



Sustainable self compacting concrete from C&D waste by improving the microstructures of concrete ITZ

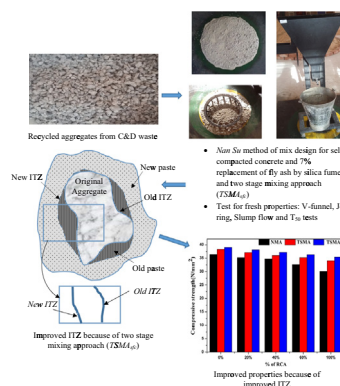
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HIGHLIGHTS

- C&D wastes were used for producing self compacted recycled aggregate concrete (SCRAC).
- Two stage mixing approach (TSM_{sfc}) was adopted by using silica-fume and fly-ash.
- Fresh properties of SCRAC were checked by slump flow, V-funnel and J-ring tests.
- Desired compressive strength properties of SCRAC with 100% replacement of RCA were found with TSM_{sfc} .
- Microstructure and WDS analysis were performed for justifying improved compressive strength.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper presents the microstructural changes and the improvement in mechanical properties of self compacting recycled aggregate concrete (SCRAC) which is prepared with the use of construction and demolition (C&D) waste. Experimental investigation reveals that with 7% replacement of fly ash by silica fume yields required fresh properties and improved mechanical properties. Proportional amount of cement is added with 7% silica fume to prepare a silica fume-cement slurry for making a proper mix with RCA in premix stage. Two stage mixing approach (silica fume, fly ash and cement) (TSM_{sfc}) is followed, where the silica fume-cement slurry fills up the weak areas in the recycled concrete aggregate (RCA) and improved interfacial transition zones (ITZs) are developed resulting higher strength in concrete. Electron probe micro-analyzer (EPMA) is used to investigate the microstructure of SCRAC by indentifying different constituents of concrete (C-S-H, CH, unhydrated cement and epoxy). This analysis confirms the improvement of ITZ because of two stage mixing approaches. Wavelength dispersive X-ray spectroscopy (WDS) is used for quantitative and chemical analysis of ITZ. Improvement in properties of SCRAC obtaining with 100% RCA and 7% silica fume using TSM_{sfc} is confirmed by EPMA examination and WDS.

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1. Introduction

The ever increasing population and urbanization has led to construction of high rise structures and demolishing existing old low

rise ones. This has become not only the cause of natural resources depletion at an alarming rate but also gradually becoming a challenge for sustainability. Concrete industry consumes a majority of natural resources especially in developing countries. In recent years, the concrete industry has started using C&D in structural concrete application owing to the availability of waste from demolition of old structures and the reduction in the cost of acquiring

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aggregates. This can allow the concrete structure to reduce its carbon footprint and thus help it to continue to grow without harming the environment. Presently, there is an extensive use of RCA in all over the world as it gives competitive properties as of virgin concrete aggregate (VCA). Extensive research work [1–6] in open literature suggested that the RCA can be used for constructing new structures as experimental results reflect that with proper mixing approaches and addition of admixtures, the RCA can attain the desired strength. Few research [7–10] results indicated in the literature that the RCA can be used as self compacted concrete (SCC). Filling ability, passing ability and segregation resistance are three prime properties of SCC in its fresh state. The basic constituents of SCC are same as that of conventional concrete. However, the difference lies in mix proportion. SCC contains more powder content, less coarse aggregate, high range water reducing super plasticizer (SP). There is also frequent use of viscosity modifying agent (VMA) for making the concrete self compacting. The powdered material like fly ash, silica fume, lime stone powder and ground granulated blast furnace slag along with cement give good quality SCC having enhanced mechanical and durability properties.

TSMA proposed by investigators gives strength to the interfacial transition zones of RCA. Different interfaces of RCA are shown in Fig. 1. Otsuki et al. [11] followed double mixing approach for improving the strength of RAC. They used four different water binder ratios and observed that after 28 days of curing the compressive strength and tensile strength are improved by 4.18% and 5.25%, respectively by 100% substitution of RCA. TSMA was first suggested by Tam et al. [12]. Authors followed TSMA for improving the properties of RAC, where the mixing process is divided into two stages and the required water is splitted accordingly. At first, fine and coarse aggregates are mixed for 60 s before half of the water required is added and mixed for another 60 s. Then total cement is added and mixed for another 30 s before the remaining half of the water is added and mixed for 120 s. The stage of mixing is shown in Fig. 2(a). Here, the compressive strength was enhanced by 21.19% for 20% of replacement of RCA in 28 days curing days. During the first stage of mixing, a thin layer of cement slurry was formed on the surface of RCA which fills up the old cracks and voids. Further, remaining water is added to complete the mixing process in second stage. Tam et al. [13] proposed other TSMA i.e. TSMA_{p1} and TSMA_{p2}. The flow diagram for TSMA_{p1} and TSMA_{p2} are shown in Fig. 2(b) and (c). In TSMA_{p1}, cement and water were splitted with the percentage of RCA and added in the first stage of

mix. In TSMA_{p2}, only the proportioning of cement content was done with the percentage of RCA. For 25% replacement of RCA, there is an improvement in compressive strength by 11.47% in case of TSMA_{p1} than the normal mixing approach (NMA). However, for TSMA_{p2} the improvement is 19.75% for 20% replacement of RCA. The authors concluded that for both the methods, there was not much difference observed for modulus of elasticity. Tam and Tam [14] also developed other types of methods and compared the result with NMA. In TSMA_s, 2% silica fume was mixed with water and then added into RCA in the premix stage. However, in TSMA_{sc}, 2% silica fume, water and proportional amount of cement was added into RCA in the premix stage. The flow diagram for TSMA_s and TSMA_{sc} are shown in Fig. 2(d) and (e). After 28 days of curing of RAC with TSMA_s, the compressive strength, flexural strength, tensile strength, and static modulus of elasticity were enhanced by 19.50% (25% RCA substitution), 20.04% (20% RCA substitution), 16.16% (10% RCA substitution) and 16.28% (30% RCA substitution), respectively. However, for RAC with TSMA_{sc}, the compressive strength, flexural strength tensile strength and static modulus of elasticity were enhanced by 19.73% (25% RCA substitution), 4.44% (25% RCA substitution), 24.22% (25% RCA substitution) and 11.92% (30% RCA substitution), respectively. Elhakam et al. [15] followed different mixing methods and compared the results with NMA. It was observed that after 28 days of curing, the compressive strength was improved by 20.5% for 75% RCA substitution when cement content was 250 kg/m³ (w/c = 0.60 and silica fume = 10%). However, the compressive strength was improved by 2.3% with 75% RCA substitution, when cement content was 400 kg/m³ (w/c = 0.45 and silica fume = 0%). The tensile strength was improved by 54.6% and 13.8% for 75% RCA substitution with 250 kg/m³ cement content and 75% RCA substitution with 400 kg/m³ cement content, respectively. The bond strength was improved by 13.1% and 42.9% for cement content of 250 kg/m³ with 75% of RCA substitution and cement content of 400 kg/m³ with 75% RCA substitution. Mortar mixing approach (MMA) and sand enveloped mixing approach (SEMA) proposed by Liang et al. [16] gave better mechanical properties as compared to NMA.

Kou and Poon [17] used coarse and fine RCA to study the fresh and hardened properties of SCC. It was observed that there is a marginal variation between properties of SCC prepared from river sand and properties of SCC prepared from different level of crushed fine recycled aggregate. Grdic et al. [18] conducted different experiments in which VCA was substituted with different percentages (0%, 50% and 100%) of RCA. Marginal variations in the properties of SCC was reported in all the three cases. Safiuddin et al. [19] observed that the fresh properties of SCC were not affected by replacing 50% VCA with RCA. Reddy et al. [20] studied different properties of SCC. Authors observed that the properties were not significantly affected by 25% substitution of RCA. Revathi et al. [21] suggested that SCC could be successfully developed by replacing VCA by RCA. Panda and Bal [22] used RCA in SCC for M25 grade of concrete. Here, VCA were replaced by RCA in various percentages (10, 20, 30 and 40). Result showed that up to 30% RCA in SCC gave desirable characteristics strength. With different percentage of RCA, different properties of SCRAC are investigated by Pereira et al. [23] and authors suggested for successful use of RCA. Khoshkenari et al. [24] studied the effect of 0–2 mm size of fine aggregates on mechanical properties of RCA for producing both high strength concrete and normal strength concrete. It was observed that the compressive strength and split tensile strength of concrete can be improved by adding silica fume and maintaining the normal size of fine aggregate to 0–2 mm. Tuyan et al. [25] investigated the effect of coarse RCA on freeze-thaw resistance, mechanical properties and transport properties of self compacted concrete. The investigators found that the compressive strength, water absorption and chloride-ion penetration properties were

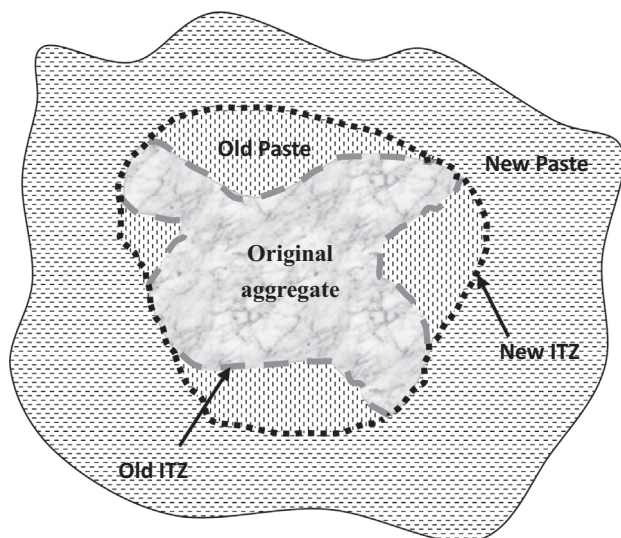


Fig. 1. Interfaces of recycled concrete aggregates [1].

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