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Effect of Crumb Rubber as Partial Replacement Materials in Concrete: A Review

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Abstract: Waste rubber tires are one of the hot issues of environmental problem and serious action should be taken to manage this problem. The increasing demand of concrete in construction industry indirectly leads to consuming large amount of cement and aggregates as the major materials used. The extraction of aggregate has been highlighted as one of the contentious land-uses and by changing a tiny part of the coarse and fine aggregates with rubber crumb produced from scrap tires, a twofold benefits of natural resource survival and the waste management may be accomplished. This paper aims to identify the mechanical and physical performances of concrete containing crumb rubber such as workability, density and compressive strength and the effect of percentage replacement for fine and coarse aggregates in concrete. To conduct the research, journals from online database such as ScienceDirect were collected and studied. Then, the results of performances of concrete containing crumb rubber will be compared and analysed in graphs to get the summary also the agreements and disagreements between authors. According to the findings, there was decreasing pattern in the strength performances of crumb rubber concrete. However, the crumb rubber can still be used as partial replacement materials when the right percentage amount are added in the concrete and the percentage of addition are not exceeding 20% whereas the recommended average of optimum percentage is 5%. It is because, there was no great difference from those ordinary mix concrete. Pre-treatment of crumb rubber also can be done in order to enhance the properties.

Keywords: Waste Rubber, Crumb Rubber, Workability, Density

1. Introduction

Rubber tires are an essential component of vehicles such as buses, automobiles and bicycles. Rubber tires are non-biodegradable materials that have become a global environmental problem [1]. About 1.5 billion tires being manufactured yearly, with one billion tires coming towards the end of their

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usable life [2]. This indicates that considerable action should be done appropriately to manage tire waste.

The usage of scrap tires as construction materials can be an excellent practical option for the construction sector because concrete is the most commonly used man-made product on the continent where aggregates and cement form the majority of it, contributing to greater demand for these materials in a wide range of building projects all over the world [3]. Based on a previous studies by [4-5], they stated that aggregates extraction has been highlighted as a contentious land-use, primarily to the social and environmental consequences involved due to aggregates extraction operations. Thus, due to the extreme increasing demand for concrete, by changing a partial percentage of coarse and fine aggregates with crumb rubber produced from scrap tires, a twofold benefits of natural resource survival and the waste management may be accomplished [3]. The partially replacement of coarse and fine aggregates with waste rubber crumb in concrete is a feasible approach to produce concrete with desirable characteristics such as better energy absorption, reduced impact strength and unit weight [6-7].

As a result, numerous academics are doing study to determine the best answer to this problem. They also had done their research to find out what are the other materials that can be used to replace aggregates in concrete construction. According to particle size, scrap tires may be divided into four categories such as slit tires (the tire is slit into two halves), shredded/chipped tires with particle sizes ranging from 300-400mm long by 100-230mm wide, ground rubber with particle sizes ranging from 19-0.15mm and crumb rubber with particle sizes ranging from 4.75-0.075mm [8]. The study also reported that the crumb rubber have a nominal size between 4.75 mm (No. 4 sieve) and 0.075 mm (No. 200 sieve).

In this paper by doing review analysis, various research findings from past researchers can be analysed and compared for the use of crumb rubber tires as partial replacement material for concrete. Moreover, the mechanical and physical performances of concrete containing crumb rubber tires could also be determined. This performances included the workability, density and compressive strength. The effect of percentage replacement of crumb rubber for fine and coarse aggregates could also be analysed.

2. Methods

The research journals regarding the study were obtained from the online sources such as ScienceDirect database. The searched keywords included crumb rubber, waste tires, workability, density and compressive strength to find related articles and journals. A total of 50 chosen research papers from previous studies collected were reviewed regarding pre-treatment process, workability, density, and compressive strength. The previous research papers are ranging from 2006 until 2021.

For this paper workflow, firstly, the title was identified, the problem statement was defined, the objective of study, scope of study and significant outcomes were determined. Next, the information from previous studies were reviewed and after that all the related data was collected. The data were then analysed by combining the results by past researchers according to the mechanical and physical performances in graphs to see the different results clearly. From the graphs, the results could be seen clearly between each papers and then the discussion were made based on the data analysis. Lastly, the conclusion and recommendation of future research were done.

3. Results and Discussion

The review analysis for the performance of concrete using crumb rubber as partial replacement materials in terms of pre-treatment, workability, density and compressive strength was discussed.

3.1 Analysis on pre-treatment

Figure 1 shows a percentage of previous research studies that used different chemicals in pre-treatment process for crumb rubber before partially replaced in a concrete mix. About 81.8% previous studies which used single Sodium Hydroxide (NaOH) solution in pre-treatment process and 18.2% used

Sodium Hydroxide (NaOH) mixed with other chemicals, such as silica fume. It was found that NaOH had the highest binding performance compared to other chemicals.

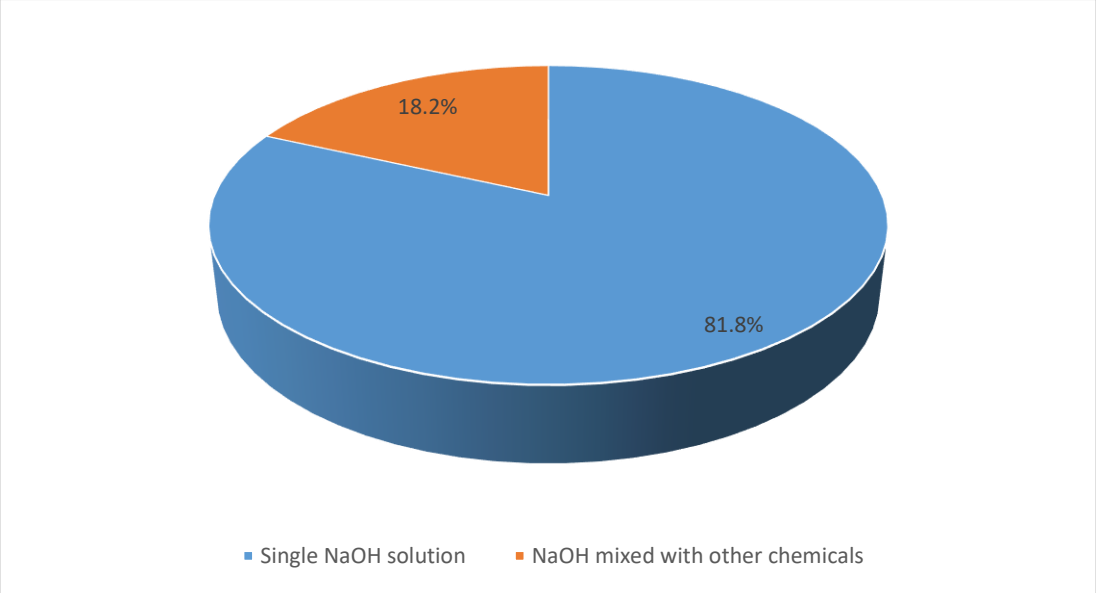

Figure 1: Pre-treatment used for crumb rubber

3.2 Analysis on workability

Workability of concrete is a broad and subjective term describing how easily freshly mixed concrete can be mixed, placed, consolidated and finished with minimal loss of homogeneity. Most of the previous studies had investigated the slump test as a test for workability. Figure 2 below shows the graph for workability of concrete with different percentage of crumb rubber added by different researchers. It was found that the workability decrease when the percentage of crumb rubber increased. However for [9], they found out the workability increase when the percentage of crumb rubber increase but at the addition of 20%, the slump values started to decrease. When up to 20% crumb rubber content was utilised, the unit weight of the mix decreased which was due to the lower unit weight of the rubber, but the unit weight remained within the permissible range for the total aggregate volume. It shows that the acceptance limit for percentage of crumb rubber content is not exceeding 20% and this results were also supported by other researchers, [10], [11], [12], [13], [14] and [15] by getting the same results stated that the additional percentage should be limit to 20 and mostly optimum at 5%.

The decreased workability can be attributed to the increased water absorption capacity of rubber compared to sand, whereas the low slump value can be related to the crumb rubber's tiny particle size [16]. Even though a finer rubberized aggregate has a greater surface area than a coarser rubberized aggregate, the workability rises with the high specific surface area of the concrete components and hence a higher drop in workability could be seen [17]. According to [15], the decreased value in workability was due to the greater particles' lower 'flow ability,' which has been found in prior research that suggests employing a higher w/c ratio for higher amounts of rubber in the mix.

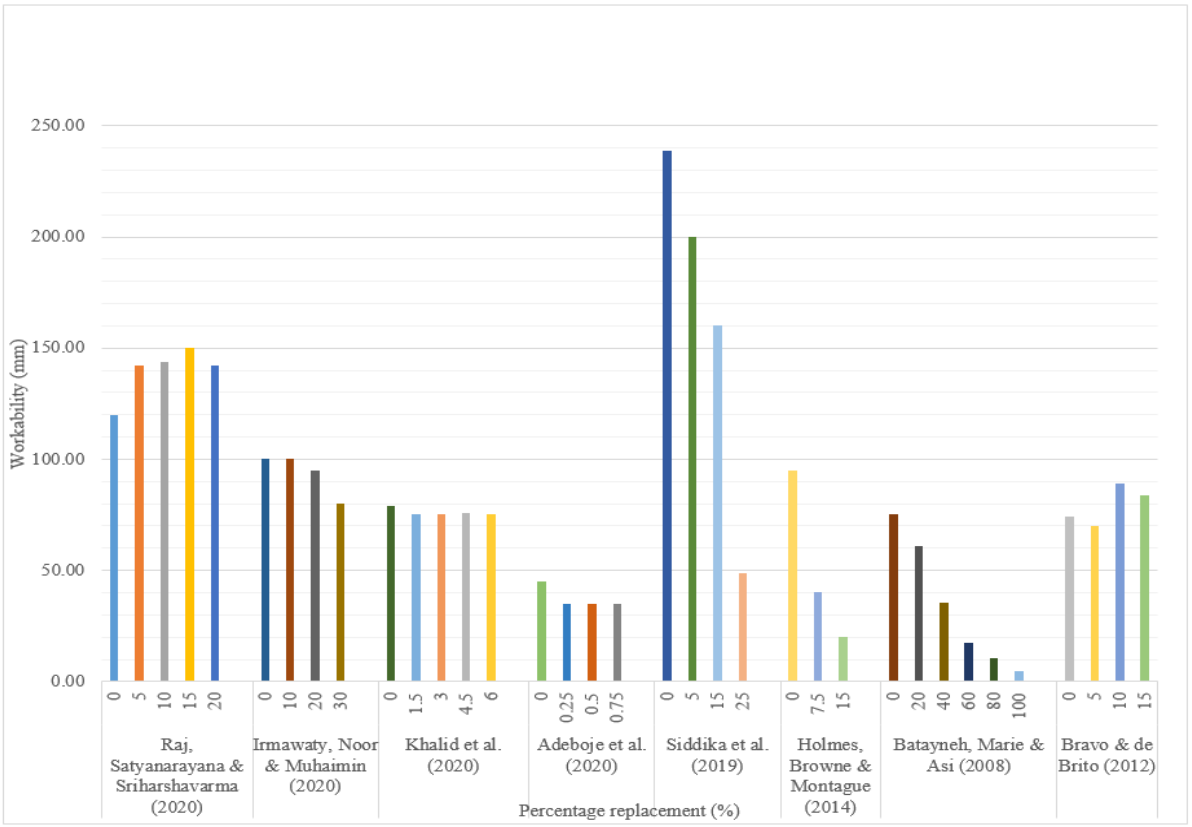

Figure 2: Workability of concrete with different percentage of crumb rubber replacement

3.3 Analysis on density

Density is a per-volume indicator of mass. A lightweight concrete has a density of 800-2000 kg/m3, whereas standard and heavy weight concrete have densities of 2001-2600 kg/m3 and more than 2600 kg/m3, respectively, according to EN 206: 2000. Figure 3 shows the density of concrete with different percentage of crumb rubber replacement by previous researchers. It was found that majority of the past research showed the density decreased when percentage of crumb rubber increased. From the graph, it can be seen that the decreasing difference was high when percentage addition of crumb rubber are 10% and 20% [18]. This shows that the acceptance limit for percentage of crumb rubber content can be up to 15%. The other researchers who stated the limit of addition is 10% and the optimum addition is 5% are [19], [20] and [21].

The explanation for the decrease in the cement mix density might be related to the different specific gravity of each crumb rubber and also fine and coarse aggregates [22]. According to the previous research findings and analyses, increasing the amount of crumb rubber used as a sand substitute in concrete lowers the bulk density of the concrete, which is consistent with the result from [13]. The specific gravity of crumb rubber is 1.14, while the specific gravity of sand is 2.63. The decrease in the bulk density of concrete due to crumb rubber may be related to the crumb rubber's lower specific gravity relative to the sand it replaced, as crumb rubber is less dense than sand [23]. In addition, the other reason that might cause the decreasing value for density was because of the rubber particles flocculating during the mixing of concrete with a greater rubber component as per results obtained by [18]. Flocculation was primarily detected in the mix with 20% replacement, which resulted in huge voids inside the block and increased porosity [18].

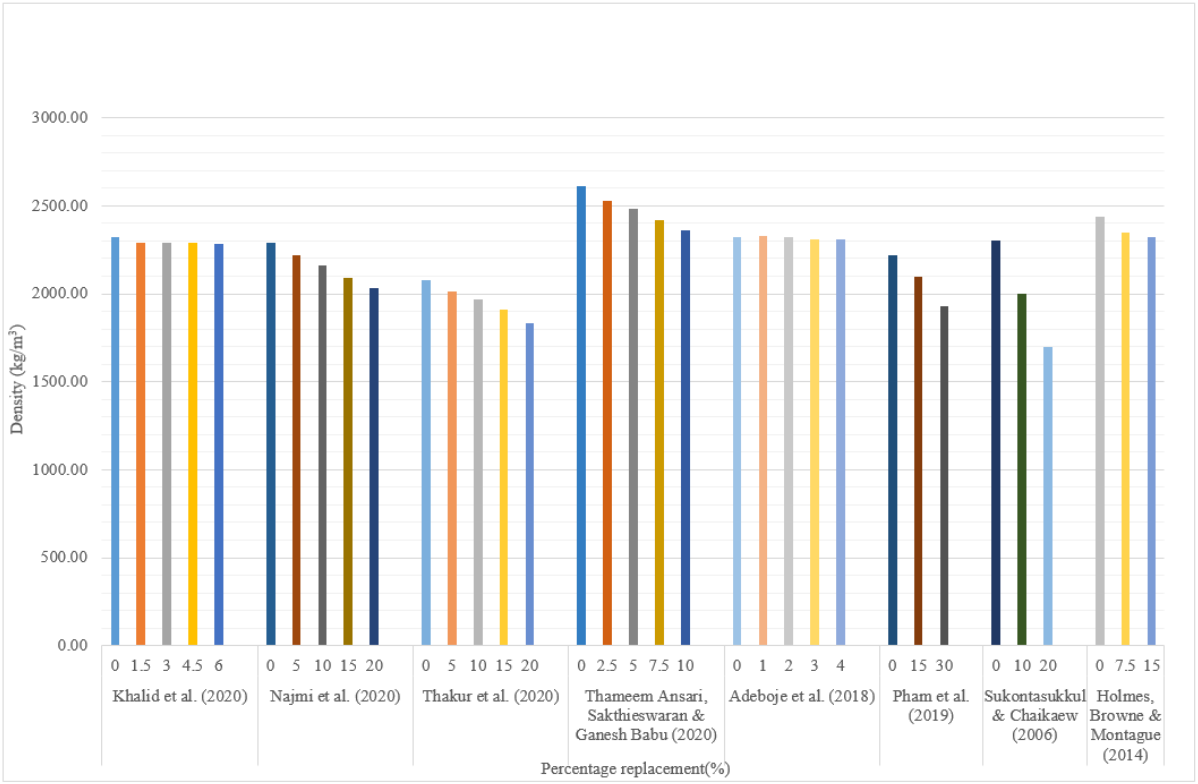

Figure 3: Density of concrete with different percentage of crumb rubber replacement

3.4 Analysis on compressive strength

Compressive strength is the measure of the ability of the concrete to resist loads acting on it. This parameter is important because it could affect the performance and behaviour of the characteristic of materials and it also could determine the finishing quality of the product. In construction, the general compressive strength varies from 15 Mpa to 30 Mpa and it gets higher in commercial and industrial buildings. Figure 4 shows compressive strength of concrete with different percentage of crumb rubber replacement of previous studies from researchers who had investigated the compressive strength performance of concrete containing crumb rubber. It was found that the compressive strength decreased when percentage of crumb rubber increased. According to these results, the compressive strength only slightly reduce when 15% of crumb rubber is used to replace the sand and if the percentage of crumb rubber added beyond 15%, the compressive strength begins to decline vigorously [24]. Thus, for a safe use of concrete, it is recommended to limit the crumb rubber content to 15% as per results obtained by other researchers [3], [9], [10], [19], [24], [25], [26], [27], [28] and [29].

The reasons for the reduction in compressive strength value for concrete containing crumb rubber were because of the comparatively low compressive strength of the rubber particles [24]. Crumb rubber is softer than natural fine aggregate and has a lower density, thus it reduces the compressive strength of concrete. This causes a fracture at the crumb rubber-cement matrix contact zone. In addition, the use of crumb rubber resulted in the formation of voids, which decreased the compressive strength of concrete [19]. Furthermore, [27] stated that in comparison to cement paste and natural aggregate, there would be a lack of appropriate bonding between rubber particles and cement paste which could be due to the non-uniform distribution of applied loads which might result in fractures.

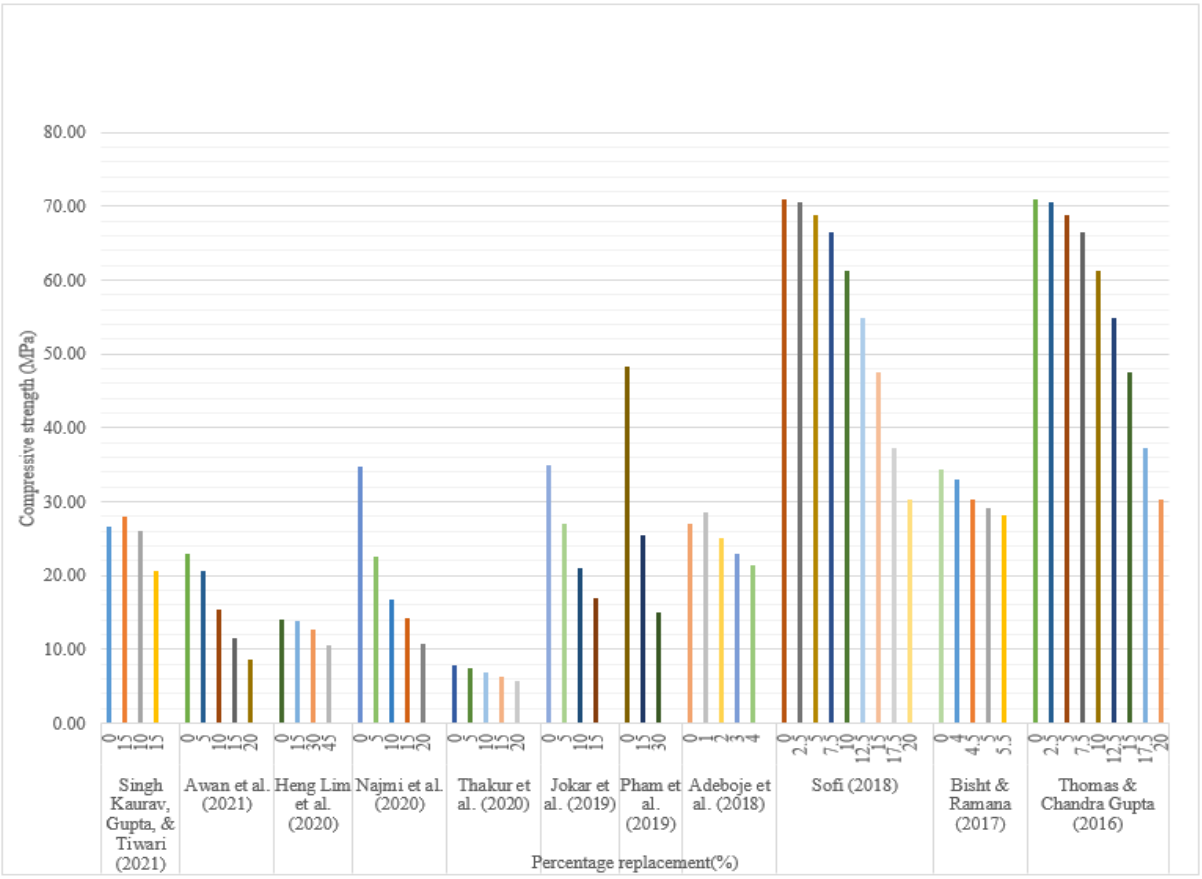

Figure 4: Compressive strength of concrete with different percentage of crumb rubber replacement

4. Conclusion

From the findings, the effect of percentage replacement of crumb rubber for fine and coarse aggregates in concrete caused the mechanical and physical performances such as workability, density and compressive strength of concrete containing crumb rubber decreased when the percentage of crumb rubber used increased. Although the results showed decreasing values for those mechanical and physical performances in the concrete containing crumb rubber, the crumb rubber can still be used as partial replacement materials when the right percentage amount are added in the concrete and the percentage of addition are not exceeding 20% whereas the recommended average of optimum percentage is 5%. It is because, there was no great difference from those ordinary mix concrete. Pre-treatment of crumb rubber also can be done in order to enhance the properties. From the results of previous papers, majority of the researchers use NaOH as the crumb rubber pre-treatment as NaOH has the highest performance compared to other chemicals. For future recommendation, it is recommended that more research for pre-treatment of crumb rubber should be done to enhance and improve the performance of concrete containing crumb rubber as a partial replacement materials.

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