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Potential use of mine tailings and fly ash in concrete

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Abstract. Tailing Material (TM) and Fly Ash (FA) are obtained as waste products from the mining and thermal industries. Studies were carried out to explore the possibility of utilizing TM as a part replacement to fine aggregate and FA as a part replacement to cement, in concrete mixes. The effect of replacing fine aggregate by TM and cement by FA on the standard sized specimen for compressive strength, split tensile strength, and flexural strengths are evaluated in this study. The concrete mix of M40 grade was adopted with water cement ratio equal to 0.40. Concrete mix with 35% TM and 65% natural sand (TM35/S65) has shown superior performance in strength as against (TM0/S100, TM30/S70, TM40/S60, TM50/S50, and TM60/S40). For this composition, studies were performed to propose the optimal replacement of Ordinary Portland Cement (OPC) by FA (Replacement levels studied were 20%, 30%, 40% and 50%). Replacement level of 20% OPC by FA, has shown about 0-5% more compressive strength as against the control mix, for both 28 day and 56 days of water curing. Interestingly results of split tensile and flexural strengths for 20% OPC replaced by FA, have shown strengths equal to that of no replacement (control mix).

Keywords: iron ore tailings; fly ash; blended concrete; strengths

1. Introduction

Leaving the waste materials generated to the environment directly may cause environmental problems. Therefore, there is ample scope for waste utilization and management from the sustainability point of view. Waste can be used to produce new products or can be used as substitute so that natural resources are used more efficiently and the environment is protected from waste deposits. Some industrial wastes are dumped in the close vicinity and the natural fertility of the soil is in question.

Aggregates are considered one of the main constituents of concrete they occupy more than 70% of the concrete matrix. In many countries there is scarcity of natural aggregates that are suitable for construction and shortage or inadequate supply of sand (fine aggregate) may affect several infrastructure projects. In order to reduce dependence on natural aggregates as the main source of

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aggregate in concrete, artificially manufactured aggregates and artificial aggregates generated from industrial wastes provide an alternative for the construction industry. Therefore, utilization of aggregates from industrial wastes can be alternative to the natural and artificial aggregates.

Iron ore mine tailing is one of the waste materials generated from the mining industry. These tailings are the residue of the milling process that is used to extract metals of interest from mined ores.

particles in tailings may cause air pollution in summer season and erosion of tailings in rainy season which affects the nearby land, surface water and underground water sources. Leaching of heavy metals is another concern with tailings. Due to this, disposal of mine tailing is a serious environmental issue for any mining projects. In India about 18 million tons of waste iron ore tailings are produced annually, handling of tailings is a serious environmental concern due to leaching of toxic constituents. Current research prominence is more on utilization of such industrial by products. The scope of this work is to study the utilization of iron ore tailings obtained from a tailing dam situated in Kudremukha, Karnataka for various civil engineering purposes. Strength property of concrete with use of iron ore tailings is studied in the present work.

Currently, the major utilization of TM includes land reclamation, re-extraction of iron or other metals, and using them as raw ingredients in producing infrastructure materials, backfilling materials, and fertilizers (Zhang *et al*. 2009). Previous studies have reported several ways to utilize iron ore tailing additives in clinker and concrete, as replacement of sand in concrete, as siliceous materials in ceramics and autoclaved aerated concrete (Karpe *et al*., 2008). Aruna *et al*. (2012) demonstrated usage of iron tailings for paving blocks manufacture. They conducted laboratory tests to assess compressive strength and water absorption of specimen. The samples were cured for 7 and 28 days. The results of the study indicate that these paving blocks were reported to have a compressive strength of 36.5 MPa for 28 days curing with modified mix with tailings (ratio 1: 0.75:0.75:3). The study also revealed that there is not much change in water absorption. The study also suggested that there is large scope for utilizing mine wastes for the manufacture of building materials and products.

Fly ash is another by-product from thermal power plants, which use coal as fuel. It is estimated that about 125 million tones of fly ash is being produced from different hectares of agriculture land for its disposal. It causes serious health and environmental problems (Vinodsinh Solanki and Pitorda, 2013). Fly ash is the finely divided mineral residue resulting from the combustion of ground or powdered coal in electric power generating thermal plant. Fly ash is a beneficial mineral admixture for concrete. It influences many properties of concrete in both fresh and hardened state. Moreover, utilization of waste materials in cement and concrete industry reduces the environmental problems of power plants and decreases electricity generation costs. (Pitroda *et al*. 2012). According to Pedro Silva and Jorge de Brito(2013, the use of additions such as limestone filler (LF), fly ashes (FA), among others, in partial substitution of cement may contribute to a reduction of the self compacting concrete (SCC) costs, as well as to an improvement of its behaviour, both in the fresh and the hardened state. Amol A Patil (2014) reported that the compressive strength of the hot cured specimen for 7 days curing is about seven times more than the strength of ambient cured sample.

Research shows that adding fly ash to concrete, as a partial replacement of cement (less than 35 percent), will benefit both the fresh and hardened states. While in the fresh state, the fly ash improves workability. This is due to the smooth, spherical shape of the fly ash particle. The tiny spheres act as a form of ball bearing that aids the flow of the concrete (Morotta 2005). This improved workability allows for water-to-cement ratios, which later leads to higher compressive strengths (Mindess *et al*. 2003). In the hardened state, fly ash contributes in a number of ways, including strength and durability of concrete and fly ash tends to increase the setting time of the concrete. The pozzolanic reaction is removing the excess calcium hydroxide, produced by the cement reaction, and forming a harder calcium silicate hydrate (CSH) (Pitroda *et al*. 2012).

In this study, an attempt is made to effectively utilize iron ore tailing materials received from tailing dam at Kudremukha, Karnataka, and fly ash from M/s Raichur Thermal Power Station, Shakthinagar, Karnataka, in concrete so as to derive their beneficial use in construction industries.

2. Materials and methods

2.1 Materials

2.1.1 Cement

The Ordinary Portland Cement (OPC) of 43 grade confirming to IS: 8112-1989 was used. The physical and chemical characteristics of cement used are presented in Table 1 and 2.

Table 1 Physical properties of cement

Sl. No.	Test conducted	Results obtained			Requirements as per IS			Remarks		
1	Specific gravity	3.10			--			W	M	Y
2	Normal consistency	31%			--			46	11	2013
3	Setting times (minutes)	Initial 65			Not less than 30 min					
		Final 270			Not more than 600 min					
4	Fineness (m^2/kg)	330			Not less than 300					
5	Soundness (mm)	Expansion: 2.50			Not more than 10 mm			Satisfies codal requirements		
6	Compressive strength (MPa)	3 day	7 day	28 day	3 day	7 day	28 day			
		28	36	48	22	33	43			

Table 2 Chemical characteristics of cement

Chemical Properties of OPC	Result
pH	11.47
Electrical conductivity (ms/µs)	6.95
Silica Oxide SiO_2 (w/w) %	19.48
Iron Oxide Fe_2O_3 (w/w) %	2.00
Aluminium Oxide Al_2O_3 (w/w) %	8.25
Calcium Oxide (CaO) (w/w) %	56.08
Magnesium Oxide (MgO) (w/w) %	5.64
Loss on Ignition (%)	4.77

2.1.2 Tailing material (TM)

Mine tailing is one of the waste materials generated from the mining industry and was collected from tailing dam situated in Kudremukha, Karnataka, India. Tailing samples were taken at a depth of 0.90 m below the surface in the tailing dam and then transported to the laboratory in sealed bags. In laboratory, the tailing samples were air dried in shade and were then stored in non-corrodible bins for further investigation. From the particle size distribution curve, it is observed that the fines percentage (silt and clay) is very less (about 5%). Further, it is noticed that the sand proportion is significant (about 95%). From the sieve analysis results, TM satisfied codal requirements confirming to zone III of IS: 383:1970.

2.1.3 Fine aggregate (Sand)

The natural river sand was used as specified by the codal requirements confirming to *zone II of IS: 383:1970*. The river sand was washed and screened, to eliminate deleterious materials and over size particles. The specific gravity and fineness modulus of sand were found to be 2.64 and 3.51 respectively. The water absorption was found to be 1.0%. Fig. 1 shows the particle size distribution curves of fine aggregate (sand) and tailing material (TM). From Fig. 1 it is observed that, the finer particles are present in the sand is less compared to TM. From the combined sieve analysis results show that, all the mixes (TM30/S70, TM40/S60, TM50/S50 and TM60/S40) satisfied codal requirements confirming to zone II of IS: 383:1970. Table 3 - 4 show the basic physical and chemical characteristics of TM and river sand.

Table 3 Physical characteristics of TM and river sand

Particulars	TM	River sand
Specific gravity	3.27	2.64
Fineness modulus	2.69	3.51
Water absorption (%)	1.2	1.0
Bulk density:		
Loose (kg/m^3)	1684	1542
Compact (kg/m^3)	1816	1650
Field Moisture content (%)	9.56	-

Table 4 Chemical characteristics of TM

Particulars	Tailing material
pH	7.45
Electrical conductivity (ms / µs)	145
Silica Oxide SiO_2 (w/w) %	62.06
Iron Oxide Fe_2O_3 (w/w) %	28.59
Aluminum Oxide Al_2O_3 (w/w) %	3.08
Calcium Oxide (CaO) (w/w) %	0.073
Magnesium Oxide (MgO) (w/w) %	0.017
Loss on Ignition (%)	2.32

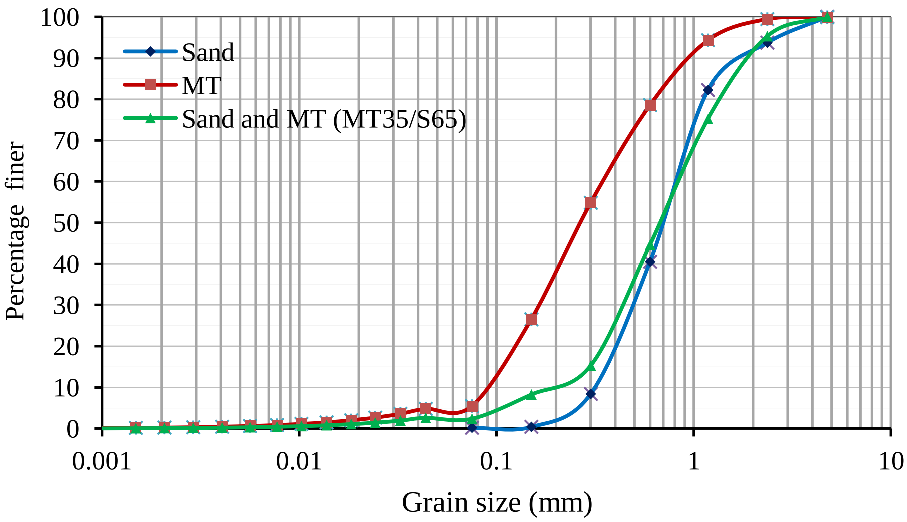

Fig. 1 Particle size distribution curves of fine aggregate (sand) and TM

Table 5 Basic physical properties of coarse aggregate

Sl. No.	Properties	Coarse aggregate	
		12.5 mm	20 mm
1	Specific gravity (G)	2.75	2.68
2	Fineness modulus	3.23	3.11
3	Water absorption (%)	0.50	0.50
4	Compacted bulk Density, (kg/m^3)	1550	1420

2.1.4 Coarse aggregate

Nominal sizes of coarse aggregates (12.5 mm & 20mm) as per IS 383-1970 were used in mix designing. Specific gravity of 20 mm and 12.5 mm coarse aggregates were 2.68 and 2.75 respectively. The water absorption was found to be 0.50%. Compacted bulk densities were found to be 1550 kg/m^3 and 1420 kg/m^3 for 12.50 mm and 20 mm size aggregates respectively. Table 5 shows the basic physical properties of coarse aggregates used in this work.

2.1.5 Fly ash (FA)

Fly ash is an industrial byproduct generated from thermal power plants during combustion of coal. Particles are glassy, spherical ball bearings finer than cement particles. Sizes of particle are 0.1µm – 150µm. It is a pozzolanic material which reacts with free lime in the presence of water, converted into calcium silicate hydrate (CSH) which is the strongest and durable portion of the paste in concrete. Fly ash from M/s Raichur Thermal Power Station, Shakthinagar, Karnataka, has been used for the present investigation, which falls under siliceous based fly ash as per IS 3812-2003. Table 6 presents the basic physical & chemical properties of fly ash.

Table 6 Basic physical and chemical properties of fly ash

Physical property	
Characteristics	Fly Ash
Specific Gravity (Le-Chatelier's flask)	2.07
Fineness (Blaine's Air permeability), m^2/kg	290
Bulk Density, kg/m^3	1100-1200
Colour (Visual observation)	Light grey
Chemical composition (%)	
pH	10.21
CaO (Calcium Oxide) w/w %	12.34
SiO_2	72.08
Al_2O_3	5.15
Fe_2O_3	0.57
MgO	4.04
Loss of Ignition (%)	0.76

2.1.6 Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. The water used was clean and free from deleterious matter.

2.1.7 Admixture

The high range water reducing and retarding superplasticizer confirming to ASTM C-494 Type G was used. The base of admixture used in this study was Sulphonated Naphthalene Formaldehyde. Super plasticizer used in the present investigation was between 0.4% and 0.65% by weight of cementitious materials.

2.2 Preliminary investigations

For the preliminary investigations, TM, cement, fine aggregates, coarse aggregates and fly ash were subjected to physical and chemical analyses to determine whether they are in compliance with the standard used. In this study, Iron ore tailings obtained from tailing dam were used as a replacement for fine aggregates, and fly ash obtained from thermal power plant was used as a replacement for cement.

2.3 Experimental programme

M40 grade of concrete was targeted by partial replacement of tailing material by varying percentage with sand to estimate the optimum percentage of tailing material. After getting optimized mix, part replacement of fly ash by varying percentage with cement to estimate optimum percentage of fly ash. Investigations are carried out to achieve high strength concrete by minimizing the quantity of sand and cement and to reduce the cost also.

2.4 Mix proportions for replacement of Iron ore tailing material with sand

To begin with IS method 10262:2009 was used to proportion the concrete mix. Control concrete was proportioned using OPC alone as binder for the target strength of 48 MPa at the age of 28 days and a slump of 100 mm ± 25 mm was maintained. Superplasticizer Fosroc, conplast SP 430 DIS, Sulphonated Naphthalene Formaldehyde was used to get the required slump. Final mix proportions were arrived based on trial castings. Table 7 shows mix proportion of control concrete and Table 8 show the various trial mix proportions for replacement of TMs with sand in concrete. The step by step procedure of the method used is shown below.

Concrete mixes taken up for this study were proportioned with total cementitious content of 440 kg/m^3. For this cementitious content 5 set of concrete mixes were proportioned with 0%, 30%, 40%, 50% & 60% replacement of fine aggregate by tailing material. High range superplasticizer was used in all the concrete mixes to achieve good workability. Unit water content was kept constant for all mixes of same cementitious content. To achieve the uniform workability, the admixture dosage was adjusted without changing the unit water content. Mix proportions of all mixes are shown in Table 8.

2.5 Mix proportions for replacement of FA with cement

IS-10262:2009 method was used to proportion the concrete mix. Final mix proportions were arrived based on trial castings. Table 9 shows the various trial mix proportions for replacement of fly ash with cement in concrete.

Table 7 Weight of various ingredients per cubic meter of concrete

Water (kg)	Cement (kg)	Fine aggregate (kg)	Coarse aggregate (kg)
176	440	681	1131

Table 8 Mix proportions for tailing replacement

Mix notation	TM %	Sand %	Mix proportion
TM0/S100	0	100	1.00:1.55:0.00:2.57
TM30/S70	30	70	1.00:1.09:0.57:2.57
TM40/S60	40	60	1.00:0.93:0.76:2.57
TM50/S50	50	50	1.00:0.78:0.95:2.57
TM60/S40	60	40	1.00:0.62:1.04:2.57

Table 9 Mix proportions for FA replacement

Mix notation	TM %	Sand %	Cement %	Fly ash %	Mix proportion
TM35/F0	35	65	100	0	1.00:0.00:1.68:2.57
TM35/F20	35	65	80	20	0.80:0.20:1.64:2.52
TM35/F30	35	65	70	30	0.70:0.30:1.63:2.49
TM35/F40	35	65	60	40	0.60:0.40:1.61:2.46
TM35/F50	35	65	50	50	0.50:0.50:1.59:2.44

2.6 Preparation of specimen

In the present investigation, three types of mixes were prepared, i.e. reference mix, modified mixes replacing tailing by sand and fly ash by cement. The modified mixes were prepared by replacing the sand with 0%, 30%, 40%, 50% and 60% of TMs. The mix designs were prepared for five mix types (Table 8). For each mix proportion 15 specimen (9 cubes of 150mm × 150mm × 150mm for compressive strength, 3 cylinders 150mm × 300mm for split tensile strength, and 3 beams 100 mm × 100 mm × 500 mm for flexural strength) were prepared.

The entire concrete specimen was prepared in accordance with Indian standard specifications IS: 516-1956. After 24 hours of casting the specimen were demoulded and submerged in water curing tank until the age of testing. The compressive strength of concrete cubes was determined at the age of 7, 28 and 56 days. Compression test was done using Universal Testing Machine (UTM). The cubes, cylinders and beams which had undergone curing for 28 days, 56 days and 90 days, were subjected to compressive strength, split tensile strength, and flexural strength tests. Similarly, the modified mixes were prepared by replacing the cement with 0%, 20%, 30%, 40%, and 50% of fly ash for the mix TM35/S65.

2.7 Testing procedure

After curing, the following tests were carried out on the concrete specimens:

- 7-day and 28-day cube compressive strength test was conducted in accordance with IS: 516- 1959 using a loading rate of 5 kN/s;
- 56-days cylinder tensile (splitting) strength test was done in accordance with IS: 5816-1999 using a loading rate of 2 kN/s; and
- 56-days flexural strength test was conducted in accordance with IS: 516- 1959 using a simple beam with third point loading at a loading rate of 0.03kN/s.

3. Results and discussions

3.1 Density variation with use of TMs

From Table 10, it is observed that there is a slight increase in the density of concrete with the increase of TMs quantity. The density of concrete increased about 3%. This is mainly due to the higher specific gravity of mine tailing which was 3.27 compared with sand which has a specific gravity of 2.64. The density is in the range of 2500 to 2575 kg/m$^{3.}$

3.2 Density variation with use of Fly Ash

From Table 11, it is observed that there is a slight decrease in the density of concrete with the increase of fly ash quantity. The density of concrete decreased about 4%. This is mainly due to the lower specific gravity of fly ash which was 2.07 compared with cement which has a specific gravity of 3.10. The density is in the range of 2400 to 2500 kg/m$^{3.}$

3.3Effect of replacement of sand by TMs

3.3.1 Compressive strength

Compressive strength of control mix and modified mixes with 30%, 40%, 50% and 60 % of sand replacement with TM was determined at 7, 28, 56 and 90 days. Table 10 shows the results of specimen tested for compressive strength. The maximum compressive strength is obtained for concrete mixes replaced with 30% & 40% tailing material; beyond that the compressive strength has reduced significantly due to increase in the free water remained in the mix in excess than that required for hydration of cement paste (Fig. 3). The excessive free water content in the mixes with high TM content causes the particles of the constituents to separate leaving pores in the hardened concrete which consequently causes reduction in the concrete strength.

The highest compressive strength was achieved by 30% and 40% replacement of TM, which was found to be about 53MPa compared to 49MPa for the control mixture. This means that there is an increase in the concrete strength of almost 8% compared to the control mix. However, mixes with 50% and 60% replacement of sand by TM gave the lowest compressive strength around 45Mpa which is almost 8% lower than the strength of the control mix.

From Fig. 3, the optimum compressive strength is obtained at 35% sand replaced by TMs. Fig. 4 shows average compressive strength of concrete at 7, 28, and 56 days of curing.

Table 10 Density and compressive strength of concrete (Sand replaced by TM)

Sl. No.	Mix notation	Density (kg/m^3)	Compressive strength(N/mm^2)			
			7 days	28 days	56 days	90 days
1	TM0/S100 (control concrete)	2505	28.0	47.9	48.4	49.2
2	TM30/S70	2513	32.6	52.3	53.2	53.9
3	TM40/S60	2544	32.7	52.2	53.0	53.5
4	TM50/S50	2555	29.3	45.3	46.8	47.3
5	TM60/S40	2573	29.6	43.6	44.0	44.44

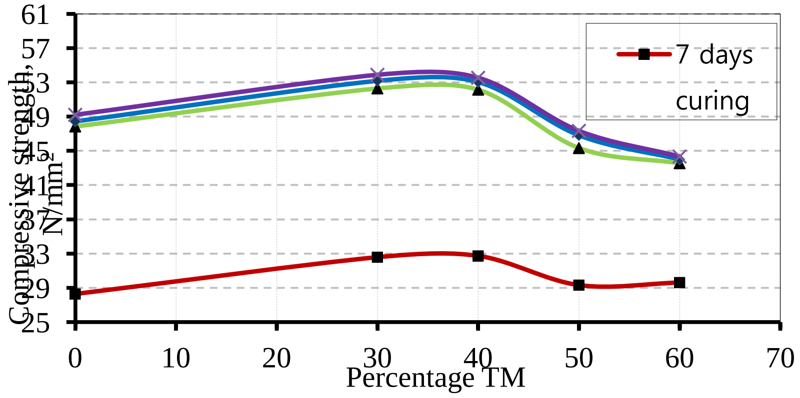

Fig. 3 Compressive strength V/s percentage TM

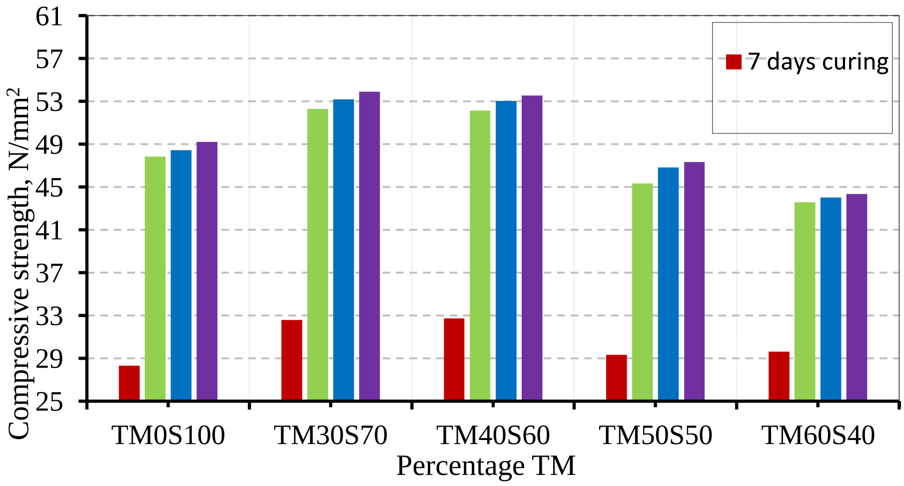

Fig. 4 Average compressive strength of concrete at 7-days, 28- days, 56 days, and 90 days of curing

3.4 Effect of replacing cement by fly ash on the strength of concrete

3.4.1 Compressive strength

Compressive strength of control mix and modified mixes with 20%, 30%, 40% and 50 % of cement replacement with fly ash was determined at 7, 28, 56, and 90 days. Table 11 shows the compressive strength results. The test results show that the early age strength of fly ash replaced for cement in design mix concrete (TM35/S65) is lower than the Ordinary Portland cement concrete (control concrete) due to the slow rate of hydration. However, the rate of hydration is influencing the strength development of TM and fly ash blended concrete after 90 days of curing. The maximum compressive strength of 57.2 N/mm^2 is obtained for concrete mix replaced with 20% fly ash, (TM35/F20) after 90 days of curing. The compressive strength has marginally

Table 11 Density and compressive strength of concrete (Cement replaced by Fly Ash)

Sl. No.	Mix notation	Density (kg/m^3)	Compressive strength (N/mm^2)			
			7 days	28 days	56 days	90 days
1	TM35/F0 (control concrete)	2533	26.1	51.9	52.9	55.0
2	TM35/F20	2501	23.6	44.0	51.0	57.2
3	TM35/F30	2457	19.2	39.1	46.8	53.5
4	TM35/F40	2445	17.0	35.0	42.2	48.3
5	TM35/F50	2429	13.6	33.3	40.0	46.7

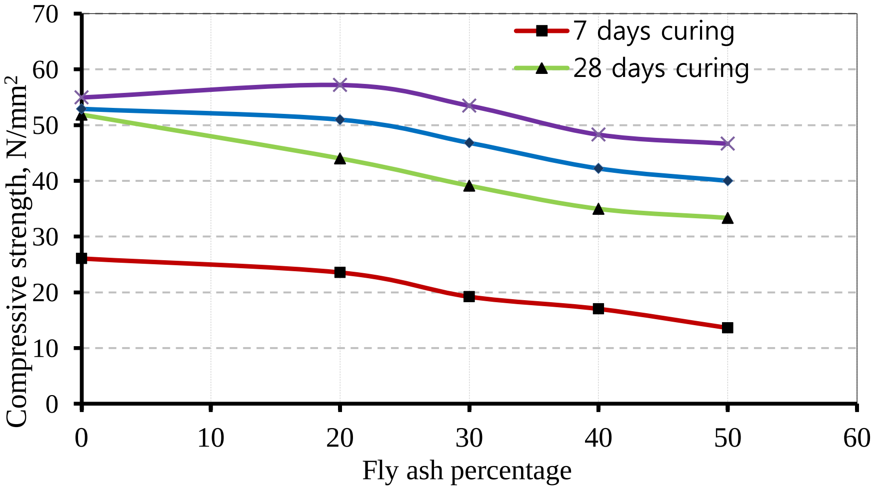

Fig. 5 Compressive strength V/s Fly ash percentage

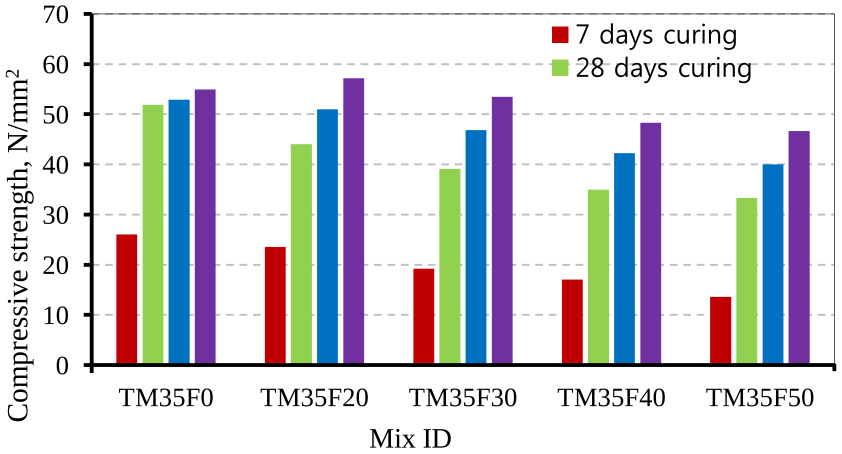

Fig. 6 Average compressive strength of concrete at 7-days, 28- days, 56 days, and 90 days of curing

reduced by about 15% with increase in percentage of fly ash after 90 days of curing. As the fly ash content increases by 20%, 30%, and 40% replacement of cement for mix TM35/S65, There is a marginal increase in the strength of about 4% for concrete mix, cement replaced with 20% fly ash (TM35/F20). Among the blended concrete, the strength in mix TM35/F20 is found higher than other blended combinations. Therefore, the mix TM35/F20 seems to be the optimum replacement in the investigation.

From Fig. 6, it is observed that beyond 20% OPC replacement the compressive strength of concrete decreases with increase in fly ash.

3.5 Split tensile strength

To determine the split tensile strength, cylindrical moulds of diameter 150mm and length 300mm were cast with different proportions of TM with sand and fly ash with cement. Tables 12 shows the results of split tensile test on cylinder specimen after 28 days (percentage increase in strength is calculated by comparing with control concrete). The variation in split tensile strength with respect to percentage increase in fly ash is presented in Fig. 7.

The results from the tensile test are presented in Table 12. It can be seen from Table 12 that the tensile strength of concrete increased for 20% and 30% fly ash replacement but the tensile strength value decreased at 40% and 50% fly ash replacement. The average tensile strength was within the permissible values in accordance with the design specifications.

Table 12 Split tensile strength of mix with Fly Ash

Sl. No.	Mix notation	Fly ash percentage	Tensile strength (N/mm^2)
1	TM35/F0	0	3.3
2	TM35/F20	20	3.4
3	TM35/F30	30	3.3
4	TM35/F40	40	3.2
5	TM35/F50	50	2.9

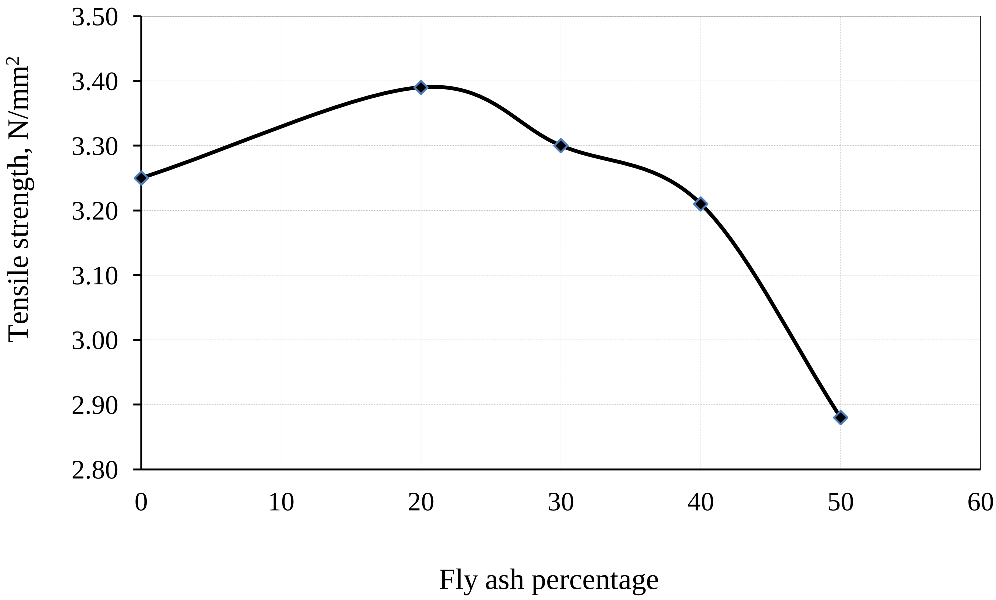

Fig. 7 Tensile strength V/s Fly ash percentage

3.6 Flexural strength

Beam specimen of size 500×100×100 mm is cast and their flexural strengths were calculated by two point flexural tests. Table 13 shows the results of flexural strength test on beam specimen after 56 days. The variation in flexural strength (20%, 30%, 40% and 50%) with variation in fly ash content is presented in Fig. 8.

It is to be noted that the flexural strength is nearly same for the case of 20% FA replacement, however there is steep drop to the tune of 20% with higher replacements studied. Table 13 indicates that the flexural strength of all mixes showed a similar behavior as that of compressive strength results.

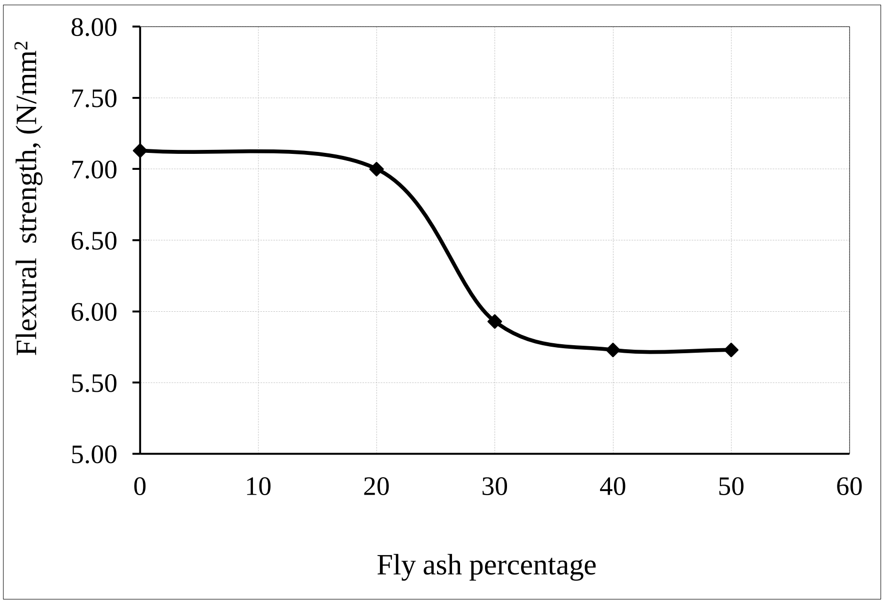

Fig. 8 Flexural Strength V/s Fly ash percentage

Table 13 Flexural strength of beams with Fly Ash

Sl. No.	Mix Notation	Fly ash percentage	Flexural strength (N/mm^2)
1	TM35/F0 (control concrete)	0	7.1
2	TM35/F20	20	7.0
3	TM35/F30	30	5.9
4	TM35/F40	40	5.7
5	TM35/F50	50	5.7

Table 14 Results of Ultrasonic Pulse Velocity Test (sand replaced by TMs)

Sl. No.	Mix notation	Pulse velocity (Km/s)	Concrete quality
1	TM0S100	4.7	Excellent
2	TM30S70	4.6	Excellent
3	TM40S60	4.6	Excellent
4	TM50S50	4.4	Good
5	TM60S40	4.3	Good

Table 15 Results of Ultrasonic Pulse Velocity Test (cement replaced by fly ash)

Sl. No.	Mix notation	Pulse velocity (Km/s)	Concrete quality
1	TM35F0	4.5	Good
2	TM35F20	4.3	Good
3	TM35F30	4.2	Good
4	TM35F40	4.1	Good
5	TM35F50	4.0	Good

3.7 Ultrasonic pulse velocity test

The Ultrasonic pulse velocity of concrete depends on the materials and the mix proportion used in making concrete and it is related to its density and modulus of elasticity. The variation in Ultrasonic pulse velocity for concrete mixes with TM and fly ash is given in Table 14 & 15. Mix IDs TM0/S100, TM30/S70 and TM40/S60 depict good pulse velocity rating and rated as excellent concrete quality (Pulse velocity > 4.5 Km/s) and Mix IDs TM50/S50 and TM60/S40 depict good pulse velocity rating and rated as good concrete quality (Pulse velocity is 3.5 to 4.5 Km/s) as specified by IS 13311 (part-1) 1992. Similarly Mix IDs TM35/F0, TM35/F20, TM35/F30, TM35/F40 and TM35/F50 depict good pulse velocity rating and rated as good concrete quality (Pulse velocity is 3.5 to 4.5 Km/s), ultrasonic pulse velocity decreases as fly ash content increased by 20%, 30%, 40% and 50% to the design mix concrete, and also the concrete quality is decreased by increase in fly ash content due to the slow pozzolanic reaction.

4. Conclusions

Following are the important conclusions drawn from the present study

1. The tailing concrete with 30 % to 40 % TM replaced for sand showed highest compressive strength after 28 days of curing. Further additions of TM caused reduction in the strength of concrete.

2. The optimum compressive strength of 53 MPa is obtained at 35 % of TM replacement for sand.

3. Mixes with 50% and 60% replacement of TM resulted in lowest compressive strength (around 45Mpa) which is almost 8% lower than the strength of the control mix.

4. It is recommended that 35 % of TMs can be used as replacement of sand in order to obtain concrete with good strength properties.

5. It is observed that compressive strength of fly ash mix concrete increases with increase in the fly ash content after 90 days of curing. Among the blended concrete, the strength in mix TM35/F20 is found 4% higher than the control concrete. Therefore, the mix TM35/F20 seems to be the optimum replacement in the investigation.

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