ISSN 2063-5346

PARTIAL REPLACEMENT OF CONCRETE BY STICKY RICE AND JAGGERY

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Article History: Received: 01.06.2023 **Revised:** 22.06.2023 **Accepted:** 21.07.2023

Abstract

The present paper summarizes partial replacement of cement by sticky rice and jaggery. These eco-friendly construction materials are blended with cement and limestone to enhance the compressive strength and workability. Also it diminishes the water-cement ratio. Concrete is an artificially manufactured construction material used on a large scale all over the world. Concrete is a composite material consisting of cement, fine aggregate and coarse aggregates. The ingredients of cement are expensive and create a bad impact on the environment due to the hazardous emission of carbon dioxide in the troposphere. The concrete industry has an overabundance of adverse impressions on the environment. To enhance the quality of construction work and curtail the cost of construction and carbon emission, sticky rice, jaggery plays a crucial role. Addition of jaggery in the concrete improves the compressive strength, split tensile strength and flexural strength. Jaggery has excellent binding properties as well as it can improve workability when added to concrete hence used as an admixture in cement concrete. This review paper also insights that scanning electron microscopy (SEM) of sticky rice pulp revealed that sticky rice is having strong binding property and also improves adhesion property.

Key words: Concrete, Compressive strength, Jaggery, Sticky rice.

Introduction

Since past decade application of cement concrete in the construction field is having incredible treads [1]. In construction materials concrete is an important component of building work [2]. The engineering work cannot be completed without concrete [3]. Concrete is the heart of civil engineers as it plays a crucial role in construction [4]. Concrete is an amalgamated material made up of coarse aggregate, fine aggregate, and cement [5]. The concrete possesses high compressive strength which is very essential for the construction activity [6]. Salient features of the construction, unique shape and strength of the construction work depends upon concrete [7]. Concrete can enhance life of the structure and make the building more durable [8]. The concrete has enormous application in construction of

bridge, dock and harbor, roads, dam, tunnel, conduit, sewage work, marine construction work, monuments, etc. [9].
In 2012, the concrete consumption all over India was around 450 million cubic meters which is upgraded to 800 million cubic meters in 2020 [10]. Universally concrete is significant construction material used due to its durability and versatility [11,12]. A tremendous amount of carbon dioxides (CO_2) is released during the production of cement as it contains limestone [13]. The calcination process of limestone produces calcium oxide and carbon dioxide [14]. The new trend of cement manufacturing released around 1.1 tons of CO_2 per ton cement production [15]. Because CO2 emission directly affects the rise in temperature and causes global warming it is an urgent need to search the alternative sources of eco-friendly construction material[16]. For infrastructure development cement concrete is prominently utilized. Universally each year concrete industries produce nearly 12 billion tonnes of concrete and utilize approximately 1.6 billion tons of Portland cement [17]. Several attempts remain in evolution to minimize the routine use of Portland cement in concrete construction by substituting it with materials such as rice husk ash., fly ash, blast furnace slag, silica fume [18]. These eco-friendly materials has a significant influence and can partially replace cement [19]. Numerous countries of the world are implementing use of fly ash, silica fume, rice husk ash to enhance the compressive strength and minimize greenhouse emissions [20]. The waste produced by the sugar industry can be reasonably added in the preparation of concrete as an admixture [21]. The Jaggery is manufactured from sugar sticky which are having good binding properties [22]. Experimentally it is proved that the strength and workability of concrete is improved by the addition of an adequate quantity of jaggery [23]. This paper insights about the partial replacement of cement by organic compounds jaggery and sticky rice.

Jaggery

Jaggery is manufactured from concentrated non-centrifugal sugarcane juice and toddy palm tree [24]. It consists of 50 % sucrose, 20 % inverted sugar, 20 % moisture, and around 10 % bagasse fibers and other ingredients [25]. As jaggery having excellent binding properties as well as more workability when added to concrete, so it is used as an admixture in cement concrete [26]. As jaggery having the greatest binding properties mixture of jaggery and limestone is used to fill the cracks of the wall, slab, in the water tank, etc [27]. Jaggery was used as a waterproofing material from16th century as it is having adhesive properties [28]. In ancient times, jaggery was used for the construction of the fort, palace of maharaja and kings [29]. The compressive strength of concrete is enhanced by the application of jaggery as an admixture [30]. Jaggery was added in the concrete as an admixture in various proportions such as 0.1, 0.2, 0.3, and 0.4 % by weight of concrete with grade M-30 [31]. Suryawanshi et al., (2014) examined the influence of sugar powder and jaggery on the cement and it is found that sugar powder having a significant impact on the strength of the cement [32]. He also revealed that compressive strength has been improved after the 28th day. The final setting time of cement was prolonged by the addition of 0.1 % jaggery to the cement. The compressive strength of cement and concrete is prolonged up to 15 - 20% [33]. To enhance the characteristics of concrete the admixtures jaggery (0.2 %), 0.1 % sugar powder, and 0.05 % fly ash were incorporated into concrete [34]. The consequence explores that the around 15 % strength has been improved. Table 1 illustrate that by the addition of jaggery in different proportion enhance the compressive, split and flexural strength of concrete.

Table 1. Properties of concrete enhanced by the addition of jaggery in the cement

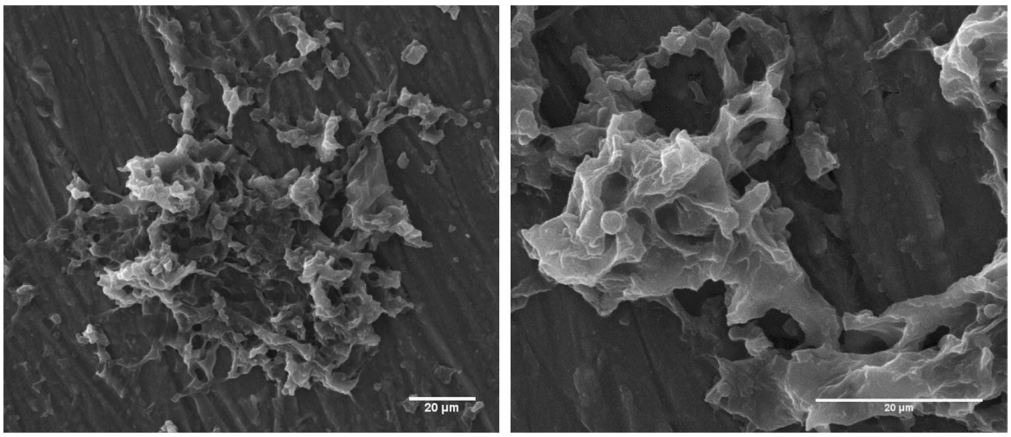
Sr. no	% of jaggery added in the concrete	Compressive strength after 28 days N/mm^2	Split Tensile	Flexural Test
1	0	34	4.47	12.88
2	2.5	36	4.51	13.23
3	5	37	4.72	13.56
4	10	40	4.82	13.65
5	12	38	4.60	13.2

Sticky rice

Sticky rice commonly recognized as waxy or glutinous rice is a type of rice primarily grown up in southeast and east Asia, characterized by its adhesive quality, impervious appearance, and high amylose, amylopectin content [35]. In China sticky rice is an essential food and apart from this extensively useful in numerous other fields including architectural, structural construction work [36]. Many researchers reported the application of lime-sticky rice as a mortar to build canals, dams, cowsheds, tombs [37]. The famous Chinese works reported sticky rice oatmeal was generally added in lime-clay-sand mortars to build Fujian Tulou and forts [37]. The admixture lime-tile dust, sticky rice pulp can improve the water retention capacity also prevents water loss. The addition of sticky rice in air lime mortar having a significant mechanism effect to gain the compressive strength [38]. The application of sticky rice in construction activity can regulate the growth of $CaCO_3$ crystals [39]. Also it is revealed that the consistency and mechanical bonding strength of air lime mortars were upgraded by the addition of sticky rice. The initial setting time, hardening has been boosted, concurrently reduces the water resistance and mortar density by the addition of 5% sticky rice flummery in air lime mortars [40]. Day by day concept of sustainable building or green building became more popular as eco-friendly construction material having better stability, durability, workability, and binding properties. Sticky rice was used in an ancient construction of China. It is found that the compressive strength of concrete is increased by adding 1% sticky rice as an admixture [41]. It is also found that architectures of Chinese implemented sticky rice, lime mortar, jaggery, etc in construction to gain the durability of the structure [42]. Investigators revealed that 10 % lime, 1% sticky rice, and 30 % slag enhance the compressive strength [43]. In ancient times, sticky rice was used as binding mortar in the construction of buildings. In Northern and Southern Reigns, sticky rice was implemented in the construction of brick vaults [44]. In central China sticky rice was used on a large scale to enhance the binding property of concrete [45]. Archaeologists explored that sticky stern ingredient are present in the cementation material of the tomb [46]. Sticky rice application as a binding mortar became a popular technology in third century. The sticky rice application enhances the compressive strength hence largely used in the construction of water conservancy projects, tombs, and urban construction [47]. Wei et al., (2012) discovered that the sticky rice slurry plays the crucial role of templating techniques as well as biomineralization in the hydration reaction of the cementitious material [48]. He also revealed that sticky rice, lime mortar, dihydrate gypsum, aluminum sulphate, and paper fiber have excellent water resistance capacity.

Templating techniques guide the shape, size, and structure of the crystalline particles [49]. In ancient China, there is a practice of combining onstruction

materials like lime, composted earth, pebble, and sticky rice [50]. In concrete preparation, application of sticky rice paste as a substitute for water is a new concept [51]. By experimentation, it is proved that the addition of sticky rice pulp in mortar act as a retarder and diminishes the water-cement ratio to a firm-level [52]. Hence in China, there is an exercise to implement various proportions of sticky rice paste in concrete. The sticky rice also plays a crucial role as a water-soluble polysaccharide (amylopectin) which develops covalent bond between ingredients used for the preparation of concrete [53]. By the addition of sticky rice pulp with coarse and fine aggregate, it is found that initially compressive strength of concrete is decreased and enhanced afterward [54]. Shrinkage is one of the important properties of the concrete which is highly related to crack formation in concrete [55]. As lime mortar has more shrinkage value which directly has an impact on water loss, in masonry work lime-mortar are prohibited [56]. It is found that by the addition of 3 % sticky rice in the lime mortar shrinkage of concrete is restrained [57]. This occurs due to the water-holding characteristics of sticky rice and glycosidic bonds developed between lime-mortar, cement, and sticky rice [58]. But as per the practical concern, it is found that in presence of fine, coarse aggregate the shrinkage property of sticky rice-lime mortar can be reduced again [59]. The well-blended sticky rice and lime-stone are having an admirable water resistance capacity [60]. The compressive strength of concrete was enhanced in the presence of admixtures like lime-stone, sticky rice, paper fibers, dihydrate gypsum [61]. The compressive strength of the concrete varies with the admixture content. The hardness of the concrete has been improved by the addition of admixture lime-stone, sticky rice, paper fiber, and dihydrate gypsum [62]. The application of sugarcane bagasse fiery debris in cement at some percentage may enhance the strength of concrete [63]. By experimentation and inspection, it is found that the addition of 15 % bagasse powder and bagasse slag can enhance the flexural strength of the concrete [64]. It is essential to apply supplementary cementitious construction material in civil work as cement is more expensive [65]. Fly ash and blast furnace slag application can minimize the consumption of Portland cement [66]. The municipalities of many cities are facing the tremendous problem of dumping non-biodegradable waste material [67]. Hence, it is essential to apply non-biodegradable waste in construction work. The sand dust and (GGBS) Ground Granulated Blast Furnace Slag are the alternative supplementary materials for fine aggregates and cement respectively [68]. The partial application of GGBS and sand dust can enhance the compressive and flexure strength of the concrete [69]. To achieve sustainable development and eco-friendly concrete artificial sand, coconut shell, and ground granulated blast furnace slag were implemented in the construction [70]. By the application of coconut shell, the mechanical properties such as flexural strength of concrete, stress-strain curve, compressive strength, and modulus of elastic have been enhanced [71]. It is found that the addition of coconut shells in the concrete can enhance the durability, water absorption capacity, and permeability properties of the concrete [72]. As the coconut shell is light in weight and porous it may enhance the temperature resistance. Compressive strength of concrete has been improved if curing is carried out in presence of conceal cured coconut shell [73]. The covalent bond strength of the coconut shell concrete is found to be more than the bond strength quantified by IS 456:2000 [74]. Author Otero et al., (2019) [75] analyzed and examined paste of dried sticky rice by scanning electron microscopy (SEM) instantly afterward evaporation of water (Fig. 1).



(a) **(b)**

Figure 1. Dried sticky rice SEM analysis (a 2000×; b 5000×) [75].

Fig 1 indicates that numerous granular nodes strongly bind and gathered composite jots bounded by protein which having impact on the carbonation rate of lump lime. Author also revealed that FT-IR analysis of sticky rice contain the starch, C-O group, - OH group, amylopectin, and multifaceted low viscosity in the range of 0.002 and 0.001 mPa. As sticky rice having low viscosity which designates the excellent infiltration into porous substrate. The consolidation rate of nano lime has been enhanced in presence of sticky rice [76]. Weathering phenomenon has wide impact on consolidation property of sticky rice and it is found that consolidation rate is degraded due to weathering process. This may be due to reduction in hydrophobicity, surface cohesion, and infiltration. The adhesion property might be improved by the addition of sticky rice in the lime, as calcite crystals (carbonate mineral) developed on the sticky rice film and developed calcite-calcite covalent bond which enhance the physical and chemical matrix of structure [75-77]. Fig 2 indicates the hydration products formed in concrete plays crucial role, in normal concrete hydration products are in disorder manner. By adding sticky rice pulp in concrete behaviour of hydration products are in a regular manner.

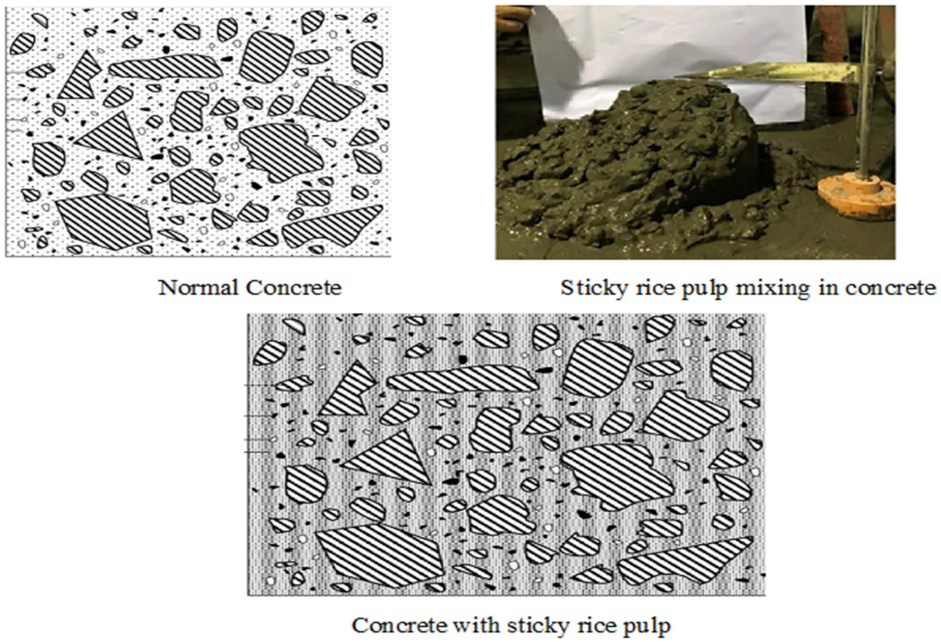


Figure 2. Hydration products in normal concrete and concrete with sticky rice pulp [75]

Fig 3a shows the significant cement hydration process occurs in normal concrete. Cement slurry progressively lose the water molecules and hydration process take place. Fig 3b., illustrated the hydrated calcium silicate effect on plasticity property of concrete. Fig 3c. elaborate the amylopectin and starch effect on nucleation of water. As sticky rice consists of starch and amylopectin there is a certain bonding consequence on fine and coarse aggregate and hence the strength of concrete has been enhanced.

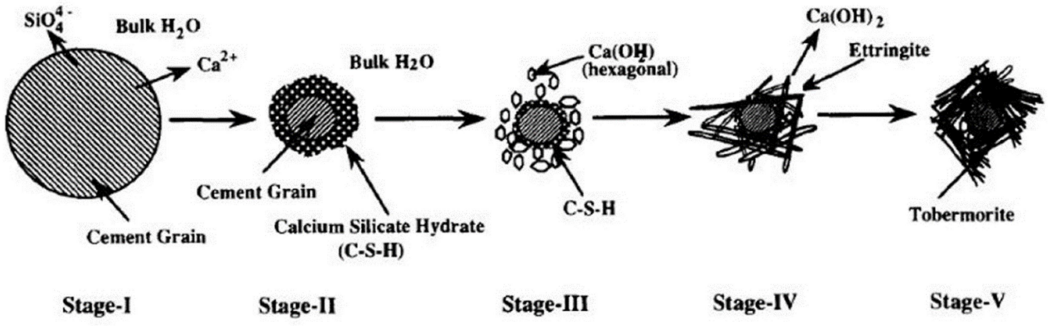


Figure 3a. Cement hydration process in normal concrete [75]

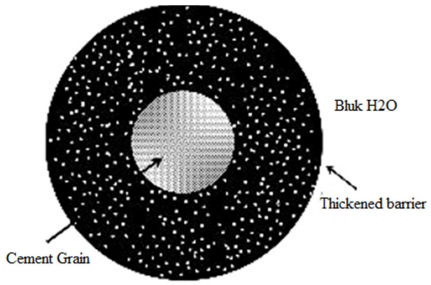


Figure 3b. Hydrated calcium silicate effect on plasticity property of concrete [75]

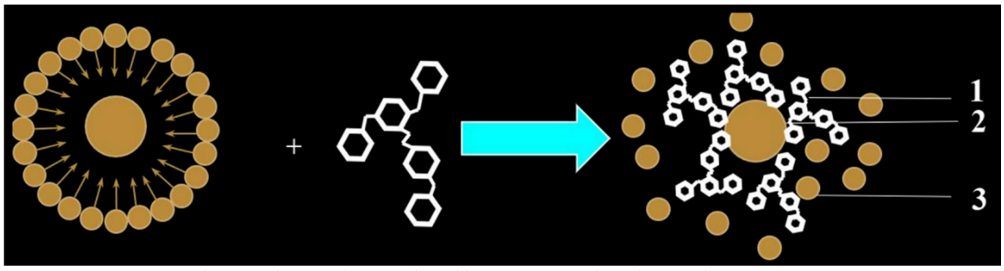


Figure 3c. Amylopectin and starch effect on nucleation of water[75]

Conclusions

The present review paper describes that jaggery is having excellent properties of binding and good workability as compared to cement. Even in 21st century jaggery is extensively used to fill the cracks of the slab, in water resource work. Properties of concrete such as compressive strength, flexure strength and split tensile strength were enhanced by the addition of jaggery in the cement concrete. The sticky rice and sticky rice pulp enhance the compressive strength of concrete and are hence implemented in China on a large scale. Ancient Architecture of Chinese, forts, vaults revealed that sticky rice was implemented for construction work. The addition of sticky rice in lime mortars shows that water retention value was increased which minimize the water loss. It is discovered that by the addition of sticky rice properties of concrete have been improved. The sticky rice accumulation with the mortars might decline fresh and hard-bitten mortar bulk density during curing, hence improving water absorption quality. By the addition of 3 % sticky rice in the lime mortar shrinkage of concrete is restrained. Sticky rice contains the starch, C-O group, -OH group, amylopectin, and multifaceted low viscosity hence easily penetrated into porous substrate.

Acknowledgements

All authors mentioned in the authors section have equally contributed for the above work.

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