International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 1 ǁ 2022 ǁ PP. 05-09

Effectively Used Industrial Waste As Fine Aggregate In Concrete: A Review

S.Raja[1] and B.Vidivelli[2]
[1] *Research Scholar, Department of Civil and Structural Engineering, Annamalai University, Chidambaram, Tamilnadu.*
[2] *Professor, Department of Civil and Structural Engineering, Annamalai University, Chidambaram, Tamilnadu*

Abstract
This study was conducted on industrial waste materials in concrete with partial replacement of fine aggregate. Waste management compensates for the shortage of natural resources and seeks new methods to preserve nature. Different variety of industrial wastes is used to replace the fine aggregate in whole or in part. This review provides a detailed assessment of industrial waste compounds, which can be properly used as a fine aggregate replacement in concrete. This review paper analysed some of such industrial waste as steel slag, copper slag, bottom ash, imperial smelting furnace slag (ISF slag), and blast furnace slag.
***Keywords**: Industrial waste, Steel slag, Copper slag, Bottom ash, Imperial smelting furnace slag (ISF slag), Blast furnace slag*

Date of Submission: 21-12-2021 Date of acceptance: 04-01-2022

I. Introduction

India produces an estimated 450 million cubic meters of concrete per annum, which is approximately 1 ton per Indian. In practical terms, aggregates are the essential constituents. They offer the concrete bodies. Also, some developed countries have experienced some strain in providing aggregates in both fine and coarse form due to the rapid growth of industrialisation. Using more and more environmentally friendly materials and industrial waste in any industry, particularly in the construction sector, is of paramount importance. sustainable construction is a reduction of the negative environmental effects produced by the building industry. Enormous studies have been conducted on natural resource protection, finding a solution to the problem of disposal, and reducing construction costs by using the waste material.

II. Literature reviews

Devi and Gnanavel (2014) concluded that concrete with partial replacement of fine aggregate by steel slag increased Compressvie, Tensile and Flexural strength and also displays hydrochloric acid (HCL) impermeability rather than sulphuric acid (H2SO4) impermeability.

Al-Jabri et al (2009 a, b, 2011) considered the effect of using copper slag as a sand substitute on high-strength concrete properties and some of the concrete properties such as physical, chemical, workability and mechanical properties

Singh and Siddique (2014) investigated that bottom ash concrete has greater dimensional durability, greater chloride particle penetration impermeability, and a sulphuric acid attack compared to conventional concrete.

Tripathi et al (2013) evaluated the ability of imperial smelting furnace (ISF) slag in concrete as a fine aggregate, taking into account the presence of toxic components (lead and zinc) and their adverse effect on cement hydration.

In their research work, Yuksel et al (2006, 2007) concentrate on the use of non-ground GBF slag in concrete as a substitute for sand. GBF Slag, which is obtained in the manufacture of pig iron from rapidly water-cooled slag from the blast furnace, was used effectively in concrete mixtures due to the lime content. The industrial wastes are Steel slag, Copper slag, Bottom ash, and Blast furnace slag as shown in figure 1.

A) Steel slag

B) Copper slag

C) Bottom ash

D) Blast furnace slag

Figure 1: Industrial wastes

III. RESULT AND DISCUSSION

The results of reviewed papers discussed are below.

1. Hardened concrete properties

1.1.1 Compressive strength

Devi and Gnanavel (2014) recorded a 27.04% rise in concrete compressive strength in which fine aggregate was replaced by 40% steel slag.

Al-Jabri et al (2009) reported that the concrete's compressive strength is slightly higher as the replacement of copper slag increases by up to 50% after the compressive strength decreased especially due to an increase in the free water exceeding the hydration requirement for cement paste. Al-Jabri et al (2009) the same researcher also performed the test by following a fixed slump in the concrete by reducing the water content as the amount of copper slag substituted increased. The highest compressive strength was reached in the 28-day concrete mix with 100% copper slag replacement which was 107.4 N / mm2 while the compressive strength for the reference concrete was 88.1 N / mm2. This indicates that the compressive strength of concrete in which the fixed slump was holding has been increased by about 22% (Al-Jabri et al., 2009).

Singh and Siddique (2014) reported that BA concrete's compressive strength of seven days decreased with the rise in the replacement stage. The compressive strength of the BA concrete mixture increased at a faster rate with the advancement of age. Bottom ash concrete mixtures achieved compressive strength at 28 days of curing, equivalent to that of concrete mixture power. At 90 days of curing, the compressive strength of bottom ash was replaced by 20%, 30%, 40%, 50%, 75% in concrete mixtures was 5.27%, 12.29%, 6.30%, 6.93%, 2.67% and 2.06% respectively, higher than that of concrete control. At 365 days of healing, bottom ash concrete mixtures with 20%, 30%, 40%, 50%, 75% replaced level gained compressive strength 33.69 %, 31.69%, 35.87%, 31.84%, 37.04% and 37.96 % respectively over their compressive strength of 28 days compared to 30.02 % gained by concrete control.

Tripathi et al (2013) stated that the compressive strength of the W.C 0.55, 0.50, 0.45 and 0.40 reference control concrete was 41.70, 43.83, 45.77 and 48.20 N / mm2 respectively. For an increase in ISF slag, compressive strength decreased for elevated W.C ratio 0.55, although this decrease was not important for sand replacements up to 60 %. The strength of ISF slag concrete mixes with a W.C ratio of 0.45 was comparable to the control mix, while the strength of the ISF slag concrete 0.40

W. Yuksel et al (2006) stated that when the replacement rate increases, the compressive strength of blast furnace slag concrete diminishes. They achieved the control mix's compressive strength of 15.47 MPa and 14.83

MPa at 25 %, 12.24 MPa at 50 %, 10.92 MPa at 75 %, 9.66 MPa at 100 % by using blast furnace slag in the concrete ratio was approximately 5–16 percent higher than the reference mix.

1.1.2 Splitting tensile strength

The strength of the splitting tensile is a well-known derivative test used for determining concrete's tensile strength. Tensile strength is perhaps concrete's most important basic properties.

Devi and Gnanavel (2014) found control mix split tensile strength to be 2.26 MPa, and 2.47 MPa for concrete mix in which fine aggregate was replaced by 40% steel slag, 9.29% higher than the control mix.

Al-Jabri et al (2009) found higher splitting tensile strength 6.2 MPa, 6.1 MPa and 6.1 MPa in the concrete mix where fine aggregates were replaced by 20%, 40%, and 50% with copper slag and found lower splitting tensile strength 5.2 MPa, 4.8 MPa, 4.7 MPa, 4.4 MPa in the concrete mix where fine aggregates were replaced by 10%, 60%, 80%, 100%, respectively. Al-Jabri et al (2011) recorded an improvement in split tensile strength with up to 80 % inclusion of copper slag in the concrete mix. Reference nix slicing tensile strength was 3.0 MPa and 3.5 MPa, 3.7 MPa, 3.8 MPa, 4.1 MPa 3.6 MPa, 3.6 MPa in concrete mix where fine aggregates were replaced by 10%, 20%, 40%, 50%, 60%, 80% copper slag respectively.

Yuksel and Genc (2007) observed that the strength of the split tensile decreases as the rate increases for replacements of the granulated blast furnace slag and no distinction in the strength of the split tensile was observed up to 10 percent. For the replacement of granulated blast furnace slag up to 30%, the decrease in the power of the split tensile is 12%.

1.1.3 Flexural strength

Devi and Gnanavel (2014) found that the flexural strength was 74.2 % higher than the reference mix for 28 days curing for 40 % fine aggregate substituting by steel slag.

Al-Jabri et al (2009) reported that with an improvement in the copper slag substitution ratio in concrete, flexural strength decreases. They found that the control mix's flexural strength was 14.6 MPa and 13.0 MPa, 12.4 MPa, 12.5 MPa, 12.9 MPa, 11.1 MPa 10.3 MPa, 10.1 MPa in concrete mix where fine aggregates were replaced by 10%, 20 % , 40%, 50%, 60%, 80%, 100% respectively. Al-Jabri et al (2011) have obtained similar findings, which decreased flexural strength with improved concrete copper slag replacement ratio.

Tripathi et al (2013) chose four water cement ratios (0.55, 0.50, 0.45, and 0.40) to test concrete flexural strength, where ISF slag was integrated as sand. The flexural strength of all concrete mix up to 60 percent ISF slag was comparable with or slightly higher than the strength of the reference concrete at all water cement ratio, above 60 percent substitution, the flexural strength of ISFS mixtures falls at all water cement ratio in all healing ages.

Yuksel et al (2006) developed two types of concrete mixtures where 0–7 mm of sand was used in one concrete mix and 0–3 mm of 0–7 mm of fine aggregates were used in another. The fine aggregate was covered in five amounts by blast furnace slag, which in all categories was 0 %, 25 %, 50 %, 75 %, and 100 %. We concluded that concrete flexural resilience diminishes as the presence of blast furnace slag in concrete decreases. The flexural strength of the concrete mix where 100 % sand was substituted by blast furnace slag is 3.56 MPa relative to the flexural strength of the control mix 5.15 MPa and other flexural strength values as described in Table 4. Yuksel and Genc (2007) found that the flexural strength improved by 10 percent relative to the control mix for the 10 percent blast furnace slag. The ten-sile intensity value is similar to the control test rating for the 20 percent and 50 percent blast furnace slag substitutions.

2. Durability of industrial waste concrete

2.1.1 Water absorption and permeability

Al-Jabri et al (2009) concluded that there is a general decrease in surface water absorption by up to 40 % sand replacement by copper slag, during which the water absorption increases rapidly. We propose that the removal of 40 % copper slag in the concrete mix would reduce the absorption of surface water.

2.1.2 Rapid chloride permeability test

Devi and Gnanavel (2014) recorded that charge in coulombs passed more than traditional concrete in 40 % fine aggregate replacement with steel slag concrete, but remain small. For bottom ash concrete mixtures, Singh and Siddique (2014) observed resistance to chloride ion penetration improved with an increase in the bottom ash content in concrete. The charge passing through all bottom ash concrete mixtures was smaller than that passing through reference specimen at all curing periods. Test findings indicate that tolerance to chloride ion penetration improved dramatically after 28 days of healing age due to pozzolanic activity of coal bottom ash. According to Yuksel et al (2006), the 2016.27, 1319.94, and 1347.03 concrete mix charges going through the concrete samples in RCPT were supplemented by 0%, 25 %, and 50 % fine aggregate granulated blast furnace slag.

2.1.3 Acid resistance

Devi and Gnanavel (2014) performed an experiment on concrete cube acid resistance in both sulphuric acid and hydrochloric acid. By their analysis, as opposed to the control concrete, the weight loss is smaller with the 40% replacement of standard sand by steel slag. By adding steel slag to fine aggregate, the acid resistance is preferable to the concrete of reference. That is attributed to the lack of hydration levels high in sulphuric acid to the point that the weight loss is higher when dipped in sulphuric acid than hydrochloric acid as compared. Once dipped into sulphuric acid, the volume of CSH gel formed by the hydration process would be smaller than when dipped into hydrochloric acid. The exterior coating of the cubes immersed in sulphuric acid was observed to have degraded further than that of the cubes immersed in hydrochloric acid. Concrete being alkaline in nature is susceptible to attack by sulphuric acid formed from either sewage system bacterium processes or atmospheric sulphur dioxide (Singh and Siddique, 2014).

2.1.4 Sulphate resistance

Concrete permeability plays an important role in protecting from external sulphate attacks. Sulphate attack may take the form of expansion, loss of compressive force and loss of concrete mass. Concrete expansion linked to sulphate is consistent with ettringite and gypsum formation (Singh and Siddique, 2014). Since magnesium sulphate attack on concrete is more serious, Singh and Siddique (2014) immersed the concrete specimen in a 10% magnesium sulphate solution and found expansion values (%) of 20 %, 30%, 40 %, 50%, 75% and 100% bottom ash concrete at 28 days of immersion. Mixtures were $53.33X10^6$, $60X10^6$, $66.67X10^6$, $60 X 10^6$, $53.33X10^6$ and $53.33 X10^6$respectively as compared to $50X10^{6}$ of control concrete.

2.1.5 Drying shrinkage

The hardened concrete suffers drying shrinkage in unsaturated soil. This is the passage of water, which allows the hardened concrete to extend or shrink (Yuksel et al., 2006). Shrinkage pressures were decreased with the rise in concrete CBA quality according to Singh and Siddique (2014). At 90 days of the drying period, the shrinkage strains of 20%, 30%, 40%, 50%, 75%, and 100% bottom ash concrete mixtures were 520 10 6, 413.33 10 6, 406.67 10 6, 366.67 10 6, 320 10 6 and 300 10 6, respectively. Where during the same period, shrinkage strain of control concrete was 493.33 10 6. Perhaps due to the lower free water cement ratio was the decreased shrinkage pressure experienced by bottom ash concrete mixtures. During the mixing process, the dry coal bottom ash porous particles retained part of the water internally. This is often assumed that, during the drying of materials, the brittle coal bottom ash particles absorbed the water. This resulted in fewer shrinking pressures on bottom ash aggregate mixtures drying out (Singh and Siddique, 2014).

IV. Conclusion

This paper has examined the use of various industrial wastes as a fine aggregate replacement. All the concrete properties such as soft, new, hardened, have been examined and compared. Micro-structural study of concrete based on toxic waste was also addressed, and contrasted with standard concrete. There are certain industrial wastes that can be used with confidence as a fine aggregate replacement such as steel slag, copper slag, bottom ash, ISF slag, blast furnace slag in concrete. The number of conclusions can be drawn, based on the review, and these are listed below.

1. Physical properties such as bulk density, specific gravity, and grain size distribution of all industrial waste are approximately equal to natural sand properties except that the particle size distribution of steel slag does not follow the grading criteria of ASTM C33 or IS-383–1970.

2.In the case of concrete where fine aggregate is substituted by steel slag slump value decreases by increasing the amount of substitution and concrete blend, in which fine aggregate substituted by copper slag and bottom ash raises the slump value by increasing the replacement ratio. Concrete with granulated blast furnace slag displays an improvement in slump value up to 20 % replacement stage, above which the slump value declines.

3 Inclusion of steel slag, copper slag, and ISF slag in the concrete density of concrete increases but in addition of bottom ash in concrete the density decreases.

4.Using steel slag up to 30% as a sand substitute in concrete mixes has a constructive result on both compressive and tensile strengths; shows better acid resistance than concrete control. RCC beams with steel slag exhibit approximately the same deflection as traditional concrete, so using them in concrete would remove one of the environmental issues generated by the steel industry.

5. It may be concluded from this study that the use of copper slag up to 40% as sand replacements increases strength and toughness characteristics at the same workability and there is a reduction in surface water absorption as copper slag quantity improved up to 40% replacement. Copper slag, an agricultural waste material, allows for the development of ultra-high strength concrete.

6. The study showed that the addition of ISF slag increases the mechanical properties of concrete at a lower water cement ratio and that ISFS-containing abrasion resistant concrete is comparable to standard sand

substitute concrete up to 50 %. Leaching from concrete mixtures of lead and cadmium with 70% ISF slag is within satisfactory limits

7. If granulated blast furnace slag is used as the source for sand replacement, the tensile and compressive strength of concrete are reduced positively. SEM analyses and water absorption experiments found that the replacement concrete was more porous than the control concrete, which may be the primary cause of the decrease in strength with an improvement in GBFS substitution levels.

8. Bottom ash as a fine mixture prompts sufficient toughness properties somewhere near 30 %, and 50% replacement proportions. During analysis of SEM images and XRD spectrum of specimens soaked in 10 % magnesium sulphate solution for up to 180 days, no signs of external sulphate attack were found. Bottom ash concrete mixtures showed better resistance to penetration of chloride ions and attack of external sulphuric acid.

Ultimately, this comprehensive analysis concluded that chemical by-products should be used for renewable quality power, toughness, and environmentally friendly concrete as part of construction developments to the greatest degree.

References

[1]. Devi, V.S., Gnanavel, B.K., 2014. Properties of concrete manufactured using steel slag. Procedia Eng. 97, 95–104

[2]. Al-Jabri, K.S., Hisada, M., Al-Saidy, A.H., Al-Oraimi, S.K., 2009. Performance of high strength concrete made with copper slag as a fine aggregate. Constr. Build. Mater. 23, 2132–2140.

[3]. Al-Jabri, K.S., Hisada, M., Al-Oraimi, S.K., Al-Saidy, A.H., 2009.Copper slag as sand replacement for high performance concrete. Cem.Concr. Compos. 31, 483–488.

[4]. Al-Jabri, K.S., Al-Saidy, A.H., Taha, R., 2011. Effect of copper slag as a fine aggregate on the properties of cement mortars and concrete. Constr. Build. Mater. 25, 933–938

[5]. Singh, M., Siddique, R., 2014. Compressive strength, drying shrinkage and chemical resistance of concrete incorporating coal bottom ash as partial or total replacement of sand. Constr. Build. Mater. 68, 39–48

[6]. Tripathi, B., Misra, A., Chaudhary, S., 2013. Strength and abrasion characteristics of ISF slag concrete. J. Mater. Civ. Eng. 25, 1611–1618

[7]. Yuksel, I., Ozkan, O., Bilir, T., 2006. Use of granulated blast-furnace slag in concrete as fine aggregate. ACI Mater. J., 203–208

[8]. Yuksel, I., Bilir, T., Ozkan, O., 2007. Durability of concrete incorporating non-ground blast furnace slag and bottom ash as fine aggregate. Build. Environ. 42, 2651–2659

[9]. ASTM C 936, 1982. Standard Specification for Solid Concrete Interlocking Paving Units. ASTM International, West Conshohocken.

[10]. ASTM C 33, 1999. Standard Specification for Concrete Aggregates. ASTM International, West Conshohocken.

[11]. ASTM 330, 2004. Standard Specification for Lightweight Aggregates for Structural Concrete. ASTM International, West Conshohocken.

[12]. ASTM C 311, 2013. Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete. ASTM International, West Conshohocken

[13]. BS 882, 1992. Specification for Aggregates from Natural Sources for Concrete. British Standards Institution, UK

[14]. IS 13311(Part 1), 1992. Methods of Non-Destructive Testing of Concrete: Part 1 Ultrasonic Pulse Velocity. Bureau of Indian Standards, New Delhi.

[15]. IS 383, 1970. Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete. Bureau of Indian Standards, New Delhi.

[16]. IS 456, 2000. Plain and Reinforced Concrete Code of Practice. Bureau of Indian Standards, New Delhi