Display the Results of Some Researcher about the use of Recycled Aggregate in New Concrete

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Abstract: ***The utilization of recycled aggregate (RA) as filler in the production of concrete can be detailed in the context of eco-friendliness and costs. Its utilization in construction is prevalent in certain developed European and Asian economies. Waste concrete that are by-products from the destruction of concrete structures represents a potential unending supply for the fabrication of concrete aggregates , while the reception of RA in the production of new concrete is dependent upon their respective qualities. The differences between concrete and natural aggregates are due to the presence of a considerable proportion of mortar being linked to the natural aggregates, consequently affecting the properties and the performance of concrete. This work intends to analyze published work and developmental studies on RA, analyze the latest usage of the aforementioned materials in the context of construction, and suggest approaches that could be useful for a wider range of applications. There are quite a few researchers that have worked on of the utilization of recycled waste material in concrete, and evidence of this is present in literature.***

Keywords: Recycled coarse Aggregate, Workability, Mechanical Properties, Performance of Recycled aggregate concrete.

1. Introduction

The destruction of old roads and buildings result in the accumulation of concrete, often seen as unusable waste materials that needs to be disposed of as soon as possible. Within this context, they are regarded and termed demolition wastes. The collection and destruction of used concrete results in recycled concrete aggregate (RCA). Buck [1] pointed out that RCA has seen heavy usage since the end of World War 2, due to excessive destroyed buildings and the surplus of waste from the US that were needed to rebuild Europe.

The obtainment of workable concrete via the utilization of RCA needs to adhere to the guidelines set by BCSJ [2], RILEM [3], DIN 4226.100 [4], and prEN 13242:2002 [5] . The properties that define concrete quality are its elemental bases; however, accurate mixtures and methods also govern their subsequent quality. RCA are made up of the initial aggregate and adhered mortar. Their physical properties correspond to the quality and amounts of adhered mortars, while its porosity relies upon its w/c ratio [6]. Factors such as crushing procedure and dimensions will determine how much of them we will be able to collect [7–10]. The presence of adhered mortar will also significantly influence both density and absorption capacity, and this value needs to be confirmed before it can be used to produce concrete, which will allow us to customize it. Absorption capacity is regarded as a crucial property, which helps differentiate RCA from raw aggregates, due to the fact that both constituents are significantly influential upon the subsequent properties of the concrete. There are researchers that believe that a limit of 30% RCA is adequate in maintaining the standard requirements of 5% required to maintain the absorption capacity of aggregates in the context of its utilization for structural concrete [11,12].

RCA is useful due to its ‗green‘‘ and environmentally friendly effect upon construction materials. The construction industry is closely linked to serious environmental challenges [13], such as ‗takes 50 % of raw materials from nature, consumes 40 % of total energy, and creates 50 % of total waste‘‘. The large-scale utilization of RCA might mitigate these effects via the reuse waste materials while preventing the harvest of more NA. As pointed out in the 9th Malaysia plan, the construction industry should be more open to the idea of using more and more recycled and reusable materials. However, current trends show scarce usage of these materials, due to the unending supply of natural aggregates [14]. The supply of natural aggregates will soon be depleted, forcing us to rely on other alternatives in the near future.

1.1 Definition of Recycled Aggregate Concrete

Recycled aggregate (RA) concrete is obtained from both crushing construction and demolition waste. It could also be regarded as recycled concrete aggregate (RCA) when it is mostly made up of crushed concrete, or more general recycled aggregate (RC) when it is made up of large amounts of materials other than crushed concrete [15].

The recycled aggregate are produced from processing material previously used in construction, such as ―construction and demolition waste (C&D), ferrous and non-ferrous slag, fired clay broken products, spent for foundry sand, mining waste, tired and glass" . Furthermore, the physical and technical properties of the recycled materials are strongly reliant upon the secondary material being used and the processing techniques. Recycled aggregates are incapable of substituting all types of applications compared to natural aggregates.

The construction and demolition (C&D) recycling/reuse (R&R) industry in North American can generally be characterized as underdeveloped in comparison to other construction-related industries. Concrete represents more than 50% of construction waste, as shown in Fig (1), and almost 73% this material can be reused in low value applications, such as fill or road sub-grade. Metals , most commonly steel, are commonly recycled despite the fact that they represent only about 4% of construction waste and less than 3% of building related waste materials, such as wood, gypsum, paper, etc ., which was pointed out to be diverted to proper (R&R) [16].

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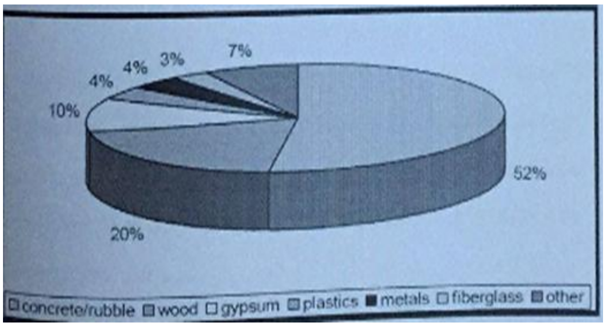

Figure 1: Institutional, Commercial &Industrial Construction C&D Waste Stream [16]

Although RCA has been used as a construction material internationally for decades, its use in the Republic of South Africa (RSA) is still limited. Landfill space and resources of NA in RSA have until now been readily available at relatively low cost, making it less of an important consideration [5]. From the information gathered from the local landfill sites, RCA in RSA is mostly used in road construction and some foundation work, despite the lack of guidelines on how to do so. It was reported that close to 2-3 billion tons of construction and demolition waste (C&DW) [6] is produced globally at an annual rate, while RSA produces 5-8 million ton [7]. These quantities are increasing with continued growth in both population and economies.

2. Properties of Recycled Aggregate

Recycled aggregate are derived from destroyed structures, and are composed of mostly broken members or components such as slab, beam, brick wall and others. Due to the fact that the quality of these broken materials, such as water cement ratio, kind of admixtures, aggregate origins and gradations, as well as the differentiation of its properties during the performance time, are unclear, its corresponding historical data physical characteristics, mechanical characteristics, and environmental characteristics are imperative in this case [13].

The main properties of the aggregate include specific gravity, the density, porosity, and water absorption, the shape and gradation, and resistance to crushing and abrasion.

2.1 Specific Gravity

In this context, the specific gravity of an aggregate is classified as the ratio of the mass of the solid within a given volume of sample to the mass an equal volume of water at the same temperature. Specific gravity is divided into multiple conditions, such as bulk, apparent, and saturated specific gravity. The prevalent specific gravity is calculated after it has been dried in an oven for 24 hours. The saturated specific gravity is incumbent upon saturated conditions vis-à-vis the aggregate. Its specific gravity will result in useful information, and increased specific gravities is related to harder and stronger aggregates [17].

2.2 Density, Porosity, and Water Absorption:

Residual adhered mortar on aggregate represents a major factor that influences the density, porosity, and water absorption of RCA. The density of RCA falls short of NA, as the adhered mortar is not as dense as the corresponding underlying rock. Limbachiya et al. [18] Proved that the relative density of RCA (in the saturated surface dry state) is approximately 7–9 % lower than that of NA.

Porosity and water absorption are intrinsically correlated to aggregates; both properties can also be linked to residual mortar. NA is known to exhibit poor water absorption from its lower porosity; however, the adhered mortar on RCA is more porous, thus increasing the water retention capabilities of the aggregates as opposed to NA.

Water absorption is defined as the capability, with respect to time, of the aggregates to absorb and retain water. This rate can be calculated using the increase of mass from an oven-dried sample when it has been immersed in water for 24 hours prior to the experiments. The corresponding ratio of increased mass, in the form of a percentage, is defined as the absorption [19]. The absorption rates affect both bond formations and specific gravity. It should also be pointed out that high water absorption rates by the concrete reduce its subsequent functionality.

Increased absorption of recycled aggregate will increase the need for water by about 5% for acceptable levels of functionality [20–25]. Using RA in dry settings weakens its functionality, mostly owing to it‘s enhance absorption. In order to avoid this, RA should be saturated before it is used in any capacity [26].

2.3 Shape and Texture of Aggregates

The corresponding shapes of an aggregate piece will influence its usability in concrete. Exteberria et al. [27] pointed out that production methods and crusher influence will influence the shape of RCA. NA is known to be distinctly angular. Sagoe-Crentsil et al. [28]at first pointed out that the plant-based RCA as being texturally grainy , while RCA is more rounded and spherical, which results in superior functionality. The jagged surface of the original aggregate can be made uniform via the utilization of the residual mortar on RCA, which improves mortar circulation vis-à-vis the aggregates. Katrina & Thomas[29] posited that RCA and NA possess similar gradation; RCA particles are round and possess more fines when broken in L.A. abrasion and crushing tests. The use of RCA in concrete as opposed to NA will result in lower compressive strength; however, it does results in yields equivalent and superior splitting tensile strength.

Ismail Abdul Rahman et al.[30]analysed the influence RA sizes upon compressive strength for multiple maximum sizes of RA, from (10 mm, 14 mm, 20 mm), that are used in the new concrete. The results pretty much proved that the 10 mm and 14 mm samples are superior to the 20 mm sample. It was also confirmed that the 10 mm and 14 mm of (RA) in RAC performs quite similarly to the 10 mm and 14 mm natural aggregate (NA) within natural aggregate concrete (NAC).

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3. Properties of Fresh Recycled Aggregate Concrete RCA

3.1 Workability

Workability means the simplicity in relocating concrete and how much it opposes segregations. Workability remains a verified property of fresh concrete, determined via slump test , and confirmed via its consistency [19]. Forondistou-Yannas [22],Malhotra[23], and Mukia [20] pointed out that RA concrete (based on coarse RA and sand) require ~5% additional water to obtain slumps that mirrors natural aggregates.

E.R.L. [31] observed that concrete made with recycled coarse and fine aggregate requires approximately 14% more free water compared to that for natural concrete produced with a corresponding natural aggregate to realize similar slumps. The high absorption rates of the recycled aggregate render it crucial that more water be added to realize similar levels of workability and slump compared to concrete made up of natural aggregates.

Rasheeduzafar and Khan [32] confirmed that the functionality of RA concrete (based on recycled coarse and beach sand) to be somewhat improved compared with the workability of corresponding natural concretes made with crushed limestone coarse aggregate and beach sand. However, the substitution of fine, poorly graded beach sand by well graded recycled fine aggregate consequently reduced workability.

Ravindrarajah and Tam [25] reported that in order to maintain the functionality of RA concrete, the water content in the concrete mix has to be ~10% higher than what is needed to make natural concrete. This result differs from the one obtained by Saleem[33] and exceeds that reported by other researchers (22,23,20)

Sabaa and Ravindarajah[34]believe that functionality is a vital component of concrete, due to the fact that it will influence placement rates and its degree of compaction.

Muhammed[35] showed that the lower workability of recycled concrete can be explained by the fact that the recycled aggregate consist of crushed and angular particles with rough surfaces, resulting in an increased amount of inter-particle interaction and locking. Furthermore, the attrition of some of old mortar from the recycled aggregate with the attendant crushes some of the aggregate particle, reducing the mean size of recycled aggregate and leading to a harsh and less workable mixes, where the reduction of workability for these mixes were 9%. Saleem [33] pretty much concluded that fresh coarse recycled aggregate concrete results in functionality levels that are on par or better than normal concrete , while also improve water retention levels of the resulting concrete.

4. Properties of Hardened Recycled Aggregate Concrete RCA:

4.1 Compressive Strength

The compressive strength of RCA concrete is affected by water/cement (w/c) ratio, the percentage of coarse aggregate replaced with RCA, and the amount of adhered mortar on the RCA. Its a compression machine is capable of determining the quantitative value of compressive strength.

There were several researchers who analysed the compressive strength of RAC and compare them to NAC vis-à-vis texture, shape of RA, and the percentage of fine particles. It was determined that these factors are detrimental towards the compressive strength of RAC, especially when taken in the context of NA [36]. It was also confirmed that the angular configuration of the RA and its jagged surface increased the compressive strength of the RA concrete [37] mostly due to the improved bonds within the internal structure of the concrete. This is especially poignant and of interest if the RA is oven-dried [38]

Yang et al. [39] believed that the inverse relationship between compressive strength and water absorption in the context of RCA to be due to the fact that low water absorption (relatively low RCA fraction) concrete possess similar compressive strengths, while higher RCA fractions and absorption compressive strengths were 60–80 % to that of the conventional control concrete. However, compressive strengths are enhanced with aging. Due to the fact that aggregates have high water retention, the retained water can be channelled in new mortar over time in its quest to feed cements for longer periods of times, which helps enhance its corresponding strengths.

Frondistou-Yannas [22] pointed out that the compressive strength of RA concrete is (4-14)% lower than that of a similar natural concrete , while Nixen [40] pretty much concluded that the compressive strength of the former is 20% lower from the latter.

Ravindrarajah and Tam [25] stated that the compressive strength of recycled aggregate concrete is between 8% and 24% weaker than that natural concrete. Also, they confirmed that the strength development with age to be similar to natural concrete and recycled aggregate concrete made with coarse recycled aggregate and natural sand . Simultaneously, [41] showed that BCSJ [10], based on their experimental results, the compressive strength of RA concrete is (14-32)% lower than that of the natural concrete.

Ravindrarajah [42] confirmed that after 28 days, conventional concrete is 8.9% stronger than that of recycled coarse aggregate concrete . These results agree with the ones reported by [40].

Muhammed [35] reported that the higher water /cement (w/c) ratios (i.e., w/c ratios of 0.63, 0.60 and 0.55) and the strength of natural aggregate concretes exceeds those of RA concretes, which increases the strength of the paste and mortar–aggregate bonds . Moreover, the coarse aggregate strength controls, and helps alleviate, concrete failure. For

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lower water /cement ratios (i.e., w/c ratios of 0.5, 0.47 and 0.40) , the differences of compressive strengths will be less pronounced. At the decrease of the water/cement ratio to 0.32, the strength of recycled aggregate concrete exceeds that of natural concrete.

Exteberria et al. [43] posited that concrete made with 100% of coarse recycled aggregate needs increased amounts of cement to increase its compressive strength, which makes it simply not economically viable. Therefore, it is suggested that these recycled aggregates be used in concrete with low-medium compression strengths (20-45 MPa).

4.2 Tensile Strength

Concrete‘s tensile strength is important when designing structures and pavements.

The splitting tensile strength is not as affected by the content of the RCA as opposed to compressive strengths. e.g., Kang et al.[44] proved that the splitting tensile strength of RCA concrete is on par with its conventional counterpart. In certain cases, the RCA concrete performed better than the NA concrete in the context of tension. According to Exteberria et al. [43] this is mostly due to the increased absorption of the mortar that is linked to the recycled aggregate and effective ITZ , which implies excellent bonding between the aggregate and mortar matrix. Despite the fact that the residual mortar might create weakening spots that helps initiate compressive failures, small and controlled amounts help enhance tensile capacity via the creation of a hassle-less transition between mortar and aggregate.

Ravindarajah and Tam [25] pointed out that the indirect splitting tensile strength of recycled aggregate concrete made with coarse aggregate and natural sand are not significantly different compared to natural concrete. Their results agree with [10], [20] and [45]. However, the saturation of the recycled aggregates will result in reduced tensile strength of the recycled aggregate concrete. The lack of any negative affect on the recycled concrete tensile strength implies the presence of excellent bonds between the aggregate and the mortar matrix. In this case, the failure mechanism of the recycled concrete specimens is expected to mirror that of the reference concrete.

However, according to Fujii[46], the indirect tensile strength of recycled concrete made with coarse recycled aggregate and natural sand are 8% and 13% lower than its natural counterpart. Similar results were reported by [47] while E.R.L. commissions [31] and [48] reported, at best, a decrease of 25% to the indirect tensile strength for recycled aggregate concrete compared to its natural counterpart. In the event that coarse and fine particle aggregates are utilized, the tensile strength of the recycled aggregate concrete was 37% lower compared to its natural counterpart, while Al-a‘araji[49], who experimented on recycled coarse aggregate concrete, reported a splitting tensile strength that is lower than that of natural concrete by (14-35)%, with similar results being reported for the recycled fine aggregate concrete.

5. Conclusion & Recommendations

This work discussed the results that help define recycled aggregate, and define its corresponding main properties. It is quite well known that residual adhered mortar on RCA influences aggregates, rendering the former more porous, absorb more water, and decrease its density vis-à-vis NA. Despite the inherent similarity between RCA and NA, the former is slightly different in a way that they are rounder and result in more broken fines when subjected to L.A. abrasion and crushing tests. Also, RCA-based concrete is weaker than its NA counterpart, but share similar splitting tensile strength . Therefore, the utilization of RCA in new concrete needs increased amounts of cement in order to realize increased compressive strength, which means increased cost and decreased economic feasibility. Therefore, RA is to be used when weaker concrete is desired (20-45MPa).

In future work, additional research should be carried out to study the influence of both fine and coarse recycled aggregate in new concrete . A cost analysis of the utilization of recycled aggregate to produce the new concrete compared with natural aggregate, taking into consideration cost of (crushing, sieving and transportation), should also be conducted.

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