Effective Utilization of Various Industrial Wastes in Concrete for Rigid Pavement Construction – A Literature Review

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Abstract

Industrial wastes disposal is a serious concern to environment and its handling requires special attention and care. The effective utilization of industrial wastes is made well in construction industry as building materials. As a part of this, scope of industrial wastes usage in rigid pavement construction is also studied and analyzed by various scholars and technical experts. Since rigid pavements are most sustainable constructions for transit of people and goods, research in improvement of their quality became essential. Incorporating some of these qualified industrial wastes in their construction not only improves quality but also reduces the disposal problems of industrial wastes. Different industrial wastes are used as different inputs in rigid pavement construction based on their properties, availability and ease of handling. Some wastes such as Fly Ash (F.A), Quarry Dust (Q.D), Silica Fume (S.F), Ceramic Wastes (C.W), Ground Granulated Blast Furnace Slag (G.G.B.S), Steel Slag (S.A), and Rice Husk Ash (R.H.A) etc. find their effective usage in different constructions. This paper gives a review and insight into research made by many scholars in usage of above industrial wastes in different proportions of concrete and understands the changes in their strength parameters. There by assessing their adaptability and incorporation in rigid pavements and other civil constructions.

Keywords: Fly Ash (F.A), Quarry Dust (Q.D), Silica Fume (S.F), Ceramic Wastes (C.W), Ground Granulated Blast furnace Slag (G.G.B.S), Steel Slag (S.S), Rice Husk Ash (R.H.A)

I. INTRODUCTION

Effective usage and proper incorporation of industrial wastes in concrete gives optimum results, for which the knowledge of their properties is essential. The major usage of industrial wastes in rigid pavements is done as partial cement replacement, fine or coarse aggregate replacement. They are often used with or without different types of fibres, chemical admixtures to enhance their performance, properties and workability. Studies are conducted to find out optimum additions of these materials in different grades of concrete mix proportioning to make their practical implementation easy. Not only this the advantages and shortcomings of usage of these industrial wastes can be well known with laboratory investigation so as their usage can be monitored.

Considering all these aspects the following is the detailing of studies conducted on such industrial generated wastes by academicians and scholars.

II. INVESTIGATIONS CARRIED ON DIFFERENT INDUSTRIAL WASTES

As the minimum grade of concrete recommended by IRC 44: 2008 [1] for pavement quality concrete is M30 , some of studies carried on M30 or higher grades of concrete with usage of industrial wastes, their composition, conclusions and recommendations from investigations performed by some of authors currently are mentioned in this review so that their implementation can be analyzed.

A. Fly Ash (F.A):

Fly ash is a solid fine waste generated from thermal power plants. It can also be called as a bi-product of thermal power generation process. About 50-100 tons of fly ash is produced daily from an average thermal power plant. They are collected by electro-static precipitators. Its disposal is a huge problem because of its particle size, it can cause several problems to humans and also plants if not disposed properly, fly ash contains good pozzolanic properties which can enhance strength of concrete, hence to deal with problem of disposal and making use of fly ash its effective usage is found in partial replacement of cement in concrete making. Fly ash is classified into different types based on its Cao content, it can also be used as sand replacement. Results of some of studies conducted on fly ash are discussed below. The chemical constituents of fly ash are shown in below Table.1
Nagesh Tatoba, Suryawanshi Samitinjay S Bhansode et al [2] [2012] studied on fly ash replacement for cement and sand to the extent of 10-30 percent and 5-15 percent for M35 grade of concrete respectively. Because of the use of fly ash, rigid pavement behaves as a semi rigid pavement causing substantial reduction in cost of construction. The study showed the usage of fly ash as a beneficial pavement material, then Vanitha Agarwal, Gupta S.M et.al [3] [2012] experimented on high performance concrete with super plasticizer for M30, M40 and M50 grades of concrete with 30% and 40% fly ash replacements. The tests were conducted to analyzepressive and flexural strengths for 7,28 and 90 days, they concluded from their study that the all mixes with fly ash replacement showed better strengths when compared to design mix and at 30% addition they are getting optimum results, the strength characteristics showed an increasing trend between 28- 90 days curing period. S. Antony Jeteandran, S. Kathirvel [4] [2013] also investigated on durability characteristics of high volume fly ash concrete with and without fibres in comparison with conventional concrete for rigid pavements, the cement was replaced in the mix in proportions of 50%, 60%, 70% and the authors concluded that HFVA attained lesser impact strength and higher alkalinity when compared to design mix, the HFVA mixes are less workable and they also stated that a replacement of 50% suitable for HFVA concrete further S. Pavan, S. Krishna Rao [5] [2014] examined the potential usage of fly ash in roller compacted concrete pavements, a mix was prepares following standards of ACI-211-3R-19 guidelines and fly ash is replaced in that mix in varying proportions of 20%, 40%, and 60%. The compressive, flexural and split tensile strengths of mixes are examined. They concluded that the optimum results were attained for 20% replacement at 28 days and at higher replacement decrease in initial compressive strength and 50% of 28 day compressive strength were noticed later Amit Kumar Ahirwar, Rajesh Joshi et.al [6] [2015] studied the effect of replacement of fly ash in M30 grade of pavement quality concrete in increments of 10% in addition with coconut fibres in different proportions and found that at 30% addition the concrete mix showed optimum results when compared to conventional mix, they also concluded that the slump value decreased with increase in fly ash content

Hence from above studies conducted by scholars it is evident that fly ash is an effective substitute and for cement partially in concrete making and a replacement of 30-50% can be made economically depending upon the working conditions without reduction in desired strength.

**B. Quarry dust (Q.D):**

Quarry dust is a solid waste produced from rock crushing units. It accounts for 20-25% of the output of stone crushing units. Quarry dust is fine in nature, it creates environmental pollution and disposal problems. To tackle this quarry dust can be effectively utilized as partial replacement of cement and fine aggregate in construction of rigid pavements depending upon the particle size and fineness. Sometimes quarry dust is also used as full replacement of fine aggregate. The fine particles in Quarry dust helps in improvement of cohesion of the concrete mix. Studies conducted in this aspect attained positive results which are discussed below. The chemical composition of quarry dust are mentioned in below Table. 2

<table>
<thead>
<tr>
<th>Oxide Composition</th>
<th>SiO2</th>
<th>Al2O3</th>
<th>Fe2O3</th>
<th>CaO</th>
<th>MgO</th>
<th>SO3</th>
<th>K2O</th>
<th>Na2O</th>
<th>L.O.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage (%)</td>
<td>62.48</td>
<td>18.42</td>
<td>6.54</td>
<td>4.83</td>
<td>2.56</td>
<td>1.21</td>
<td>3.18</td>
<td>-</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*Source: Anzad Hamid Mir [12]*
Fig. 2: Quarry dust

R. Illangovana, N. Mahendrana et.al [7] [2008] studied on fully replacing fine aggregate with quarry dust for M20, M30, M40 grades of concrete by using different mix design methods such as IS method, ACI method, USBR method etc. and found that an increase in compressive and flexural strength from 10-15% for full replacement in all methods and also concluded that IS method gave the best results, Venkata Sairam Kumar, N. B. Pandurangarao, Krishna Sai M.L.N et al [8] [2013] have made investigations on partial replacement of cement with quarry dust for studying mechanical properties of concrete. The percentages of quarry dust partial replacement of cement in concrete are 0%, 10%, 15%, 20%, 25%, 30%, 35%, and 40% for M20, M30 and M40 grade concrete. From the experimental studies 25% of partial replacement of cement with quarry dust improved hardened concrete properties. Later A.V.S Sai Kumar, Krishna Rao [9] [2014] studied about the usage of quarry dust as a partial replacement to cement, they experimented on M30 grade of concrete and found its optimum replacement as 25% and later they also experimented with metaoklin. This shows the suitability of quarry dust as an effective cement replacement material also further more Ramarao Chimita, Venkateswara rao .J [10] [2015] investigated on replacement of sand used in rigid pavement construction with locally available rock dust and performed cost benefit analysis, the replacement of sand with rock dust was made up to 70% in increments of 10% for M40 grade of concrete and concluded that 50% replacement is the optimum and the %increase in compressive and flexural strengths are 15.33% and 16.14% when compared to conventional M40 concrete, A. Suri Babu, U. Ranga Raju et.al [11] [2015] also investigated on the usage of quarry dust as replacement to fine aggregate in concrete, they worked on M25 and M40 grades of concrete and found that the compressive and flexural strengths of samples with fine aggregate replacement increased by nearly 10% when compared to conventional concrete.

From above investigations it is clear that quarry dust can be effectively used as a replacement for cement and fine aggregate in concrete and used in rigid pavement construction, which in turn reduces the overall cost of construction of pavement.

C. Silica Fume (S.F):

Silica fume is a good reactive pozzolanic waste material also called as micro silica, it is the bi-product of the ferrosilicon alloy production. It is very fine in particle size and rich in silica content, researches showed significant improvement in strength of concrete by utilizing silica fume in its production. It can reduce permeability and thereby reducing corrosion. The fineness of silica fume adds to the improved strength of concrete. Silica fume can be used as an individual replacement or with combination of other pozzolanic materials in different proportions. Thus the effective utilization of silica fume in rigid pavement concrete not only improves the durability of pavements but also reduces environmental pollution problems. The composition of silica fume is shown below in Table. 3

Fig 3: Silica Fume

<table>
<thead>
<tr>
<th>Oxide Composition</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>SO₃</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>L.O.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage (%)</td>
<td>78.50</td>
<td>1.22</td>
<td>1.27</td>
<td>2.13</td>
<td>5.32</td>
<td>0.15</td>
<td>4.11</td>
<td>1.78</td>
<td>4.93</td>
</tr>
</tbody>
</table>

*Source: Yilmiz Kozak [18]
K. Perumal, R. Sundara Rajan [13] [2004] investigated on effects of partial replacement of silica fume with cement in high performance cement of grades M60, M70 and M110. The replacements of silica fume was done in proportions of (0, 2.5, 5, 7.5, 10, 12.5 and 15%) by weight of cement respectively and concluded that 10% replacement showed optimum results for all high performance mixes. Samples with silica fume replacement also showed high acid resistance, sea water resistance, abrasion resistance and impact resistance there by improving durability of mixes. Pawde Prasanth Y. Nagar Naik P.B et.al [14] [2010] studied on effect of silica fume on M30 grade of concrete as a partial replacement of cement with varying proportions of (0, 4, 8, 12%) by weight of cement and checked the compressive and flexural characteristics of samples. It was found that the addition of silica fume to the mix from 8-12% did not bring any significant changes in strength parameters and authors concluded that the optimum amount of replacement is 8% later steel fibres were also used in the investigation. Further N.K. Amrudhavalli, Jeena Mathew [15] [2012] studied on effect of cement replacement with silica fume in proportions of (0, 5, 10, 15, 20%) for M35 grade of concrete and concluded that optimum results were attained between 10-15% replacement and they also stated that the weight loss and reduction in compressive strength for acid attack test reduced by 2.23% and 7.69% for 10% replacement of silica fume, Magudeaswara P, Eswaramoorthy P [16] (2013) studied the effects of partial replacement of cement with silica fume and fly ash for high performance concrete of M60 grade. They replaced silica fume and fly ash in proportions of (0, 5, 10, 15, 25, and 30%) and (0, 2.5, 5, 7.5, 10, 12.5%) in combinations they concluded that for (10%F.A+5%S.F) combination compressive strength increased by 13.9% and (15%F.A+7.5%S.F) split tensile and flexural strengths increased by 12.5 and 16 % respectively when compared to design mix. Then R. L. Ramesh, Nagaraja, P. S, [17] (2015) investigated on compressive strength characteristics of high strength M 70 grade concrete by usage of silica fume and high reactive metaoklin in varying proportions with and without addition of steel fibres and found that strength of silica fume concrete increased by 23.6% when compared to conventional concrete.

From the investigations carried out it is concluded that the inclusion of silica fume in concrete improves its micro structure and enhances the strength properties when compared to conventional concrete and it can replace cement from 10-15% by weight successfully without losing the desired strength characteristics of the mix and even providing better strength and durability.

D. Ceramic Waste (C.W)

With growth of industrial and housing needs the ceramic production in the country also increased vastly from past 10-20 years these industries produce a huge amount of ceramic waste in the form of broken ceramic materials and polishing wastes, the fine waste produced by these industries are settled down and dumped which is causing a heavy dirt pollution, the effective utilization of these wastes can be made in concrete making for rigid pavements. As these wastes are rich in pozzolanic properties their addition will enhance the strength of constructions and also saves economy of construction. Ceramic tile wastes such as broken tiles and from other sources like sanitary wastes, electric insulation wastes can be graded and used as partial coarse aggregate replacement. Studies conducted in above aspects are mentioned below. The composition of Ceramic waste are shown in below Table. 4

![Fig. 4: Ceramic Waste](image)

**Table – 4**

<table>
<thead>
<tr>
<th>Oxide Composition</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>SO₂</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>L.O.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage (%)</td>
<td>63.29</td>
<td>18.29</td>
<td>4.32</td>
<td>4.46</td>
<td>0.72</td>
<td>0.10</td>
<td>2.18</td>
<td>0.75</td>
<td>1.61</td>
</tr>
</tbody>
</table>

*Source: Amit Kumar D. Raval, Indrajit N Patel et.al [24]

Electricwala Fatima Ankit Jhamb Rakesh Kumar et al [19] [2013] have done experimental studies on concrete (M35) was made by replacing up to 30% of cement with ceramic dust which showed an increment in compressive strength, flexural strength. The results show that compressive strength increase by 3.9% to 5.6% by replacing 20% cement content with ceramic dust. It was observed that no significant change in flexural strength when compared to the conventional concrete, Amit Kumar D. Raval, Indrajit N. Patel, Jayesh Kumar Pitroda [20] [2013] studied on economical and ecofriendly usage of ceramic industry waste in concrete making he added ceramic waste to M30 grade of concrete in increments of 10 % and concluded that up to 30% addition optimum results were attained without disturbing fresh and hardened properties of concrete, later B. Krishna Rao,
Manthena Srilakshmi [21] [2013] investigated on tile dust as a replacement to cement for M30 grade of cement in increasing proportions of 10% up to 50% and the development of compressive flexural and split tensile strengths of samples were observed for 7, 28 and 56 days. The authors concluded from their study that optimum results are attained between 10-20% replacement and replacement can be done up to 30% feasibly without much loss in strength characteristics. Jagnnathan Sravanan, G. Srinivasan et.al [22] [2014] investigated on partial replacement of Ceramic aggregate as coarse aggregate and foundry sand as fine aggregate for M30 grade of concrete in proportions of 15%, 20% and 30% samples were casted and tested for compression, flexural and split tensile strengths for 28 days and concluded that a replacement of coarse aggregate with ceramic aggregate can be done up to 20% without affecting design strength, further more Ponnapati Manogna, M. Sri Lakshmi [23] [2015] studied experimentally about the atrial replacement of cement by tile waste in M30 grade of concrete in increments of 10% up to 50% and compressive, tensile and flexural strength tests were conducted for 7, 28 and 56 days respectively and concluded that a replacement up to 30% can be made without compromising the design strength and optimum results for compression flexure and tension were attained at 10% replacement.

The above studies conclude that the ceramic waste usage in concrete making can effectively increase the properties of concrete, reduce cost of construction and reduce problems of waste disposal. Considering all these factors ceramic waste admixed concrete can be used in rigid pavement construction also. It can be concluded that fine ceramic waste as cement replacement can be used from 20-30% without compromising strength. When used as coarse aggregate based on the availability replacement can be done up to 20%.

E.  *Ground Granulated Blast Furnace Slag (G.G.B.S):*

G.G.B.S is a fine material produced from the slag residue of blast furnace of iron making. During the production of iron and steel large amount of slag is attained this slag is converted to coarse Granulated Blast Furnace Slag (G.B.S) by spraying water jet at high velocities on molten slag, later this G.B.S is ground finely to produce G.G.B.S. Granulated blast furnace slag can be used as a partial replacement of fine aggregate and G.G.B.S is effectively implemented as partial cement replacement in concrete making. Addition of G.G.B.S as partial replacement of cement in concrete making imparts chemical resistance, corrosion resistance and high strength to the mix. The waste slag produced is dumped in the production plants which can be used effectively as a pavement construction material. Some of studies conducted in that aspect is mentioned below. The composition of G.G.B.S is shown below in Table. 5

<table>
<thead>
<tr>
<th>Oxide Composition</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>SO₃</th>
<th>K₂O</th>
<th>Na₂O</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage (%)</td>
<td>34.06</td>
<td>18.8</td>
<td>0.7</td>
<td>32.4</td>
<td>10.75</td>
<td>0.85</td>
<td>0.98</td>
<td>0.31</td>
<td>0.65</td>
</tr>
</tbody>
</table>

*Source: Venu Malagavelli, P.N. Rao et.al [25]*

Venu Malagavelli, P.N. Rao et.al [25] [2010] studied the characteristics of high performance concrete by replacing cement with G.G.B.S and fine aggregate with robo sand. Cubes and cylinder samples were casted for compression and tensile testing. G.G.B.S was replaced from 40-60% and robo sand from 0-30% in 5% increments for M30 grade of concrete and concluded that the replacement of G.G.B.S and robo sand at proportion of 25% and 50% for fine aggregate and cement gave optimum results. Abhinav. S. Pawar, K. R. Dhabekar [26] [2014] studied the behavior of rigid pavement (concrete) which occurs when cementing waste material (G.G.B.S) and steel fibres are added and to compare with normal concrete of M40 grade. G.G.B.S replacement ratios (10%, 20%, 30%, 40% and 50%). The comparison between normal concrete, G.G.B.S concrete and with steel fibre concrete was made. Optimum results were found at addition of 30% G.G.B.S and 1% steel fibres to the mix. Later Ranjith, M. Amritha. E.K [27] [2015] experimented on replacement of cement with G.G.B.S and fine aggregate with G.B.S for M30 grade of concrete and examined the compressive, flexural and split tensile strengths of mixes to know the optimum amount of addition, G.G.B.S and G.B.S were replaced in proportions of 20, 25, 30% and 25, 50, 75% in the mix respectively. The authors concluded that addition of 25% G.G.B.S gave the optimum results and recommended its usage then it was followed by Christina Mary V, Kishore C.H [28] [2015] experimented on replacement of cement with G.G.B.S for M40 grade of cement in increments of 10% up to 50% with 50% constant replacement of fine aggregate with M sand and investigated on various strength and durability characteristics. The authors concluded from his study that for replacement of (10%S.F+50%M sand) the compressive strength
and tensile strength increased considerably when compared to design mix also this mix resisted chloride attack and reduction in compressive strength because of acid attack better than other mixes however flexural strength showed an increase for mix with (30%S.F+50%M sand) replacement further A. Krishna Moorthy, R. Ashwini [29] [2015] studied on properties of M30 grade of concrete in which cement is partially replaced by G.G.B.S in increments of 10% up to 50% and fine aggregate is fully replaced by quarry dust and concluded that at 50% replacement of G.G.B.S the mix attained maximum compressive strength and corrosion resistance.

By above studies a G.G.B.S can be stated as an effective supplementary cementitious material for construction of civil engineering structures with better and enhanced properties. Apart from above mentioned studies there are also numerous other researches going on in this aspect, from the above it can be concluded that replacement of cement with G.G.B.S can be done up to 50% by weight of cement. Optimum addition can be attained from 30-40% addition depending upon the mix and working conditions.

**F. Steel Slag (S.S):**

Steel slag is an outcome of steel manufacturing process, it is attained as a residue from the electric furnace where the ore is heated. It is not easily disposable hence causing several problems related to disposal and handling. Steel slag can be used as fine aggregate and coarse aggregate in concrete making based on particle size, availability. Because of the properties of steel slag it is highly recommended for usage as aggregate in concrete making, some such studies conducted on usage of steel slag as fine and coarse aggregate are mentioned below. The composition of steel slag is given in table 6.

<table>
<thead>
<tr>
<th>Oxide Composition</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>P₂O₅</th>
<th>S</th>
<th>MnO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage (%)</td>
<td>12.1</td>
<td>6.8</td>
<td>29.5</td>
<td>22.8</td>
<td>4.8</td>
<td>0.3</td>
<td>0.2</td>
<td>7.9</td>
</tr>
</tbody>
</table>

*Source: Nippon Slag Association [35]

N. Sumi, R. Malathy [30] [2013] investigated on usage of steel slag as fine aggregate replacement for M40 grade concrete along with 30% constant fly ash replaced cement, the replacement was done in incremental proportions of 10% and optimum replacement was found at 40% where the compressive strength and flexural strength values showed an increment more than values recommended by IRC 58-2002 [6], they also conclude that a cost reduction of 15% was achieved which makes usage of steel slag a cost effective measure, Praveen Mathew, Leni Stephen et.al [31] [2013] studied experimentally on natural coarse aggregate replaced with steel slag aggregate in incremental proportions of 20% up to 100% for M40 grade of concrete, compressive, flexural and split tensile strengths were evaluated for these replacements and compared with conventional concrete and the authors concluded that optimum values of compression, flexural and split tensile strengths attained at 20% replacement of aggregate. Then M.H. Lungaria, Gatesi Jean De Dieu [32] [2015] investigated on the effects of replacement of natural coarse aggregate with steel slag aggregate in M40 grade of concrete in incremental proportions of 10% up to 40%. The authors concluded that increase in steel slag replacement increased the slump value, the compressive strength increased up to 30% replacement and split tensile strength of mix increased up to 40% replacement, P. Murthy, S. Alan, C. Chakravarthy [33] [2015] studied the replacement of natural coarse aggregate with steel slag aggregate for M30 and M20 grades of concrete. The replacement done was 50% in both the cases. Along with steel slag replacement fly ash is also replaced partially in place of cement, ultra-sonic pulse velocity testing was done on samples, carbonation depth is determined and compressive strength is assessed and the authors concluded that mix having (50% steel slag+ 30% fly ash + 20% OPC) gave the optimum results and recommended usage of steel slag as coarse aggregate. Rahat Gul Ziramal, Rena N Shukla [34] [2016] investigated on the replacement of natural 20mm coarse aggregate with steel slag aggregate and cement with fly ash for M30 grade of concrete, mixes were prepared for various replacements of them with fly ash ranging from 0-25% in increments of 5% and steel slag ranging from 0-50% in increments of 10% and the author made the following conclusions, addition of steel slag and fly ash improved the properties of concrete and optimum results are attained at (15%fly ash+ 30% steel slag ) replacement.

From the above studies it can be concluded that steel slag can be used effectively as a replacement to natural coarse aggregate, the physical and mechanical properties of steel slag enhances the concrete strength. This in turn reduces environmental problems.
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and achieves sustainability. It can also be concluded that 20-30% of replacement of natural coarse aggregate with steel slag aggregate is beneficial structurally and economically.

**G. Rice Husk Ash (R.H.A):**

Rice husk is the waste produced from the rice milling industry, after the paddy is milled the husk is produced as waste. The husk is burnt for the production of steam in milling industries resulting in formation of rice husk ash. It is a good pozzolanic material, its particle size ranges between 4-7µ in India where agriculture is the main occupation and paddy production is high the generation of rice husk ash is also high, this ash can be used and adapted in concrete making as partial cement replacement to attain sustainable mixes, there by its effective utilization can be done, the studies conducted in that area are discussed below. The composition of R.H.A is shown below in Table. 7

<table>
<thead>
<tr>
<th>Oxide Composition</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>K₂O</th>
<th>Na₂O₃</th>
<th>L.O.I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage (%)</td>
<td>88.32</td>
<td>0.46</td>
<td>0.67</td>
<td>0.67</td>
<td>0.44</td>
<td>2.91</td>
<td>0.12</td>
<td>5.81</td>
</tr>
</tbody>
</table>

*Source: Habeeb, Ghassan Abood, & Mahmud, Hilmi bin [41]*

Fig. 8: Rice Husk Ash

Ramakrishnan. S, Velraj Kumar. G et.al [36] [2014] experimentally investigated on the replacement of cement partially with rice husk ash in proportions of (0, 5, 10, 15, 20, 25%) for M40 grade of concrete. the variations in various strength parameters for the replacements are studied. The authors stated that there is a reduction in compressive, flexural and tensile strengths with increase in rice husk ash addition, the porosity and impact strength also decreased with increase in rice husk ash addition above 10% hence it is concluded that a replacement of 5-10% is optimum. Followed by Jiendar Kumar, Varinder Singh et.al [37] [2015] also investigated on effects of fly ash and rice husk ash on pavement quality M40 grade concrete as a partial cement replacement individually and in combination, flexural and compressive strengths were conducted on samples with R.H.A replacements of 10%, 20% and 30% individually and 10%, 10%, 20% replacement for 10%, 20%, 10% fly ash replacement combination and it was observed that individual replacement of R.H.A does not have any significant impact on compressive and flexural strengths when compared to conventional mix but at 10% replacement with 0.30% w/c showed higher strength than other R.H.A mixes and author concluded which is in par with MoRT&H standards, then Rohit Siwach, S.S Kajal et.al [38] [2015] studied on partial replacement of cement with rice husk ash and fly ash in pavement quality concrete individually and in combination, rice husk ash is replaced with cement in proportions of 10%, 20%, 30% individually and 10%, 10%, 20% replacement for 10%, 20%, 10% fly ash replacement combination. Tests were conducted to analyse compressive and flexural strengths. It was concluded from study that the mixes with only rice husk ash did not achieve desired strength for pavement quality concrete (M40) for any % of addition, although 10% addition showed a compressive strength of 32.44 for 28 days it is less than the target strength. Hence the suitability of rice husk ash replacements for high strength mixes should be checked. Mahesh Bhai Prajapathi, Jayesh Kumar Pitroda [39] [2016] studied on partial replacement of cement with rice husk ash along with steel fibre in M30 grade of concrete. The replacement of rice husk ash is done in proportions of 10%, 15% and 20% with 2% steel fibres, the study is done for rice husk replacement with two different types of steel fibres. There in an increasing trend in compressive strength up to 15% addition and then followed a downward trend. The optimum results attained at (15% Rice husk ash+2% Steel fibers (both types) mix proportion. Furthermore M.M. Sravanan, M. Sivaraja [40] [2016] investigated on partial replacement of cement in M40 grade of concrete with rice husk ash in incremental proportions of 10% up to 30% along with 0.5% basalt fibre to improve split tensile strength characteristics. Tests were conducted to assess split tensile strengths and it was concluded that 10% addition of rice husk ash with 5%basalt fibre resulted in increase of split tensile strength when compared to conventional concrete.

From the above studies it can said that R.H.A can be used as an effective partial replacement to cement in concrete which saves economy, at lower grades the replacement is more efficient when compared to higher grades and attained good results. A replacement of 10-15% is suggested from studies for optimum results.
III. SCOPE OF USAGE OF OTHER INDUSTRIAL WASTES

Above mentioned are materials on which prominent and significant researches are conducted in past and going on in present also apart from them there are also different new types of industrial wastes on which there is only a few studies are carried out, materials such as coconut shells, rubber scrap, recycled concrete aggregates, plastic wastes, waste tins, lagoon ash, sugar cane bagasse ash, cement kiln dust, marble dust, metaoklin, granulated blast furnace slag, paper industry sludge, bottom ash, pond ash, glass powder, foundry sand etc. should also be experimented and investigated to find their usage potential in concrete making, not only this combination of wastes and inclusion with fibres can also be experimented to attain improved results there by reducing constructional costs of rigid pavements, reducing problems related to industrial wastes resulting in innovative and sustainable pavement construction.

IV. CONCLUSIONS

The following conclusions can be drawn based on review of above mentioned studies
1) Based on investigations on cement replacement with fly ash a replacement within a range of 30-50% gave optimum results for different mixes, cement replacement with fly ash is recommended for high strength concrete mixes also
2) The usage of quarry dust and relative stone dust material proved beneficial usage for 20-25% replacement for different grades based on above studies, but when used as fine aggregate replacement studies showed that it can be replaced fully also depending upon availability but optimum replacement ranges from 40-50% replacement.
3) A partial replacement of cement with silica fume can be done up to 10-15% for attaining satisfactory results. Further addition of fibers could enhance is strength
4) Experimental investigation on partial cement replacement of cement with fine ceramic waste can be done from 20-30% without compromising design strength, when used as coarse aggregate a replacement level of up to 20% is suggested
5) Cement can be replaced with G.G.B.S in concrete up to 50% without considerable change in strength parameters as suggested from above studies, the optimum results can be attained at 30-40% replacement levels.
6) Replacement of natural coarse aggregate enhances the properties of hardened concrete as per above mentioned studies and a replacement range of 20-30% is suggested.
7) The partial replacement of cement with rice husk ash in concrete can be done within range of 10-15% as per studies for attaining better results, the rice husk ash replacement is not recommended for high strength concretes as it is not highly effective.
8) Laboratory investigations on more such types of new and innovative materials usage in concrete making should be encouraged to achieve the goal of sustainable pavements construction
9) The utilization of these industrial wastes in rigid pavements are thus recommended in above proportions for usage considering the studies conducted by above mentioned authors, although there may be possible changes based on working conditions, quality of materials used and various of other such factors.
10) The usage of these wastes in pavement construction helps in reducing environmental disposal issues and there by leading to sustainable construction

REFERENCES


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