Compressive Strength Test Evaluation of Mortar with Concrete Demolished Waste as Partial Replacement to Sand

Jayrus C. Biliwang [1], Vincent D. David [1], Kelvin Cier N. Gonzales [1], Darwin L. Pineda [1], Edson D. Yanga [1], Johnly R. Zacarias [1], Mildred M. Fabian [2], Charles G. Lim [2]

[1]*Student, Department of Civil Engineering, Don Honorio Ventura State University, Villa de Bacolor, Pampanga, Philippines.*

[2]*Faculty, Department of Civil Engineering, Don Honorio Ventura State University, Villa de Bacolor, Pampanga, Philippines.*

Corresponding Author: jayrusbiliwang03@gmail.com

Abstract: -This study specifically examined concrete waste recycling at construction and demolition sites. Recycling considerations must be made throughout the design phase in order to expand the potential for recycling in the future. The only material that does not see significant competition from other recycled materials is concrete. Crushed stone, which is accessible, is its main rival. However, several Philippine regions, particularly Pampanga, do not generate crushed stone despite having a need for aggregates that recycled concrete could fill. Therefore, there is enough space to recycle all of the concrete produced. In most parts of Metro Manila, recycling concrete is the favored technique of management from an environmental standpoint. Additionally, the local sources of aggregate are practically worn out mandating the importation of aggregate from other quarries. The goal of this experimental investigation was to partially replace fine aggregate in a mortar mixture with crushed concrete waste. The proportions of different replacement mixture of concrete wastes will be 0%, 5%, 10%, 20% and 40%. As a result, all replacement ratio exceeded the required compressive strength of mortar according to ASTM but the best or advisable percentage of concrete waste was 20%, it has a compressive strength of 2380psi or 16.39mpa which is under Type S mortar (minimum compressive strength is 1800psi) it is appropriate for patio construction and below-grade external walls. However, recycled fine aggregates mixtures are better than to the natural fine aggregate mixture.

Key Words: — *Concrete Waste, Mortar, Natural Fine Aggregates, Recycled Fine Aggregates, Compressive Strength.*

I. INTRODUCTION

The main sources of concrete waste are building and demolition sites. It's among the rubbish that's produced the most worldwide; up to 2012, 40 different countries produced more than 3.0 billion tons annually (Akhtar & Sarmah, 2018).

Due to rapid urbanization, some old buildings in Pampanga areas are being demolished to make way for new and more modern ones. Reusing or recycling demolished concrete is extremely rare.

Manuscript revised June 18, 2023; accepted June 19, 2023. Date of publication June 20, 2023.

This paper available online at www.ijprse.com

ISSN (Online): 2582-7898; SJIF: 5.59

Demolished concrete waste disposal is a major issue in urban areas due to stringent environmental laws and a lack of dumping sites.

Recycling has become a standard practice in the building sector as part of environmental considerations. Construction and demolition (C&D) waste is the waste material that remains after building, renovating, or demolishing any structure, including homes, businesses, highways, and bridges. Common waste components include wood, drywall, asphalt shingles, metal, cardboard, plastic, and dirt, as well as concrete constructed of Portland cement and asphalt. Only recently have worries regarding the environmental effects of this waste material come to light. Where to place the waste is something that developers, contractors, and builders must think about when doing construction, restoration, or demolition. In order to develop innovative approaches to problems, studies, research, and tests are carried out, taking into account alternative locations for the garbage and what can be done to lessen its disposal in landfills.

Recycling is one solution to the growing environmental issue associated with the disposal of garbage in landfills, which is why it is important to consider all of the potential solutions. Recycling also ensures ease and safety.

The engineering sector and other businesses may benefit greatly from a plan to create new methods and use resources that are currently discarded. Construction and demolition waste (CDW) is one of the primary causes of environmental contamination, and its volume has been rising globally for decades. Concrete damage restoration, patching or filling, rendering, floor leveling, and the creation of precast items are just a few of the many uses for cement mortar composite. It has different types according to its specified compressive strengths, and a very important role in the construction industry when it comes to strength, aesthetics, and form of the structure. A good mortar has the quality of possessing good adhesion and high durability that can really last for long years and not signing of different damages (Ramakrishna & Sundararajan, 2019).

According to the research article by Oliveira, et al. (2015), the usage of these modified mortars has potential benefits for the environment and the economy. In actuality, less energy is required to create cement, thus making mortar has a lower direct cost.

In the research done by Ledesma, et al., (2014), They found that it was possible to replace up to 40% of sand (NA) with recycled sand (RCA) in an experiment where they looked at the qualities of the material mortars by substituting natural silica sand with recycled sand in various amounts (0%, 5%, 10%, 20%, and 40%).

In this study, the feasibility of reusing remaining concrete from demolished buildings and new construction was investigated experimentally. The focus of the current inquiry was to recycle the demolition of waste materials to lower the cost of construction and address the housing issues of low-income neighborhoods around the globe, and to test this material partially if can these replacement ratio meet the allowable strength of a mortar. Crushed trash from demolished concrete is separated by several tests conducted after sieving to acquire the aggregate sizes needed.

II. Conceptual Framework

Gathering information about the impact of demolished concrete waste on the environment and in the engineering, industry was done using the related literature in journals, studies, and statistics which can support the research. The collection of materials was held in Pampanga and the concrete waste refining was performed in Mexico, Pampanga. The crushed concrete was sieved using sieve # 200 and the mixing and curing of mortar with refined concrete waste was performed at the Laboratory Testing Center in Pampanga. The Input-Process-Output as shown in Figure 1.7 was used as the framework in the conduct of the study. For the input, it includes the concept that there are several demolished concrete wastes being thrown into some landfills and are not being abandoned. Sand is the most used and high-demand material in the building and in the development of infrastructures. As the researchers came up with this study, it may possibly decrease the ratio of sand in combination with the crushed demolition waste for it still has a portion of sand.

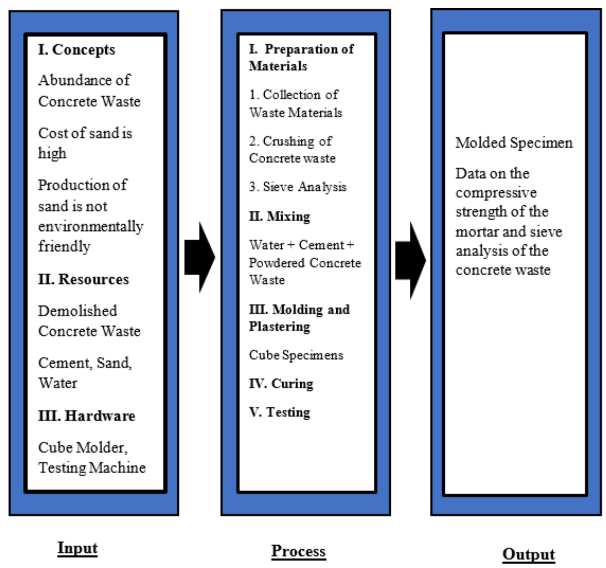

Fig.1. Conceptual Framework

III. Methodology

The researchers used an experimental study where variables are manipulated in a laboratory setting. It was employed to identify the different properties of mortar by using concrete waste as a partial replacement for fine aggregates. Actual tests and a series of experiments were conducted to test the different proportions of mixtures. The entities were carefully observed qualitatively and were described using words and photographs. Data were also quantified and measured. These are the following stages were required in conducting the study: collection of materials, crushing and sieving, mixing, molding of specimens, curing of mortar specimens, testing the properties of mortar. Lastly, evaluation. The process flow chart is shown in Figure 2.

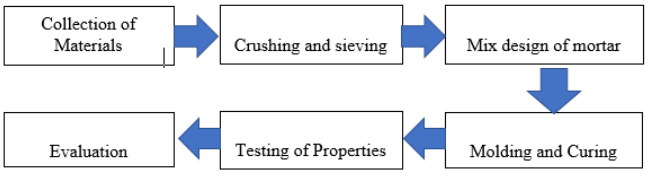

Fig.2. Process Flow of Research Study

IV. Procedure

4.1. Gathering of Materials

4.1.1 Aggregates

In this work, the following are the two types of aggregates that were used:

- The natural fine aggregate (NFA).

- The residual concrete waste from Brgy. Gandus, Mexico Pampanga was employed as the recycled fine aggregate (RFA) in this study. Recovered at the site of an old building's collapse. These were manually crushed through hammer. Safety tools were used to ensure safety.

*4.1.2 Binde*r

The binder used in this study was an Ordinary Portland Cement provided by Holcim Company. The decision to work with this cement was made since, as the top provider of building solutions in the world, it is widely used in construction. They have been operating in the Philippines for more than 50 years, supplying necessary materials for the construction of significant constructions.

4.1.3 Water

The Mixing water used to make mortars was the drinking water of Villages Water Supply Incorporation (VWSSI) in Mexico, Pampanga.

4.2. Crushing and Sieving

The concrete scrap was manually crushed with a hammer and graded using the Standard Specification for Manufactured Sand for Masonry Mortar described in ASTM C33, with 100% passing the No. 4 sieve and 10% passing the No. 200 screen.

4.3. Mix Designation of Mortar

Recycled fine aggregate (RFA) was substituted by natural fine aggregate (NFA) at 0 %, 5 %, 10 %, 20 %, and 40 %. These were named as follows: Specimen 1 (control mortar), Specimen 2 (5%), Specimen 3 (10%), Specimen 4 (20%), and Specimen 5 (40%). The graded crushed concrete waste was mixed with water and cement with a 1:3 ratio of cement by weight of the NFA of control. The number of materials used is on the Table 1.

Table 1. Mix Designation of Mortar per Specimen

MIX DESIGNATION					
	S1(Control)	S2	S3	S4	S5
Replacement Ratio	0%	5%	10%	20%	40%
Cement	100g	100g	100g	100g	100g
(NFA)	300g	285g	270g	240g	180g
(RFA)	0g	15g	30g	60g	120g
Water	100g	100g	100g	100g	100g

4.4. Molding and Curing

For this compression test, the molder used was 50 mm cube. The curing procedure started immediately after the product was cast in 24hrs. The specimens were cured by water curing to achieve better compressive strength. On the seventh, fourteenth, twenty-first, and eighteenth days of curing, the specimens were molded, and then they underwent a compression test.

4.5. Testing and Evaluation

For compression test, each sample was tested after the 7th, 14th, 21st, and 28th days of curing. The compressive strength ASTM C109 using 50mm cubes of mortar with varying percentages of demolished concrete waste was tested and compared, to determine which of these replacement mix can be used as a partial replacement for sand. The results were then evaluated based on the tests applied to the specimens. The tests conducted on the specimens were then used to analyze the results. This was done to see whether the outcomes met or failed the ASTM requirements for mortar. The ASTM C 270 Standard Specification for Mortar for Unit Masonry was used to classify mortar. The four primary varieties of mortar are listed below in decreasing order of strength. Additionally, Type K mortar is occasionally used but is no longer covered by ASTM C 270. (Refer to the table 2)

Table 2. Determining Mortar Type

Mortar Type	Average Compressive Strength at 28 Days (min. psi)
M	2,500
S	1,800
N	750
O	350
K	75

V. Results And Discussion

5.1. Sieve Analysis Results

Based on the results of the sieve analysis test, which the researchers performed on a sample of 3275.7g of concrete waste, the fineness modulus of 2.9 that was obtained corresponds with the ASTM Range of Fine Aggregates Specification, which is between 2.3 and 3.1 Concrete waste has a computed Fineness Modulus of 2.9, which indicates that the sample's average value falls between the 2nd sieve and 3rd sieve. As shown in Figure 7, the average diameter size of fine aggregates is between 0.297mm and.59mm.

Fig.3. Value of Fineness Modulus of Concrete Waste

5.2. Compression Test Results

Fig.4 illustrates the changes in stresses of the standard mix and the combination of concrete waste at various ratios after 7, 14, 21, and 28 days of curing. On the 28th day of curing, the highest average compressive strength for each mixture was attained. It shows that sample 4 (20%) had the highest stress in 7th, 14th, 21st, and 28th days. Therefore, the best or advisable replacement of concrete waste for sand is 20% and it classifies as type S mortar. On the other hand, the average compressive strength of standard mortar mixture (0%) results has the weakest among the replacement ratios except at the seventh day of curing. However, all of the combinations had compressive strengths that were higher than what was allowable for mortar.

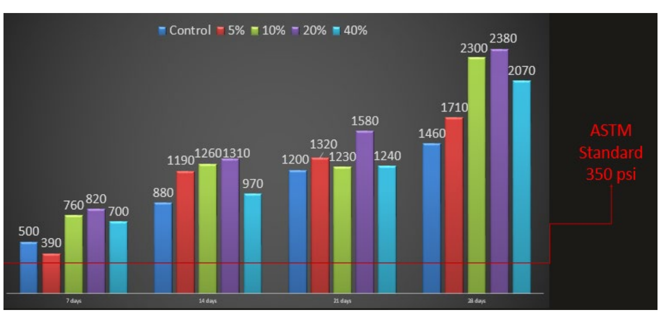

Fig.4. Average Compressive Strength of All Replacement Ratios with Different Days of Curing

VI. Conclusion

The researchers come to the following conclusions as a result of the observations made during the experiments: (a) All replacement ratios of recycled fine aggregates (RFA) to natural fine aggregates (NFA) on the new concrete mortar mixtures can produce positive results at the minimum with reference to its compressive strength test. (b) The best or highest minimum compressive strength of concrete waste mixture obtained a 20% of concrete waste was on the 28th day of curing. (c) The acceptable replacement percentage of concrete waste was 5%, 10%, 20% and 40%. But, the advisable to use was 20% of concrete waste in making mortar. (d) For external walls that are below grade as well as other outside projects like patios, the 20% concrete waste replacement will be employed. Additionally, compared to type N (general purpose), it has higher bonding and lateral strength, making it a better option for withstanding mild soil pressures below grade. Applications that are below grade with average to heavy loading. These are found in places where masonry meets the ground, like paving or shallow retaining walls. However, other concrete waste mixtures passed and can be used with their respective type (mortar type). (e) For all specimens at the14th, 21st and 28th day of curing, the RFA's mixtures are better than to the standard mixture (control).

VII. Recommendation

The following topics are suggested for future research in light of the study's limitations and results. First, explore and seek more research about the sustainability of concrete waste. Search and innovate the easiest way to crash demolish concrete instead of doing the manual crushing. Second, make an effort to look into different volume substitutions to get high-strength concrete that has been reinforced with superplasticizers and a further decrease in the water that concealment ratio so that it may add impact to a very high strength may be produced. Future studies may increase the use of RFA, recycled fine aggregates, or crushed concrete waste as a partial replacement for other materials used in the construction industry, such as beam, columns, slabs, pavement, plastering, and other construction material, and ultimately help us meet our millennium development goals (MDG), while also enhancing the economic power of the rural dwellers if they are global green environment initiative and greatly influenced by the reduction in carbon emissions. Study concretes with the presence of different cement content and allow them to cure for 28 days or more days to evaluate the maximum of strength of mortar. Lastly, find the range with which the mortar's strength begins to decrease.

REFERENCES

[1]. Akhtar, A. (2018). Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. AGRIS: International Information System for the Agricultural Science and Technology.

[2]. Ganiron, T. U. (2013). Use of Recycled Glass Bottles as Fine Aggregates in Concrete Mixture. International Journal of Advanced Science and Technology, 61, 17–28.

[3]. Ramakrishna, G., & Sundararajan, T. (2019). A novel approach to rheological and impact strength of fibre-reinforced cement/cementitious composites for durability evaluation. In Elsevier eBooks (pp. 389–406).

[4]. Braga, M. M., De Brito, J., & De Brito, J. (2012). Incorporation of fine concrete aggregates in mortars. Construction and Building Materials, 36, 960–968.

[5]. Ledesma, E., Jiménez, J., Fernández, J. F., Galvín, A. P., & Barbudo, A. (2014). Properties of masonry mortars manufactured with fine recycled concrete aggregates. Construction and Building Materials, 71, 289–298.

[6]. Li, L., Zhan, B., Lu, J., & Poon, C. S. (2019). Systematic evaluation of the effect of replacing river sand by different particle size ranges of fine recycled concrete aggregates (FRCA) in cement mortars. Construction and Building Materials, 209, 147–155.

[7]. Assaad, J. J., Mikhael, C., & Hanna, R. (2022). Recycling of waste expanded polystyrene concrete in lightweight sandwich panels and structural applications. Cleaner Materials, 4, 100095.

[8]. Kou, S. C., & Poon, C. S. (2013). Effects of different kinds of recycled fine aggregate on properties of rendering mortar. Journal of Sustainable Cement-Based Materials, 2(1), 43–57.

[9]. R. Martínez-García, M. I. Sánchez de Rojas, J. M. Morán-del Pozo, F. J. Fraile-Fernández, A. Juan-Valdés, Evaluation of Mechanical Characteristics of Cement Mortar with Fine Martínez-García, R., De Rojas, M. I. S., Del Pozo, J. M. M., Fraile-Fernández, F. J., & Juan-Valdés, A. (2021). Evaluation of Mechanical Characteristics of Cement Mortar with Fine Recycled Concrete Aggregates (FRCA). Sustainability, 13(1), 414.

[10]. Neno, C. U., De Brito, J., & De Brito, J. (2013). Using fine recycled concrete aggregate for mortar production. Materials Research-ibero-american Journal of Materials, 17(1), 168–177.

[11]. Oliveira, R. M. S., De Brito, J., & De Brito, J. (2015). Reduction of the cement content in rendering mortars with fine glass aggregates. Journal of Cleaner Production, 95, 75–88.

[12]. Braga, M. M., De Brito, J., & De Brito, J. (2012b). Incorporation of fine concrete aggregates in mortars. Construction and Building Materials, 36, 960–968.

[13]. Husain, A., & Assas, M. M. (2013). Utilization of demolished concrete waste for new construction. ResearchGate.

[14]. Monish, M., Srivastava, V., Agarwal, V. C., & Kumar, R. (2012). Utilization of demolished waste as fine aggregate in Concrete. ResearchGate.

[15]. Torretta, V., Sirpa, R. C. F., Lizarazu, E. G. G., Conti, F., & Torretta, V. (2022). Construction and demolition waste recycling in developing cities: management and cost analysis. Environmental Science and Pollution Research.

[16]. Ganiron, T. U., & Chemical, A. (2015). Recycling Concrete Debris from Construction and Demolition Waste. International Journal of Advanced Science and Technology, 77, 7–24.

[17]. ASTM C109/C109M (2016) Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens). ASTM International, West Conshohocken, PA. - References - Scientific Research Publishing. (n.d.).

[18]. Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens). (n.d.).

[19]. Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. (n.d.).