Utilization of Rice Straw Ash and Micro-Silica as Sustainable Highway Pavement Applications: A Review

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ABSTRACT: *The response for concrete remains to mature with intensification in population and increased development. This demand, in turn, upsurges the necessity to decrease the ecological influences of concrete while remaining to provide the identical or improved performance. Cumulative population also generates rising demand for food and energy wealth. Rice biomass, for example husk and straw, can be combusted and used as a renewable energy source and, under precise burning conditions, the subsequent ash can be used by means of a supplemental cementitious solid or valuable filler in the manufacturing of concrete, which can theoretically lead to condensed environmental impacts in concrete. This review study reviews both rice straw ash as well as micro-silica and theirinfluence on concrete Characteristics, to report current understanding of these ashes, as a substitute mineral admixture. The review of the writings shows that under appropriate burning conditions as well as through use of pre- and post-combustion treatments, extremely pozzolanic (reactive) ash can be shaped from rice hulls and straws. Other than this, the core purpose of the research is to study the effects of binary and ternary mixtures of Micro-Silica on the durability of a high-performance and self-compacting concrete. It was observed that a broader particle size spreading creates a low porosity, progresses packing density, drops water demand in comparison with mixtures with the correspondingquantity of total addition using only Nano-Silica, and deliversgreater compressive strength and an enriched durable performance. The porous network in mixtures through Nano-Silica involved a lesser pore diameter with respect to control, proportional to the quantity of Nano-Silica. In concretes with Micro-Silica, there was a lesser overall porosity with an average pore size comparable to the reference concrete. Both the above discussed materials were reviewed so as to predict their materialistic properties and it was observed that both the materials can be used as supplementary cementitious materials so as to enhance the properties of rigid concrete pavement. From the results and outcomes of literature studies it was concluded that micro-silica gives better deterministic results as compared to rice straw ash.*

Keywords: Rice Straw Ash, rigid Pavement, Micro-Silica, Supplementary Cementitious Materials.

INTRODUCTION

General

Conflicting to generalconviction, concrete and cement are not the identical things, cement is essentially just anelement of concrete. Concrete is made up of three straightforwardconstituents: water, aggregate and Ordinary Portland cement. Cement, generally in powder usage, acts as a voluntary agent when assorted with water and aggregates. This grouping, or concrete mixture, will be transferred and harden into the hard-wearing material with which we are all accustomed. Concrete pavement which is infrequently called firm pavement is a concrete cover that is in interaction with traffics unswervingly and it is used for diverse purposes and applications. The concrete used for pavements can be altered and transformed in different ways as per the constraint. Not only does the concrete pavement requisite to be solid and hard-wearing but also it must be practicable and cost operational because it is commonly prone to unembellished environmental circumstances. Concrete pavements offer several benefits which is not possessed by bituminous pavement strategies, for example, it is considerably fit for large point loads, endure diesel leakage and other destructive materials, appropriate for cases where sub-grade strength is low-slung, repel high temperature, and countless more benefits.

Figure: Concrete Pavement

Rice Straw Ash

Rice straw is manufactured as a derivative of rice fabrication at harvest. Rice straw is detached from the rice grains in the course of harvest and it finishes up being piled or spread out in the field contingent if it was harvested physically or using machines. Ratio of straw to paddy ranges from 0.8-1.5contingent on the diversity and development. Globally, roughly 900 to 1100 million tons per year of rice straw is manufactured, with about 700 to 900 million tons annually manufactured in Asia. This remains to promptly upsurge due to dumpier turnaround time requisite for intensified rice cropping. The starter of game changing combine harvesters which resolves the extraordinary labor cost connected with manual straw assortment, addresses only partial the battle. Straw amalgamation in soil for fertilization in severe systems is also not conceivable with two to three crops annually because the improvement time is too diminutive for decomposition, resulting to pitiable soil fertilization properties which in the long runobstructs crop setting up.

Rice straw is a rice by-product manufactured when harvesting paddy. Each kg of milled rice manufactured results in roughly 0.8–1.5 kg of rice straw contingent on variabilities, wounding height of the stubbles, and dampness content during ingathering. Rice straw is detached from the grains after the plants are threshed either by hand, using standing threshers or, more recently, by means of combine harvesters. Biomass left-over from rice straw has many supervision problems, including field dismissal causing unembellished air contamination and natural organic decomposition occasioning in methane emission. The transfiguration of this left-over to ashes may offer the opportunity of reusing them in cementing arrangements.

Figure: Origin and Burning of Rice Straw at Fields

Figure: Collection and Purification of Rice Straw Ash at Site

Table: Chemical Composition of Rice Straw Ash

Type	Percentage
Silicon dioxide (SiO_2)	60.78
Aluminum oxide (Al_2O_3)	1.82
Titanium oxide (TiO_2)	0.12
Ferric oxide (Fe_2O_3)	1.16
Calcium oxide (CaO)	4.10

Magnesium oxide (Mg O)	3.37
Sodium oxide (Na_2 O)	0.62
Potassium oxide (K_2 O)	17.61
Phosphorus oxide (P_2 O_5)	7.08
Sulphur trioxide (SO_3)	2.69

Micro-Silica

Micro silica (silica fume) is a consequence from silicon metal or ferrosilicon industries, is an amorphous silicon dioxide – SiO2 which is produced as a fume in plunged electrical arc furnaces during the decrease of very pure quartz. As the melted metal is manufactured, a silica-based gas is released. This vaporous fume, as it increases, refrigerates rapidly and forms tremendously minute, amorphous, sphere-shapedsubdivisions. The micro silica is unruffled in a bag house, an arrangement for sieving the hot air and smokes expelled from the furnace. This gas vapor is compressed in bag house gatherers as very acceptable powder of spherical elements that average 0.2 to 0.4 microns in diameter with a surface area of 18 to 32 m^2/g.

Figure: Densified structure of Micro-silica

Table: Chemical Composition of Micro-Silica

Type	Percentage
Silicon dioxide (SiO_2)	81.10
Aluminum oxide (Al_2 O_3)	3.13
Titanium oxide (TiO_2)	0.12
Ferric oxide (Fe_2 O_3)	1.23
Calcium oxide (Ca O)	0.37
Magnesium oxide (Mg O)	7.57
Sodium oxide (Na_2 O)	0.50
Potassium oxide (K_2 O)	1.07
Phosphorus oxide (P_2 O_5)	3.76
Sulphur trioxide (SO_3)	2.69

LITERATURE REVIEW

(Szeląg, 2020)studied the formation features of the cracking pattern and fracture lines of low alkaline cement matrix transformed with micro silica. In this, the researcher examined the mechanical characteristics of the materials under the two stages of the thermal load (before and after). For identify the cracks on the cement matrix surface, the computer image analysis (double segmentation procedure) was adopted. The formation features of the cracking patterns (CP) were developed by various parameters like total crack area (TCA), crack density (CD), the fractal dimension of cracking pattern (CPDB) and to describe the fracture lines, the parameters like the fractal dimension of fracture lines (FLDB), fracture line length (FLL) were used. After analysis of the CP, the low alkaline cement matrix was made liable to mechanical tests to determine the flexural tensile test (FCF) and compressive strength (FC). The mechanical properties of these samples were carried out with the thermal loads and also compared these samples without thermal load. The cement matrix was developed in two stages, first the normal cement matrix, secondly the modified cement matrix with the addition of 5% micro silica (by weight of cement).The water-cement ratios were used as 0.45, 0.50 and 0.55 and total 18 samples were made. To obtain the cracking pattern, the samples were heated at 350°C in the initial stage and 450°C second stage. The conclusion of this study comes out, the values of TCA modified cement matrix with micro silica shows greater results as compared to normal cement matrix. But for the CD results, this relation was opposite i.e. out, the values of CD modified cement matrix with micro silica shows lesser results as compared to normal cement matrix. In the fractal analysis, the values of the fractal dimension of the cracking pattern (CPDB) was higher as compared with normal cement matrix.

(Mermerdaş, İpek, Algın, Ekmen, & Güneş, 2020)investigated the combined effects of micro silica, fly ash, steel fibers and artificial lightweight aggregates on the fresh and high durability cementitious composite. In this study, mechanical and shrinkage behaviour were examined. The mechanical properties were determined by the compressive and flexural tests whereas the shrinkage properties were determined by autogenous and dry shrinkages. To find out the results of the test, there were total 12 samples were made and M30 grade of concrete in which the different proportions of micro silica, fly ash, steel fibers and artificial lightweight aggregates. The proportion of fibres used in samples were 0%, 1% and 2% and the length of fiber 6mm used. The lightweight aggregates proportions were used 0% and 20% and MS was used as a proportion of 0% and 25%. The autogenous and dry shrinkages were calculated after 60 days curing. The mechanical properties of high durability cementitious composite and shrinkage behaviour have improved with the increase of fiber and the negative effects of aggregates can be eliminated by MS.

(Pandey & Kumar, 2019a)investigated the effect of the micro-silica (MS) and Rice straw ash (RSA) on the evaluation of durability properties of the pavement quality concrete. The main aim of this study to check the effect of RSA (with and without MS) on pavement quality concrete. In this study, the OPC was partially replaced with some proportions of the micro-silica (MS) and Rice straw ash (RSA). There was a total of ten samples were prepared to achieve the results of this study. The OPC replaced with RSA with some proportion i.e. 5%, 10% and replaced with MS with some proportion i.e. 2.5%, 5%, 7.5% and the combination of RSA and MS replaced with some proportion i.e. 5% RSA, MS, 5% RSA 7,5% MS, 10% RSA 5% MS and 10% RSA 7.5% MS. The results were prepared in terms of water absorption test and chloride ion penetration test. For the chloride ion test, the holes were drilled on the prepared samples up to depth 10-15mm and 25-35mm, and check the chloride percentage. The conclusion comes out that the RSA and MS both were finer than the cement particles, due to this fineness there was better resistance to water absorption and chloride ion would be expected. The maximum reduction of both the test showed in the proportion of 10% RSA and 7.5% MS as compared to the reference sample. The air content of fresh concrete was kept constant when more than 15% RSA and MS were replaced.

(Xu et al., 2019)studied the hydrated mechanism and sintering characteristics of the hydratable alumina with the addition of Micro silica at various proportions. The study investigates in terms of rheological, hydration and formation features of the prepared samples. The rho alumina-micro silica-water system was gained its properties when the addition of MS in it and to clarify the hydration process involved. The formation features of the prepared samples were analyzed by XRD, TG-DSC and infrared techniques. The prepared samples were sintered at 1400 degree Celsius for the formation features observation used by SEM techniques. The overall conclusion of this research that the 6% addition of MS made the hydratable alumina for the good binding. The presence of MS effectively controls the expansion of prepared samples during hydration.

(Roselló et al., 2017)studied the properties of rice straw ash (RSA) for the cementing materials. In this study, the researchers investigated different parts of the rice plant like rice leaf, rice leaf sheath and rice steam and were characterized by the chemical composition: rice leaf ash, rice leaf sheath ash and rice steam ash. The silicon dioxide presents in all the rice ashes. Before analyzing the work these rice leaf, rice leaf sheath and rice steam were stored in plastic bags under 4^{o}C. The microscopic study was carried out to know the character of the cells tissues. After that, the calcination of leaves was carried out under the temp of 450, 500, 550 and 600^{o}C. After all the microscopic process have been done the RSA replaced with OPC with 10 and 25%. The prepared samples were tested and results were compared. The yield strength comes out 107% and 98% with a proportion of 10 and 25%. Hence the RSA was very useful and gained strength in the cementing material.

(Munshi & Sharma, 2019)studied the properties of RSA in the construction works. In this study, RSA was used to construct the house walls and some proportion of OPC partial replaced with RSA. The various tests i.e. destructive (compressive test) and non-destructive test UV test and Rebound hammer test) were performed on that RSA wall. SEM and energy destructive spectroscopy test were also performed on that wall. For concrete making, the OPC was partially replaced with 5% RSA and for mortar, the 10% RSA was used. The compressive strength test results were checked after 7, 14, 28 and 54 days. The conclusion comes out that the addition of RSA in our construction work, there were not majorly effect on our structure. The results of both destructive and non-destructive test were almost the same. This shows that at the age the RSA strength increases.

(Ekinci, Türkmen, Kantarci, & Karakoç, 2019)investigated the problems of alkali ash raised from biomass combustion by taking advantages of kaolin, RSA and coal in a pilot-scale grate fired combustor. The main aim of this research was I) to assess kaolin as an additive for RSA and investigated the feasibility of the ash relating problem, ii) to conduct firing with al-anthracite waste, iii) to understand the synergetic benefits by using combined kaolin-anthracite. After burning the ashes, the SEM and EDX and mapping analysis were adopted to find the properties of this ash. The successive addition of kaolin, co-firing with anthracite or both combination has lowered the density of the fouling was associated with an interaction between silicon and Al in kaolin-anthracite with RSA. Coal is rich in silicon and Al such as anthracite was desirable.

(Zaky et al., 2008)studied the production of silica nanoparticles from the burning of rice straw. In this, the semi burned RSA was produced from the gaseous products of the rice straw and this semi burned RSA used to prepare the silica particles for the construction purposes. The box

Behnken design method was used to check the effectiveness or efficiency of the silica. 15 samples were prepared for checking the efficiency of the silica at a different time and temperatures 1 2 3 hours and 80 90 and 100 degrees Celsius. To check the characterization of the semi burned RSA, XRD and SEM tests have been adopted, while for measured the amount of silica, the UV and spectrophotometer tests were adopted. The result shows that 62% silica available in semi burned RSA. The conclusion comes of this study that if the stoichiometric value increased at 3, the efficiency of the sample also increases and reached 99% at time 4hours.

CONCLUSIONS

From the above discussed literature studies over usage of rice straw ash and micro silica several conclusions aredrawn which are as follows:

- The hydraulic nature of rice straw ash and micro silica when used as a supplementary cementitious material lead to increase the workability and consistency of concrete and cement paste respectively. It was observed that due to the higher surface area associated with both the materials it helps to improve the micro structure of the cement paste.
- The usage of micro silica does not impact the settling time of the concrete but in case of rice straw ash, due to its limited as well as controlled usage under specific conditions it leads to improve and intensifies the settling time of the concrete and cement paste.
- From the maximum research studies, it was observed that the application of rice straw ash in concrete and cement paste leads to increase the materialistic and strength properties of concrete. It tends to increase the compressive strength, tensile strength and flexural strength of concrete. But in case of micro-silica it was observed that the strength tends to decrease with the application of micro-silica over both cement paste and concrete.
- Concerning the results for both the materials, most of researches were done separately over these materials and it was noted that the mineral content of rice straw ash was more as compared to the micro-silica, due to which in long term considerations, the usage of rice straw ash under controlled conditions will improve the life of rice straw ash made concrete structures and concrete pavements.

FURTHER CREDITS

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