA was 57%, while the mortar with 50% RCA (SW120U) exhibited a workability of 56%. For hardened properties, the compressive strength of the control cubes (SW120UC) at 28 days was 10.21 MPa, whereas the cubes containing 50% RCA (SW120U) achieved a compressive strength of 16.52 MPa. The maximum load capacity of the RCA wall panels (SW120U) was 90 kN with a stress of 1.6 MPa, compared to 70 kN and 1.2 MPa for the control panels (SW120UC). Furthermore, the highest load versus deflection analysis revealed that SW120U with RCA reached a maximum load of 90 kN with a vertical deflection of 1.49 mm, whereas SW120UC with 0% RCA exhibited a maximum load of 50 kN and a deflection of 0.6 mm. These results demonstrate that RCA can significantly enhance the structural performance of concrete wall panels by improving compressive strength and load-bearing capacity while maintaining acceptable workability.

Keywords: Mortar; recycled concrete aggregate; wall panel; compressive strength

INTRODUCTION

The use of concrete as a primary building material has been integral to global construction due to its durability, versatility, and cost effectiveness. However, the environmental impact of concrete production, which accounts for approximately 8% of global carbon dioxide emissions, necessitates the adoption of sustainable practices within the industry. Cement, the key component of concrete, is a major contributor to these emissions, with global cement production witnessing a significant surge over the past two decades (Al-Omari 2023). This increase not only raises environmental concerns but also escalates the demand for natural aggregates, essential elements of concrete (Zalyatdinov 2023).

Natural aggregates, comprising sand, gravel, and crushed stone, constitute a substantial portion of concrete, with the global demand projected to rise significantly. This escalating demand poses environmental challenges such as resource depletion and habitat destruction, emphasizing the need for alternative materials to mitigate these impacts while upholding concrete's structural integrity. In response to these challenges, the utilization of recycled concrete aggregates (RCA) has emerged as a viable alternative to traditional natural aggregates, offering benefits such as waste reduction and decreased reliance on virgin resources.

Despite the historical roots of recycling concrete materials dating back to Roman times, the modern application of RCA has gained prominence, particularly in Europe, post-World War II (El-Hassan 2021). However, incorporating RCA into structural concrete presents challenges, primarily related to its mechanical properties. RCA differs from natural aggregates, often containing residual mortar and impurities that can compromise concrete quality and strength (Sameena 2024). Additionally, RCA typically exhibits characteristics like lower density, higher porosity, and increased water absorption, which can lead to reduced mechanical properties and structural integrity (Verian et al. 2018).

Research indicates that while RCA can enhance certain aspects of concrete, such as loadbearing capacity, challenges persist regarding its mechanical properties (Dimitriou et al. 2018). Studies have shown that concrete mixtures incorporating RCA can achieve comparable or superior compressive strength to those made with natural aggregates (Akbarnezhad et al. 2011). However, the impact of RCA on critical mechanical properties like deflection, deformation, and crack patterns requires further exploration to ensure that RCA-enriched concrete meets performance standards for structural applications (Zhang et al. 2015).

In addition to RCA, the incorporation of lightweight aggregates like perlite offers another avenue for improving concrete properties (Katz, 2004). Perlite, a volcanic glass with excellent insulating properties, can reduce concrete density and enhance thermal insulation, making it suitable for applications requiring lightweight and insulating characteristics (Qasrawi, 2014).

While the individual benefits of perlite and RCA in concrete are known, their combined effects on concrete properties remain understudied, necessitating further research to optimize mix designs for both performance and sustainability The exploration of innovative materials and structural systems in civil engineering has seen significant advancements in recent years, particularly in the context of enhancing the performance and sustainability of construction practices. Jamaludin et al. (2024) conducted a comprehensive study on the structural performance of cross-dapped connections in vertical wall-to-wall connections of precast wall panels.

In a related study, Md Nor et al. (2024) investigated the influence of recycled concrete aggregate (RCA) and expanded perlite on the performance of mortar. By incorporating RCA and expanded perlite, the study demonstrated how alternative materials could enhance mortar performance while reducing the environmental impact associated with traditional concrete production. Furthering the discussion on structural performance, Ruslan et al. (2024) examined the mechanical behavior of solid wall panels with varying slenderness ratios under uniformly distributed loads. A detailed analysis of how slenderness ratio affects the stability and load-bearing capacity of wall panels.

This study outlined aims to evaluate the impact of incorporating 50% RCA on the structural performance of wall panels, focusing on key mechanical properties such as workability, compressive strength, deflection, maximum load, and crack patterns (Anastasiou et al. 2014). By replacing natural fine aggregate with RCA in varying proportions, the study seeks to assess how RCA influences concrete performance characteristics (Yu et al. 2013). Furthermore, the inclusion of perlite in the concrete mix allows for an examination of its combined effects with RCA on concrete properties, providing insights into optimizing concrete mixtures for enhanced sustainability and structural efficiency (Gojević, 2023).

The environmental benefits of using RCA in concrete production are significant, including waste reduction and conservation of natural resources (Jiang, 2024). By minimizing construction and demolition waste sent to landfills and reducing the demand for virgin aggregates, recycling concrete aligns with global efforts to promote sustainable construction practices and reduce the industry's environmental footprint (Kumar et al. 2021). However, the performance of RCA in concrete is influenced by various factors, such as the quality of the recycled material, proportion used, and specific mix design, highlighting the need for careful consideration in its application (Penazzato, 2024).

Perlite, known for its insulating properties and low density, offers advantages in concrete applications by reducing density and improving thermal insulation (Stratoura et al. 2023). Its unique characteristics make it suitable for producing lightweight panels and structures, contributing to energy efficiency and building performance (Mohammad et al. 2020). While the benefits of perlite in concrete are well-established, its interaction with RCA and the combined effects on concrete properties warrant further investigation to optimize mix designs for sustainability and performance (Cojocaru et al. 2023).

In conclusion, the study's comprehensive evaluation of RCA and perlite in concrete applications addresses critical gaps in understanding their impact on mechanical properties and performance characteristics. By advancing knowledge on sustainable construction materials and practices, the research aims to optimize concrete mixtures for improved sustainability and structural efficiency, supporting the broader goal of promoting environmentally friendly construction practices (Öztürk 2021).

METHODOLOGY

MATERIALS

The recycled concrete aggregate was produced from waste material from the tested concrete cubes collected from the batching plant. The tested concrete cubes were collected from the MDC plant in Bertam, Penang. The concrete quality of the tested cubes was in the range of 20 – 30 MPa. Figure 1 (a) shows the tested cubes collected from the batching plant. The size of the tested concrete cubes was crushed using a chipper. The concrete cubes were then crushed into smaller pieces using a jaw crusher. After the recycled concrete aggregate was refined, the crushed RCA was sieved, and the maximum RCA was 5 mm. Both RCA and the natural fine aggregate were sieved to determine the particle size distribution. Both were compared with each other to ensure that they had the same characteristics or properties. Part of the mortar mix design was used in the production of mortar. 45 per cent recycled concrete aggregate, 50 per cent natural fine aggregate and 5 per cent perlite were used in the mix. The percentage of recycled concrete aggregate was calculated based on the total volume of mortar. The mortar with the recycled concrete aggregate was produced with a constant water/cement ratio of 1.0. Different water-cement ratios were used to produce the mortar. In this case, a small amount of water must be added to the RCA-containing mortar mix to achieve a water-cement ratio of 1.0. This is done to ensure that the new mortar can be processed correctly. Percentages of the RCA and Perlite used in the mix are shown in Table 1.

TABLE 1. Percentages of the RCA and Perlite in the Mortar Mix (Ruslan et al. 2024)

Sample	Materials		
	Perlite	Recycled concrete aggregate (%)	Natural fine aggregate (%)
RCA	5	50	45
Control	0	0	100

FIGURE 1. a) Collection of the tested cubes b) Jaw crusher was used for crushing the tested cubes.

FIGURE 2. Recycled Concrete Aggregate passing 5 mm sieve.

Figure 1(b) shows the preparation process for recycled concrete aggregates (RCA). In Figure (a), the tested mortar cubes are being collected after undergoing compressive strength tests. These cubes, which were essential for evaluating compressive strength, are then prepared for further processing. Figure (b) displays the jaw crusher used to crush the tested cubes into smaller aggregates. These crushed materials are subsequently used as RCA in further experiments, underscoring the study's focus on sustainable construction practices through material recycling. Figure 2 shows a recycled concrete aggregate that had passed through a 5 mm sieve.

PREPARATION OF SAMPLES

A total of 6 samples were prepared for two groups with the same dimensions, as shown in Table 2. The first group of samples was prepared for the controlled sample, which does not contain RCA in the mixture. The second group of samples was prepared for the wall panel sample containing RCA. Prior to the casting process, the moulds for each group of wall panels were prepared to ensure that the casting process could proceed smoothly. The moulds for the test cubes measuring 50 mm x 50 mm x 50 mm were also prepared in advance. The cubes were used to determine the early compressive strength of the mortar. A total of 6 cubes were produced, three from each group. The control sample was prepared with a mortar mixture with a ratio of 1:4 cement: natural fine aggregate. The mortar mix for the RCA sample was 1:2:2 for cement: recycled concrete aggregate: natural fine aggregate.

All materials were mixed and poured for each ratio. After the designated fresh mortar was mixed, a flow test was performed on each batch prior to pouring to assess the workability of the fresh mortar. The wall panels were cured by covering them with large bags and wetting them until they were wet. Moistening was carried out three times a day, in the morning, afternoon and evening. For the cubes, all cubes were immersed in a bucket filled with water.

TABLE 2. Sample Types with the Sizes, and Quantities Prepared for Testing

Samples	Size of samples	Number of samples
Control wall panel	1000 mm X 480 mm X 120 mm	3
Wall panel containing 45% RCA and 5% perlite	1000 mm X 480 mm X 120 mm	3
Cubes	50 mm X 50 mm X 50 mm	6

PREPARATION OF WALL PANELS

For casting the wall panel, oil was applied to the formwork and mold surfaces before pouring the mortar into the formwork. Figure 3 shows an isometric view of the mini wall sample, measuring 1000 mm x 480 mm x 100 mm. The formwork was opened at the sides and bottom to facilitate the curing process. To prevent damage to the wall panels, care was taken during this process. The wall was then covered with a gunny sack, which was sprayed with water daily for 28 days, in accordance with ASTM C31 standards for making and curing concrete specimens in the field.

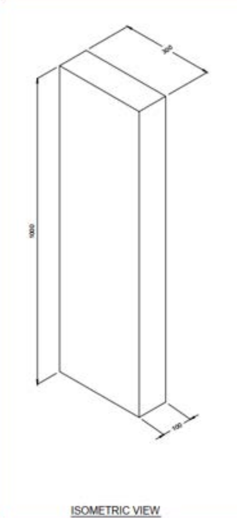


FIGURE 3. The Isometric View of Mini Wall Sample of Size 1000 mm x 480 mm x 100 mm

FIGURE 4. Test Setup for The Wall Panel with All Instruments

COMPRESSIVE STRENGTH OF THE WALL PANEL

The wall panels were statically loaded to failure. The load was evenly distributed on the top of the wall panel. The displacement check was performed before the wall was loaded. The same loading rate of 0.2 mm/min was used throughout the test of all wall panels. During the loading of the wall, two strain gauges and two linear variable differential transducers (LVDT) were used to analyse the strain and deflection of the sample. The position of all sensors is shown in Figure 4. The deflection of the wall at these locations was determined using the LVDTs. LVDT 2 was located halfway up the wall and LVDT 1 was located 750 mm from the base of the wall. The strain gauges were placed 2 cm from each LVDT. The third LVDT was placed at 250 mm from base and was malfunctioning, hence no data was captured during the experiment. In this study, Linear Variable Differential Transformers (LVDTs) were strategically positioned at key locations on the wall panel to accurately assess its deformation and flexural behavior. Specifically, LVDTs were placed at the center and near the edges of the panel. The LVDT at the center of the wall was employed to measure the maximum deflection, which typically occurs at this location due to the greatest flexural deformation under applied loads. This central measurement provides critical insights into the overall performance and structural integrity of the wall panel. In addition, an LVDT positioned near the edge of the wall was used to monitor deformation in areas close to the supports or boundaries. These regions often experience higher flexural stresses and are prone to potential cracking. By capturing deformation near the edges, this placement enables a detailed examination of the wall's behavior under load in these critical areas.

RESULTS AND DISCUSSION

FLOWABILITY OF THE FRESH MORTAR

The results of the flow table tests for the controlled sample and the sample with recycled concrete aggregate shows an average spreading diameter for the sample with RCA is slightly higher than that of the control sample without RCA with an average spreading diameter of 39.8 and 39.6 mm respectively. The percentage of flowability for the control sample and the sample with RCA was 56 per cent and 57 per cent respectively. The value of the flow test ranged from 0 to 150 per cent, indicating a high workability of the concrete mortar. The most notable differences between the tested samples can be seen in two parameters: the increasing threshold value for the pore radius as the replacement of natural fine aggregate by RCA increases, and the detection of zones of greater quantitative changes as the pore volume of pores increases.

The workability of mortar made from Recycled Concrete Aggregate (RCA) is influenced by various factors as discussed in the literature. Studies have shown that the average spreading diameter of mortar samples containing RCA was slightly higher than that of control samples without RCA, indicating improved workability (Roque et al. 2020). Additionally, the percentage of flowability was slightly higher in samples with RCA, further supporting enhanced workability (Yu et al. 2019). The flow test results, ranging from 0 to 150 per cent, indicated a high workability of the concrete mortar (Rizwan et al. 2022). One significant factor affecting the workability of mortar with RCA is the presence of adhered mortar on the surface of RCA. This adhered mortar can increase internal friction during mixing, impacting overall workability (Yin et al. 2013). Moreover, the replacement of natural fine aggregate by RCA can alter the pore structure of the mortar. As the replacement level increases, there is a shift in pore characteristics, affecting workability (Roque et al. 2020). Furthermore, the inherent properties of RCA, such as density, porosity, and water absorption, play a crucial role in determining mortar workability. RCA typically exhibits lower density, higher porosity, and increased water absorption compared to natural coarse aggregate, influencing overall workability (Zhang et al. 2023). In conclusion, the workability of mortar containing RCA is influenced by factors like adhered mortar on RCA, changes in pore structure due to aggregate replacement, and the properties of RCA itself. Understanding these factors is essential for optimizing mix designs and achieving the desired workability in mortar with RCA.

DENSITY AND COMPRESSIVE STRENGTH OF MORTAR CUBE

In terms of the relationship between the density and the compressive strength, the decreased density decreases the compressive strength of material. BS EN 206-1 (2003) defined the lightweight concrete (LWC) as having an oven-dry density of not less than 800kg/m^3 and not more than 2000kg/m^3 by replacing dense natural aggregates either wholly (100%) or partially (50%) with lightweight aggregates. When the lower density aggregate contributed, the concrete can produce density lower to 1850 kg/m^3 than normal weight concrete (NWC) which is 2400 kg/m^3 (Bremner, 2008). In this project, the mortar density obtained from the calculation using Archimedes' Principle are 2005 kg/m^3 and 2064 kg/m^3 for specimen SW120UC and SW120U, respectively as shown in Figure 5. This justified that using combination of lightweight and normal-density aggregate in mortar are still in range where the density not less than 1850 kg/m^3 and not more than 2400 kg/m^3.

The relationship between the density and compressive strength of materials is crucial in understanding the performance of concrete mixes. According to BS EN 206-1 (2003), lightweight concrete (LWC) is defined by having an oven-dry density ranging from 800 kg/m^3 to 2000 kg/m3, achieved by replacing dense natural aggregates with lightweight aggregates either wholly or partially (Roque et al. 2020). In a study by Bremner (2008), it was noted that concrete with lower density aggregates could achieve densities lower than 1850 kg/m^3, compared to normal weight concrete (NWC) with a density of 2400 kg/m^3 (Roque et al. 2020). The mortar density calculations in a specific project showed values within the acceptable range, indicating that a combination of lightweight and normal-density aggregates in mortar can maintain the desired density levels (Roque et al. 2020).

Regarding the impact of density on compressive strength, Othman et al. (2021) highlighted that decreased density leads to reduced compressive strength of the material (Yu et al. 2019). Wang & Zhao (2019) supported this by stating that while the use of Recycled Concrete Aggregate (RCA) can enhance strength, the replacement percentage should be limited to 50%, as higher RCA content leads to a reduction in strength (Rizwan et al. 2022). Specifically, the compressive strength was observed to decrease by 14.2% to 19.9% when the RCA replacement content increased from 50% to 100% compared to control specimens (Rizwan et al. 2022). Safiuddin et al. (2011) further emphasized that concrete with 100% RCA exhibited lower compressive strength than control concrete, particularly at 28 days, with a reduction of 12.2% compared to the control (Yin et al. 2013). However, in the same project, a 38% increase in compressive strength was noted when the RCA replacement content increased from 0% to 50% (Roque et al. 2020).

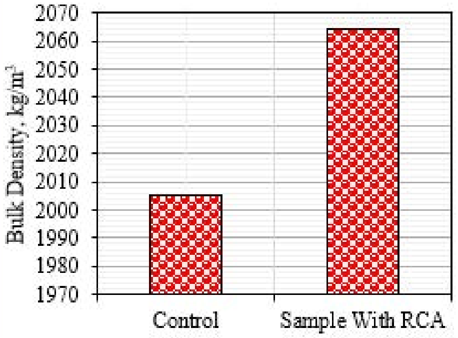


FIGURE 5. Bulk Density of control and sample with RCA mortar

Although perlite is known for its lightweight properties and typically reduces the bulk density of concrete, the slight increase in density observed in the SW120U specimen suggests that the proportion of perlite used may not have been sufficient to achieve a significant reduction. The presence of RCA, which has a higher density than perlite, might also contribute to the higher overall density. The marginal increase in density with the inclusion of perlite and RCA indicates that there may be a trade-off between reducing bulk density and maintaining structural performance. The additional weight of RCA could offset some of the density reduction benefits of perlite. In summary, while the density of the SW120U specimen with perlite and RCA was slightly higher than that of the control specimen, the inclusion of perlite still offers potential benefits in terms of thermal insulation and workability.

When recycled concrete aggregates (RCA) replaced natural fine aggregates in mortar cubes at 28 days of age, the compressive strength of the mortar increased, as illustrated in Figure 6. The normal mortar cube had a mean compressive strength of 10.21 MPa with a standard deviation of 0.17, while the mortar cube with RCA achieved a higher mean compressive strength of 16.52 MPa with a standard deviation of 0.57. The coefficient of variation (COV) was calculated as -0.052. These results confirm previous studies. Several studies have investigated the use of recycled concrete aggregates in concrete mixtures. Knaack & Kurama (2011) explored the design of normal strength concrete mixtures with recycled concrete aggregates as a substitute for natural aggregates. Jochem & Cheriaf (2014) studied the influence of fine sand from construction-demolition wastes in mortar properties, highlighting the effects of pre-wetting and performance in mortar composition with recycled aggregate. Additionally, examined the impact of adding marble and porcelain waste on the mechanical properties of concrete containing recycled aggregate, demonstrating that the use of recycled coarse aggregate can lead to higher compressive strength and modulus of rupture compared to original concrete (Al-Luhybi 2017).

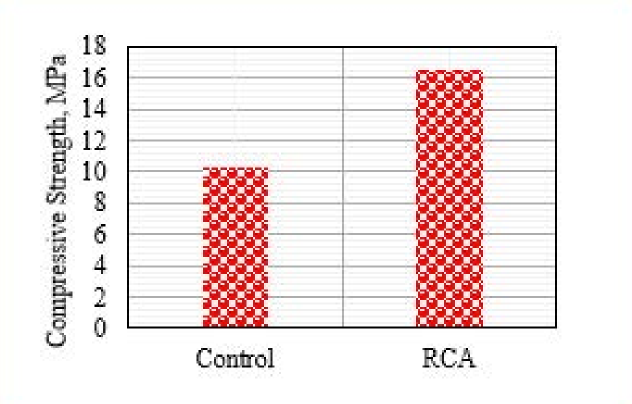


FIGURE 6. Compressive strength of the mortar

LOAD AND DEFLECTION- RELATIONSHIP

In structural behavior of wall, the deflection defined the degree of wall to deflect or buckle under load applied. It revealed in distance (mm) unit. In this project, the initial vertical deflection at 1/3 and 1/2 of the wall were recorded using LVDTs. 1/3 and 1/2 of the wall height expected to have the minimum and the maximum deflection when load applied. Figure 7 shows the graph of load -deflection for SW120UC and SW120U. In the first compression test, conducted on SW120U wall, UTM machine with bearing 400 kN was used to apply the load directly onto the wall panel. When load applied, the wall shows some deformation where it becomes larger on a small increase applied load. The lateral deflection of structures under load is a critical aspect in structural engineering. Situmorang et al. (2020) observed that lateral deflection increases rapidly as the load increased. This finding aligns with previous studies that have investigated the behavior of structures under lateral loads. Situmorang et al. (2020) conducted experiments on slab pavement with piles on soft soil, showing that an increase in lateral loading led to a proportional increase in slab deflection. Similarly, Kumar & Rao (2012) studied the deflection response of an embedded caisson in marine clay and found that deflection levels increased with higher load eccentricity ratios.

On the contrary, some researchers have reported contrasting results regarding the effect of load on deflection. suggested that the strength improvement is more significant when mineral admixtures are used over an extended period, indicating a complex relationship between load and deflection. This variability in findings underscores the importance of considering different factors that can influence the deflection behavior of structures under lateral loads.

Understanding the relationship between lateral deflection and applied loads is crucial for designing resilient and safe structures. Factors such as material properties, load distribution, and structural geometry play a significant role in determining the deflection response of structures under lateral loading conditions. A maximum vertical deflection of 1.49 mm was recorded on applying a load of 90 kN. Additional deformation could not be recorded due to the broken strain gauge. The wall deformed in linear elastic manner throughout the test because when the wall was unloaded, damage was found on the wall. This behavior indicates that the SW120U wall deflected simultaneously during the application of load.

In the second compression test, conducted on SW120UC wall, UTM machine with bearing the same bearing 400 kN was used to apply the uniformly distributed line load directly on top of the wall panel. When the load applied, the wall shows some deformation after 10 minutes which is shorter in time compared to SW120U wall, the deform start at minutes 20. The deformations became larger on the increases of load. In the graph above, the SW120UC wall shows the large deflection values is between 0.4 mm to 0.6 mm under maximum load 44 kN. Due to instability of specimen, the wall was unable to take high load more and broke the strain gauge.

From the result, both of specimens failed at the highest load. The highest load for SW120U is 90 kN with maximum vertical deflection of 1.49 mm, while for the SW120UC the highest load does not exceed than 50 kN with maximum vertical deflection of 0.6 mm. Compared to previous study (Rahman et al. 2021), the maximum deflection of wall specimens increases from 1.93 mm to 2.97 mm for increment of specimen ratio 17 to 23. Since this project has similarity specimen height with specimen ratio 8, the maximum deflection of 1.49 mm and 0.6 mm were lower than 2.97 mm for SW120U and SW120UC, respectively.

There is quite different maximum load applied between of the two walls due to material factor, the ultimate load capacity clearly increased as RCA content used. The deflection of the wall that contained RCA was greater than the reference control wall. The sample wall contained 50 % of recycled concrete aggregate as partial natural fine aggregate makes the wall to have the highest strength than the wall with 0% of recycle concrete aggregate.

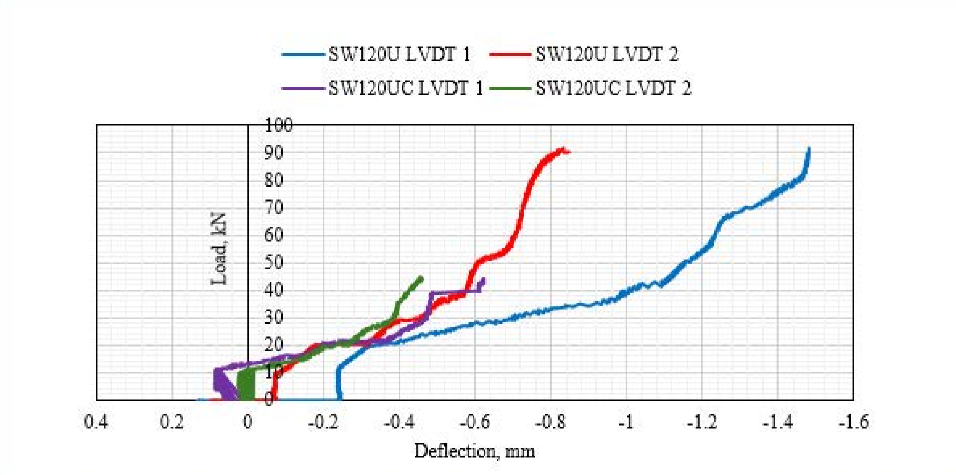


FIGURE 7. Load versus Deflection for SW120UC and SW120U

LOAD-STRAIN RELATIONSHIP

FIGURE 8 shows the graph of load-strain for SW120UC and SW120U.For specimen SW120U, the three strain gauge values remain zero to the applied load and maintained as the load increased. After 20 minutes, it was observed that the strain gauge at the side of the wall started to have shear value, while the two strain gauges at the front surface of the wall still maintained zero reading. After 30 minutes, the first crack was observed at the top of the side of specimen SW120U. The load is maintained at 90 kN while the strain increases range 0 to 4000 micro mm/mm while the other strain gauge still has zero strain with increased load up to 70 kN. This indicates, the strain at the side of the wall obviously had more impact compared to the strain at the front surface of the wall. The structural resistance of the wall is still maintained until the strain goes up to 6000 micro mm/mm and the wall failed.

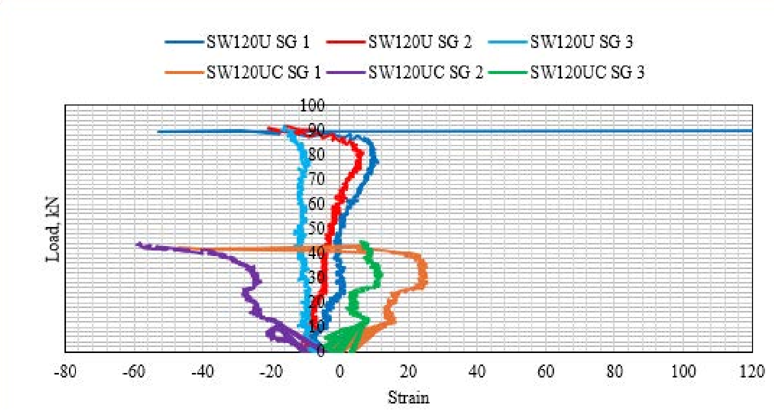


FIGURE 8: Relationship between load and the strain at specific location for SW120UC and SW120U

For specimen SW120UC, the strain values remain zero to the applied load and maintained as the load increased. After 10 minutes, the first crack had occurred on the wall and the graph become maintained as non-linear but still having the load. Same goes to specimen SW120U, the strain at the side of the wall obviously got more impact compared to the strain at the front surface of the sample wall. The strain gauge at the side of the wall indicates the load maintained at 40 kN while the strain increases range 0 to 500 micro mm/mm . The crack travels more into the wall cross section and the wall failed with higher strain 1500 micro mm/mm. The statement that the stress-strain curve for mortar is non-linear and that lateral deflection increases rapidly as the load is increased is supported by Rahman et al. (2021) and Sutumorang et al. 2020). This observation aligns with findings from studies on the behavior of structures under lateral loads. conducted experiments on slab pavement with piles on soft soil, demonstrating that an increase in lateral loading led to a proportional increase in slab deflection (Situmorang et al. 2020. Additionally, studied the deflection response of an embedded caisson in marine clay and found that deflection levels increased with higher load eccentricity ratios (Kumar & Rao 2012).

On the contrary, Kumar & Rao (2012) suggested that the strength improvement is more significant when mineral admixtures are used over an extended period, indicating a complex relationship between load and deflection. This variability in findings underscores the importance of considering different factors that can influence the deflection behavior of structures under lateral loads.Both specimens failed at the top of the wall at the side of the wall since the line load more affecting the side of the wall.

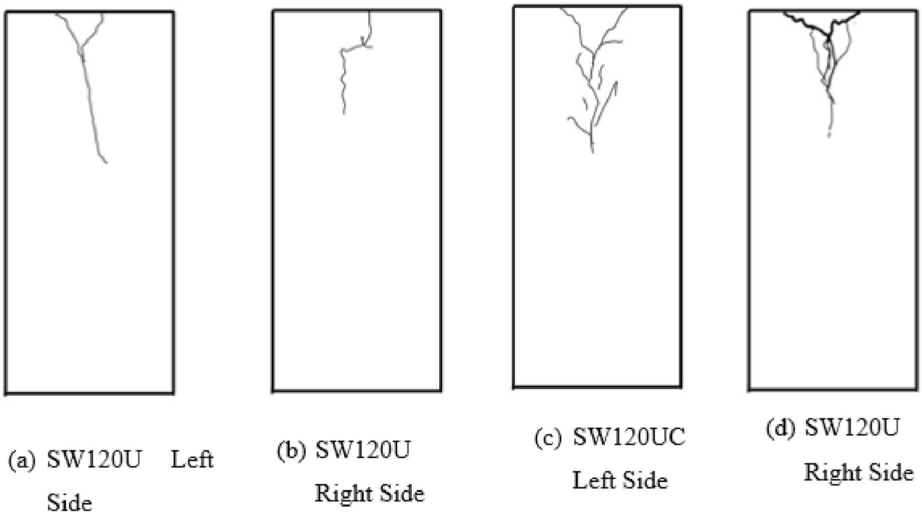
In comparison, the specimen SW120U has a higher strain value when load applied compared to specimen SW120UC. The strain goes up to 6000 micro mm/mm for load around 90 kN for specimen SW120U but for specimen SW120UC, the ultimate load is around 40 kN with 1500 micro mm/mm strain. The strains value obtained in specimen SW120U was very small ranges from 0.0001 to 0.0002 and much lower than the strain in specimen SW120UC.

In terms of load and slenderness ratio, the ultimate load decreases by increasing the panel slenderness ratio, defined H/t, where H is the total height and t the overall thickness of the panel (Benayoune et al. 2007). Both wall specimens have same slenderness ratio but has different value resist load. This proves that the characteristic wall is not only influenced by slenderness ratio, but it might also be influenced by material used.

In terms of material, the mortar wall made up by 50% partial natural fine aggregate replacement has the higher load and strain compared to the 0% partial natural fine aggregate replacement. It is concluded that the use of RCA a replacement of natural fine aggregate changed the strain variations and increased the structural resistance of the wall.

CRACK PATTERN

Figure 9 shows the summary of crack occurring on both specimens. The first crack occurs at the top of the wall when load applied because the mortar wall was designed without tension material consideration. In conclusion, it is observed that the failure mode of the wall specimens was same which are vertical crack regardless of loading conditions. Since all the specimens were short and have a similar slenderness (height to thickness ratio of 8), no buckling failure was observed. The cross-section of the wall fully contributed by cracking in resisting the applied load. The cracks pattern for both specimens were initially small but started to spread in the cross section of specimen under the load applied. The maximum crack width increases with the load applied but drops almost to zero when the specimen is unloaded. This means that the crack will stop once the loading is removed. However, the wall strength increased significantly on sample wall due to 50% RCA replacement.


(a) SW120U Left Side

(b) SW120U Right Side

(c) SW120UC Left Side

(d) SW120U Right Side

FIGURE 9. The Crack Pattern for SW120UC and SW120U

CONCLUSION

This paper presents the effects of using recycled concrete aggregates as a substitute for fine aggregates in the production of mortar cubes and wall panels. The compressive strength of the mortar cubes was tested after twenty-eight days. The compressive strength of the wall panel was tested after more than 28 days under a uniformly distributed load. Based on the results, it is possible to conclude that:

1. In term of fresh properties, the workability of sample mortar (SW120U) that contain 0% RCA is 57% while for control mortar (SW120UC) that contain 50% RCA is 56%.
2. In term of hardened properties, the value of compressive strength or cubes at 28 days for control cube (SW120UC) that contain 0% RCA is 10.21 MPa and sample cube is (SW120U) that contain 50% RCA is 16.52 MPa.
3. The maximum load for specimen SW120U is 90 KN with 1.6 MPa stress while for specimen SW120UC the maximum load is 70 KN with 1.2 MPa stress.
4. For load versus deflection, the highest load for SW120U is 90 KN with maximum vertical deflection of 1.49 mm, while for the SW120UC the highest load does not exceed than 50 KN with maximum vertical deflection of 0.6 mm.

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DECLARATION OF COMPETING INTEREST

None.

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