

Effect of iron ore tailing and glass powder on concrete properties

Efecto de los relaves de mineral de hierro y polvo de vidrio en las propiedades del concreto

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Abstract

The aim of this research is to test the characteristics of concrete by substitute fine aggregate with iron ore tailings and partial glass powder as in the place of cement. Concrete with waste products such as glass powder and iron ore tailings offers technical, economic and environmental advantages. In this experimental investigation, glass powder is replaced with cement by 10%, 20% and 30% and iron ore tailings with fine aggregates by 30% which is the optimum percentage. To study the role of glass powder and iron ore tailings combination in concrete, The properties such compressive strength, flexural strength, tensile strength and also durability parameters likely water absorption investigation for M40 concrete is carried out with different percentages of glass powder by keeping the iron ore tailings percentage constant. At 30% glass powder substitution as cement and sand with IOT increases concrete effectiveness. The concrete with 10% glass powder & 30% iron ore tailings showed a higher strength compared to the conventional mix for 28 days. Concrete mix containing 10% GP and 30% IOT showed higher flexural strength of 5.05 MPa for 28 days. Splitting tensile strength value is also increasing i. e for 10% glass powder and 30% IOT, obtained splitting tensile strength was 4.48 MPa and modulus of elasticity value has also increased. Water absorption experiment consequences results that water absorption decreases with an increase in GP percentage. The concrete workability tends to decrease when with glass powder content increase. Concrete containing 10% glass powder and 30% IOT showed maximum strength and it is considered as the optimum dosage.

Keywords: Glass powder, iron ore tailing, cement replacement, fine aggregate replacement, fresh properties, hardened properties

Resumen

El objetivo de esta investigación es probar las características del concreto por sustitución de agregado fino con relaves de mineral de hierro y polvo de vidrio parcial como en lugar de cemento. El hormigón con productos de desecho como polvo de vidrio y relaves de mineral de hierro ofrece ventajas técnicas, económicas y medioambientales. En esta investigación experimental se reemplaza polvo de vidrio por cemento en un 10%, 20% y 30% y relaves de mineral de hierro con agregados finos en un 30% que es el porcentaje óptimo. Para estudiar el papel del polvo de vidrio y la combinación de relaves de mineral de hierro en el concreto, las propiedades como la resistencia a la compresión, la resistencia a la flexión, la resistencia a la tracción y también los parámetros de durabilidad, la investigación de absorción de agua probable para el concreto M40 se lleva a cabo con diferentes porcentajes de polvo de vidrio manteniendo el hierro. porcentaje de relaves de mineral constante. Con un 30 % de sustitución de polvo de vidrio como cemento y arena con IOT aumenta la eficacia del hormigón. El concreto con 10% de polvo de vidrio y 30% de relaves de mineral de hierro mostró una mayor resistencia en comparación con la mezcla convencional durante 28 días. La mezcla de concreto que contenía 10 % de GP y 30 % de IOT mostró una mayor resistencia a la flexión de 5,05 MPa durante 28 días. El valor de resistencia a la tracción de división también está aumentando i. e para 10% de polvo de vidrio y 30% de IOT, la resistencia a la tracción por división obtenida fue de 4,48 MPa y el valor del módulo de elasticidad también aumentó. El experimento de absorción de agua da como resultado que la absorción de agua disminuye con un aumento en el porcentaje de GP. La trabajabilidad del hormigón tiende a disminuir cuando aumenta el contenido de polvo de vidrio. El concreto que contenía 10% de polvo de vidrio y 30% de IOT mostró la máxima resistencia y se considera la dosificación óptima.

Palabras clave: Polvo de vidrio, relaves de mineral de hierro, reemplazo de cemento, reemplazo de agregados finos, propiedades frescas, propiedades endurecidas

1. Introduction

A frequently used mode of transports is the road transport. We are in need to found alternate materials in roadway. Iron ore tailings is one of the mine wastes which is available in India. The safe disposal is very important aspect for safety of human being and animals and soil. To minimize the negative impact of IOT on environment and low cost construction, this can be utilized in concrete production as substitute of fine aggregate (Vieira et al., 2017); (Carvalho et al., 2021); (Karthikeyan et al., 2021); (Han et al., 2019). The viability of the tailings of iron ore as a substitute material on behalf of FA in the concrete for construction of concrete pavements. The transformation of fly ash and IOT into foaming geopolymer leads to the formation of porous structure encouraging Cu²⁺ sorption (Duan et al., 2016); (Shettima et al., 2016); (Duan et al., 2016). The Size distribution curve of composite binder containing IOT was very close optimization curve. So By Adding the IOT Packing density increased (Han et al., 2020); (Wang et al., 2016); (Thomas et al., 2013); (Lv et al., 2021); (Zhang et al., 2020). Water to binder ratio reduced means, it will give maximum strength. Also IOT Substitution in with nominal percentage increases the compressive strength of concrete (Ma et al., 2016); (Zhao et al., 2021); (Almeida et al., 2020); (Cai et al., 2016).

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Glass powder is a kind of pozzolanic material because it has that nature and characteristics. Use of glass powder has much influence in setting time and cement expansion (Soliman and Tagnit-Hamou, 2016); (Omran and Tagnit-Hamou, 2016); (Lee et al., 2018); (Aliabdo et al., 2016). Concrete with cement replaced by 15% and 30% glass powder gives more strength as well as lowest porosity (Du et al., 2017); (He et al., 2019). The maximum compressive strength (136 MPa) was arrived when 20 % glass waste added in RPC-Reactive powder concrete (Kushartomo et al., 2015). Concrete with Fly ash and glass waste gives improvement in durability characteristics. Concrete with 20 percentages gives the nominal strength as compared to conventional concrete (Schwarz et al., 2008); (Sadiqul Islam et al., 2017); (Shayan et al., 2006). Objective of this study is to evaluate the suitability of Iron Ore Tailing as fine aggregate and Glass waste as cement. Also to find the various properties (Fresh and hardened) of concrete with IOT and glass waste.

2. Methodology

Following methodology is adopted to achieve the above objectives

- *Physical properties of cement, glass powder, fine aggregates, coarse aggregates and iron ore tailing should be assessed by conducting the tests such as specific gravity and grain size distribution.*
- *Mix design of M40 grade concrete is done by selecting suitable ingredient of concrete and determine their proportion.*
- *The samples were casted for 5 different mix proportions such as control mix and for optimum percentage of IOT of 30% and for varying the percentages of glass powder for cement replacement by keeping IOT constant at optimum percentage.*
- *Cube size of 100mm*100mm*100mm, cylinder of diameter 150mm and length 300mm, beams of dimensions 500mm*100mm*100mm, for RCPT test cylinder of diameter 100mm and length of 200mm were casted for M40 grade concrete mix and curing was done for 7, 28 days.*
- *To find the mechanical properties of the concrete in which partially replaced cement with glass powder at 0%, 10%, 20% and 30% and sand replaced by 30% IOT for M40 grade of concrete.*
- *Mechanical properties of concrete consisting of glass powder and iron ore tailing will be determined by experimental investigations.*

3. Material and Properties

Studying suitability of biased substitute of cement by glass powder at different percentages and fine aggregates by iron ore tailings, laboratory tests were conducted. Initially, the concrete mix proportions were considered based on the 30% optimum replacement of iron ore tailings with 10%, 20%, 30% glass powder be a cementations material in mix of concrete. In second stage, modulus of elasticity, Compressive strength, tensile strength & flexural strength experiments were carried out toward determine mechanical properties containing iron ore tailings and glass powder. In third stage, water absorption test conducted for study durability property of mix of concrete.

3.1 Materials used

Materials use in support of experimental study were sand, cement, iron ore tailing glass powder, aggregates and water. The description of each of the materials is given in the following sections.

3.1.1 Cement

OPC 53grade conforming (BIS, 2013) is used this experimental examination. Physical properties of cement are given in (Table 1).



Table 1. Cement Physical property

Sl no	Properties	Values obtained	Requirement as per IS 12269:2013
1	Specific gravity	3.15	-
2	Initial setting time	60 minutes	Should be more than 30 minutes
3	Final setting time	450 minutes	Should be less than 600minutes

3.1.2 Glass powder

Finely powdered glass powder of specific gravity 2.6 is used. Glass powder used for this study is shown in (Figure 1).

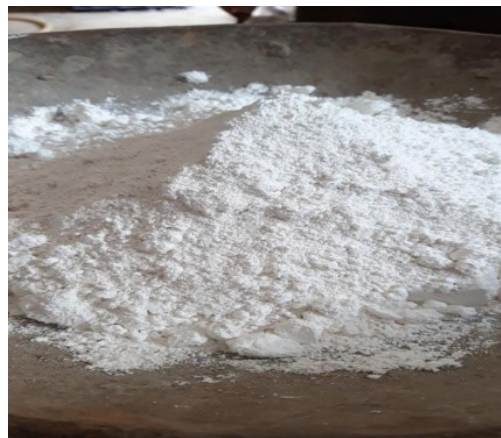


Figure 1. Glass powder

3.1.3 Iron Ore Tailings

Iron ore tailing passing through 2.36mm IS sieve is used for this experimental programme. Specific gravity of IOT was discovered to be is 3.31. Iron ore tailing used for this study was shown in (Figure 2).



Figure 2. Raw iron ore tailings and crushed iron ore tailings

3.1.4 Fine Aggregates

The sand used does not contain any organic matter and it is free from impurities. SG of river sand be determined as per (BIS, 1963). River sand conforming (BIS, 1970), passing through sieve 4.75 mm is worn for present investigation as fine aggregate. The specific gravity was found to be 2.70. Sieve analysis results of fine aggregate given in (Table 2).

Table 2. Sieve analysis result of fine aggregate (Sample-1000 gms)

Is sieve (mm)	Weight Retained (gram)	% weight Retained	Cumulative % weight Retained	% weight passing	IS 383:1970 Requirement for grading Zone-2
10	-	-	-	100	100
4.75	0	0	0	100	90-100
2.36	26.3	2.63	2.63	97.37	75-100
1.18	178	17.8	20.43	79.57	55-90
0.60	250	25	45.43	54.57	35-59
0.30	382	38.2	83.63	16.37	8-30
0.15	147.2	14.72	98.35	1.65	0-10

3.1.5 Coarse aggregate

Stone of size 10mm&20mm size which be locally available is used as coarse aggregate. In current analysis, the aggregates were 20 mm and 10 mm in size, respectively proportion 60 % and 40% by weight are used. Confirms to (BIS, 1970) "specifications for coarse and fine aggregates". Physical properties of CA given in (Table 3) and sieve analysis report of CA given in (Table 4).

Table 3. coarse aggregate Physical property

Sl no	Tests	Results	IS Recommendation (IS 383:1970)
1	Specific gravity	2.8	-
2	Water absorption	1.7	< 2%
3	Impact value	10.9	< 30%
4	Crushing value	13.8	30% maximum for Road, Runway and Pavement



Table 4. coarse aggregate sieve result (Sample-5kg)

IS sieve size (mm)	Weight Retained (kg)	% weight Retained	Cumulative % Weight retained	% passing	IS 383:1970 Requirement (% passing graded aggregate of nominal size 20mm)
40	0	0	0	100	100
20	0.21	4.2	4.2	95.8	95-100
10	3.48	69.6	73.8	26.2	25-55
4.75	1.27	25.4	99.2	0.8	0-10

3.1.6 Water

Water is very important in concrete mix; it directly affect strength property plus the workability of mix. Specific quantity of water is required for hydration reaction to gain strength. Adequate water should add in concrete mix to attain desired strength and workability.

3.1.7 Admixture

Super plasticizing admixture is a type of high range water reducing chemical admixture. In this study conplast SP430 is used in concrete mixes as chemical admixture to make keep concrete in workable condition and to avoid particle segregation (gravel, coarse and fine sand).

4. Mix Design

The various weights of ingredients for dissimilar concrete mix are given inside (Table 5) below.

Table 5. weight of ingredients

Material	GP-0% IOT-0%	GP-0% IOT-30%	GP-10% IOT-30%	GP-20% IOT-30%	GP-30% IOT-30%
Cement(kg)	394	394	354.6	315.2	275.8
Glass powder (kg)	-	-	39.4	78.8	118.2
Fine aggregate (kg)	807.408	862.12	858.49	854.86	852.44
Coarse aggregate(kg)	1156.28	1156.28	1151.4	1146.53	1143.28
Water(l)	157.6	157.6	157.6	157.6	157.6
Super plasticizer(kg)	7.88	7.88	7.88	7.88	7.88

5. Experimental Investigation

5.1 Fresh Properties of concrete



5.1.1 Workability Test

Concrete Workability is the trait of fresh concrete mix, which represents the mixing, transporting, moulding, compacting ability of concrete. Workability is directly depending on water- cement ratio; workability rises with the rise in water to cement relation. Workability of fresh concrete is helpful to knowing the bleeding and segregation. 100mm is the top diameter, 200mm is the bottom diameter and 300mm is the height of slump cone. Tempering rod was used to compact and remove the air voids. Slump value of concrete measured in 'mm' as per (BIS, 1959). Slump value for various mixes given in (Table 6).

Table 6. Slump values of mixes

Concrete mix	Slump(mm)
Control mix	45mm
0% GP and 30% IOT	43mm
10% GP and 30% IOT	41mm
20% GP and 30% IOT	39mm
30% GP and 30% IOT	38mm

5.2 hardened Properties of concrete

5.2.1 Density of concrete

Density of cubes for all concrete mix with varying glass powder and constant iron ore tailings as replacement was determined. Density of concrete cubes was determined on concrete cube of 100mm x 100mm x 100 mm size at 7 and 28 days curing. The density of different mixes at 7 days shown in the below (Table 7).

Table 7. Density of mixes

Concrete mix	Density(kg/m ³)
Control mix	2456
0% GP and 30% IOT	2510
10% GP and 30% IOT	2521
20% GP and 30% IOT	2604
30% GP and 30% IOT	2548

5.2.2 Compressive Strength

The compressive strength value is important criteria for study the properties of concrete. To found the compressive strength a cube of 100*100*100mm casted and the testing of cubes were done in compression testing machine capacity 2000kN, as per (BIS, 1959). Maximum load at which the sample fails can be written down to calculate compressive strength. Compressive strength results for various mixes shown in (Figure 3).



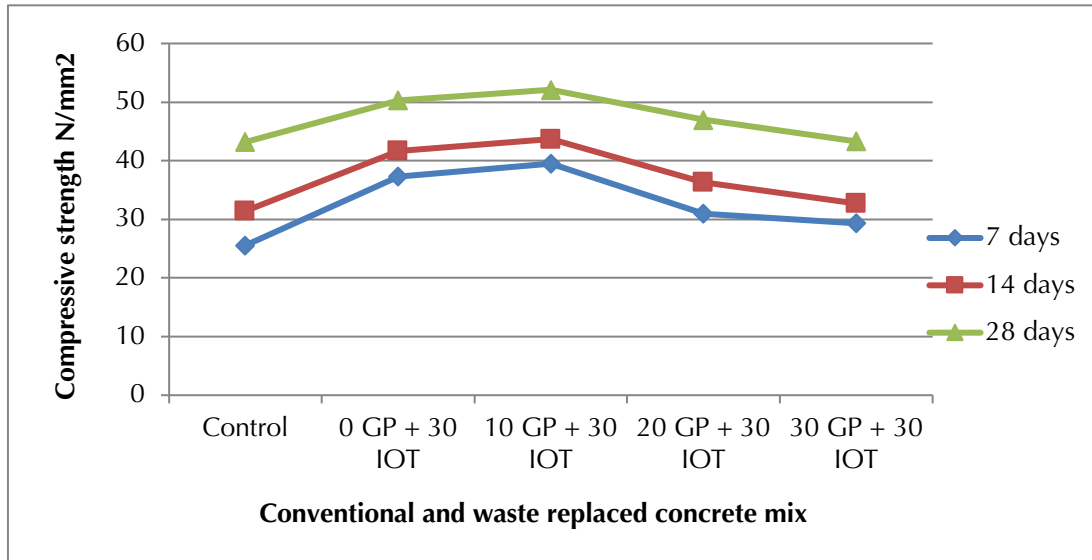


Figure 3. Compression strength of concrete of all mixes

5.2.3 Split Tensile Strength

Similar to compressive strength values, flexural strength values, splitting tensile strength values for 10% glass powder concrete mix were maximum. Hence for concrete mix with 10% glass powder and 30% IOT flexural strength is maximum. Split tensile strength results for various mixes shown in (Figure 4).

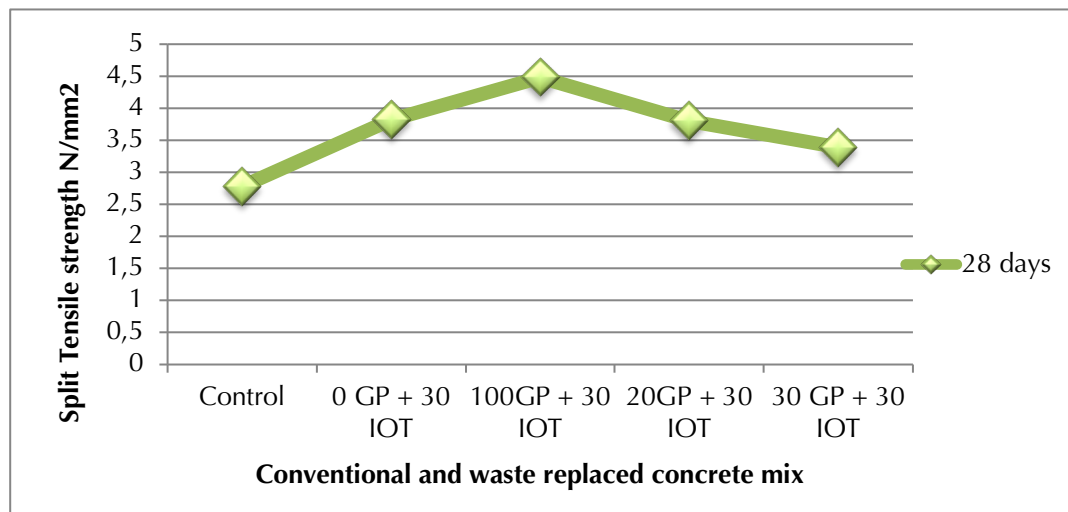


Figure 4. Splitting tensile strength of all mixes

5.2.4 Flexural Strength

Same as the compressive strength test results, flexural strength for 10% glass powder concrete mix showed maximum strength. Hence for concrete blend with 10% glass powder and 30% IOT, flexural strength be maximum. Flexural strength results for various mixes shown in (Figure 5).



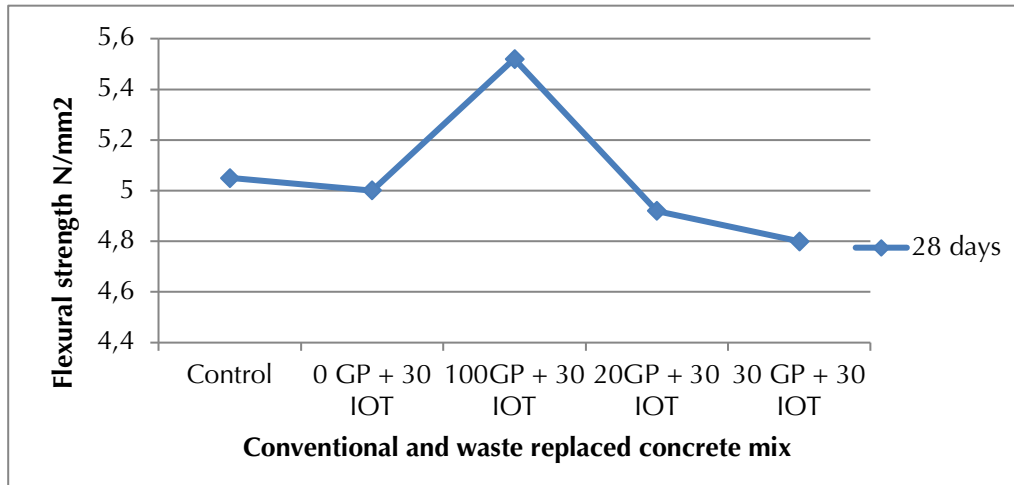


Figure 5. Flexural strength of concrete mixes for 28 days

5.2.5 Water absorption

Absorption of Water test conducted on 100*100*100 size cubes. From the test result values, water absorption for mixes decreasing with increasing percentage of GP. Water absorption results for various mixes shown in (Figure 6).

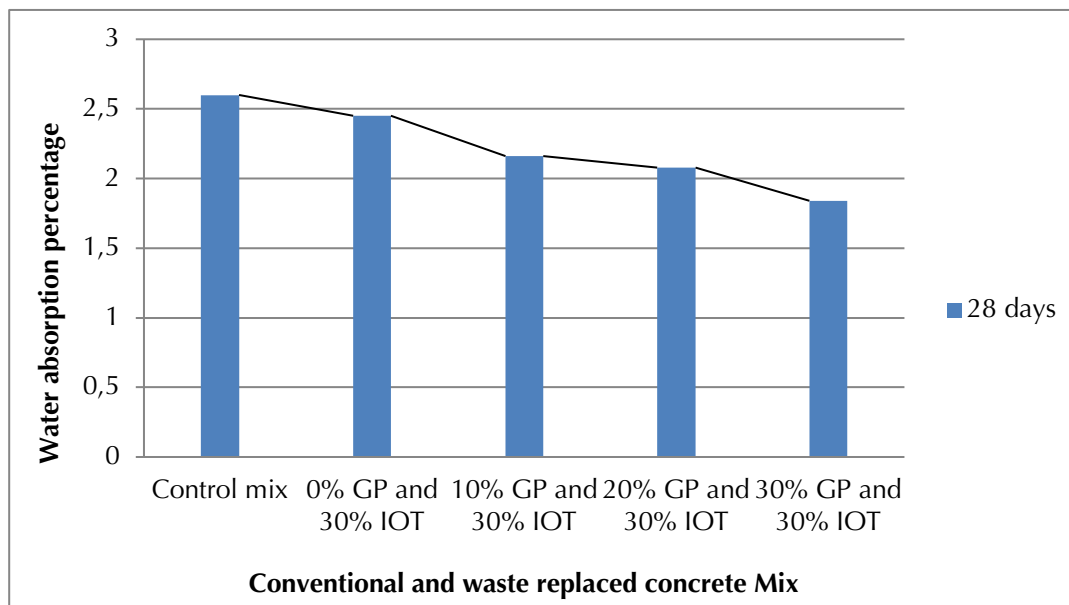


Figure 6. Water absorption of cubes for 28 days

5.2.6 Modulus of elasticity of concrete

Compressive strength predominantly affects stress to strain value of concrete. Maximum Young's modulus of concrete achieved at 10% substitution of cement with glass powder. Modulus of elasticity results for various mixes shown in (Figure 7).



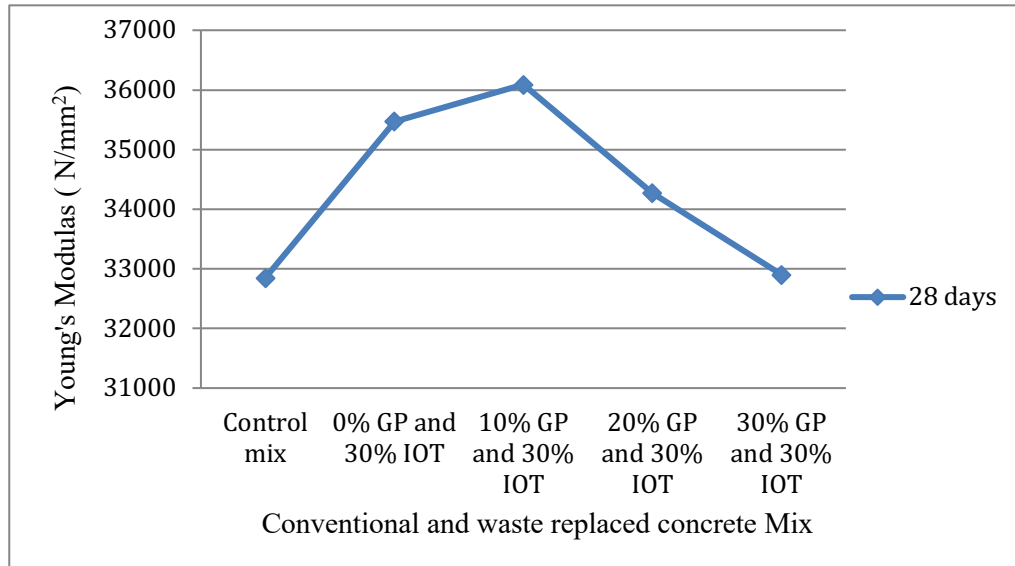


Figure 7. Modulus of elasticity results for various mixes

6. Results and Discussion

Study was conducted to find the optimum percentage of replacement of glass waste as cement and Iron ore tailing as fine aggregate. It is observed that concrete with 10 percent glass waste and 30 percent IOT gives more compressive strength comparing all mix including conventional concrete mix. Result from experimental investigation was discussed as follows.

6.1 Workability of concrete

From slump cone test, we get to know that concrete with zero percent glass waste as cement and 30 percentage as FA gives more slump (43 mm) comparing all other mix. Also the result shows that when increase in glass waste replacement percentage with 30 percentages IOT leads to reduction in Slump value.

6.2 Density of concrete

Concrete with 20 % GP as cement +30 % IOT as fine aggregate was given 6 % more density (2604 kg/m³) by comparing conventional concrete density (2456 kg/m³). From results, we can conclude that, when increase in GP percentage with 30 percent IOT leads to increase in density of concrete.

6.3 Compression strength of concrete

Compressive strength of conventional concrete at age 7, 14 and 28 days was 25.56 N/mm², 31.43 N/mm² and 43.19 N/mm² respectively. When replacing GP with 30 % IOT results in high strength in all mix, but concrete with 10 % GP and 30 % IOT gives 54% (39.5 N/mm²), 39% (N/mm²43.70) and 20 % (52.11 N/mm²) more strength at age of 7,14 and 28 days. From results we observed that, 10 percentage of GP with 30 %b IOT is the nominal mix percentage to produce concrete with high compressive strength. Concrete with 20% and 30% Glass powder gives 10 % (47 N/mm²) and 21 % (43.33 N/mm²) less compressive strength compared to concrete with 10 % GP and 30 % IOT at 28 days.

6.4 Split Tensile Strength of concrete

At 28 days, the split tensile strength of conventional concrete was found 2.78 N/mm², it was 61 % less compared to tensile strength of concrete with 10 % GP + 30 % IOT (4.48 N/mm²). Results show that there was an increase in tensile strength when GP replaced as cement with 30 % IOT. But about 10 % GP, there was a reduction in tensile strength. So we can fix 10 % GP waste as nominal replacement percentage to get high tensile strength.



6.5 Flexural Strength of concrete

Flexural strength of concrete with 10 % GP+ 30 % IOT was 5.52 N/mm² at 28 days; it was 9 percentages more comparing to Conventional concrete flexural strength 5.05 N/mm². From results its observed that 10 percentage GP and 30 % IOT produces more flexure concrete comparing all other mixes.

6.6 Water Absorption

Concrete with 30 % Glass powder and 30 Percent IOT absorbing less water 1.84 % at 28 days, it was 41 percentage less compared to water absorption of conventional concrete 2.6 %. So when percentage of GP replacement increases means, it will reduce the water absorption level of concrete.

6.7 Modulus of elasticity

Concrete with 10 % GP with 30 % IOT gives maximum modulus of elasticity 36.09 * 10³ MPa at 28 days .it was 9 percentages more compared to conventional concrete 32.85 * 10³ MPa. From investigation we concluded that use of Glass powder with 30 percentages IOT results in increment of young's modulus, but 10% GP + 30 % IOT produces maximum.

7. Conclusion

- Replacement of glass powder as cement and 30 % IOT as fine aggregate enhances the compressive strength of concrete than conventional concrete. From results we found that 10 percent of GP with 30 % IOT gives more compressive strength at all ages compared to conventional.
- Tensile strength for mix containing 10% GP and 30% IOT showed higher results (4.48 N/mm²) compare the control mix tensile strength (2.78 N/mm²) in age 28.
- Concrete with 10 percent GP and 30 % IOT gives maximum flexural strength (5.05 N/mm²) at 28 days, It was 9 % more comparing Flexural strength of conventional concrete (4.6 N/mm²).
- Concrete mix Stress to strain value high when containing 10% GP and 30% IOT and its higher compare with control mix at 28 days.
- Water absorption test results show water absorption reduction with rise in GP percentage.
- Workability of concrete tend decreased when increase the glass powder substance In order to ensure a longer period of workability, higher doses of super plasticizer tend to require. Compressive strength at 30% of glass powder found to decrease.

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