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Mechanical Properties of Concrete Containing Coconut Shells as Coarse Aggregate Partial Replacement

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KEYWORDS

Mechanical properties
Coconut shells
Coarse aggregate

ABSTRACT

In most tropical countries, especially in Asia, where afflicted nations included the Philippines, Thailand and Malaysia, agricultural waste was disposed of in enormous amounts. Poorly designed garbage disposal techniques are one of the biggest environmental ills. Environmental conservation efforts have been severely hampered by the disposal and management problems posed by wastes produced by industrial and agricultural operations. This study was carried out to find optimal replacement of coconut shell taken at 7, 14, and 28 days of curing by conducting mechanical properties tests. In this investigation, coconut shell concrete was produced by replacing coarse aggregate with coconut shells by 0%, 10%, 20%, and 30% of the total coarse aggregates. The results suggest that 10% replacement of coconut shell produces the optimum value for coarse aggregate replacement based on the compressive strength and Schmidt rebound hammer test results.

1. INTRODUCTION

Construction sector is one of the vital industries that contributes to Malaysia's economy growth. When there is a positive growth there will be a negative point of view, the negative part of these fast developments is harm to the environment. One of the environmental issues is caused by poor planned waste disposal methods. Wastes generated by industrial and agricultural operations have caused disposal and management issues, posing severe obstacles to environmental conservation efforts [11].

Agricultural waste was disposed in huge quantities in most tropical nations, especially in Asia, such as the Philippines, Thailand and Malaysia. So as a solution to overcome these environmental issues, it is proposed to use agricultural waste material as an alternative to replace concrete material. Coconut shells (CS) will be one of the most suitable waste materials that can be used as replacement for natural aggregates in concrete. The coconut plant is incredibly adaptable, and many elements, including the roots, stems, nuts, leaves, and even other tree parts, can be utilised. Because it is biodegradable, strong and durable, it takes a while for it to break down. Adding onto that, since a significant quantity of CS and fibres wind up in the environment as trash, using these materials for building will be a significant step toward improving sustainability and environmentally friendly construction [16].

CS offers excellent durability, hardness, and abrasion resistance capabilities and may be found in sufficient quantities. According to a study [16] on CS concrete, the coarse aggregate in concrete may be substituted with CS and the resulting concrete has a strength of 65% that of conventional concrete. When compared to regular concrete, CS concrete has a great impact resistance. The CS is more resistant to acidic and alkaline attack. Hence, replacing conventional coarse aggregate with CS in concrete is an effective approach in both, preventing environmental pollution and designing economical buildings. With respective to this research, the possibility of replacing conventional coarse aggregate with CS can develop a new market and provide an alternative for construction industry in selecting materials for replacement.

1.1 Problem Statement

Increasing construction development has caused depletion of material issues to happen. So, when the demand rises the

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price also rises eventually. Building costs have risen due to the high cost of construction materials such as cement and reinforcing bars. For these reasons, many researchers have concentrated on using agricultural waste materials as a potential alternative material in construction industry. Agricultural waste materials such as rice husk, groundnut husk, maize cob, and coconut shell have posed an environmental concern, necessitating the development of new technologies to reduce their environmental impact by converting them into usable resources in the construction industry and to minimize negative impact on the environment [20].

1.2 Coconut Shell Waste Material as Replacement

Recently, the quality of CS in concrete as replacement to coarse aggregate in construction material, were investigated [2]. As mentioned to previous research [7, 8], the CS is mostly utilised as a decorative item and a source of activated carbon. Plastics, glues, and abrasive materials are all industries that employ powdered shell.

According to [13], the flat surface on one side of the shells, makes it easier to work with. When compared to regular concrete, CS concrete has a great impact resistance. CS has a higher moisture retention and water absorption ability than ordinary aggregate. Furthermore, as a solid waste in the form of waste coconut shells, it contributes to the nation's pollution problem. Natural conventional aggregates are rapidly decreasing and becoming rare due to high demand.

Research conducted [1] stated that CS concrete is lighter than natural aggregate concrete in lightweight concrete to achieve the requisite concrete strength. Furthermore, in compared to other agricultural waste, CS absorbs less moisture due to its reduced cellulose concentration. According to [3], CS is a natural product because of CS has strong durability qualities, high toughness, and abrasion resistance, it is suited for long-term usage. A previous research [7] stated that, CS has a low cellulose content, it absorbs less moisture than other agricultural waste. It has non-biodegradable shells. They may be employed quickly and in concrete that has practically all the properties of the original concrete form. Because the sugar in the CS is not in the form of free sugar, it has no effect on the setting and strength of concrete. CS have been discarded might be used as a substitute. A study [1] has investigated on the mechanical characteristics of CS as a fine and coarse aggregate substitute in concrete and the CS concrete was constructed with CS as a replacement for fine and coarse aggregate at 10%, 20% and 30%, respectively, with a characteristic strength of 30 MPa.

1.3 Physical Properties of Coconut Shell

The physical qualities of CS must be determined without altering their identity. It is critical to confirm the physical qualities of the CS before using them in concrete mixtures. According to [3], The CS had an average moisture content of 4.20%, which are much lower than those reported in typical aggregates. This might be the case since CS falls under the category of lightweight aggregate when used in concrete. Adding onto that, because CS is a lightweight material, it has more pores than regular coarse aggregate and due to the porous nature of lightweight aggregate concrete, the interfacial transition zone has a large pore area. The weak interfacial transition zone of lightweight aggregate has an impact on concrete strength and liquid infusion, which is a key criteria for long-term concrete durability [15]. From this finding it can be concluded that, CS falls under lightweight aggregate.

1.4 Concrete containing Coconut shell

In the previous research conducted [1] results from various method and specification on the usage of CS in concrete has obtained. Upon the experiment some characteristic has been stated out for further use. When the fine and coarse aggregate replacement in CS concrete was raised to 30%, the concrete slump increased evenly to 5mm, indicating enhanced workability. While CS concrete had a lower density than the control, ranging from 2102 kgm^3 to 1903 kgm^3. Adding onto that, we can acquire better concrete strength characteristics than the nominal mix by adding 20% CS as a partial substitute for coarse aggregates and cement in the concrete mix. When more than 25% of the coconut shells are changed in the concrete, the strength qualities steadily deteriorate.

In another point of view, when compared to the reference mix of CS with 0% replacement, test results for fresh characteristics such as slump and compaction factor show that using CS in concrete as a partial substitution for coarse aggregate reduces the workability in marginal rate. However, according to [21] as a practical solution, CS may be used to replace coarse aggregate up to 20% of the time without damaging the concrete's fresh qualities. The compressive strength of concrete is influenced by the cement matrix strength and the aggregate particle tensile strength. Rather than the water-cement ratio, it is frequently connected to the cement content, needed workability, and air content, because determining how much of the entire mix water is absorbed by the aggregate and hence how much water is accessible for hydration processes is challenging. In a study [1], the compressive strength of a concrete specimen with natural fine and coarse aggregate control specimen is 50.56 MPa after 28 days, indicating that the strength reduction increases as the percentage of replacement increases, reaching nearly half of the control strength (25.21 MPa) after 30% replacement. [21] proved and stated that, the compressive strength test can be used to measure the material's resistance to external loading. The 20% substitution of the material mix resulted in a higher compressive strength than conventional concrete

2. EXPERIMENTAL WORK

The materials used in this experiment were CS, cement, coarse aggregate, fine aggregate and water. The laboratory tests that were conducted were slump test, physical properties test and mechanical properties tests. For the mechanical properties tests, the destructive test was compressive strength test and non-destructive test was Schmidt Rebound Hammer were carried out. Four series of CS specimens which comprises of four (4) different replacement levels of CS, that are 0%, 10%, 20% and 30% were prepared.

1.1 Material Preparation

In this experiment, Ordinary Portland Cement (OPC) was used. The fine aggregate used was river sand, which was devoid of all organic and inorganic materials. A 10mm mesh size is used to sift the sand. While 20mm gravel stones make up the coarse aggregate utilised in the combination. CS should replace coarse aggregates by percentages of 10%, 20%, and 30% of the total amount of course aggregate to be utilised, with a minimum size requirement of 20 mm. The tap water used was maintained to 6 pH. The CS are a residue produced during crushing process of coconut. These CS were collected from local mini marts and proceeded to be broken by hammer into smaller size. The crushed materials were than washed and allowed to dry under ambient temperature. The coconut shell's range of particle sizes was set at 20 mm.

Fig. 1. Crushed Coconut Shells

1.2 Mix Proportion

A total of four (4) batches of concrete mix were created for 0.5 water cement ratio. The mix proportion of the concrete is indicated in Table 1 below. The CS was made up 0% of the coarse aggregate in S1, which is the control sample created for M40 strength. The CS used were 10%, 20%, and 30% for S2, S3 and S4 respectively.

Table 1. Concrete Mix Proportion

Sample	Cement (Kg)	Water (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Coconut Shells (Kg)
S1	16.53	8.27	29.13	51.78	-
S2	16.53	8.27	29.13	46.60	5.18
S3	16.53	8.27	29.13	41.42	10.36
S4	16.53	8.27	29.13	36.25	15.53

A total 36 samples were made for 150 mm x 150 mm x 150 mm cube. All the samples were water cured at 7, 14 and 28 days of water curing. The water cement ratio used for this study was 0.5. The total amount of fine aggregate, cement and water were constant in the mix proportion.

1.3 Test Procedures

The aggregate was tested using particle size distribution test. According to BS 812103:1:1985, a sieve analysis was done to determine the aggregate's particle sizes. As seen in Figure 2, the aggregates were sorted using a mechanical sieve shaker. The pans were stacked and placed on the motorised sieve shaker in the proper order. A 20 mm filter was utilised to filter the used coarse aggregate and CS.

Fig. 2. Conducting Sieve Analysis

After sieving the CS, the moisture contest test was carried out in accordance with the BS 812: Part 109. The process that was used to carry out in this test was oven drying method. The coconut shells were cleaned and let to pass through sieve, then the coconut shells were weighed and placed in a container. Then the container was set to dry for 24 hours in a hot air oven. After 24 hours the container was taken out and set to cool then finally proceed to record the final weight. Figure 3 shows dried sample is being weighed for final weight.

Fig. 3. Weighing Dried Coconut Shell Sample

All the materials were mixed properly as per proportion. A slump test is conducted to determine the workability of freshly mixed concrete and, as a result, the ease with which it flows. It can also be used to detect a batch that has been poorly mixed. The concrete mix is placed properly inside the slump cone each one a third of the height of the mould. Using the metal rod in a circular motion, each layer is tamped 25 times. Turning the slump cone upside down and placing it on the specimen with the steel tamping rod put on the slump cone, the slump height will be measured. Figure 4 shows the measurement of slump after cone is lifted.

Fig. 4. Obtained Slump Height

The 150mm x 150mm x 150mm concrete cube mould was used in this study. The moulds were greased before being filled with concrete to prevent the formation of a strong bond between concrete specimens and moulds. Then was continued to compaction, to avoid compaction of new concrete and entrapped air in concrete, a table vibrator was used for compaction purpose. The cast specimens were left to harden under ambient temperature for 24 hours.

The specimens were subsequently demolded after having water cured at 7, 14 and 28 days. Then the specimens were tested for non-destructive test which is Schmidt rebound hammer test. This non-destructive test was performed in line with British Standard EN 12504-2:2001. Rebound numbers were obtained at five spots on each surface of the cube to determine the hardness of the concrete within the cube. The plunger was then permitted to strike perpendicular to the sites pointed at a 90° angle. Figure 5 shows the Schmidt rebound hammer upon testing.

Fig. 5. Schmidt Rebound Hammer

Then it was proceeded to compressive strength test. On the machine's base plate, the specimen is positioned in the centre. Up until it meets the concrete, the height is changed. Figure 6 shows the compression device and the position of the concrete cube before any force is applied. Until the samples fail, a constant load is applied.

Fig. 6. Compression Testing Machine

2. Results and Discussion

To test the mechanical characteristics of the concrete mixture, different percentages of CS were replaced for coarse aggregate in this study. The mechanical characteristics of the mixture were then modified by adding enough CS. Prior to testing, all of the concrete samples were cured in water for 7, 14 and 28 days. The results of all concrete cube specimens are discussed here, along with samples of conventional concrete and samples that substituted 10%, 20%, and 30% CS for coarse aggregate.

2.1 Average Moisture Content for Aggregates

Figure 7 shows average moisture content test obtained for coconut shell and crusher stone aggregates. The amount of water vapour and other volatile components contained in a sample is determined by the moisture content. Observing the bar chart, it can be seen clearly that coconut shell has higher moisture content than the crushed stone aggregates. The average moisture content that coconut shell obtained was 4.21% while crushed stone aggregate obtained around 1.15%, both coconut shell and crusher rock has obtained more 1% of moisture content so that the aggregate can be used later in the concrete mixing. Moisture content level affect the strength of concrete. The compressive strength of concrete is reduced when moisture levels rise. In this case, moisture content of CS is 4.21% even though it has passed the optimum level for an aggregate that need to be used in concrete mixing, it is also has quite high moisture content and this requires more water upon mixing. Since the water was kept constant upon the experiment and this resulted less strength for higher CS coconut shell replacement concrete sample.

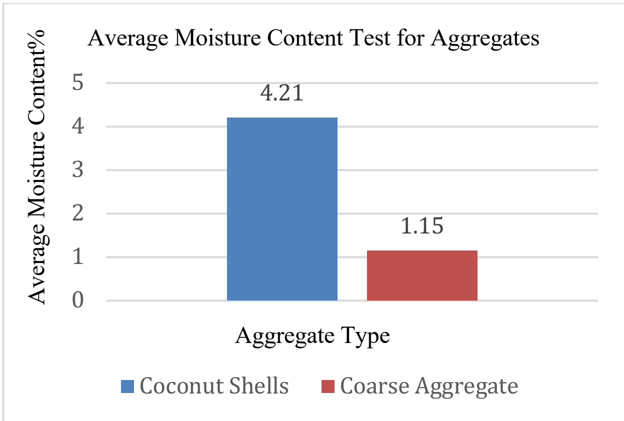

Fig. 7. Average Moisture Content Results

2.2 Workability of Coconut Shell Concrete

For both the control samples and the concrete samples made from CS, the slump test was used to measure how easily fresh concrete could be shaped. The graph in Figure 8 depicts the results of the slump test for the specimens. According to sample order, the slump values for control samples and concrete samples made from CS were 52mm, 55mm, 57mm and 58mm. It has been seen that when more coconut shell is added to the mixture, the slump value increases. According to the data, adding more CS to the concrete resulted in a more workable mixture.

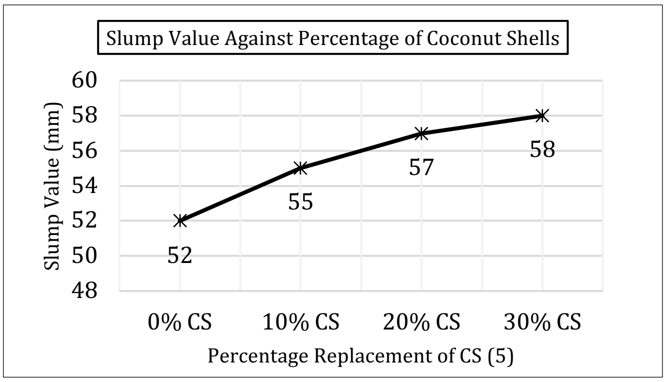

Fig. 8. Slump Test Results

The CS particle have improved the workability of the CS concrete. Additionally, given that sand's density is significantly higher than that of CS and that an increase in the quantity of CS likewise leads to an increase in specific surface, flat-shaped CS particles could not have decreased the aggregate particles overall mobility in concrete and increased workability. As a result of the smooth surface on one side of the shells and the smaller size of coconut shells, CS concrete has superior workability. This outcome is also in line with the earlier research [1], which revealed a similar pattern of decline in slump value for concrete made from coconut shells.

2.3 Schmidt Rebound Hammer Test

The strength of the concrete may be estimated using the rebound number, which is based on the concrete's surface hardness. Numerous factors, including as cement type, aggregate type, moisture, building age, and carbonation level, affect the rebound number. The control specimen and different percentage of CS concrete were tested to evaluate the strength of concrete. The average rebound number for all sample is summarized in Table 2. The data also has been plotted and presented in Figure 9.

Table 2. Average Rebound Number Reading with CS Replacement Level (N/mm^2)

CS Replacement level	7 Days	14 Days	28 Days
0%	27	29	34
10%	26	27	32
20%	25	26	29
30%	23	26	28

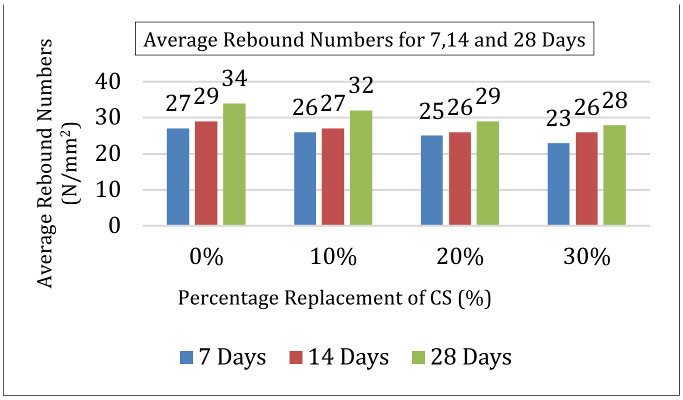

Fig. 9. Schmidt Rebound Hammer Results

From the bar chart it can be seen clearly that the sample with 0% CS replacement has reached the highest average rebound number of 27 N/mm^2. After 7 days of curing, the 10% CS replacement sample exhibited a rebound number of 26 N/mm^2. The average rebound for CS replacement of 20% and 30% was 25 N/mm^2 and 23 N/mm^2 respectively. The 10% sample had the greatest average rebound number when compared to the 20% and 30% CS replacement levels.

Based on the bar graph, conventional concrete with no CS replacement had the highest average rebound number among the samples, coming in at 29 N/mm^2. This was the average value for 14 days of curing. When compared to 20% and 30% CS replacement samples, the 10% CS replacement has also achieved a larger number of rebound values, according to the average value of rebound numbers acquired by CS aggregate samples. The average rebound number for the 10% replacement sample was 27 N/mm^2, whereas the values for the 20% and 30% replacement samples were both 26 N/mm^2.

Schmidt Rebound Hammer Test average results after 28 days of cure. The bar graph indicates that after 28 days of curing, the 0% CS replacement sample had attained an average rebound number of 34 N/mm^2. On the other hand, the 10% CS replacement sample showed a decrement of 5.8% and a rebound number of 32 N/mm^2. Both 0% and 10% CS replacement achieved rebound number values of more than 30 N/mm^2 and will be installed under high concrete quality. The average rebound number values for the 20% and 30% CS replacements were 29 N/mm^2 and 28 N/mm^2, respectively. Both the 20% and 30% CS replacement level will still stay on the fair concrete quality category but when compared to 0% and 10% CS replacement level it is obvious that 20% and 30% replacement level has gotten lower level on rebound number values after 28 days of curing.

As a result of carefully examining the Schmidt Rebound Hammer Test results for each sample, it is clear that after 28 days of curing, each percentage of CS replacement of coarse aggregates has successfully attained the required minimum rebound number of 20 N/mm^2 to be categorised as fair quality concrete. Based on the bar graph conventional concrete has the highest rebound number in 7, 14 and 28 days of curing followed by 10% coconut shell aggregate concrete. While, 20% and 30% obtained lower rebound number values.

Thus, 10% CS aggregate concrete may be used as an ideal degree of replacement for concrete. Due to some instances, when there were void presence as the CS replacement level increased, 20% and 30% CS replacement did not acquire higher readings. Additionally, another aspect that was noted in this experiment was the presence of wetness on the surface, which might lead to less accurate readings from the rebound hammer test.

2.4 Compressive Strength Test

To determine the effect of substituting CS as coarse aggregates on the compressive strength of concrete, the compressive strengths of conventional concrete and the other three concrete batch mixes that contained varied percentages of coconut shell aggregates were examined. The replacement of coarse aggregate with CS in four consecutive batches of concrete mixtures ranged from 0% to 30%. The average compressive strength for all sample is summarized in Table 3. The data also has been plotted and presented in Figure 10.

Table 3. Average Compressive Strength reading with CS Replacement Level (Mpa)

CS Replacement Level	7 Days	14 Days	28 Days
0%	31.16	36.23	41.23
10%	29.76	34.50	37.50
20%	25.20	29.26	34.26
30%	24.66	27.80	33.16

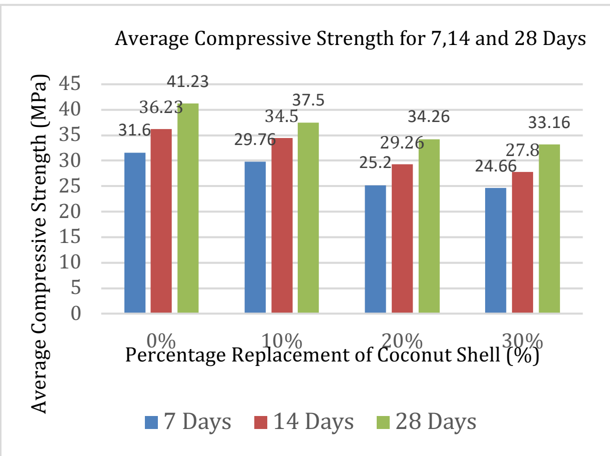

Fig. 10. Compressive Strength Results

The average value of the compressive strength test findings after 7 days of curing is shown as a bar chart in Figure 10. When compared to different percentages of CS replacement, the pattern showed that normal concrete with 0% CS substitution for coarse particles produced the greatest value of compressive strength, 31.16 MPa. When 10% of the concrete was replaced, the compressive strength value was 29.76 MPa, which is 4.49% less than the strength reported for standard concrete. Strength was reported at 25.2 MPa for 20% of CS replacement, with a strength decrement percentage of 15.32%. The value was 24.66 MPa with a strength reduction of 2.14% with 30% CS substitution.

While the compressive strength for the 10% CS replacement was 29.76 MPa, which is about the desired goal strength of 40 MPa after seven days of curing, the strength for the 20% and 30% coconut shell replacements steadily declined to roughly 20 MPa and above. After 14 days of curing, conventional concrete still has the highest compressive strength value, measuring 36.23 MPa, according to the data for each percent of CS replacement. The observed result for compressive strength after 14 days of curing with 10% CS substitution was 34.5 MPa This demonstrates that the 10% substitution of coconut shell in coarse aggregate has met the desired compressive strength of 40 MPa. After 14 days of healing, the 10% replacement can be regarded as the ideal replacement percentage. The compressive strength declined from 10% replacement to 20% replacement, as can be seen clearly from the bar graph. After 14 days of curing, the compressive strength in a 20% replacement was measured at 29.26 MPa with a decrement of 15.18%, and in a 30% CS replacement, it was recorded at 27.8 MPa with a degradation of 4.98%. It is obvious that the 20% and 30% CS replacement failed to reach the desired strength of 40 Mpa. Only 10% CS replacement level achieved the minimal strength after 14 days of curing which is 90% of the target mean strength of 40 MPa.

By analysing all compressive strength values after 28 days of curing, it is apparent that conventional concrete with 0% replacement of CS with coarse aggregates achieves the maximum compressive strength value of 41.23 MPa. Next, from the bar chart above all percentage level has reached the target compressive strength which is 40MPa. For 10% of CS replacement the strength obtained was 37.5 MPa. When gets compared with 7,14 and 28 days curing the pattern showed similar pattern where 20% and 30% CS replacement have lower average compressive strength compared to 0% and 10% replacement, which is 20% replacement with the value of 34.26 MPa and 30% replacement with 33.16 MPa. It also can be said that compressive strength of all mixes increased gradually together when the day of curing increases. In my research the control specimen which is the conventional concrete has achieved the highest compressive strength on all the three curing ages and followed by 10% of coconut shell replacement having the closest compressive strength to the target compressive strength of 40MPa on 7th day of curing and achieving the target strength as well on 14th and 28th day of curing. 20% and 30% CS replacement also fulfil the requirement.

This outcome might be produced by using the same size CS with the proper amount of coarse aggregates. 20% and 30% of coconut shell replacement did not meet the requirement of compressive strength and failed to gain strength in the later days of curing. This might caused by lack of sufficient bond between the particles. At the earlier stage of curing, compressive strength can be based on paste strength and in the later curing age compressive strength is based on the paste strength and strength of bonding between the aggregate and paste. During the compression of the compressive strength, it was observed that CS had less bonding with the aggregates in 20% and 30% replacement. So, this caused the decrement in compressive strength for 20% and 30% CS replacement. Not only that, but it can also be observed and deduced that the compressive strength decreases as the percentage of CS increases. This due to poor bonding.

3. CONCLUSION

The goal of the studies is to determine the optimum ratio for replacing coarse aggregate in concrete with CS by conducting mechanical properties of the concrete.

3.1 Summary

As per the findings and test that were conducted, it can be said that CS aggregates with the right replacement level can give excellent strength which is close to the conventional concrete. CS utilized as replacement to coarse aggregate can be categorized under lightweight concrete. Not only that, as CS is a waste product and can be easily obtained its usage can be implemented to produce lightweight concrete in the industry.

Based on the findings, 20% and 30% CS replacement did not obtain the target value of strength and both the replacement level is not advised to be used because it can lead to failure while 10% CS replacement level showcased to good strength value. So, 10% coconut shell replacement to coarse aggregate can be taken as an optimum level of replacement. Moreover, it has also been observed that the compressive strength of CS concrete decreased as the coconut shell replacement level to coarse aggregate increased.

Not only that, but similar pattern was also observed during the rebound hammer which is as the CS replacement increases the rebound number decreases. This clearly explain that the higher replacement percentage will reduce the concrete strength. To add on, decrement in strength was also the result of void in CS concrete. From the above research it can be concluded that, 10% coconut shell replacement level obtained better strength which is close to the conventional concrete. Thus, the replacement level of 10% CS blends is the best, however they are only appropriate for low strength, indoor, and dry applications.

3.2 Recommendations

The effects of altering the quantity of CS on additional characteristics, such as sound insulation, thermal conductivity, impact, flexural strength and water absorption, may be studied in addition to compressive strength and Schmidt rebound hammer. Based on the research carried out it is wise to agree that there is still opportunity for advancement that may be made. The decrement in strength can be corrected by adding more cement to CS concrete as it can lead to better bonding for aggregates in the concrete. This will increase the compressive strength and eliminate the voids in the concrete.

REFERENCES

[1] Azunna, S U, Aziz, A., Bakar, A., & Nasir, N. A. M. (2018). Mechanical properties of concrete with coconut shell as partial replacement of aggregates. https://doi.org/10.1088/1757-899X/431/3/032001

[2] Azunna, Sunday U., Aziz, F. N. A. A., Cun, P. M., & Elhibir, M. M. O. (2019). Characterization of lightweight cement concrete with partial replacement of coconut shell fine aggregate. SN Applied Sciences, 1(6). https://doi.org/10.1007/S42452-019- 0629-7

[3] Gunasekaran, K., Pennarasi, G., Soumya, S., & Shruti, L. (2017). ALL-IN-ONE ABOUT A Momentous review study on coconut shell as coarse aggregate in concrete. International Journal of Civil Engineering and Technology (IJCIET), 8(3), 1049– 1060. http://iaeme.com/Home/journal/IJCIET1049editor@iaeme.comhttp://iaeme.com/Hom e/issue/IJCIET?Volume=8&Issue=3http://iaeme.com

[4] Gupta, N., & Gupta, A. (2021). Condition assessment of the structural elements of a reinforced concrete structure using non-destructive techniques. IOP Conference Series: Materials Science and Engineering, 1116(1), 012164. https://doi.org/10.1088/1757-899x/1116/1/012164

[5] Hilal, N., Mohammed Ali, T. K., & Tayeh, B. A. (2020). Properties of environmental concrete that contains crushed walnut shell as partial replacement for aggregates. Arabian Journal of Geosciences, 13(16). https://doi.org/10.1007/S12517-020-05733-9

[6] Jonida, P., Ahmed, A., John, K., & Fraser, H. (2018). Palm Oil Fuel Ash as A Cement Replacement in Concrete. Mod App Matrl Sci, 1(1). https://doi.org/10.32474/MAMS.2018.01.000102

[7] Kanojia, A., & Jain, S. K. (2017). Performance of coconut shell as coarse aggregate in concrete. Construction and Building Materials, 140, 150–156.

[8] Kaur, M., & Kaur, M. (2020). A review on utilization of coconut shell as coarse aggregates in mass concrete. International Journal of Applied Engineering Research,

[9] Kazemi, M., Madandoust, R., & de Brito, J. (2019). Compressive strength assessment of recycled aggregate concrete using Schmidt rebound hammer and core testing. Construction and Building Materials, 224, 630–638. https://doi.org/10.1016/J.CONBUILDMAT.2019.07.110

[10] Kumar Mahro, S., Ali Abbasi, R., Das Bheel, N., Kumar Meghwar, S., Ahmed Ghunio, I., & Hussain Shaikh, Z. (2020). Use of Sugarcane Bagasse Ash as Cement Replacement Materials in Concrete. https://www.researchgate.net/publication/339434486

[11] Mary Ealias, A., P, R. A., Life John, A., Anju Paul, A., student, Bt., & professor, A. (2019). Improvement of Strength of Concrete with Partial Replacement Of Course Aggregate With Coconut Shell and Coir Fibres. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE, 11(3), 16–24. Retrieved December 16, 2021, from www.iosrjournals.org

[12] Naidu, G. G., Babu, N. R., & Ravikumar, P. (2021). Strength Characteristics of Concrete by Partial Replacement of Coarse Aggregate with Coconut Shells & Cement with Glass Powder. https://doi.org/10.1088/1757-899X/1126/1/012060

[13] Narayan Sonawane, Y., & Chitte, C. J. (2017). Volume 5 Issue 4, April 2016 www.ijsr.net Licensed Under Creative Commons Attribution CC BY Waste Coconut Shell as a Partial Replacement of Coarse Aggregate in Concrete Mix-An Experimental Study. International Journal of Science and Research (IJSR) ISSN. www.ijsr.net

[14] Prakash Chandar, S., Gunasekaran, K., Prasanth, K., & Senthil Kumar, G. (2018). AN Experimental investigation and durability property on recycled concrete with partial replacement to fine aggregate in coconut shell concrete. Rasayan J. Chem, 11(2), 702–708. https://doi.org/10.31788/RJC.2018.1123003

[15] Prakash, R., Thenmozhi, R., Raman, S. N., Subramanian, C., & Divyah, N. (2021). An investigation of key mechanical and durability properties of coconut shell concrete with partial replacement of fly ash. Structural Concrete, 22(S1), E985–E996. https://doi.org/10.1002/SUCO.201900162

[16] Rahate, K., Singh, S., Kelkar, R., & Khajanwadkar, M. (2017). Replacement of Coarse Aggregate by Using Naturally Available Materials. Retrieved December 16, 2021, from www.ijert.org

[17] S, A. V, Wilson, B., N, H. V, & Assistant Professor, P. M. (2017). Palm Oil Fuel Ash as Partial Replacement of Cement in Concrete. Retrieved January 31, 2022, from www.ijert.org

[18] Saifullah, I., Rahman, M. M., Halim, A., & Islam, R. (2019). Mechanical and Bond Properties of Lightweight Concrete Incorporating Coconut Shell as Coarse Aggregate. American Journal of Civil Engineering and Architecture, 7(1), 38–46. https://doi.org/10.12691/ajcea-7-1-5

[19] Siddika, A., Mamun, M. A. Al, & Ali, M. H. (2018). Study on concrete with rice husk ash. Innovative Infrastructure Solutions, 3(1). https://doi.org/10.1007/S41062-018- 0127-6

[20] Taku, K., & Utsev, J. T. (2012). Coconut Shell Ash as Partial Replacement of Ordinary Portland Cement in Concrete Production Characterization of soybean husk- OPC-nanosilica blend as a binder

material in concrete and mortar View project Sustainable Construction Materials View project Coconut Shell Ash as Partial Replacement of Ordinary Portland Cement in Concrete Production. International journal of scientific & technology research, 1(8). www.ijstr.org

[21] Tangadagi, R. B., Manjunatha, M., Preethi, S., Bharath, A., & Reshma, T. V. (2021). Strength characteristics of concrete using coconut shell as a coarse aggregate – A sustainable approach. Materials Today: Proceedings, 47, 3845–3851. https://doi.org/10.1016/J.MATPR.2021.03.265

[22] Wahab Abro, A., Ali Shar, I., Aizaz Dayo, A., Bheel, N., Shaikh, S., & Hussain Shaikh, Z. (2019). Use of Rice Husk Ash as Cementitious Material in Concrete. https://doi.org/10.48084/etasr.2746

[23] Xu, Q., Ji, T., Gao, S. J., Yang, Z., & Wu, N. (2018). Characteristics and applications of sugar cane bagasse ash waste in cementitious materials. Materials, 12(1). https://doi.org/10.3390/MA12010039