

# Strength Assessment of Controlled Low Strength Materials (CLSM) Utilizing Recycled Concrete Aggregate and Waste Paper Sludge Ash

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**Abstract**— This paper studies the strength development of low-strength material (CLSM) is controlled by using waste paper sludge ash (WPSA) in CLSM mixtures without adding Portland cement. Series of four (4) compounds which is the CLSM containing 5%, 10%, 20% and 30% of waste paper sludge ash (WPSA) as a substitute for Portland cement. CLSM cubes the sizes of 100mm x 100mm x 100mm compressive strength were tested at age 7, 14 and 28days. It was found that this activity contributes to strength development pozzolonic paper waste sludge ash (WPSA) depending on the percentage of the added waste paper sludge ash. So, it was found that the activity pozzolonic has been activated by the alkaline and calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) contributed from recycled concrete aggregate (RCA). In this study, the alkaline releases when soaked in water for 28days. Compressive strength of controlled low-strength materials affected by both the ratio of fine aggregate and coarse aggregate and mixture characteristics during maturation developed CLSM. Cube test results show that CLSM with a ratio of 1:2 and 1:1 RCA and 20mm recycled coarse aggregate, 30% of WPSA content expressed as mass percentage of RCA is to produce a uniform mixture with a constant high-strength (maximum strength of 6.04MPa).

**Keywords:** Controlled Low Strength Materials (CLSM), Waste Paper Sludge Ash (WPSA), Recycle Concrete Aggregate (RCA), compressive strength.

## I. INTRODUCTION

The use of aggregate from demolished concrete structures have been introduced to the practice many years ago and it has been considered in two aspects of environmental waste storage, improve problem solving and protection of natural resources are limited aggregate. Concrete crushing to produce coarse aggregate for new concrete production is one of the most common way to achieve concrete more environmentally friendly. This reduces the use of natural resources and the use of landfill required for concrete wastes. At present, there is widespread use of new operational strategies aimed at prevention and reduction of wastes as close as possible to the resources that aims to pursue sustainable environmental development in charge.

For effective use of waste concrete, it is necessary to use the waste concrete as recycled aggregate for new concrete. To make this technology implemented, the number of worldwide importance of experimental work has been carried out. Previous investigations especially those involved in the processing of demolished concrete, mix design, and physical properties and mechanical as well as increased resistance [11].

Sustainable industrial development pose serious problems of construction and demolition waste disposal. While on the one hand, there is a critical shortage of natural aggregate (NA) for the production of new concrete, the other the amount of the demolished concrete produced from deteriorated and dilapidated structures create severe ecological and environmental problems [8]. One way to solve this problem is to use waste concrete as aggregate [13]. The recycled aggregate can also be a reliable alternative to using natural aggregates in concrete construction.

There are many studies concerning the mechanical properties and durability of RCA. Tests have shown that mechanical properties depend on the properties of recycled concrete used to produce a percentage of the aggregate and coarse aggregate replacement in new concrete [12]. In general, concrete accounts for nearly 75% by weight of all construction materials [15]. By finding new applications for concrete waste and create a market for use, we can reduce the need to take the original virgin aggregate and at the same time saves landfill space. Until now, RCA has been used primarily as a granular base in road works or in conjunction with natural aggregates in concrete applications. In terms of using the RCA in the concrete structure, research has shown that the use of RCA 30% and 70% of natural aggregate in high strength concrete to produces the same strength as concrete containing only natural aggregates [9].

Combustion of WPSA, which when leached with alkali produces a material with potential applications as a binder [10]. There are several studies WPSA involved as a binder. WPSA absorb water more quickly than other cementitious materials such as Portland cement. Unlike Portland cement, WPSA particles showing various size and composition, and therefore do not behave in a way similar to Portland cement [14]. This paper presents results of studies investigating the possibility of using the RCA and SCM, without using a PC, to produce CLSM for various applications. The current CLSM applications require compressive strength of 2.0MPa or less [1]. Lower power requirements are necessary to enable the excavation of CLSM future. Long-term compressive strength for compacted soil-cement often exceeds the maximum limit established for CLSM 8.27MPa. Long-term compressive strength is lower than 0.70MPa concrete [16]. CLSM is used primarily to fill the cavity in the civil engineering works, where the granular fill applications either impossible or difficult [1]. Production technology is similar to concrete production. High workability is achieved through the use of a high amount of mixing water or by using additives (air entraining agents, plasticizers, and others).

## II. MATERIALS AND METHODS

### A. Experimental Method

This study investigated the practical use of CLSM using only RCA and supplementary cementing materials (SCM) Portland cement without additives. If the project is successful, it will not only benefit the construction industry and also help to reduce the disposal of concrete waste disposal sites and maintain the natural aggregate. Economic aspects such as the increase in tip charges, the distance of transportation and fuel costs for disposing of concrete waste in landfills will decrease. In addition, CLSM using RCA is beneficial and necessary from the standpoint of environmental conservation and efficient use of resources.

### B. Selection of Materials

Waste concrete cubes were crushed in the laboratory to produce recycled fine aggregate through-BS410 5mm test sieve. BS882:1992 gives grading limits in the weight percentage of fine aggregate. Sieve is crushed to a maximum size of 20mm. Sieve analysis process and the grading limits for coarse aggregate is successful in the laboratory. Size-20mm complied with in accordance with the procedure describes in BS812: Part 103:1985.

RCA has been immersed in distilled water to obtain the total alkali contributed RCA form. Contribute alkaline paste RCA is believed to help balance the WPSA pozzolanic reaction active. RCA sample size of 20 mm maximum particle was soaked in distilled water for 28days to obtain a complete concentration of cautions has been attributed to the RCA in the solid water ratio 1:5. Soaked in water pH level are 12.9 with a pH meter.

WPSA is derived from paper manufacturing industry, Malaysian Newsprint Industries (MNI) Sdn Bhd, which is located in Mertakab, Pahang used as a substitute for mineral filler and as a supplementary cementing material (SCM) in various CLSM mixtures. The potential applications of WPSA are as possible with pozzolonic activities in the production of cement. In this study, CLSM mixtures containing fine RCA has been prepared using the WPSA content of 5%, 10%, 20% and 30% expressed as a percentage of dry mass of the RCA.

### C. The Proportion of Mixed

Raw materials available for recycling mixed CLSM including fine aggregate, coarse aggregate recycling, water soaked and waste paper sludge ash (WPSA) at the rate required proportions shown in Table I. CLSM refers to the ratio of recycled coarse aggregate concrete mix recycling, recycled fine aggregate and water soaked. Because there are no standard design methods without Portland cement concrete mix, each weight of material is based on two ratios, as shown in Eq. (1) and (2).

Fine recycle aggregate and coarse recycle aggregate = Eq. (1)  
1 (Fine): 1 (Coarse)

Fine recycle aggregate and coarse recycle aggregate = Eq. (2)  
1 (Fine): 2 (Coarse)

A conical frustum 300mm prepared under standard conditions [2] is allowed and the deterioration or reduction in height of the cone is taken to measure the consistency or the

wet mixture. Appropriate impairment test in this study is approximately  $\geq 150$  mm for CLSM. CLSM workability evaluated using cone impairment test in which the deterioration of 150mm minimum required to meet the minimum flowability CLSM [1].

TABLE I. THE DETAIL OF MIX PROPORTION OF CLSM

| Ratio | WPSA (%) | RCA Coarse aggregate (kg) | RCA Fine aggregate (kg) | Soaked water (kg) | WPSA Weight (kg) | Water Binder | Slump (mm) |
|-------|----------|---------------------------|-------------------------|-------------------|------------------|--------------|------------|
| 1:1   | 5        | 13.25                     | 13.25                   | 5.30              | 1.33             | 4.00         | 154.0      |
|       | 10       | 13.25                     | 13.25                   | 5.71              | 2.65             | 2.15         | 159.0      |
|       | 20       | 13.25                     | 13.25                   | 6.52              | 5.30             | 1.23         | 153.0      |
|       | 30       | 13.25                     | 13.25                   | 7.95              | 7.95             | 1.00         | 160.0      |
| 1:2   | 5        | 17.76                     | 8.75                    | 5.30              | 1.33             | 4.00         | 153.0      |
|       | 10       | 17.76                     | 8.75                    | 5.71              | 2.65             | 2.15         | 160.0      |
|       | 20       | 17.76                     | 8.75                    | 6.52              | 5.30             | 1.23         | 159.0      |
|       | 30       | 17.76                     | 8.75                    | 7.95              | 7.95             | 1.00         | 162.0      |

In accordance with BS8110-4: 1997, CLSM cube size used is 100mm x 100mm x 100mm in determining the compressive strength. CLSM cubes tested for their compressive strength after 7days, 14days and 28days after stored at room temperature. Compressive strength has a definite relationship with all other properties of CLSM. Compressive strength (f) is calculated by Eq. (3).

$$f = Q / A \quad \text{Eq. (3)}$$

**Note:** Q = maximum compressive load is applied  
A = maximum cross-sectional area

## III. RESULTS AND DISCUSSIONS

### A. Compressive Strength

Compressive strength of controlled low strength material (CLSM) is influenced by both the ratio of recycled fine aggregate and recycled coarse aggregate and mixture characteristics during maturation developed CLSM. Cubes were tested after 7, 14 and 28days with Compression Machine.

From the graph (Figure 1), it states that CLSM with 5%, 10%, 20% and 30% of the WPSA to reach the age of 7 days compressive strength of 0.88MPa, 2.40MPa, 4.27MPa and 5.19MPa. Meanwhile, the compressive strength of CLSM 1:2 recycle ratio of fine aggregate and recycled coarse aggregate to the age of 14 days 0.91MPa, 2.63MPa, 4.64MPa and 5.78MPa respectively. Compressive strength of CLSM to the age of 28 days is 1.07MPa, 2.83MPa, 4.81MPa and 6.04MPa respectively.

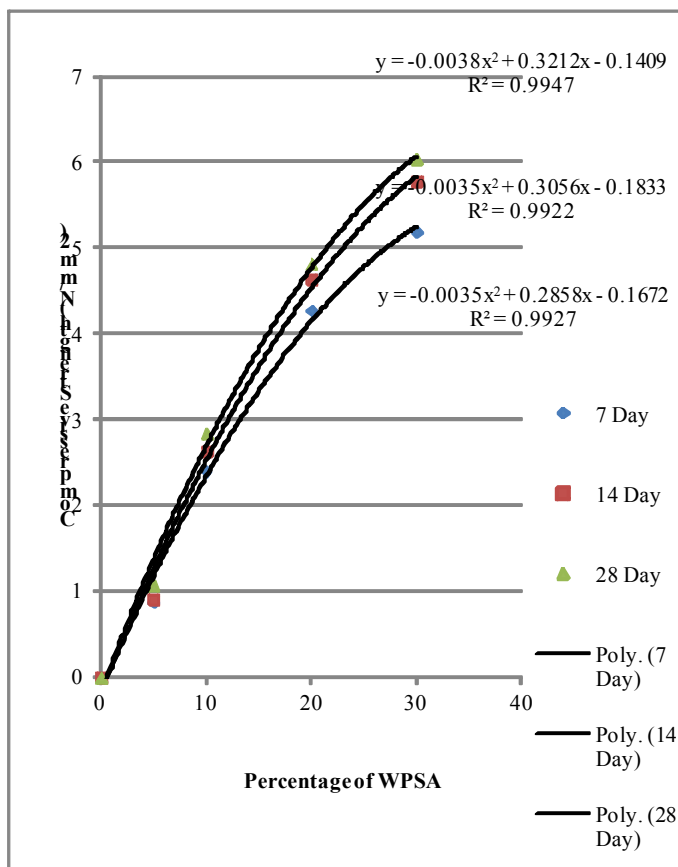


Figure 1. Strength Development of CLSM with Ratio 1:2 of Fine Aggregate and Coarse Aggregate and Coarse Aggregate size of 20mm

Based on Figure 2, it shows that the compressive strength increased with the percentage of the WPSA added in CLSM. It is clear that increasing the WPSA contribute to the development of strength. The development of this strength is due to the WPSA pozzolonic activities. So, it is believed that the activities pozzolonic has been activated by the alkali and calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) contributed from the RCA. The figure shows the CLSM that with 30% of the WPSA higher compressive strengths than the rest of CLSM% 5 WPSA. It is believed that this development contributes to the strength of the WPSA pozzolonic activity depends on the percentage of the added waste paper sludge ash.

Based on the graph, it is stated that CLSM with 5%, 10%, 20% and 30% of the WPSA to reach the age of 7 days compressive strength of 0.72MPa, 1.94MPa, 2.64MPa and 2.71MPa. Meanwhile, the compressive strength of CLSM to the age of 14 days is 0.84MPa, 2.01MPa, 2.74MPa and 2.94MPa respectively. Compressive strength for 28 days is 0.92MPa, 2.12MPa, 2.93MPa and 3.11MPa respectively. The maximum compressive strength of CLSM over 28 days for 30% of the WPSA is 3.11MPa. Figure 2 shows that the CLSM for ages 7 days, 14 days and 28 days, there is lower increase in strength in strength when more than 20% of WPSA is used compared to mixture with 30% of WPSA. It is observed that the weight of the unit mix with 30% WPSA and WPSA percentage added to the mixture which is higher than CLSM mixture with 20% of WPSA. This low density and the percentage WPSA can be caused by a lower strength.

Otherwise, CLSM with 30% of the WPSA produce higher compressive strength at 28 days. It is believed that this development contributes to the strength of the WPSA pozzolonic activity depends on the percentage of the added waste paper sludge ash.

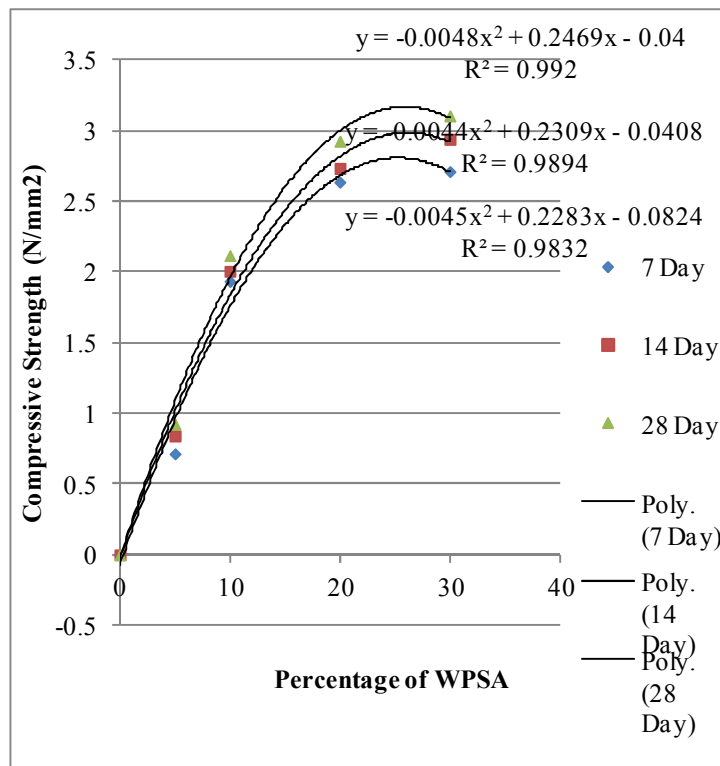


Figure 2. Strength Development of CLSM with Ratio 1:1 of Fine Aggregate and Coarse Aggregate and Coarse Aggregate size of 20mm

### B. Strength Development of CLSM with Different Ratio of Fine Recycle Aggregate and Coarse Recycle Aggregate on 7, 14 and 28days.

Higher compressive strength accounted for the ratio of recycled coarse aggregate in the mixture of recycled coarse aggregate CLSM. Referred to the two graph lines CLSM mixtures with the same ratio of 01:02 RCA but the amount of recycled coarse aggregates of different shows that a higher ratio of recycled coarse aggregate in the mixture given CLSM higher than the compressive strength.

It is clear that the strength for the CLSM made with 1:1 coarse recycle aggregate size produced lower compressive strength compared to 1:2 coarse aggregate size. This shows that, the strength of the CLSM mixtures with 1:2 coarse recycle aggregate size suitable for the engineering non-structural applications compared to the 1:1 coarse recycle aggregate size. The amount of coarse aggregate recycling contributes to the development of CLSM strength that produces high strength and toughness on the applied load.

In addition, the percentages of WPSA also help accelerate the release of alkali, reaction pozzolonic of WPSA. Ratio (1:2) to contribute to a better aggregate packaging recycling unit weight of concrete or higher also resulted in higher compressive strength. Recycled aggregate amount obtained for CLSM can be due to better packaging recycled concrete

aggregate, reflected in higher unit weight obtained. This is due to the increasing integration of the mixture when a larger amount of recycled coarse aggregate used. Ratio (1:2) mixture of RCA in CLSM specimens contributed to the high density that can lead to high compressive strength. So, this can cause high compressive strength. This is due to the increasing integration of the mixture when a larger amount of recycled coarse aggregate used.

#### IV. CONCLUSIONS

For the range of the materials investigated in this study, the following conclusions were:-

- i. Mixtures of RCA and WPSA were produced and found to gain strength without the need to add Portland cement. The strength of CLSM cubes increased with increasing percentages WPSA as supplementary cementing materials (SCM) in the CLSM mixtures.
- ii. WPSA result in strength due to their hydraulic response and pozzolonic. Both believed to be promoted by alkali extracted from the remaining paste in the RCA. Development of strength resulting from the hydration of the particles in the RCA WPSA has been assessed and found to have an effect on strength development.
- iii. The types of CLSM with a 1:2 ratio of RCA and recycled coarse aggregate of 20mm suitable for use in concrete construction engineering (non-structural) applications because of the constant development of strength in which a relatively high strength (up to 6.04 MPa).
- iv. 1:2 ratio of fine aggregate to coarse aggregate recycling units has been given greater weight. CLSM specimens of high density can lead to high compressive strength.
- v. In general, the WPSA that can act as a cement replacement for Portland cement for the production of CLSM and maintain the natural aggregates by using waste materials and industrial recycling.

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