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Utilization of Agricultural By-Products as a Partial Replacement of Cement in Construction: A Review

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Abstract

Food and Shelter are the two main requirements for surviving in this cosmos. More than 50% of the geographical area of the country is under cultivation. After harvesting the rice crop there is a common practice to set fields on fire. This stubble burning creates havoc causing a large number of health hazards and also affects the soil properties. This method of decomposition of agricultural residue including rice straw and rice husk if replaced with some standard combustion conditions, temperature, and rapid cooling of ash produced, will prove beneficial to the construction industry. This review paper explores the possibility of utilizing these agricultural waste products i.e. Rice Straw Ash (RSA) and Rice Husk Ash (RHA) as a partial replacement of cement in concrete and analyzing the fresh and hardened properties of concrete. Research gaps and future scope of this study are also highlighted in this review paper. It has been observed that the physical, chemical, and strength properties of concrete are mostly affected by the pozzolan city of the ashes and compressive strength and tensile strength of concrete increases with increase in replacement level of cement with the agricultural ash up-to certain optimal levels. Various other factors that contribute to the enrichment of the existing properties of the resulting concrete include grinding, fineness and porosity of ashes.

Keywords: *Rice Husk Ash, Rice Straw Ash, Concrete, Pozzolana, Workability, Tensile strength, Compressive strength.*
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I. INTRODUCTION

role in developing the economy of a country. As per the report of the Directorate of Rice Development (2022) [1], India ranks second next to China in terms of agricultural production. India has an agrarian economy. According to the annual report of the Department of Agriculture and Ministry of Farm Welfare (2022–2023) [2], India has a total geographic area of 328.7 million hectares, of which 139.3 million hectares is the net sown area and 197.3 million hectares is the gross cropped area with a cropping intensity of 141.6%. It is estimated that more than 500 million tons of crop residue is produced every year [3]. As per the available estimate of National Policy for Management of crop residue-Report (NPMCR 2019) in India [4], the production of crop residue is highest in Uttar Pradesh (60 Million Tones) followed by Punjab (51 Million Tones) and Maharashtra (40 Million Tones) as shown in Fig. 1.

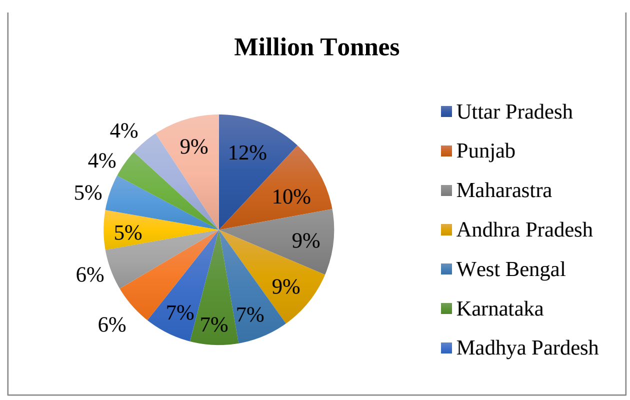

Fig. 1. Residue from crop production (National Policy for Management of crop residue report 2019) [4]

The most important food crop of India is rice and it covers 23.3% of the total gross cropped area (Directorate of Rice Development Department of Agriculture and Farm Welfare Annual Report 2022) [1]. Each year, 680 million tons of rice is produced. The total rice production in India is estimated at

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122.27 million tons [5]. The cultivation of rice is increasing due to the adoption of upgraded varieties of seeds and fertilizers (Fig. 2). The massive amount of rice production after harvesting gives rise to byproducts, such as rice straw and rice husk. The production of rice results in more than 980 million tons of crop residues worldwide each year [6]. The residue from rice in India is reported to be 178.5 million tones and 225.5 million tons [7], [8].

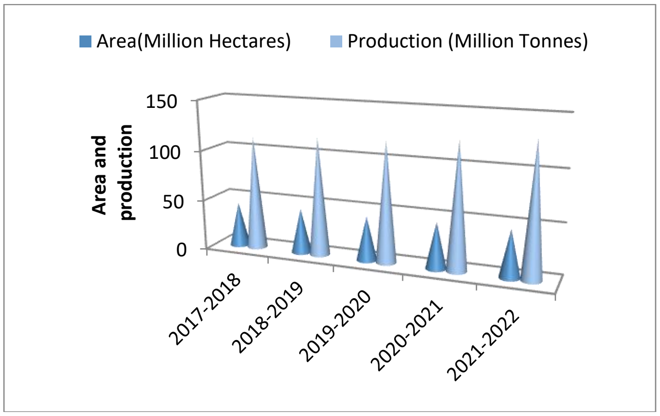

Fig. 2. Area and production of rice in India ((Department of agriculture and ministry of farm welfare 2022-2023) [5]

The production of rice-based ash is harmful because it can cause methane emission which finally results in air pollution and organic decomposition [9]. Agriculture, environment, and energy are all impacted by the management of agricultural byproducts like rice husk and rice straw. Rice husk and rice straw burning, soil inclusion, or processing for energy purposes are currently used tactics for the management of the residues produced. Each has very diverse effects, especially on greenhouse gas emissions. A common practice these days is open field burning of rice leftovers which prepares the fields for the next sowing by eliminating the residues. The burning of crop rice increases pollution by releasing carbon-dioxide (CO_2), carbon-monoxide (CO), ammonia (NH3), nitrous-oxides (NOX), Sulphur oxides (SOX), non-methane hydrocarbons (NHMC), volatile organic compounds (VOCs), and particulate matter (PM) [10], [11]. Researchers of [12] reported 5.34±2.33 Megaton carbon-dioxide (CO_2), 44±14 kiloton methane (CH4), 422±179 kiloton carbon monoxide (CO), 2±2 kiloton nitrogen oxides (NOX), 2±2 kiloton Sulphur oxides (SOX), 38±22 kiloton of particulate matter (PM) 2.5, 43±29 kiloton of particulate matter (PM) 10,2±1 kiloton black-cotton and 14±5 kiloton of organic compounds are produced by burning rice residue.

Authors of [13] worked to find the emissions of pollutants by taking into according the pre-harvest and post-harvest periods in particular agricultural areas in Indo Gangetic Plain. The study conducted showed that particles with aerodynamic diameter of 2.5µm or less (PM2.5) concentration were 3to4 times more than the standard (35µg/m3) values given by National Ambient Air Quality (NAAQ). The research also revealed that high potassium concentrations were detected during the post-harvest period and field emission scanning electron microscopy with energy dispersive X-ray spectroscopy (FESEM-EDX) (Fig. 3) was used to do this analysis. 1.21 Mt of particulate matter for the year 2008–09 was emitted [3]. This may be related to crop residue burning or biomass combustion. Human health issues associated with this burning, particularly when it occurs close to significant urban populations, have resulted in the practice's out-lawment. The biggest drawback of burning rice residue is that it results in nutrient and energy loss in addition to air pollution. Thus these pollutants can also act as possible human carcinogens. This residual ash if produced under controlled burning conditions can benefit both agricultural as well as construction sectors. The ash from rice straw and rice husk can act as an important supplementary cementitious material in concrete.

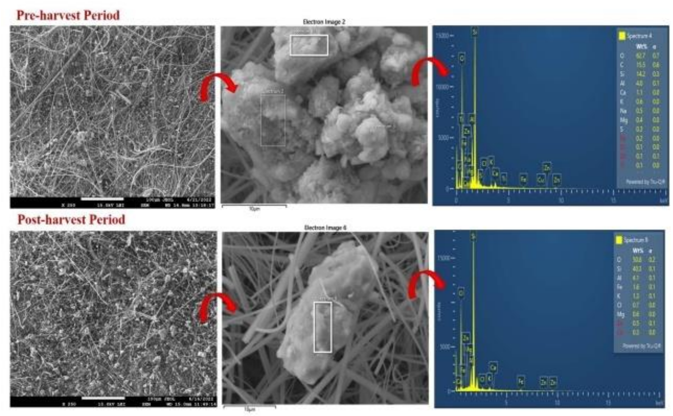

Fig. 3. FESEM –EDX Images of PM2.5 during pre- harvest and post- harvest period [13]

Over the past 50 years, concrete has been produced at a higher rate than other construction materials due to urbanization, industrialization, and the resulting rise in infrastructure demand, with per capita consumption growth rates exceeding population growth rates. Concrete production has gained a lot of popularity around the world; its rate of production growth is outpacing that of most other infrastructure materials [14].

Concrete has environmental impacts as well ie., it accounts for 8–9% of anthropogenic greenhouse gas (GHG) emissions, 2%–3% of the world's annual energy demand, and 10%–15% of industrial water withdrawal. The annual production of concrete is estimated to increase 50%, by 2050 [14]. Concrete is a mixture of cement, aggregates, water, and admixtures if necessary. Cement acts as a binder which helps to keep the various ingredients of concrete together. The raw materials (Limestone and clay) required for manufacturing of 1ton of cement are heated at a temperature of 14500C which can approximately produce 1 ton of carbon –dioxide (CO_2) [14], [15], [16]. This production of carbon-dioxide (CO_2) results in climatic changes, environmental hazards, human health problems, fossil fuel depletion as well and photochemical ozone formation. It is widely acknowledged that one of the main gases contributing to the greenhouse effect, which is to blame for global warming, is carbon-dioxide (CO_2). About 7% of the world's total carbon dioxide carbon-dioxide (CO_2) emissions are attributable to the industry alone [17]. India is the second largest polluter of cement manufacturing across the globe [18]. As per the International

Energy Agency (IEA-2022) [19], [20], cement production is increasing as depicted in Fig.4.

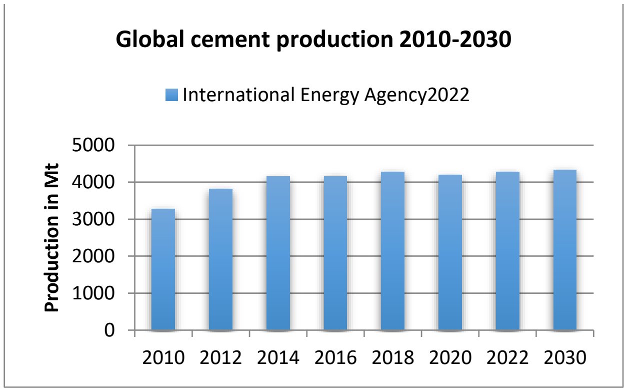

Fig. 4. Global cement production 2022

The solution to this global issue is to use alternate materials or waste materials preferably generated from the agricultural sector and the industrial sector of the country. This review study emphasizes the need for partial replacement of cement in the concrete mixture with agricultural waste ash (Rice straw and Rice Husk) to improve sustainability. The pozzolanic behavior of the binder plays an important role in the partial replacement of cement in concrete. A basic component needed for a pozzolanic reaction is silica. This reaction is an acid-base reaction between silicon oxide (silica) and calcium hydroxide, which is created when cement hydrates, i.e.,

$$SiO_2 + Ca\,(OH)_2 = C\,S\,H\,(gel)$$

Calcium silicate hydrate gel (C S H), which has cementing capabilities, is produced by the chemical reaction. A Supplementary Cementitious Material (SCM) is referred to as a pozzolan when it exhibits this behavior and has pozzolanic characteristics. Concrete production by using Supplementary Cementitious Materials (SCM) produced from agricultural products (Rice Husk, and Rice Straw) can fulfill the requirement of cement as a partial substitute and can give desirable results to a greater extent in terms of physical, chemical, and strength properties. Cement, rice straw ash, and rice husk ash production is broadly obtained in two steps) Production of raw materials and grinding of raw material to obtain the fine material which can be used as a binder in concrete. The production of binder used in concrete mainly depends on these factors i.e., methods adopted for the production of ash(Controlled and uncontrolled burning), the temperature at which binder is produced, the rate of grinding, and the carbon content released during the production The uncontrolled burning affects the environment but if these by-products are subjected to controlled burning at a particular temperature will produce the ash which will be having good pozzolanic properties and reactivity.

It is believed that if the carbon content is more than 30% then it can adversely affect the pozzolanic nature of binder. Also at temperatures between 500-800 ^{0}C [21], [22], [23] the silica produced is amorphous and has good pozzolanic properties. But if the temperature is increased, it gets converted to the crystalline form and thus does not act as a good pozzolanic material. The pozzolanic property in general plays an important role in enhancing the concrete properties

II. Physical Properties of Cement, Rice Husk Ash (RHA) and Rice Straw Ash (RSA)

Literature review shows that researchers have recommended different codes for analyzing the physical properties of cement and Supplementary Cementitious Materials (SCM). The various codes used by researchers are mentioned below:

- ASTMC618-19: Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete
- BIS3892-Part1-1997: Specification for pulverized-fuel ash for use with Portland cement
- IS4031-Part11-1988: Methods of physical tests for hydraulic cement
- IS1727-1995: Methods of test for pozzolanic materials
- IS3812:Part1-2003: Pulverized fuel ash-Specification
- IS 12269:1989: Chemical and physical requirements of OPC

The various physical properties of cement, rice straw ash and rice husk ash as found in literature are depicted in Table I.

TABLE I. Physical property of Cement, Rice Straw Ash and Rice Husk Ash

Property	Cement	RSA	RHA	Ref.
Specific surface area (m^2/g)	0.30	1.85	-	[24]
	-	0.36	-	[25]
	3.30	-	0.24-0.37	[26]
	0.34	2.05	-	[27]
	-	1.85		[28]
	0.41	-	2.33	[22]
	0.38	-	0.60	[29]
Specific gravity	3.20	2.25	-	[30]
	-	2.1	-	[25]
	3.12	-	Rapidly Cooled 2.10; Slowly Cooled 2.10	[31]
	3.10	-	2.06	[32]
	3.10-3.30	-	2.10-2.20	[26]
	3.14	2.20	-	[27]
	3.17	-	1.75	[33]
	3.16	-	2.10	[22]
	3.11	-	-	[34]
Mean grain size (μm)	17	3.30	-	[24]
	4.60-10.50	-	5.0-7.40	[26]
Bulk density (g/cm^3)	Loose 1.16; Dense 1.56	-	Loose 0.40; Dense 0.49	[32]
Fineness passing (45μ sieve)	85	-	99	[32]
Fineness (90micron sieve (%))	6.0	-	-	[33]
Colour	Grey	Grey	-	[27]

Normal Consistency (%)	29-32	-	26.80	[29], [33], [35]
Initial setting time (Minutes)	45-110	175	280	[25], [33], [35]
Final setting time (Minutes)	325-520	250-280	425	[25], [33], [35]

Authors of [32] investigated the specific surface area by BET's method, specific gravity, fineness, bulk density, and setting time as per 4031(parts)-1995 and IS1727-1995 and concluded that the specific surface area of Rice Husk Ash (RHA) is more than Ordinary Portland Cement (OPC). It was also stated that the trend followed for the initial setting was increasing while it was decreasing for the final setting time with the increase in partial replacement level of Rice Husk Ash (RHA). Authors of [35] reported that the fineness of blended cement increased with the increase in partial replacement level from 0%-25% and the results for soundness of partially replaced cement (Rice Straw Ash (RSA) & Rice Husk Ash(RHA)) were reported in a range of 4.0mm to 6.00mm which also showed a positive change in the graph as compared to Ordinary Portland Cement (OPC). [25], [28], [30] also carried a research on the physical properties of cement and agricultural residue ash (Rice Straw Ash (RSA) & Rice Husk Ash (RHA)). The various parameters discussed in the literature were specific gravity, grain sieve analysis, surface area, and setting time and it was concluded that replacement of cement with agricultural ash can prove advantageous in terms of these properties.

By reviewing the literature it can be concluded that physical properties play an important role in maintaining the pozzolanic nature of cement and if cement is partially replaced with Supplementary Cementitious Materials (SCMs) (i.e., Rice Straw Ash & Rice Husk Ash). Also, it is found that the data on Rice Husk Ash (RHA) as partial replacement is abundant however sparser work is reported on Rice Straw Ash (RSA). It is noted that the specific surface area of ash depends on the method of burning i.e., controlled and uncontrolled burning. It is seen that the ash obtained from uncontrolled burning produces residual carbon and requires extra grinding to meet the reactivity requirements to behave as pozzolanic material and to form C-S-H gel which are the parameters of utmost importance for partial replacement of cement. The increase in surface area results in good pozzolanic nature by consuming calcium hydroxide present in concrete. Apart from this high specific surface area of agricultural ash (Rice Husk Ash) can enhance the viscosity of concrete by increasing the water retaining capacity and ultimately the chances of segregation in concrete become negligible.

The particles of rice straw ash are finer than cement which will increase the strength properties of concrete by providing more area for water cement reaction. This water cement reaction results in the formation of Bougas compound that will add pozzolanic nature to the Supplementary Cementitious Materials (SCMs) and finally result in the enhancement of various physical properties .In most of the research the criteria mentioned for classifying fly ash (ASTMC-618) is used as the thumb rule for determining the physical properties of other Supplementary Cementitious Materials (Rice Husk Ash &Rice Straw Ash). According to ASTMC-618 if Rice Husk Ash has a specific area of more than 1.15m2/gm, then it can attain the pozzolanic activity.

The replacement of cement with agricultural ash increases the setting time (Initial and Final setting time) because the hydration reaction is slowed due to the reduction in surface area of cement and this will be beneficial to the strength and durability properties of concrete. Also, gypsum is added as a retarder to cement so that its initial setting time gets slowed down but in Supplementary Cementitious Materials (SCM) the requirement of gypsum seems negligible. So it can be concluded that on the basis of physical properties Supplementary Cementitious Materials (SCM) gives the results that are acceptable and partial replacement of cement can prove beneficial in concrete.

III. CHEMICAL PROPERTIES OF CEMENT, RICE HUSK ASH AND RICE STRAW ASH

The pozzolanic behavior of a material can only be defined on the basis of its chemical composition of the calcareous and argillaceous materials. As perASTM-C-618 if the sum of Iron oxide (Fe2O3), Silicon Oxide (SiO2) and aluminum oxide (Al2O3) is more than 70% then material would be declared as pozzolanic material. On the other hand, some literature review recommends the presence of higher silicon oxide (SiO2) and absence of Calcium oxide (Cao) is the main reason for the pozzolanic nature of a material [30]. The Chemical composition of a material can be analyzed by performing Energy –dispersive-x-ray, high pressure-x-ray diffraction and total scattering methods. The various chemical properties of cement. Rice Straw Ash (RSA) and Rice Husk Ash (RHA) available in literature are reviewed and are given in Table II, Table III and Table IV respectively.

TABLE II. CHEMICAL PROPERTIES OF CEMENT

Material	Sio_2	Al_2O_3	Fe_2O_3	Cao	Mgo	SO_3	Other Elements	Reference
CEMENT (OPC)	21.28	4.64	3.35	61.92	3.83	3.41	2.44	[27]
	26.34	6.13	3.7	42.16	14.79	1.73	4.304	[30]
	2.0	5.50	3.50	64.25	2.50	2.90	1.84	[29]
	20.90	4.76	3.41	65.41	1.25	2.71	3.91	[21]
	19.49	7.36	2.68	62.51	3.7	2.4	-	[28]
	19.80	6.9	3.85	62.45	2.35	2.95	-	[31]
	21.40	4.93	3.90	64.80	1.70	2.30	1.69	[25]
	20.25	5.04	3.16	63.61	4.56	-	0.59	[32]
	20.01	4.89	3.23	62.71	2.54	2.64	8.85	[35]
	14.18	4.07	-	72.04	0	-	10	[36]

TABLE III. CHEMICAL PROPERTIES OF RICE STRAW ASH (RSA)

Material	SiO_2	Al_2O_3	Fe_2O_3	Cao	Mgo	SO_3	Other Elements	Reference
RSA	78	-	1.45	10.05	-	0.40	6.10	[27]
	79.82	1.13	0.24	0.37	7.54	-	10.54	[30]
	65.92	1.78	0.2	2.40	3.11	0.69	-	[28]
	77.0	0.69	0.63	4.96	2.65	1.90	-	[25]
	72.37	1.09	-	5.06	0	-	20	[36]

TABLE IV. CHEMICAL PROPERTIES OF RICE HUSK ASH(RHA)

Material	SiO_2	Al_2O_3	Fe_2O_3	Cao	Mgo	SO_3	Other Elements	Reference
RHA	67	0.46	0.55	1.30	1.77	-	6.54	[33]
	77.34	6.92	4.89	3.56	1.59	0.34	8.77	[29]
	92.0	0.29	0.1	1.28	0.37	0.94	6.04	[21]
	94.95	0.39	0.26	0.54	0.90	-	2.11	[37]
Slow cooled RHA	89.50	0.40	2.86	0.30	0.25	-	-	[31]
Rapidly cooled RHA	84.0	1.39	2.01	0.60	0.85	-	-	
	87.32	0.22	0.28	0.48	0.28	-	4.16	[32]
	82.14	1.34	1.27	1.21	1.96	0.17	8.67	[35]

A wide range of differences in the chemical properties of Rice Straw Ash (RSA) &Rice Husk Ash (RHA) is attributed to various factors such as geographic and climatic conditions of soil, pre-combustion, combustion conditions (Uncontrolled, controlled, temperature & technology), and post-combustion conditions (cooling process & grinding). It is observed that the combustion temperature and grinding of ash affect the reactivity of Supplementary Cementitious Materials (SCMs) to a greater extent. If the ash is obtained by uncontrolled burning it will form crystalline silica which is of no use from a reactivity point of view. The reactivity of grounded Supplementary Cementitious Materials (SCMs) will be more than ungrounded Supplementary Cementitious Materials (SCMs) and it will increase the pozzolanic activity if subjected to proper levels of grinding. The cooling process of ash also plays an important role in the reactivity of Supplementary Cementitious Materials (SCMs).

The reactivity of Supplementary Cementitious Materials (SCM's) means that it has got good amount of silica which itself does not have any kind of cementitious property but once it reacts with water it can act as a good substitute for cement up to certain levels. Also, the ash obtained from rapid cooling has a better reactive surface than the slow-cooling ash which results in the emission of silanol groups that hurt the pozzolan city of ash. The presence of amorphous and absence of high levels of potassium and other unwanted compounds will have a positive effect on the chemical composition of ash and thus the production of oxides will be under permissible limits as mentioned by different codes and will be free from any kind of sulfate attack, unsoundness, etc. It is noted that agricultural ash contains more silica content than cement which will enhance the pozzolan city of concrete. Also, the silica dioxide (SiO2) and calcium oxide (Cao) are responsible for the formation of Bouge's compound (Tricalcium silicate, Dicalcium silicate, Tricalcium aluminate, and Tetra-calcium-alumina ferrite) which will affect the hydration reaction as well as early age strength and later strength of concrete. The various other alkali compounds if present in excess in ash can hamper the properties of concrete formed.

IV. FRESH AND HARDENED PROPERTIES OF CONCRETE CONTAINING CEMENT AND PARTIAL REPLACEMENT OF CEMENT WITH RICE HUSK ASH AND RICE STRAW ASH

The properties of concrete that can be analyzed when concrete is in its plastic state i.e., it can be molded into any shape is termed as fresh property of concrete. Fresh properties of concrete can be checked by performing the slump test and the value of slump will define the workability of concrete.

Hardened property of concrete is defined once the concrete loses its plastic stage and is fully cured. The various hardened properties of concrete include compression strength, tensile strength, permeability carbonation depth etc. The various codes used by researchers to find the strength properties of concrete are given below:

The fresh and hardened properties according to different literature review are mentioned in Table V, Table VI, and Table XII respectively.

A. *Workability:*

Workability is defined as the ease with which material can be handled. The fresh properties of concrete are depicted in Table V.

TABLE V. FRESH PROPERTIES OF CONCRETE (CONTROL MIX, PARTIAL REPLACEMENT OF CEMENT WITH RICE STRAW ASH (RSA) & RICE HUSK ASH (RHA))

Mix		Slump (mm)	Reference
Control mix		97	[33]
Replacement of cement with RHA (%)	10	82	
	20	77	
	30	65	
Control Mix		95	[29]
Replacement of cement with RHA (%)	6	105	
	12	112	
	18	123	
	24	135	
Control Mix		98	[32]
Replacement of cement with RHA (%)	5	106	
	10	115	
	15	91	
	20	81	
	25	74	
	30	64	
		41	
Control Mix		97	[34]
Replacement of cement with RSA (%)	9	81	
	12	77	
	15	65	

Mix		Slump (mm)	Reference
Control Mix		62	[36]
Replacement of cement with RSA (%)	5	51	
	10	47	
	15	39	
	20	10	
	25	0	
	30	0	

The graphical representation of variation of slump when cement is partially replaced with Rice Straw Ash and Rice Husk Ash is given in Fig. 5 and Fig. 6.

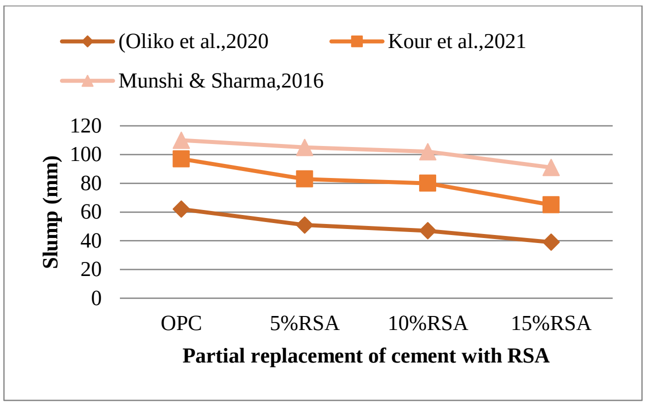

Fig. 5. Variation of slump (Partial replacement of cement with Rice Straw Ash (RSA))

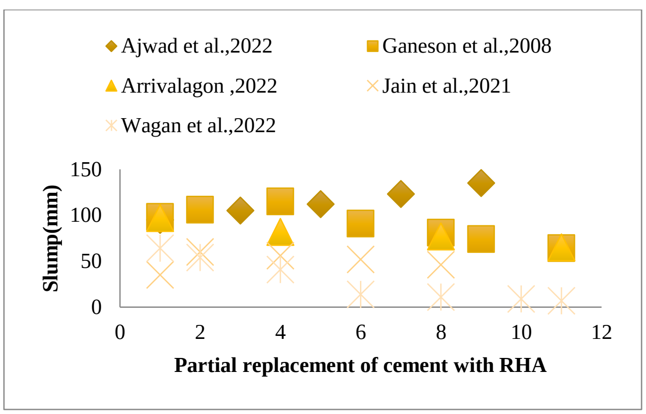

Fig. 6. Variation of slump (Partial replacement of cement with Rice Husk Ash (RHA))

Workability of the concrete incorporated with agricultural ash (Rice Straw Ash & Rice Husk Ash) is investigated by different researcher's by using standard test like slump cone j-ring flow test, inverted slump cone flow test, inverted slump j-ring flow test (IS5512-1983). The literature suggests that there the trend followed for workability, when cement is replace with rice straw ash and rice husk ash shows variation [29], [32], [36], [38].

It can be concluded from the literature that partial replacement of cement with Rice Straw Ash decreases the slump value and partial replacement of cement with Rice Husk Ash shows variation in results, which is clearly depicted in Fig. 5 and Fig. 6. The decrease in slump value of Rice Straw Ash is due to the high surface area of ash which results in increased water demand. It has been also observed that the water demand of agricultural Ashe is more than the cement due to its hydrophilic nature and porosity of ash. The cellular structure of the ash can also be the reason for increased water demand which is due to the high specific surface area of ash. The other factors that can affect the workability of agricultural ash is that whether the ash is grounded or ungrounded because fineness is important factor that affects the water cement ratio of Supplementary Cementitious Materials (SCMs). The improved particle packing and flow characteristics of Rice Husk Ash can also be the reasons for reducing the water demand of concrete incorporated with Rice Husk Ash. This makes the placing of concrete easier and economical construction will take place. The concrete incorporated with agricultural ash having low slump can also give the desirable results due to cohesiveness and if required additional water or super-plasticizer's can be used.

B. Compressive Strength

Compressive strength of concrete can be found adhering various Indian and international codes. The cubical samples or cylindrical samples are prepared according to the mold and then compressive strength is checked by using compression testing machine. The compressive strength of concrete incorporated with cement and partial replacement of cement with Supplementary Cementous materials (Rice Straw Ash& Rice Husk Ash) by various researchers for different curing period is depicted in Table VI, Table VII and Table VIII respectively.

TABLE VI. COMPRESSIVE STRENGTH (MPA) OF CONCRETE (CONTROL MIX)

	3 Days	7 Days	14 Days	28 Days	56 Days	90 days	Reference
Control Mix	-	13.04	18.00	28.00	-	-	[25]
	-	19.34	23.23	29.45	-	-	[33]
	20.76	31.89	-	39.41	42.54	-	[29]
	32.80	29.30	-	19.70	-	15.70	[39]
	-	27.20	32.3	37.10	-	38.30	[32]
	-	27.90	33	35.95	36.55	38.70	[36]

TABLE VII. COMPRESSIVE STRENGTH (MPA) OF CONCRETE (PARTIAL REPLACEMENT OF CEMENT WITH RICE STRAW ASH (RSA))

Partial replacement of Cement with RSA (%)	3 Days	7 Days	14 Days	28 Days	56 Days	90 days	Reference
5	-	12.60	19	29	-	-	[25]
10	-	12.60	20	32	-	-	
15	-	11	16	26	-	-	

5	-	32	36.70	38.30	40.25	41.3	[36]
10	-	33.65	37.10	40.20	41.80	42.65	
15	-	28.70	31.60	32.30	33.70	34.70	
20	-	28.40	29.55	31.80	32.60	33.45	
25	-	24	26	28.7	31.85	32.80	
30	-	10.85	15.25	18.95	20.05	23.10	

TABLE VIII. COMPRESSIVE STRENGTH (MPA) OF CONCRETE (PARTIAL REPLACEMENT OF CEMENT WITH RICE HUSK ASH (RHA))

Partial replacement of Cement with RHA (%)	3 Days	7 Days	14 Days	28 Days	56 Days	90 days	Reference
10	-	22.73	27.45	29.67	-	-	[33]
20	-	25.22	29.34	32.50	-	-	
30	-	27.67	32.56	39.34	-	-	
6	3.38	7.53	-	14.64	25.40	-	[29]
12	3.29	6.05	-	13.09	21.74	-	
18	2.88	5.81	-	12.05	20.02	-	
24	2.58	5.42	-	11.30	17.43	-	
10	24.70	24.10	-	18.70	-	16.60	[39]
15	28	24.10	-	20.20	-	17.60	
20	27.60	23.60	-	20.60	-	19.30	
25	22	20.10	-	18.90	-	18.20	
30	18	17.80	-	17.60	-	15.90	
5	-	27.60	34.20	40	-	43.30	[32]
10	-	28	35.30	41.30	-	44.80	
15	-	29.30	36	41.80	-	45.70	
20	-	29.70	39.30	42.50	-	46	
25	-	28.70	36.10	38.80	-	43	
30	-	27.40	33.50	37.60	-	38.70	
35	-	25.70	31.10	35.10	-	37.20	

The graphical representation of variation of Compressive Strength when cement is partially replaced with Rice Straw Ash and Rice Husk Ash is given in Fig. 7 and Fig. 8 respectively.

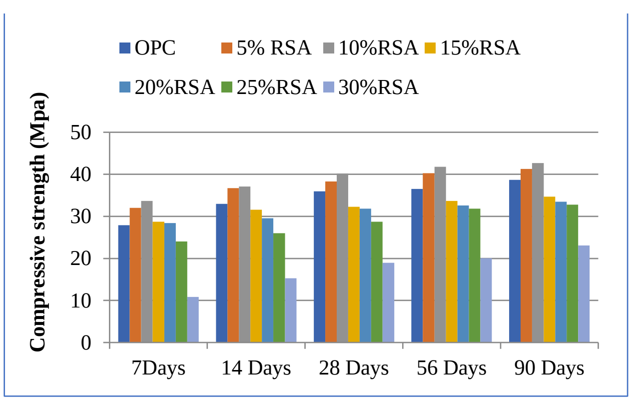

Fig. 7. Variation of Compressive Strength (Mpa) (Partial replacement of cement with Rice Straw Ash) [36]

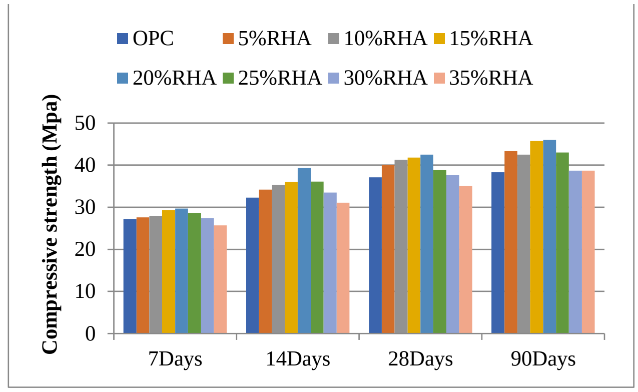

Fig. 8. Variation of Compressive Strength (Mpa) (Partial replacement of cement with Rice Husk Ash) [32]

Researches [34], [36], [38] conducted experimental work to find out the compressive strength of concrete with partial replacement of cement with Rice Straw Ash (RSA). The various replacement levels used for replacement were between 5% - 35%. It was concluded that the partial replacement of cement with Rice StrawAsh (RSA) gave desirable results for little value of replacement ie, up to 20% and after this, a decrease in compressive strength was reported. In the same manner the study on using Rice Husk Ash (RHA) as a partial replacement for cement was conducted by [29], [32], [39]. It was concluded by them that the replacement of cement with Rice Husk Ash (RHA) gave better results than Ordinary Portland Cement (OPC) and also good value of strength was noted with the increases with the period up to certain levels of replacement.

The compressive strength of concrete incorporated with Rice Straw Ash (RSA) and Rice Husk Ash (RHA) is more than the concrete without any kind of partial replacement. It is observed that the early-age strength of concrete in most cases is less than the later-age strength however there is variation in results according to some authors. The replacement of cement with Rice Husk Ash (RHA) and Rice Straw Ash (RSA) shows increases within the optimum values of replacement ie,10% for rice straw ash and 20% for rice husk ash. The compressive strength of concrete depends on combustion treatment, pre-combustion, and post-combustion. The presence of amorphous silica in agricultural ash affects its pozzolanic reactivity of ash and the filler ability of the ash fills the voids in the concrete thus increasing the concrete's compressive strength of concrete. The grinding of the agricultural ash increases the bulk density and fineness of ash which will also affect the compressive strength positively. It is also observed that the strength of concrete increases with the curing period. At later ages, the strength is gained due to the filler effect and pozzolanic nature which is gained by the formation of C-S-H gel.

The presence of a high percentage of silica is one of the important factors for increasing the compressive strength of concrete. It has been observed that once the compressive strength of concrete incorporated with Rice Husk Ash (RHA) and Rice Straw Ash (RSA) reaches the optimum value i.e.,20% &10% respectively then it shows a decreasing trend. The main reason for the decrease in compressive strength can be concluded as higher replacement values of cement. The more the replacement, the lesser will be the production of calcium hydroxide and the rate of hydration reaction will slow down thus affecting the compressive strength negatively.

C. Tensile Strength

Tensile strength of concrete samples incorporated with agricultural can be analyzed by performing splitting cylinder tensile test by the following standard code procedures. The tensile strength of concrete incorporated with cement and partial replacement of cement with Supplementary Cementitious Materials (Rice Straw Ash& Rice Husk Ash) is given in Table IX and Table XI respectively.

TABLE IX. TENSILE STRENGTH (MPA) OF CONCRETE (CONTROL MIX)

	3 Days	7 Days	14 Days	28 Days	56 Days	90 days	Reference
Control Mix	0.95	1.17	-	1.89	3.58	-	[29]
	-	--		4.5	-	-	[32]
	-	-	-	3.48	3.5	3.5	[36]

TABLE X. TENSILE STRENGTH (MPA) OF CONCRETE (PARTIAL REPLACEMENT OF CEMENT WITH RSA)

Partial replacement of Cement with RSA (%)	3 Days	7 Days	14 Days	28 Days	56 Days	90 days	Reference
5	-	-	-	3.51	3.53	3.8	[36]
10	-	-	-	3.6	3.8	3.9	
15	-	-	-	3.1	3.3	3.4	
20	-	-	-	2.5	2.57	2.7	
25	-	-		2.39	2.5	2.55	
30	-	-		1.7	1.8	1.9	
5%	-	1.79	3.57	-	-	-	[40]
10%	-	2.31	3.74	-	-	-	
15%	-	2.38	4.34	-	-	-	
20%	-	2.21	3.83	-	-	-	

TABLE XI. TENSILE STRENGTH (MPA) OF CONCRETE (PARTIAL REPLACEMENT OF CEMENT WITH RICE HUSK ASH (RHA))

Partial replacement of Cement with RHA (%)	3 Days	7 Days	14 Days	28 Days	56 Days	90 days	Reference
6	1	1.281	-	2.124	3.563	-	[29]
12	0.863	1.014	-	1.275	3.049	-	
18	0.884	0.932	-	1.597	2.844	-	
24	0.836	0.891	-	1.329	2.570	-	
5	-	-	-	4.6	-	-	[32]
10	-	-	-	4.7	-	-	
15	-	-	-	4.8	-	-	
20	-	-	-	4.9	-	-	
25	-	-	-	4.77	-	-	
30	-	-	-	4.6	-	-	

The graphical representation of variation of Compressive Strength when cement is partially replaced with Rice Straw Ash (RSA) and Rice Husk Ash (RHA) is given in Fig. 9. and Fig. 10.

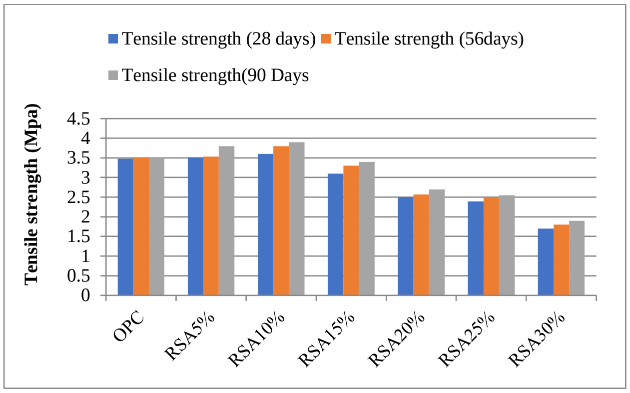

Fig. 9. Variation of Tensile Strength (Mpa) (Partial replacement of cement with Rice Straw Ash (RSA)) [36]

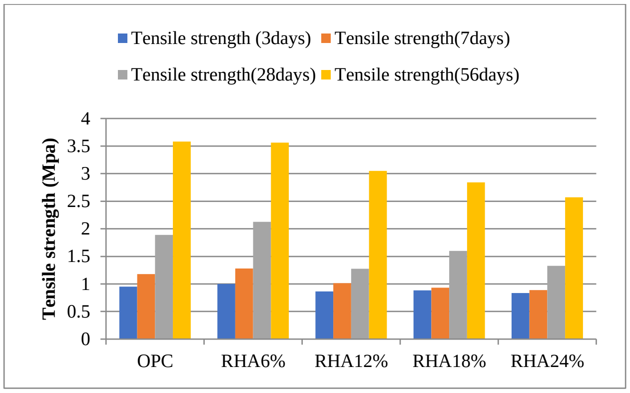

Fig. 10. Variation of Tensile Strength (Mpa) (Partial replacement of cement with Rice Husk Ash (RHA)) [32]

The tensile strength of concrete incorporated with agricultural ash (Rice Straw Ash &Rice Husk Ash) shows a similar trend of increasing at optimum levels and then decreasing for higher values of replacement, as that of compressive strength. The optimum value of the replacement of cement with Rice Husk Ash (RHA) and Rice Straw Ash (RSA) lies between 10%-15% [28], [36] as depicted in the graphs. The tensile strength at early ages is less as compared to the tensile strength at later ages. It also depends on the combustion condition, temperature, and water-binder ratio to a greater extent. It is observed that if the ash is prepared in controlled conditions and a splitting cylinder tensile test is used, it will depend on the water to binder ratio and will give better results under controlled conditions. The methods and time of grinding also affect the tensile strength. The increased surface area of agricultural ash (Rice Straw Ash & Rice Husk Ash) results in more bulk density which will finally enhance the tensile strength of concrete containing Supplementary Cementitious Materials (SCMs).

V. COST OPTIMIZATION OF CONCRETE INCORPORATED WITH SUPPLEMENTARY CEMENTITIOUS MATERIALS (RICE STRAW ASH &RICE HUSK ASH)

The cost of cement in conventional concrete can be optimized by partially replacing cement with Supplementary Cementitious Materials (SCMS) obtained from agricultural industry (Rice Straw ash & Rice Husk Ash). The replacement of cement up to certain replacement levels with Rice Straw Ash and Rice Husk Ash can solve the problem of waste decomposition and carbon dioxide emission. Apart from these two problem's , soil-related problems, and cost of concrete can be reduced by such utilizations. [41] state that the cost efficiency of concrete is increased by 65% by using Rice Husk Ash as a partial replacement of cement. Reference [42] also studied the economic aspects of using Rice Husk Ash (RHA) as a partial replacement of cement and concluded that the cost of concrete was reduced by 12.5%. researchers of [42] also found that such replacements can prove beneficial for low–income communities and to the areas which are closer to agricultural land. Authors of [43] did an experimental investigation to build low-cost housing facilities. It was found that cement is responsible for 42% of the cost of concrete and 7% of this cost of concrete can be saved by using 15% Rice Husk Ash in concrete.

However, the data available on utilization of Rice Straw Ash as a partial replacement of cement also followed the same economic profile as that of Rice Husk Ash. But cost–benefit analysis of concrete incorporated with Rice Straw Ash (RSA) requires proper analysis in order to prove its benefit in terms of cost.

TABLE XII. COMPARISON OF AGRICULTURAL RESIDUAL ASH WITH OTHER SUPPLEMENTARY CEMENTITIOUS MATERIALS (SCMS)

Reference	Supplementary Cementitious Material (SCM) Type	Workability	Mechanical properties	Durability
[44]	Sugarcane ash	Increased	Increased	Increased
[45]	Silica Fume	-	Increased	Increased
[46]	Glass Powder	Slight Variation	Increased	-
[47]	Egg shell	-	Increased	-
[48]	Blastr Furnace Slag	-	-	Increased

VI. FUTURE SCOPE

The optimal use of agricultural ash (Rice Straw Ash & Rice Husk Ash) in concrete needs more exploration.

- There is not much study available on the chemical composition of Rice Straw Ash (RSA). Also the results available for the workability of concrete incorporated with Rice Husk Ash (RHA) show variation so there is a need for further research of the fresh properties of concrete.
- The cost of construction of concrete incorporated with Supplementary Cementitious Materials ((Rice Straw Ash & Rice Husk Ash) needs comparison with the conventional concrete.
- A lookout for the usage of Supplementary Cementitious Materials (Rice Straw Ash & Rice Husk Ash) in making lightweight concrete blocks, ultra-high-performance concrete, and self-compacting concrete also needs to be made.
- The research of Supplementary Cementitious Materials (Rice Straw Ash & Rice Husk Ash) with fiber inclusion and reinforcements also needs exploration so that partial replacement of cement can be beneficial in reinforced cement concrete.

The address of these research gaps would instill confidence in the construction industry to use these crop residues as a partial replacement of cement in concrete in turn providing a sustainable solution to the huge disposal problem posed by them. All these key aspects would come into the limelight if there is enforcement by the government and the center government bodies ensuring the optimum usage of the various types of residues generated from the agricultural sector, especially in the cement industry

VII. CONCLUSION

Rice straw, rice husk and various other by products from agriculture have been regarded essentially as waste materials. The growing environmental concerns and the disposal issue posed by the crop residue sash been the motivation behind this review on the available literature, the research gaps and the future scope of study in this area. This paper revolves around the beneficial usage of the crop residues from the production of rice in the partial replacement of cement in concrete and in turn a detailed study of their composition and characteristic properties of the concrete. It was found that these agriculture-based wastes when treated properly under pre combustion, combustion and post combustion conditions results in the production of ash with good amount of silica and calcium oxide, which are regarded as the basic oxides for pozolanicity of SCM's (RSA&RHA). The reactivity, fineness silica content are the main reasons for the enhancement of properties of conventional concrete. It was noted that the workability of concrete decreased at a constant rate with increase in replacement level of ash whereas the abrupt decrease is also reported by some researchers. On the other hand, the hardened properties of concrete i.e. compressive strength and tensile strength depicted an appreciable increase with the replacement of cement with rice husk ash and rice straw ash. An average increase of 10%-20%was observed as compared to ordinary Portland cement. This usage of the agricultural by products not only helps construction industry by improving the properties but it can also help in reducing the cost of construction and apart from it the problem of waste management is solved. The use of agricultural ash can help to produce green concrete and can give better results than the conventional pozzolanic material.

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