JUEM
Research across Technical Disciplines

Journal of UTEC Engineering Management
Volume 01, Issue 01, 2023, Pg. No. 28-40
OPEN ACCESS

Research Article https://doi.org/10.36344/utecem.2023.v01i01.004

Analyzing the Performance of Construction Demolition Waste Aggregates on strength for Non-structural Concrete

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Journal of UTEC Engineering Management (ISSN: 2990-7969)

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Date of submission
January 29, 2023
Date of Acceptance
May 25, 2023

ABSTRACT

Construction and demolition waste (CDW) refers to the waste generated from demolished structures in the construction industry. This waste can include concrete and brick materials. In this study, the focus is on evaluating the physical and mechanical properties of coarse aggregates derived from CDW, as well as the compressive strength of non-structural concrete made by mixing CDW aggregates with natural aggregates (NA) in different proportions. The study involved preparing different mix proportions of concrete using various combinations of CDW coarse aggregates, natural coarse aggregates, and brick aggregates. The mix proportions were categorized into three groups:100% natural coarse aggregate,CDW concrete coarse aggregate mixed with natural aggregate in three proportions: (90% NA, 10% CA), (80% NA, 20% CA), and (60% NA, 40% CA) and Mixtures of natural coarse aggregate, CDW concrete aggregate, and brick aggregate in four proportions: (90% NA, 5% CA, 5% BA), (80% NA, 10% CA, 10% BA), (60% NA, 20% CA, 20% BA), and (80% NA, 30% CA, 30% BA).

The physical and mechanical properties of the different mix proportions were analyzed, and it was found that all proportions, except (80% NA, 30% CA, 30% BA), met the specified limits. In terms of compressive strength, the concrete mixture with a proportion of (90% NA, 10% CA) exhibited the highest value (27.04 MPa), while the mixture with a proportion of (60% NA, 20% CA, 20% BA) had the lowest value (17.19 MPa). The mixture with a proportion of (80% NA, 30% CA, 30% BA) did not meet the targeted strength of 15 MPa.

Conclusion: Based on the analysis of the test results, it can be suggested that CDW aggregates can be used as a replacement for natural aggregates up to a maximum of 40%. Additionally, a combination of CDW concrete and brick aggregates in equal proportions (20% - 20%) can be used as a replacement for natural aggregates to achieve a concrete strength of 15 MPa.

Keywords: Natural Coarse Aggregate (NCA), Construction Demolition Waste (CDW)

How to cite this article: Dhungana S., Awasth K.D. & Bohara N., (2023). Analyzing the Performance of Construction Demolition Waste Aggregates on Strength for Non Structural Concrete, JUEM 1(1), 28-40
https://doi.org/10.5281/zenodo.8116776

INTRODUCTION

Construction and Demolition Waste (CDW) refers to the debris generated during construction and demolition activities. Nepal, being prone to destructive earthquakes, experiences a significant amount of CDW due to the damage caused to buildings and infrastructure. The amount of CDW generated in Nepal is estimated to be around 55-65 million tons, which is twice the amount generated after the Great East Japan Earthquake in 2011. Proper management of CDW is crucial for sustainable development and environmental protection.

CDW management in Nepal is a pressing issue, with estimates suggesting that approximately 28.5 tons of CDW is generated per day in the Kathmandu Valley alone. The inadequate management of CDW can pose challenges for future development and emergency relief efforts. Additionally, the production of construction materials worldwide consumes three billion tons of raw materials annually, highlighting the significance of CDW management for environmental sustainability.

Research studies have focused on comparing the economic aspects of using natural aggregates (NA) versus CDW aggregates in various countries. These studies have shown that CDW aggregates can be produced at a lower cost than NA. Moreover, the transportation costs associated with NA production, which relies on petroleum, can be higher in areas such as the Kathmandu Valley.

Concrete is a widely used construction material, with an annual global production exceeding 12 billion metric tons. Non-structural concrete, characterized by its low strength, is commonly used when only small compression or temporary loading is involved. Recent advancements in concrete production techniques aim to enhance its strength and durability, reducing construction difficulties.

Overall, the effective management of CDW holds great potential for environmental protection, sustainable development, and cost savings in the construction industry.

OBJECTIVES

The main objective of the research is to identify possibility of replacement of NCA with CDW coarse aggregate for production of non-structural concrete with specified compressive strength.

Construction and Demolition Waste (CDW)

Construction and Demolition (C&D) Waste comprises of the debris generated during construction and demolition activities. Every time when buildings and civil-engineering structures are built, renovated or demolished a sizable amount of C&D Waste is generated. This waste often includes a variety of material depending on how and where it was generated including concrete, metals, bricks, glass, plastics, organics, etc. 'We know that every structure is designed for a specific life period, generally 100 years. The existence of the structure after the service life period is very dangerous to its occupants and surrounding buildings. Therefore it becomes essential to demolish the building' (Rathi & Khandve, 2014).

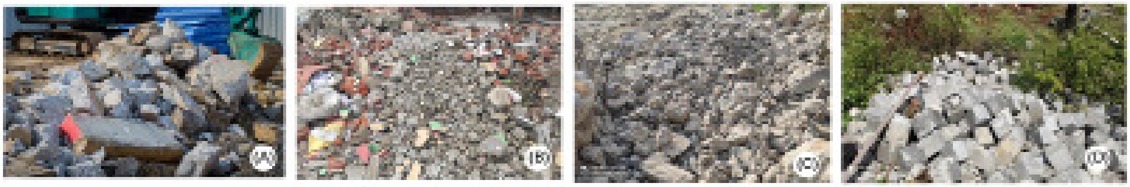

Figure 1: Construction and Demolition waste: (a) Demolished Concrete Waste at Bharatpur (b) Demolished Building Waste Bharatpur (c) Demolished Road Pavement at Gondryang-Pulchowk Road, Chitwan(d) Broken Concrete Cube Specimen at Laboratory

LITERATURE REVIEW

Construction and Demolition Waste (CDW)

Construction and Demolition (C&D) Waste refers to the debris that is generated during construction and demolition activities. Whenever buildings and civil-engineering structures are constructed, renovated, or demolished, a significant amount of C&D Waste is produced. This waste consists of various materials, depending on the nature of the construction or demolition project, including concrete, metals, bricks, glass, plastics, organics, and more.

It is important to recognize that every structure is designed with a specific lifespan, typically around 100 years. After the service life period, the continued existence of the structure can pose risks to its occupants and the surrounding buildings. Therefore, it becomes necessary to demolish the structure in order to ensure safety.

The demolition process results in the generation of C&D Waste, which needs to be managed effectively. Proper management of C&D Waste is crucial for several reasons. Firstly, it helps in reducing the environmental impact associated with construction and demolition activities. Secondly, it enables the recovery and recycling of valuable materials, reducing the demand for virgin resources and minimizing waste sent to landfills. Additionally, effective C&D Waste management contributes to the overall sustainability of the construction industry.

Researchers and practitioners in the field of waste management have been exploring various strategies to handle C&D Waste more efficiently. These strategies include waste segregation, recycling and reuse of materials, and the adoption of sustainable construction practices. By implementing these measures, the construction industry can reduce its environmental footprint and contribute to a more circular and sustainable economy.

In conclusion, C&D Waste is a byproduct of construction and demolition activities and consists of various materials. Proper management of C&D Waste is crucial for environmental sustainability, resource conservation, and the overall well-being of the construction industry(Rathi & Khandve, 2014).

Recycled Aggregate

The construction industry generates a significant amount of debris, and recycling and reusing this debris as recycled aggregates (RAs) can be an effective solution for reducing waste and promoting sustainability. The use of RAs allows for the partial or total substitution of natural aggregates in construction materials.

Recycling aggregates not only helps in waste reduction but also contributes to energy conservation. By utilizing recycled materials, the demand for extracting and processing natural resources is reduced, leading to a more sustainable construction industry. Additionally, recycling aggregates can help mitigate the environmental impact associated with quarrying and mining activities(Kenai 2018).

Recycled aggregates typically consist of original aggregates, such as crushed concrete or masonry, and adhered mortar. The physical properties of recycled aggregates are influenced by both the quality of the adhered mortar and the amount of adhered mortar present. The adhered mortar is a porous material, and its porosity depends on factors such as the water-to-cement ratio (w/c ratio) used in the production of recycled concrete (Nagataki, 2000).

The quality of the adhered mortar in recycled aggregates can affect their performance in construction applications. Therefore, it is important to carefully manage the production process of recycled aggregates to ensure that the adhered mortar meets the required quality standards. Techniques such as crushing, screening, and washing can be employed to remove impurities and enhance the quality of recycled aggregates.

Overall, the use of recycled aggregates in construction materials offers several benefits, including waste reduction, energy conservation, and environmental sustainability. By promoting the recycling and reuse of construction debris, the construction industry can contribute to a more circular economy and reduce its ecological footprint. These problems were highlighted by Sharma et al,2022 and Mishra and Aithal,2022 in case of Nepal with an open question for further research.

The classification of recycled aggregate (RA) proposed by Silva et al. (2014) provides a categorization based on the source and processing of the recycled materials. The four main categories are as follows:

a. ***Recycled Concrete Aggregate (RCA):*** This category includes aggregates that are derived from crushed concrete made with natural aggregates (NA). RCA is obtained by crushing and processing waste concrete from demolition sites or construction activities. The resulting aggregate can be used as a substitute for natural aggregates in various construction applications.

b. ***Recycled Masonry Aggregate (RMA):*** RMA consists of aggregates derived from masonry rubble, which can include materials such as ceramics, bricks, and sand-lime bricks. Similar to RCA, RMA is obtained by crushing and processing masonry waste materials. It offers an alternative source of aggregate for construction purposes.

c. ***Mixed Recycled Aggregate (MRA):*** MRA is a category that comprises mainly a combination of RCA and RMA. It includes recycled aggregates that are obtained from a mixture of crushed concrete and masonry waste materials. MRA provides a blended aggregate option that combines the benefits of both RCA and RMA.

d. ***Construction and Demolition Recycled Aggregate (CDRA):*** CDRA refers to recycled aggregate that has not undergone proper processing from construction and demolition waste. It may consist of a mixture of various materials, including concrete, masonry, wood, metals, and other debris. CDRA is typically obtained from unsorted or minimally processed construction and demolition waste.

The classification of recycled aggregate into these categories helps in better understanding and managing the different types of recycled materials available for use in construction. It enables researchers, engineers, and practitioners to assess the suitability and performance of specific types of recycled aggregate in different applications. Additionally, proper processing and quality control measures are crucial for ensuring the usability and performance of recycled aggregates in construction projects.

The use of recycled aggregate, particularly in lower-level applications, offers a sustainable solution for managing construction and demolition waste. Concrete engineers have conducted research that demonstrates the feasibility of treating and reusing such waste as aggregate in new concrete. Here are some common applications of recycled aggregate:

1. ***Road Base and Sub-base:*** Recycled aggregate can be used as a base or sub-base material for road construction. It provides a stable foundation and helps to improve the load-bearing capacity of the road.
2. ***Pavement Construction:*** Recycled aggregate can be incorporated into the production of asphalt concrete or used as a base material for pavement construction. It contributes to the sustainability of road infrastructure by reducing the demand for natural aggregates.
3. ***Structural Fill:*** Recycled aggregate can be used as a fill material in construction projects. It can be employed for backfilling trenches, utility excavations, and other applications where structural support is required.
4. ***Landscaping and Soil Stabilization:*** Recycled aggregate can be used in landscaping projects, such as creating pathways, walkways, or garden beds. It can also be utilized for soil stabilization in areas where erosion control is needed.
5. ***Non-structural Concrete:*** Recycled aggregate can be used in non-structural

concrete applications where lower strength requirements are sufficient. This includes applications such as sidewalks, curbs, and non-load-bearing elements.

By incorporating recycled aggregate into these applications, the construction industry can reduce the reliance on natural aggregates and minimize the amount of construction and demolition waste sent to landfills. However, it is important to consider the quality and characteristics of the recycled aggregate to ensure its suitability for specific applications. Proper processing, quality control, and adherence to relevant standards and guidelines are essential to achieve optimal performance and durability when using recycled aggregate in construction.

METHODOLOGY

Research methodology refers to the specific procedures and techniques used to identify, select, process, and analyze information in a research study (Kumar, 2019). According to Creswell & Tashakkori, 2007, research methodologies explicate and define the kinds of problems that are worth investigating; what constitutes a re-searchable problem; testable hypotheses; how to frame a problem in such a way that it can be investigated using particular designs and procedures; and how to select and develop appropriate means of collecting data. Research methodology is a way to systematically solve the research problem and research methodology shall identify the research basis, research hypothesis or questions, research design and research analysis (Abraham & Millar, 2008).

Preparation of Coarse Aggregate

In this study there are three types of coarse aggregate from different sources of materials. First one is natural crushed aggregate collected from quarries and stone crusher available at Bharatpur, second is aggregate produced from demolished concrete from different locations and third one is brick aggregate from different locations.

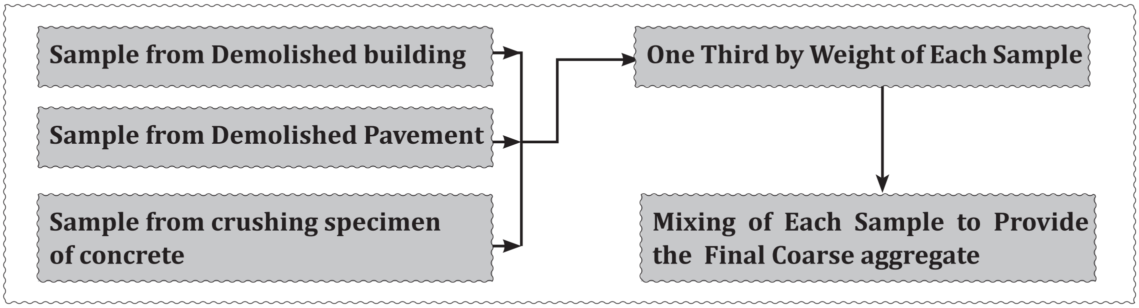

Figure 2: Sample of Coarse Aggregate from Demolished Concrete

After collecting the concrete aggregate from different sources, the final coarse aggregate used for concreting was prepared by mixing the natural aggregate, concrete and brick aggregate in different proportion to check the compressive strength of the concrete. For proportioning different properties of aggregates were accessed and the stipulations for proportioning for the grade and condition has been shown in Table.

Table1: Stipulations for Proportioning

Type of Concrete	PCC
Grade Designation	M15
Shape of Particle	Angular
Water- Cement Ratio	0.64
Exposure Condition	Mild
Concrete Placement	By Hand
Degree of Supervision	Good

During the breaking of CDW, it was observed that it was very difficult to break the concrete waste collected from pavement while comparatively it was easier for the concrete cube specimen.

Figure 3: Recycled Aggregate: (a) Recycled Concrete Aggregate from Waste Concrete Cube Specimen (b) Recycled Concrete Aggregate from Demolished Building (c) ecycled Concrete Aggregate from Demolished Road Pavement (d) Recycled Brick Aggregate from Demolished Building

Testing on coarse Aggregate

Table 2: Tests on coarse Aggregates

SN	Test	Test Standard	Apparatus Required	Coarse Aggregate Type
1.	Sieve Analysis	(IS: 2386 part-I) 1963	Weighing Balance, Sieves, Oven	All proportion of aggregate
2.	Impact Test	(IS: 2386 part-IV) 1963	Impact value test machine, Weight balance, Measuring Cylinder, Cylindrical test cup, Temping rod	All proportion of aggregate
3.	Abrasion Test (Loss Angeles)	(IS: 2386 part-IV) 1963	Los Angles Abrasion Machine, Steel balls: 11no., Weighing balance, Sieves: 20, 12.5, 10, 1.7mm	All proportion of aggregate
4.	Shape Test	(IS: 2386 part-I) 1963	Thickness gauge, Length gauge, Weighing balance, IS Sieves	NA, CA & BA
5.	Specific Gravity & Water absorption	(IS: 2386 part-III) 1963	Density basket, Weighing balance, Water tank,	

Aggregates are tested for strength, toughness, hardness, shape, and water absorption in reference to Indian Standard as given in Table 2 . In order to decide the suitability of the aggregate for use in concrete construction, following tests were carried out in this study:

Test on Concrete

Basically two types of tests i.e. Slump Test to determine the workability of fresh concrete and compressive strength test to determine compressive strength of hardened concrete was conducted. The mixed sample for the test procedure was as figure 4.

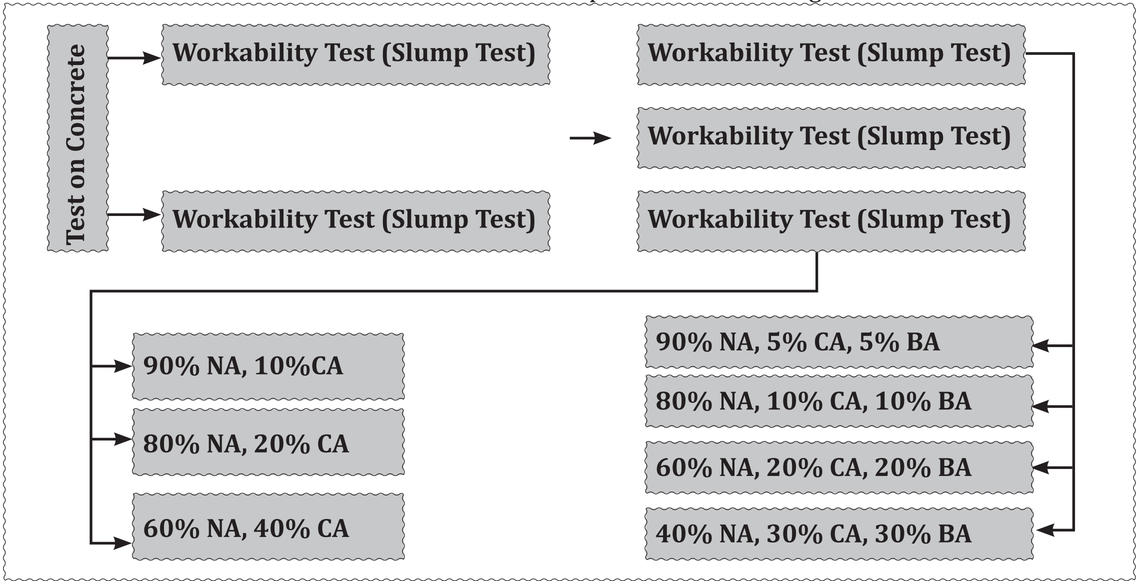

Figure 4: Flowchart for test on concrete

RESULT AND DISCUSSION

Los Angeles Abrasion & Aggregate Impact Value Test of Coarse Aggregate

After analyzing the result, aggregate with proportion [60% Natural Aggregate (NA) & 40% Concrete Aggregate (CA)] has better performance in both LAA and AIV than other proportion. But the aggregate with proportion [40% NA, 30% CA, 30% Brick Aggregate (BA)] has poor performance than others proportion.

It was observed that, with increased in proportion of CA decreased in LAA and AIV value but increased in proportion of BA caused increased in LAA and AIV value. The change in reddish color of the test sample during testing of LAA and AIV with increased in proportion of BA clearly indicated that the brick is weaker in abrasion and impact loading. Hossain et al. 2012 had also stated that the crushing and impact resistance of brick aggregate is lower than NA. Beyond 30% replacements of natural aggregate is not suggested as Specific Gravity, water Absorption and Impact value have almost surpass the permissible limit (Hamar & Lalramsanga, 2017). In this study the abrasion and impact value also beyond the limitation beyond 30% mix of CA and BA.

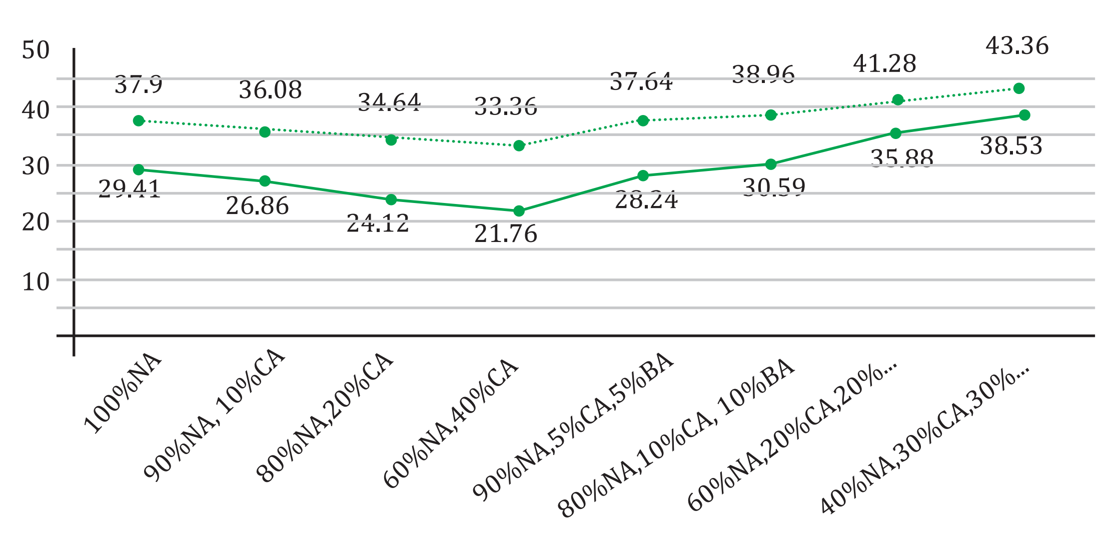

Figure 5: LAA and AIV Test Result

Flakiness Index Test of Coarse Aggregate

After analyzing the test result data from laboratory presented the flakiness index value of the BA, NA & CA. From the result, the BA was found with the better performance flaky (16.52%) whereas the CA was found more flaky (21.32%) compared to others.

More flaky and angular aggregate required more water to produce workable concrete also such irregular shaped aggregate, cement content may also be increased to maintain water cement ratio. Flakiness and the shape of coarse aggregate in general have an appreciable effect on the workability of concrete. An increase in angularity from minimum to maximum would reduce the compacting factor by about 0.09 (Ataalla, 2016). In this study, the increased in proportion of CA also reduced the workability.

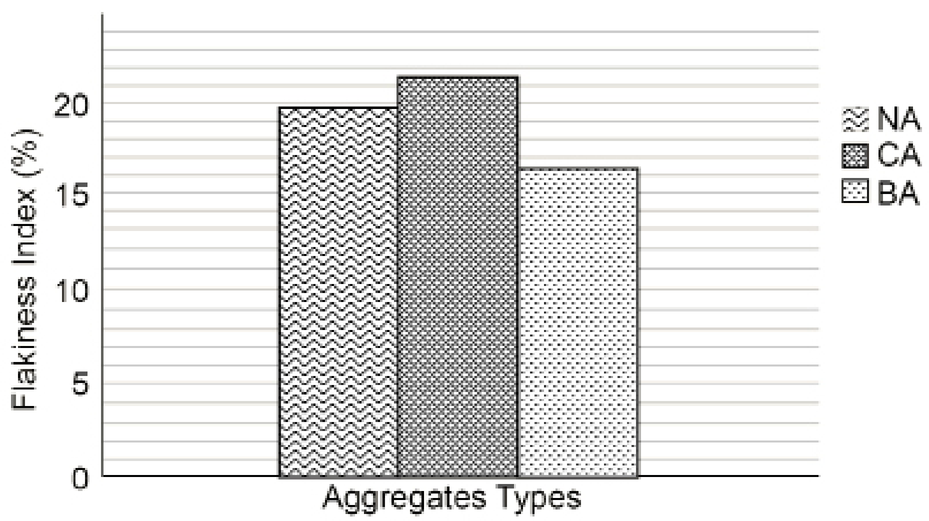

Figure 6: Flakiness Index Test Result

Specific Gravity and Water Absorption Test of Coarse Aggregate

After analyzing the result obtained from the test presented the specific gravity of natural aggregate had more specific gravity (2.567), then concrete aggregate (2.169) and brick aggregate had lowest value of specific gravity (1.950). Furthermore, the water absorption rate of brick aggregate is higher (19.73%) than CA (7.759) and NA (1.664).

The result represents that the porous and absorptive characteristics of NA, CA and BA. The porosity and absorption of aggregate may affects the water/cement ratio and hence the workability of concrete. Aggregates having more absorption are more porous in nature and are generally considered unsuitable, until it is found acceptable based on strength, impact and hardness tests. Hence increasing in proportion of BA was more porous coarse aggregate reduced the workability of concrete and can't be preferable for damp proof concrete structures.

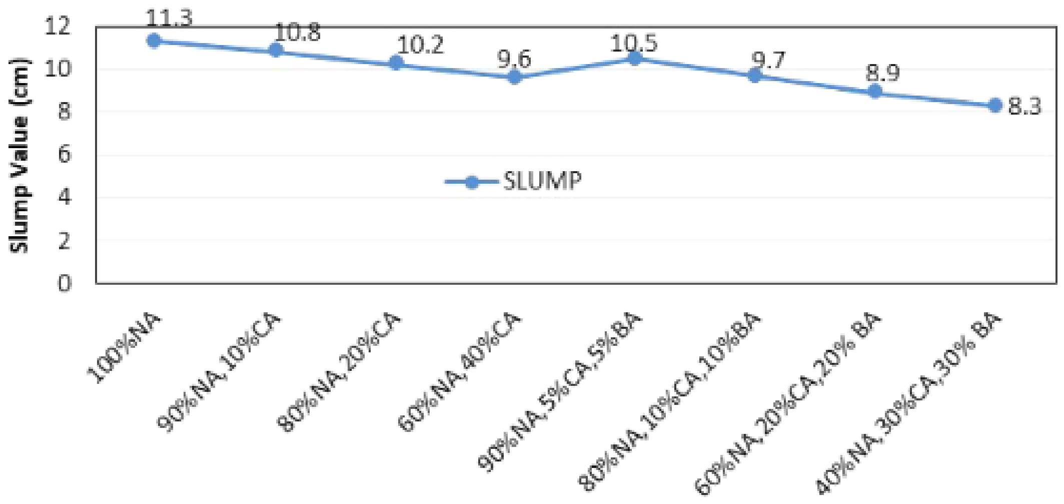

Figure 7: Slump Test Result of Coarse Aggregate with same W/C ratio

Compressive Strength Test

In this study the targeted compressive strength of concrete which can be used for the non-structural concrete at 28 days of curing was M15. The maximum proportion of CA mixed with NA was 40% but the result obtained for that proportion at 28 days curing age was 23.05 Mpa which satisfied the targeted compressive strength. Similarly, the mix of NA, CA & BA in which the mix proportion up to (60% NA, 20% CA, 20% BA) satisfied the targeted compressive strength of 15 MPa. Furthermore, by increasing the proportion of CA and BA and reducing the proportion of NA beyond that proportion, the obtained result of compressive strength at (40% NA, 30% CA, and 30% BA) was 13.63 MPa which did not satisfy the targeted compressive strength of 15 MPa.

All the procedures for laboratory experiments were followed the test related IS standards and the equipment used in this study was well maintained and calibrated which confirms the validity of obtained data.

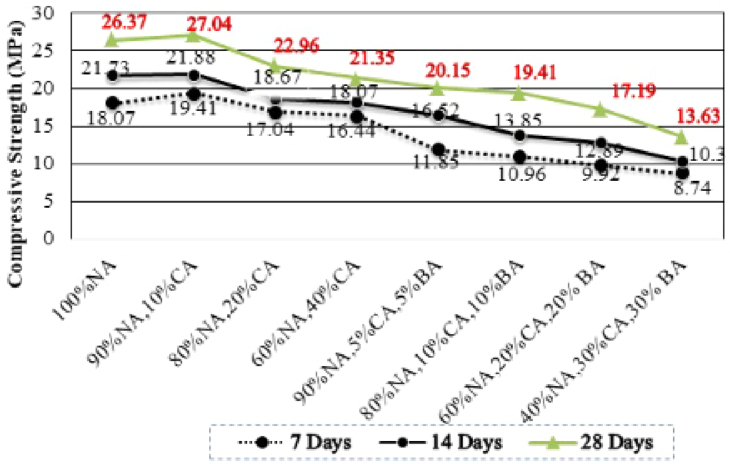

Figure 8: Compressive Strength Result at different Proportion

CONCLUSION

After carried out the different physical properties of coarse aggregate (NA, CA & BA) and test of concrete made with mixing these aggregate in different proportion, the following conclusions can be drawn:

1. The ability to resist wear and impact by the coarse aggregate decreases with increase in mixing proportion of CDW.
2. The water absorption of BA is greater than CA and NA but NA has lowest water absorption capacity compared than other two aggregates.
3. The specific gravity of NA is higher than that of other two aggregates and BA has lower specific gravity than others two aggregates.
4. The fresh concrete using 100% NA has higher slump value and by increasing the mixing proportion of CDW aggregate with NA decreases the slump value due to higher water absorption capacity of CDW than NA.
5. Non-structural concrete of grade M15 can be achieved by mixing up to 40% of construction demolition waste concrete coarse aggregate with Natural aggregate.
6. M15 grade concrete can be achieved also by using demolished Concrete and Brick coarse aggregate mixing up to (20% - 20%) each with Natural aggregate.
7. The main factor affecting the compressive strength of concrete was replacement proportion of CDW coarse aggregate with natural coarse aggregate.

RECOMMENDATION

After carried out this study, the following suggestions and recommendations are suggested for further study regarding this thesis title:

1. The test experiment can be conducted to determine the different properties of CWD aggregate and compressive strength of concrete by replacing the natural aggregate.
2. The same experiment can be conducted by increasing the proportion of concrete aggregate (i.e more than 40%) for the replacement of natural aggregate.
3. Hammering has been done to produce the CDW coarse aggregate in this study but the aggregate from recycled plant can be used for further study in which the properties of coarse CDW aggregate may be improved and compressive strength can be achieved.

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