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Effect of Industrial Waste on Strength Properties of Concrete

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ABSTRACT

Industrial wastes generally pumped into water bodies and soil that would pollute the atmosphere. As a control measure, industrial wastes products utilized as waste building materials. In the present research, waste products from various industries like illuminate sludge and glass bottle powder used in different dosages as a replacement for fine aggregate and metakaolin used as a cement replacement. Split tensile strength and compressive strength of the concrete samples examined for M30 grade. Fine aggregate is substituted by glass bottle powder (i.e. 10 to 40%) and illuminate sludge (i.e. 10 to 30%). Metakaolin substituted for cement replacement (i.e. 4 to 12%). Glass bottle does not pollute the atmosphere, but the disposal of waste glass results wastage of land. Thereby glass bottle powder can be utilized as a cement replacement in the construction industry. Then the metakaolin and illuminate sludge are the waste products from the titanium product. The experiment performed to assess the strength properties by incorporating various industrial wastes in different dosages. Physical tests of all three products have carried out according to the code requirements. Three specimens have been tested for each industrial waste products ratio to examine the tensile and compressive strength of concrete at 7th day, 14th day and 28th day and eventually to cure to achieve the optimum strength of concrete. Addition of these industrial wastes into the concrete showed an outstanding improvement in modulus of rupture, split tensile strength and compressive strength at an early and later ages.

1. INTRODUCTION

There are so many forms and quantities of waste produced by various manufacturing industries. These waste products from different sectors will pollute the water, soil and air sources, and eventually end up in the sea. Industrial waste disposal is one of the critical components of the industrial waste management system. Groundwater and land are heavily contaminated by industrial waste and effluents. Many of our waste sources highly contaminated by industrial waste and also affect those people who consume this water. The dumping of industrial waste in the sea also allows it to be unfit for the survival of marine life.

In the current research, illuminate sludge and glass bottle powder incorporated as a fine aggregate replacement, and metakaolin utilized as a cement replacement. This study concerned with the substitution of waste products for various components with different dosages in the concrete to achieve an enhancement in the strength properties of the concrete than reference mix and also with the reduction of environmental pollution.

Anwar [1] investigated properties of M40 grade of concrete with binder substitution by 5%, 10% and 15% to 50% by mass. The optimum strength observed with 10% substitution, and that would enhance modulus of rupture by 7%, tensile strength by 8% and compressive strength by 17%. Glass powder incorporated into concrete as a cement and fine aggregate replacement by Shayan [2]. Glass powder particles ranging from less than 10μ, 4.75 mm to 0.15 mm and 12 mm to 4.75mm utilized as cement, fine and coarse aggregate, respectively. According to his report, fine and coarse aggregate replaced by 50% and cement replacement by 30% glass powder in concrete with an acceptable range of strength [3-9]. Dinakar et al. showed that 10% substitution of metakaolin gives the maximum split tensile strength and compressive strength to produce high performance and high strength concrete [10]. Replacement of cement with 5%, 10%, 15% and 20% metakaolin reported by Dr. Felixkala and Narmatha [11]. From their research, increased metakaolin quantity enhanced tensile and compressive strength by up to 15% cement substitution [11]. According to Ligoria and Balakrishnan, cupola slag used for fine as well as coarse aggregate replacement with 15% on M25 and M20 grade of concrete, the results showed maximum compressive strength [12].

Therefore, in this study, the effect of illuminate sludge and glass bottle powder as fine aggregate substitution and metakaolin as cement replacement on strength properties of concrete will be investigated.

2. MATERIALS

2.1 Cement

53 grades of ordinary Portland cement have been used in the current research. Cement is usually glue or binding agent of the concrete, which not only binds all the various concrete

components together but also give strength to the concrete. Table 1 shows the physical properties of cement.

Table 1. Physical properties of cement

Parameter	Obtained results
Final setting time	350 minutes
Initial setting time	148 minutes
Specific gravity	3.13
Fineness of cement	4.35%
Consistency	30%

2.2 Coarse aggregate

Crushed granite was used as coarse aggregate in this study. The coarse aggregate was free from impurities. The maximum size of the coarse aggregate was 12 mm, and its specific gravity is 2.64 and satisfying the BIS 383-1970 requirements [13]. Physical properties of coarse aggregate are shown in Table 2.

Table 2. Physical properties of coarse aggregate

Parameters	Obtained Results
Water absorption	0.49%
Specific Gravity	2.68
Fineness modulus	2.59
Impact	30

2.3 Fine aggregate

In the present research, river sand utilized as fine aggregate and it should be free from organic matter, hard and clean for the better-quality concrete mix. Table 3 shows the physical characteristics of fine aggregate.

Table 3. Physical characteristics of fine aggregate

Parameter	Obtained results
Specific gravity	2.7
Fineness modulus	2.8

2.4 Water

Water is essential for the hydration process in the cement concrete. Topwater is used for the production of concrete and pH value of the water is observed to be 6.9 that indicate the water is free from the organic matters.

2.5 Glass bottles

Waste glass bottle from the beverage industry has been obtained from the roadside. Glass bottles are cleaned and crushed into small size comparable to zone II sand grading after drying. Crushed particles sieved with the help of IS sieve of size 4.75 mm and 150µ is used for this research. Physical characteristics of glass bottles powder are shown in Table 4. Physical appearance of glass bottle powder is shown in Figure 1.

Table 4. Physical characteristics of waste glass bottle powder

Parameter	Value
Fineness modulus	3.4
Specific gravity	3.7

Figure 1. Glass Bottle powder

2.6 Metakaolin

Metakaolin is one of the materials which is Pozzolanic in nature. It can be used as a cement substitution in the production of concrete. The metakaolin of size less than 75µ is used in the current research. The physical properties and appearance of metakaolin are shown in Table 5 and Figure 2, respectively.

Table 5. Physical properties of metakaolin

Parameter	Value
Normal consistency	28
Specific gravity	2.2

Figure 2. Metakaolin

2.7 Illuminate sludge

Illuminate sludge is a by-product in the production of titanium dioxide. Illuminate sludge is dried under the sunlight. It has been sieved through IS sieve of the size of 75µ. Physical appearance and characteristics of illuminate sludge are shown in Figure 3 and Table 6, respectively.

Table 6. Physical properties of Illuminate sludge

Parameter	Obtained results
% Bulking	12%
Water absorption	24%
Initial setting time	140 minutes
Fineness modulus	3.01
Normal consistency	31
Specific gravity	4.1

Figure 3. Illuminate sludge powder

3. METHODOLOGY

Materials are expected to be gathered and checked as recommended by The IS. Fineness modulus, water absorption, impact and specific gravity tests have been carried out in coarse and fine aggregate according to IS 2386-1963 [14] and obtained test values are within the permissible limits. Physical properties tests on cement-like final and initial setting time, fineness, specific gravity and consistency have been performed as per IS: 4031 – 1988. Illuminate sludge and glass bottle powder was incorporated to concrete by partially substituting fine aggregate in 10%, 20%, 30% and 10%, 20%, 30%, 40%, respectively. Cement is partially replaced by metakaolin with a dosage of 4%, 8% and 12%. Tensile strength and compressive strength of concrete specimens have been tested at 7th, 14th and 28th day to know the variation in strength parameters incorporating industrial waste products.

4. MIX PROPORTION

A concrete mix of M30 grade (1:1.9:34) with 0.45 water to cement ratio has been designed according to the IS 456-200 [15] and IS 10262-1982 specifications [16].

5. FABRICATION OF CONCRETE SPECIMENS

For the right mixing, adequate monitoring has been performed. The compressive strength test has been performed on cube samples of size 150 mm and cylindrical samples of size 300 mm long and 150 mm diameter was used to assess the tensile strength of concrete. Twenty-four hours is reserved for the setting of concrete in the mould in a levelled surface. After 24 hours, concrete samples are shifted from steel mould to curing tank for 7 days, 14 days and 28 days.

6. TESTING

Cylindrical and cube samples were tested to examine tensile strength and compressive strength, respectively. Tensile strength and compressive strength have been performed on compression testing machine of 3000 kN capacity with a rate of loading 2.5kN/s was adopted which is nearly equivalent to 140 kg/cm^2/minutes as stated in IS: 516 – 1959 [17].

7. RESULTS AND DISCUSSION

7.1 Compressive strength

Compressive strength (CS) of concrete was improved with adding of glass bottle powder, illuminate sludge and metakaolin up to 30% replacement to fine aggregate, 10% replacement with cement, 8% replacement with cement, respectively.

Figure 4, the strength enhancement with 30% glass replacement by 22.496%, 22.465% and 22.515% at 7, 14 and 28 days, respectively. The compressive strength was improved with 10% replacement illuminate sludge with cement by 9.6542%, 9.632% and 9.668% at 7, 14 and 28 days, respectively, as shown in Figure 5. From Figure 6, the strength enhancement was observed at 8% replacement of cement with metakaolin by 78.625%, 78.589% and 78.61% at 7, 14 and 28 days, respectively. The strength enhancement was more with metakaolin in concrete compared to illuminate sludge and glass bottle powder at 7, 14 and 28 days for M30 grade of concrete. The CS of concrete was increased by filling of micro-pores with metakaolin, glass bottle powder and illuminate sludge powder at an early and later age [18-20].

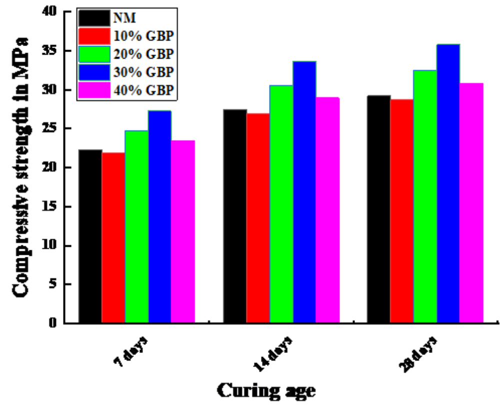

Figure 4. CS of concrete with % glass replacements

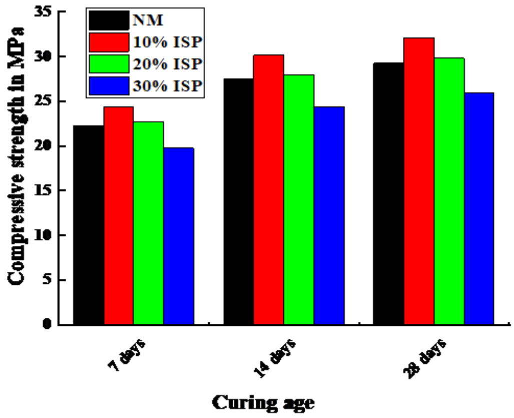

Figure 5. CS of concrete with % illuminate sludge powder

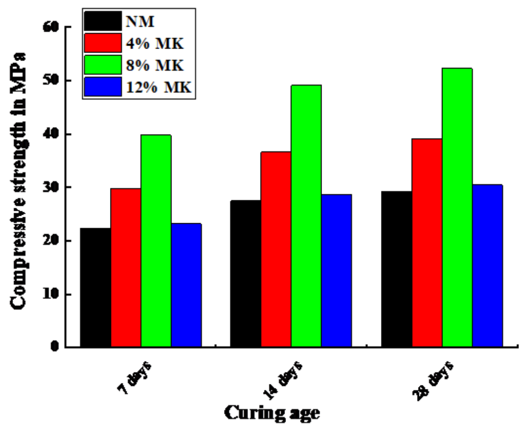

Figure 6. CS of concrete with % metakaolin replacement

7.2 Split tensile strength

Split tensile strength of concrete was increased with adding of glass bottle powder, illuminate sludge and metakaolin up to 20% replacement to fine aggregate, 10% replacement with cement, 8% replacement with cement, respectively. From Figure 7, the strength enhancement with 20% glass replacement by 84.78%, 54.11% and 51.93% at 7, 14 and 28 days, respectively. The compressive strength was improved with 10% replacement illuminate sludge with cement by 65.94%, 66.40% and 66.29% at 7, 14 and 28 days, respectively, as shown in Figure 8. From Figure 9, the strength enhancement was observed at 8% replacement of cement with metakaolin by 166.66%, 167.05% and 167.40% at 7, 14 and 28 days, respectively. The strength enhancement was more with metakaolin in concrete compared to illuminate sludge and glass bottle powder at 7, 14 and 28 days for M30 grade of concrete. The split tensile strength of concrete was enhanced due to improvement of inter transition zone with the addition of metakaolin, glass bottle powder and illuminate sludge powder at an early and later age [21-25].

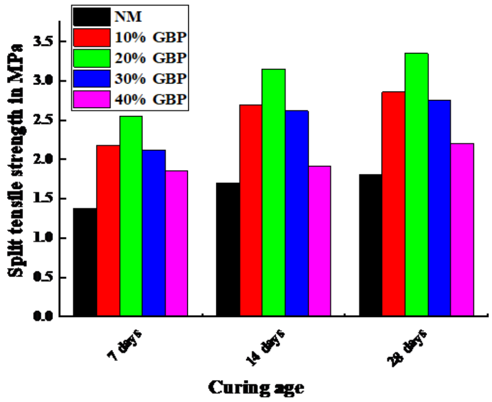

Figure 7. Graphical representation of SPS of concrete with % glass bottle powder

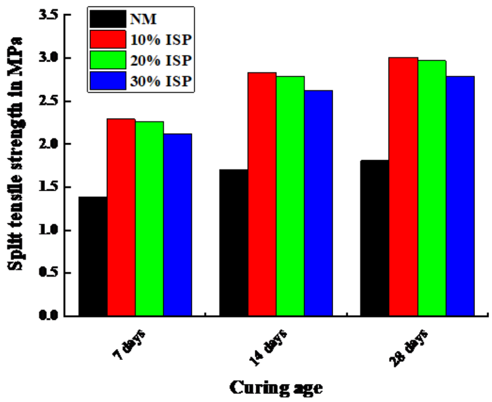

Figure 8. Graphical representation of SPS of concrete with % illuminate sludge powder

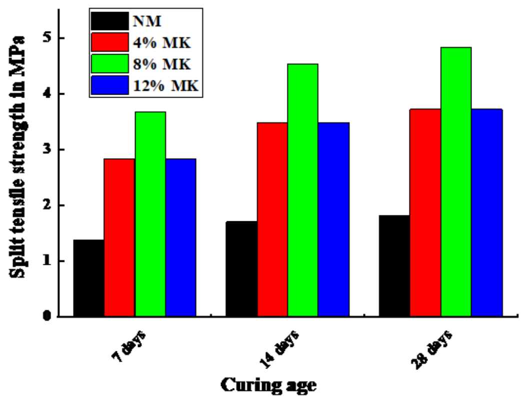

Figure 9. Graphical representation of SPS of concrete with % metakaolin powder

7.3 Modulus of rupture

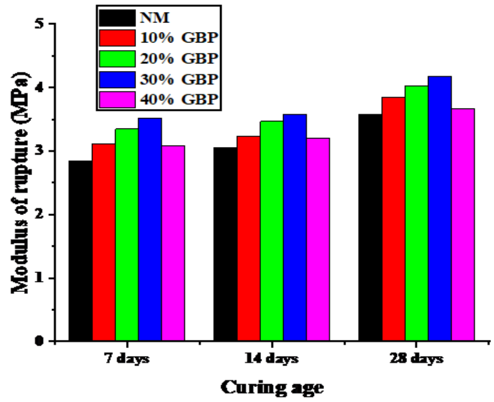

Figure 10. Graphical representation of MOR of concrete with % glass bottle powder

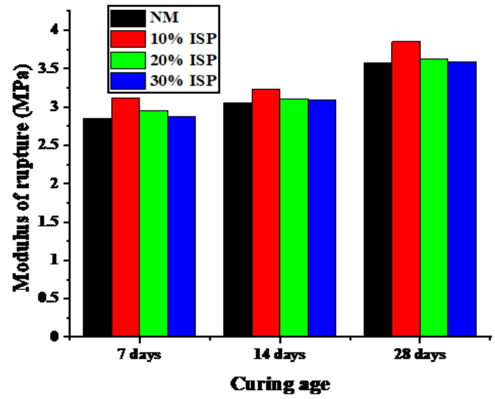

Figure 11. Graphical representation of MOR of concrete with % illuminate sludge powder

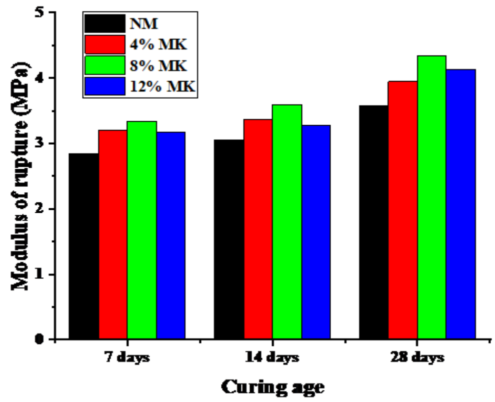

Figure 12. Graphical representation of MOR of concrete with % metakaolin powder

Modulus of rupture (MOR) of concrete was enhanced with incorporating bottle powder, illuminate sludge and metakaolin up to 30% replacement to fine aggregate, 10% replacement with cement, 8% replacement with cement, respectively. Figure 10, the MOR enhancement with 30% glass replacement by 20%, 22% and 18% at 7, 14 and 28 days, respectively. The MOR was improved with 10% replacement illuminate sludge with cement by 8.12%, 10.235% and 7.895% at 7, 14 and 28 days, respectively, as shown in Figure 11. From Figure 12, the MOR enhancement was observed at 8% replacement of cement with metakaolin by 50.24%, 53.21% and 44.23% at 7, 14 and 28 days, respectively. The MOR enhancement was more with metakaolin in concrete compared to illuminate sludge and glass bottle powder at 7, 14 and 28 days for M30 grade of concrete. The MOR of concrete was increased by filling of micro-pores with metakaolin, glass bottle powder and illuminate sludge powder at an early and later age [18-20].

8. CONCLUSIONS

From this research, it is concluded that the maximum compressive strength was observed while incorporating Illuminate sludge and glass bottle in 10% and 30%, respectively by fine aggregate replacement and metakaolin of 8% as cement replacement. Maximum tensile strength was achieved by the addition of 20% glass bottles, and 10% illuminate sludge by fine aggregate substitutions and metakaolin of 8% as a cement replacement into the concrete. Maximum modulus of rupture was observed while incorporating Illuminate sludge and glass bottle in 10% and 30%, respectively by fine aggregate replacement and metakaolin of 8% as cement replacement. Replacements showed significant enhancement in the concrete due to filling of pores by these waste materials. As a result, incorporating industrial waste will develop high strength concrete as well as being economical and environmentally friendly.

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NOMENCLATURE

CS	Compressive strength
SPT	Split tensile strength
MKP	Metakaolin powder
GBP	glass bottle powder
ISP	illuminate sludge powder