# A STUDY OF PROPERTIES OF CONCRETE MODIFIED WITH WASTE PAPER ASH

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**Abstract**

*Used paper is frequently discarded and sizable portions of it either burn or become waste that litters the environment before biodegrading. The use of waste papers as a partial replacement for cement in the proportions of 0 to 15% at intervals of 5% was the focus of this investigation. For each replacement (0-15%), concrete cubes with a mix design ratio of 1:2:4 and a water cement ratio (W/C) of 0.5 were cast, and allowed to cure for 7, 14, 21, and 28 days. The flexural and split strengths of the resulting concrete were predicted; tests such as workability, specific gravity consistency, water absorption, and compressive strength in line with British Standard were conducted. The results showed that the aggregate particle sizes were well graded. True slumps exist in cast concrete. The specific gravities of waste paper ash (WPA) and cement are within the same range of 3.12 to 3.15 accordingly for 5 to 15% WPA.The specimen at 15% has the most water absorption (3.06%) whereas the specimen at 0% has the lowest (2.30%). In comparison to control (25.56 N/mm$^2$), changed concrete (5-15%) had compressive strengths of 27.71 N/mm$^2$, 15.32 N/mm$^2$, and 26.82 N/mm$^2$ at 28 days. In terms of strength loss, compressive strength followed the same pattern as flexural and split strength. It may be inferred that waste paper ash, when employed as a cement substitute within the experimental range, has qualities similar to those of regular Portland cement and also reduce the economic burden faced in providing housing for all.*

***Keywords***: *Cement, Concrete, Waste paper ash, Replacement, and Strength*

## Introduction

Concrete is one of the most versatile and commonly used materials in the construction industry. It is the mixture of aggregates (coarse and fine), cement and water with or without admixtures. Cement is the most essential material needed in the production of concrete. Cement manufacturing depletes natural resources hence environmentally hostile. The cost of abstraction of the natural resources involved in production of cement is enormous consequentially, the resulting concrete from such operation exorbitant and not masses-friendly.

The yearly consumption of concrete is rising astronomically with the significant and rapid urbanization and population expansion occurring in many developing nations. There is a higher need than in previous years for housing and infrastructure construction. The desire to meet the deficit in the built environment demands high tonnage of cement thereby leaving a great pressure on the constituent materials.

Consequently, the need for an economical and more environment-friendly material led the way to the use of additional cementing materials in concrete. The usage of different materials to replace cement has become a trending practice in the construction industry. Presently, a lot of supplementary pozzolanic materials are in usage as partial substitution of cement. Some of these materials include waste paper ash, fly ash, waste glass, pumice, paper pulp, paper sludge, waste glass, silica fume, sugarcane bagasse ash, ceramic waste, glass powder, glass waste, recycled tire aggregates, rice husk ash, eggshell, blast furnace slag and so on.

According to Pera and Amrouz (2003) calcined paper sludge mixed with calcite and metakaoline at 650$^o$C can be used as partial replacement for ordinary Portland cement up to 20% in concrete. It was discovered that the mixture rapidly consume hydroxide than pure metakaoline.The resulting concrete has reduced size of pores and better compressive strength. Gallardo and Andajar (2006) studied the possibility of using paper mill sludge as partial substitute of fine aggregates in the production of fresh concrete for low cost housing project. The result showed that sludge is a good substitute between 5-10% of fine aggregates; also reduction in tensile and compressive strength was witnessed at higher percentages. The reduction of strength was however traced to high water absorption due to the affinity of paper for water. Jayeshkumar et al. (2013) studied the characteristics of paper ash in cement and reported that the compressive strength increases as paper replaces cement. An increment in paper ash is proportional to increase in compressive strength but brought about decreases in tensile strength. It was concluded that paper ash can be innovative additional cementitious material in the construction industry. In an experimental study conducted by Abdullah et al. (2014), waste paper was used to partially replace cement in order to examine how well concrete held its shape. When hypo sludge is substituted for cement by 10%, as opposed to regular concrete, the tensile strength of M20 and M30 concrete grade was found to increase. After a 20% increase in the hypo sludge, the strength is equal to that of regular concrete, but after a 30% substitution, the strength started declining. After conducting experiments on the usage of paper mill sludge as recycled materials and additives in concrete mixes for use in construction projects, Nazar et al. (2015) discovered a significant correlation between the concrete's density and strength when including paper mill sludge.

The purpose of this study is to find out what happens when waste disposal papers are used in place of cement binder for making concrete. Physical qualities like as workability, consistency, setting time, and compressive strength are the physical factors that will be examined. The aim of this research is to investigate what occurs when cement binder is substituted in the manufacture of concrete with waste disposed papers. The physical parameters to be studied are physical properties: workability (effectivity), consistency (uniformity), setting time and compressive strength.

**MATERIALS AND METHODS**

The waste papers used in this experimental research were from a Cyber café waste dump area in Ilaro (6˚53' 00" N, 3˚ 01' 00" E). The papers were cut into smaller pieces and burnt to ashes (Figure 1) in a furnace at 550˚C. The ashes were sieved to guarantee passing through a 50μm sieve and meeting the grading requirements specified in BS 882:1992 in order to partially replace Ordinary Portland Cement (OPC). The geochemical analysis using X-Ray Fluorescence (XRF) was conducted to determine chemical composition of oxides in waste paper ash (WPA).

**Figure 1: Waste paper and its ash.**

All concrete combinations were made with commercially available Portland cement from Elephant Portland Cement Company, which complies with BS 12:1996 requirements for Portland cement. Coarse aggregates with maximum size of 19mm; and fine aggregates were bought in Ilaro, Ogun State. Potable water was obtained from the Material Testing Laboratory of the Federal Polytechnic Ilaro. Sieve analysis was carried out on both coarse and fine aggregate sizes. WPA was substituted at 0%, 5%, 10% and 15% for cement respectively (Table 1).

**Table 1: Material Batching (in kilograms)**

| Materials | 0% | 5% | 10% | 15% |
|---|---|---|---|---|
| Cement | 11.00 | 10.45 | 9.90 | 9.35 |
| Fine Aggregate. | 22.00 | 22.00 | 22.00 | 22.00 |
| Coarse Aggregate | 44.00 | 44.00 | 44.00 | 44.00 |
| Waste Paper Ash | 0 | 0.55 | 1.10 | 1.65 |

Seventy-two (72) cubes were cast at mix design ratio of 1:2:4 with water-cement ratio of 0.5, and cured in water for 7, 14, 21 and 28 days and thereafter, crushed. Engineering tests on specimen were carried out in accordance to British European Standards.

**RESULTS & DISCUSSIONS**

The results with the subsequent discussion are presented below:

**Particle Size Distribution**

The result of the sieve analysis carried out in accordance to BS 1377 on fine aggregate (Figure 2) indicates that the co-efficient uniformity, $C_u$, is 2.13 (1-3) and the co-efficient of curvature, $C_c$, of 0.91 which lies between 0.5 and 2 while the finesse modulus is 3.59 which lies between 2 and 4.

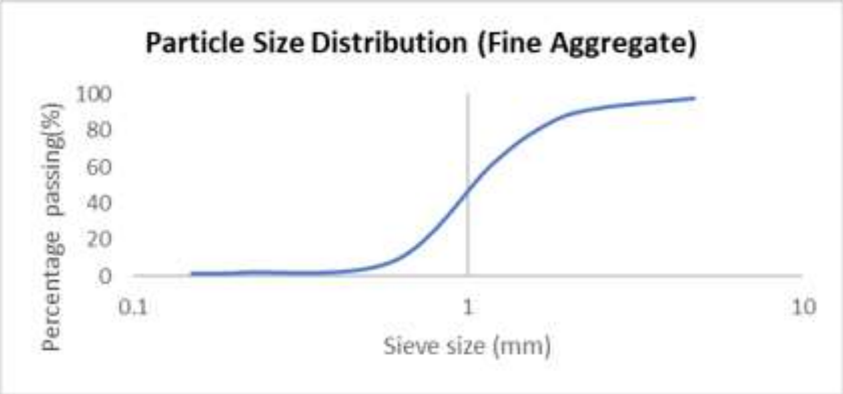


**Figure 2: Particle Size distribution curve for fine aggregates**

This means that the average size that is dominant lies between 1.15mm and 2.36mm while the coarse aggregate as depicted in Figure 3 below has $C_u$ of 1.38 which is less than 6 and $C_c$ of 1.05 and finesse modulus of 2.66. This depicts that both fine and coarse aggregates are suitable and good to produce efficient concrete.

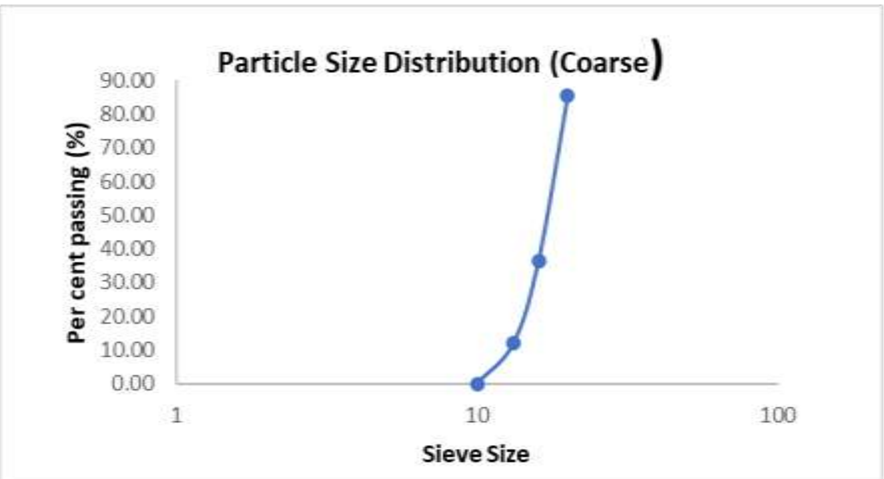


**Figure 3: Particle Size distribution curve for coarse aggregates**

In table 2 below, it was observed that Silicon IV oxides ($Sio_2$), Alumilium III Oxides ($Al_2O_3$), Iron III Oxides ($Fe_2O_3$) and Calcium II oxides (CaO) in WPA fall below the range of oxides in cement.

**Table 2 X- Ray Fluorescence Spectrophotometry of WPA and Cement**

| Oxides | WPA (%) | Cement (%) |
|---|---|---|
| $SiO_2$ | 4.17 | 17-20 |
| $Al_2O_3$ | 2.11 | 3-8 |
| $Fe_2O_3$ | 0.92 | 0.5-6 |
| $TiO_2$ | Nil | 1-3 |
| CaO | 0.18 | 60-67 |
| $P_2O_5$ | 0.65 | 6.85 |
| $K_2O$ | 2.16 | < 1 |
| MnO | 0.06 | 1.44 |
| $Na_2O$ | 3.12 | < 1 |
| MgO | 0.76 | 1-3 |
| CL | 47.02 | 0 - 0.4 |
| LOI | 38.85 | 6.71 |

## 3.2 Specific gravity

Specific gravity is a measure of the ratio of the unit weight of a substance to the unit weight of standard liquid (water). Specific gravity test was carried out on the materials to determine their suitability for use in concrete production. In essence, specific gravity describes how much heavier a substance is relative to water or a standard substance of equal volume.

**Table 3: Specific gravity of specimen**

| PERCENTAGE REPLACEMENT | SPECIFIC GRAVITY |
|---|---|
| 100% Cement | 3.13 |
| 100% WPA | 3.10 |
| 5% WPA+95% Cement | 3.12 |
| 10% WPA+90% Cement | 3.13 |
| 15% WPA+85% Cement | 3.15 |

From Table 3 above, the specific gravity of cement is 3.13 while the modified variants range from 3.10 to 3.15. Going by this analysis, it can be deduced that the cement variants deployed in the research is 3.10 to 3.15 times heavier and sinks in water than water of the same quantum and volume. The SG also indicates that WPA is well pulverized and grinded into powder. Tab. 3 shows that WPA and OPC have almost the same specific gravity. From above table 5%, 10% and 15% cement modification shows that the higher the WPA percentage, the higher the specific gravity.

**Consistency Test and Setting Time of Cement Paste**

The consistency test was run to figure out how much water should be added to cement to get it to a standard consistency or normal consistency. This test was conducted in accordance with the BS 12 standard description. All dosages fell within 5 and 7mm, which are considered good range.

**Table 4: Standard Consistency Test**

| Vicat apparatus | 0% | 5% | 10% | 15% |
|---|---|---|---|---|
| Needle penetration(mm) | 5 | 5 | 5.5 | 6 |

**Setting time of cement**

The cement pastes' initial and final setting time tests were performed using Vicat equipment in accordance with BS12.

It was observed that OPC and other modified cement set initially between 110minutes and 165 minutes as shown in table 5 above. It was also observed that conventional cement set finally at 165minutes and all other substitutes of cement (5, 10 and 15%) set at 185,185 and 262 minutes respectively. The final setting time of all the substitutes is deemed satisfactory in accordance to BS 12, 1978 and BSEN196-3:1995.

**Table 5: Cement Paste Setting time**

| Sample | Initial Setting Time (min) | Final Setting Time (min) |
|---|---|---|
| Cement | 110 | 165 |
| 5%WPA+95%Cement | 145 | 185 |
| 10%WPA+90%Cement | 157 | 185 |
| 15%WPA+85%Cement | 165 | 262 |

## 3.3 Workability

The ability and uniformity with which freshly mixed concrete or mortar may be mixed, put, cemented, and finished is determined by this attribute (ACI, 1990). Fresh concrete was subjected to a workability test using the slump method in accordance with BS 1881-102; 1983. The results are shown in Figure 4 below.

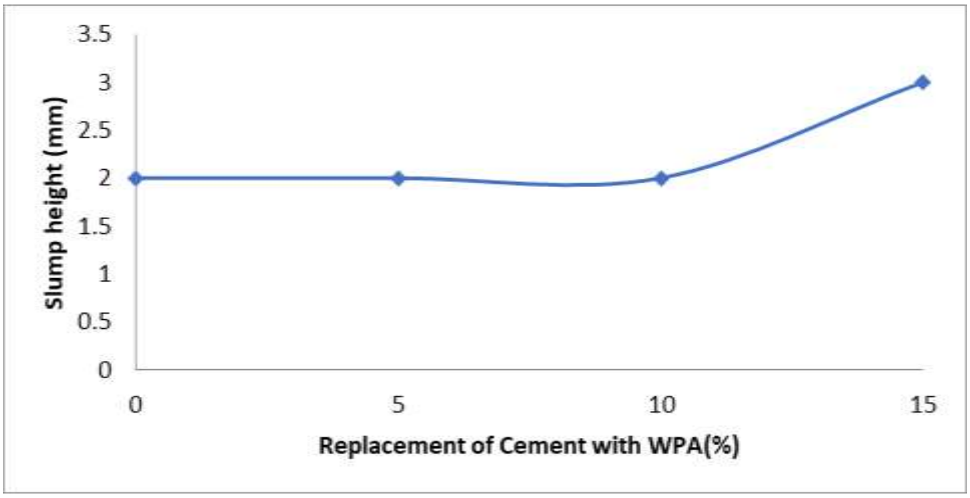


**Figure 4: Slump height of conventional concrete and modified concrete with WPA**

It was observed that 0% replacement, the slump height was 2mm; at 5% WPA replacement, it remains at 2mm, still maintain the height at 10% but at 15% it moved up to 3mm. From this interpretation, it was observed that the modified concrete behaved almost as the control sample, as both concrete recorded true slump which lies between 0 and 25mm.This means that the modified concrete can be used for the various concreting works ranging from reinforced to plain concrete.

### 3.6 Mass Density

Prior to testing, the weight of each concrete cube was obtained to determine its density. This was accomplished in compliance with BS 1881-114. (1983).Mass/Volume equals density.

The outcome was shown in table 6 below.

**Table 6: Mass Density of Concrete Specimen at 28days**

| Treatment Percentage (%) | Density(Kg/m$^3$) |
|---|---|
| 0 | 2331.852 |
| 5 | 2355.556 |
| 10 | 2405.926 |
| 15 | 2441.481 |

Referring to Table 6 above, the density of the control specimen was 2331.852kg/m3, and it grew to 2355.556kg/m3 at 5% WPA replacement, 2405.926kg/m3 at 10% cement replacement with WPA, and finally 2441.481kg/m3 at 15% replacement. It was found that the density is between 2300 and 2500 kg/m3, which is within the range of typical concrete's density. This is because, at that amount of replacement, WPA and cement have about the same specific gravity (Table 3), and specific gravity affects a substance's density.

### Water Absorption

The weight of the cubes was assessed after 7, 14, 21, and 28 days of water curing in line with BS 813-2 (1995) in order to measure water absorption.

Water absorption rate is calculated as (Final cube weight after curing - Initial cube weight before curing) / Initial cube weight before curing. The outcome is shown in Table 7 below.

**Table 7: Water Absorption**

| Sample replacement (%) | 7 days | 14 days | 21 days | 28 days |
|---|---|---|---|---|
| 0 | 2.30 | 2.44 | 2.56 | 2.72 |
| 5 | 2.62 | 2.70 | 2.81 | 2.91 |
| 10 | 2.75 | 2.78 | 2.93 | 2.98 |
| 15 | 2.84 | 2.88 | 3.02 | 3.06 |

According to Table 7 above, concrete has a water absorption rate of 2.30, 2.62, 2.75, and 2.84% after 7 days of curing in water at 0, 5, 10, and 15% treatment of WPA respectively. Water absorption of 2.44, 2.70, 2.78, and 2.88 were seen and recorded at 14 days of curing in water at the same dosage, and at 21 days, water absorption rate of 2.65, 2.81, 2.93, and 3.02% were recorded. The 28 days water absorptions for all treatment were observed, at 0%, the specimen's water absorption was 2.72%; it sped to 2.91 at 5%, changed to 2.98 at 10%, and then showed a minute change to 3.06 at 15%. The reason for this slight but noticeable change in water absorption is that unlike cement

WPA cannot store much water; cement has bigger hygroscopic oxides (CaO) than WPA (Table 2). As WPA is increasing in the concrete matrix, it is displacing space where cement should fill. It may be deduced that the cement with the largest WPA replacement has the highest water absorption. Additionally, according to The Maritime Code BS 6349, water absorption should not go over 3% or 2% in critical situations like exposure to highly aggressive chloride or freeze-thaw conditions.

**Compressive Strength**

The cubes having undergone 7, 14, 21, and 28 days of curing, were tested for compressive strength in line with BS 1881-116 (1983). Compressive strength (N/mm$^2$ or MPa) is the product of compressive force and cross-sectional area.

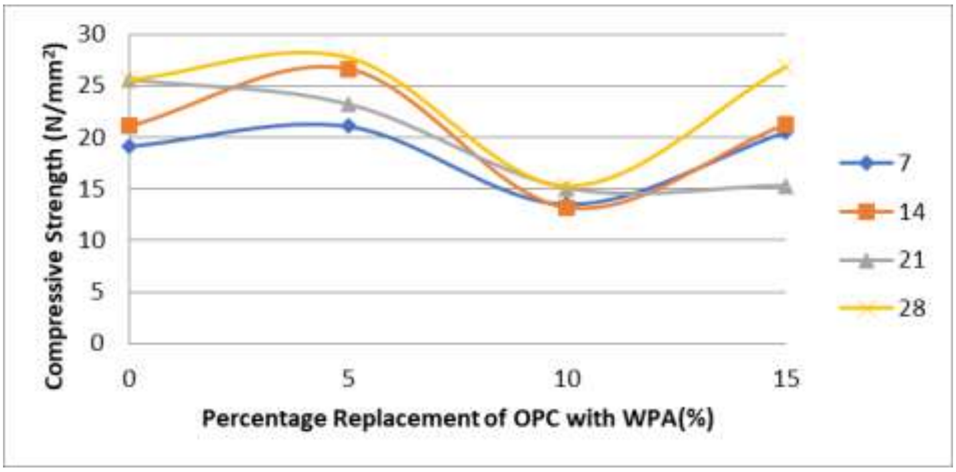


**Figure 5: Compressive Strength Development**

The results of the compressive strength test were obtained by substituting WPA for cement (binder) as indicated in Figure 5 above. In comparison to control concrete, which has compressive strengths of 19.14, 21.09, 25.66, and 25.56N/mm$^2$ for the corresponding curing days, the greatest compressive strength was attained when 15% of WPA was substituted at 7, 14, and 28 days with compressive strengths of 25.56, 27.71, and 26.82 N/mm$^2$ respectively. This is higher and is considered the most desirable of all samples.

**3.7 Mathematical Predictive Model for Flexural Strength**

The flexural strengths of beam were determined for the modified concrete using the model by BS 8110 (1997) and I.S. 456-2000, which was developed using relationship between compressive strength and flexural strength.

$$_{st} = 0.7fck^{0.5}$$

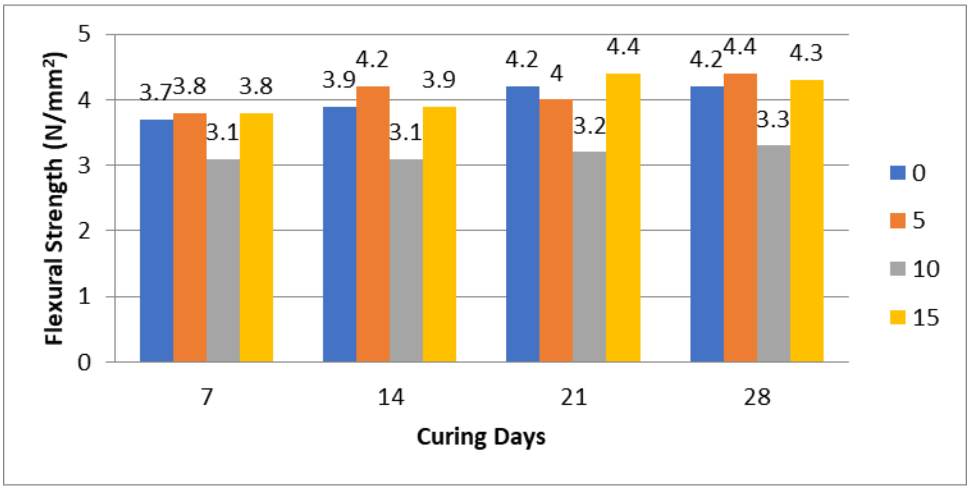


**Figure 6: Flexural Strength (N/mm$^2$) against Percentage Replacement of Cement Using WPA**

From Figure 6 above, 28 days flexural strength of control specimen (beam) was predicted to be 4.2MPa, and for 5% substitute it was 4.4MPa which is 0.2MPa more than that of the control. The strength dropped at 10% to 3.3MPa and later climbed up to 4.3N/mm$^2$ at 15%. This could be said that the flexural strength is within the same range between the control and up to 15% substitution except for 10% WPA substitution.

**Mathematical Predictive Model for Spilt Tensile Strength**

The model is derived from the equation $f_{sp} = 0.56\ fck^{1/2}$ that links compressive strength to split tensile strength. The pattern for split tensile strength was the same as for split flexural strength. The split tensile strength (Figure 7) at 0% substitution lies between 3.3 and 3.8MPa for the 7, 14, 21 and 28 days curing and it kept increasing for 5% substitution while a significant reduction was noticed throughout the curing days at 10% replacement but, an appreciable increase was observed in the 15% replacement for all the curing days with the strength ranging from 3.4 – 4.9MPa.

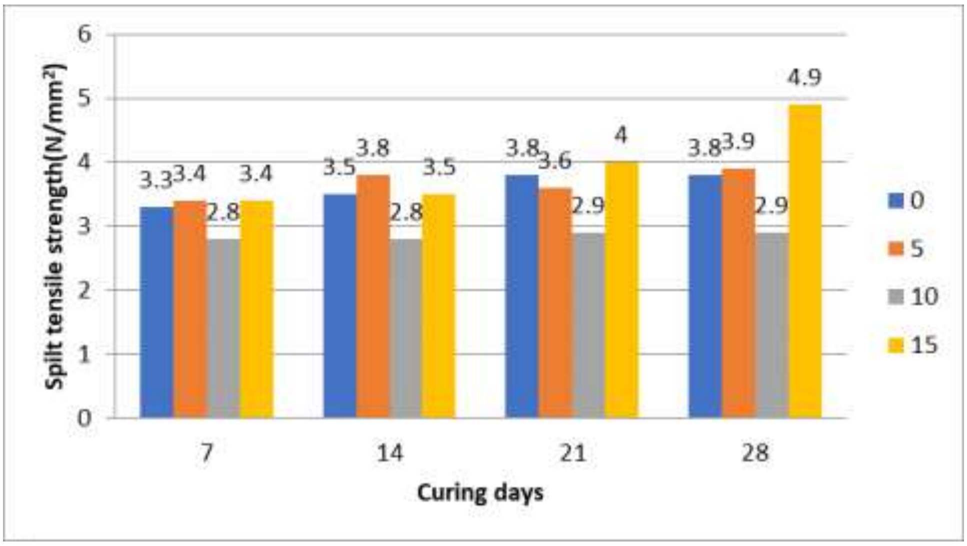


**Figure 7: Split Tensile Strength (N/mm$^2$) Against Percentage Replacement of Cement Using WPA**

## CONCLUSION

This study looked into the feasibility of replacing cement in part with waste paper ash. Additionally, the procedure of using paper ash in place of cement in percentages of 0, 5, 10, and 15 was investigated, and the parameters of slump, compressive strength, and unit weight were measured. The following findings and conclusions were attained in the end:

1. Amounts of 15% are the most common usages of waste paper ash as cement.
2. Paper trash is removed from the environment when it is used to make cement. Utilizing waste paper is regarded as positively economical (cost reduction) in addition to reducing the usage and requirement of raw materials (cement and coarse aggregate).
3. It has been discovered that using WPA as a cement substitute reduces the need for cement.
4. Using paper waste in concrete production causes no remarkable negative effect in the properties of cement.

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