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Optimum Fly Ash and Fiber Content for M20 Grade Concrete

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ABSTRACT: *The hardened concrete is a brittle material which is comparatively strong in compression but weak in tension. The tensile strength as well as the brittle behavior of concrete can be improved by the introduction of small discrete fibers in the concrete matrix. However, the addition of such fibers has an adverse effect on the workability of concrete which increases with increase in fiber content. This reduction in workability of fiber reinforced concrete can be made up by the addition of mineral admixtures such as fly ash which also improves the durability of concrete.*

In this paper, an attempt has been made to study the fresh and hardened properties of concrete with different percentages of class F fly ash and hooked end steel fibers. The cement in concrete is replaced with the percentage of 5 %, 10%, 15%, 20% and 25% by weight of fly ash. There was a decrease in 28 day compressive strength of 0.9%, 1.2%, 1.8%, 3% and 7% respectively. The addition of fly ash increased the workability by 2.7%, 4%, 6.7%, 26.7% and 40% respectively. When cement in concrete was replaced with 0.5%, 1%, 1.5% and 2% by weight of steel fiber, the compressive strength increased by 0.9%, 2.1%, 3.3% and 0.3% respectively. The improvement in flexural strength was 4.3%, 8.7%, 17.4% and 4.3% respectively. The addition of fibers however, drastically reduced the workability by 20.8%, 33.7%, 48.9% and 63.9% respectively. From the experiment, it was concluded that the most optimum fiber content that gives the maximum compressive strength and flexure strength was 1.5%. The reduction in workability due to fiber addition can be compensated by the addition of fly ash. Finally, a concrete mix with a fiber content of 1.5% and fly ash content of 20% was tested. The improvement in compressive and flexure strength was 2.5% and 17.4% respectively. However, the workability of the concrete mix only reduced by 20%. This is because the reduction in workability due to addition of steel fiber was compensated by increase in workability due to the fly ash particles.

Keywords: *Concrete, Class F fly ash, steel fiber, compressive strength, flexure strength, workability.*

I. INTRODUCTION

Many attempts have been made in the past to improve the tensile strength of concrete. One of the recently developed techniques is the addition of fibers in concrete. These fibers act as crack arrestors and prevent the rapid propagation of the cracks. They are uniformly distributed and randomly oriented in the concrete matrix. The addition of fibers improves the post cracking response of the concrete, i.e., it improves its energy absorption capacity and apparent ductility, and also provides crack resistance and crack control [1]. Among all the fibers, the most durable and commonly used are the steel fibers. Steel fibers of different sizes and shapes may be used depending on the application.

Fly ash is a byproduct obtained from thermal industry which is used as mineral admixtures in concrete. The addition of fly ash improves the latter strength and durability of the concrete. This is due to the pozzolanic reaction of fly ash to produce calcium silicate hydrate. However, the rate of this pozzolanic reaction is slow and hence, the addition of fly ash generally decreases the early strength [2]. Due to its smooth spherical size, the addition of fly ash also improves the workability of concrete [3].

1.1 STEEL FIBERS

Steel fibers are the most commonly used type of fibers. Glass and natural fibers when used may get deteriorated in the alkaline medium inside the concrete matrix. Steel, however, shows excellent durability. The steel fibers may sometimes get rusted and lose its strength. But investigations have proved that fibers get rusted only at the surfaces [4]. Steel has high modulus of elasticity. Use of steel fibers provides significant improvements in flexure, impact and fatigue strength of the concrete. To provide better pull out resistance, hooked end steel fibers with round cross section are used in this project. The properties of the steel used in this study are summarized below.

Table 1.1 Specification of steel fibers

Specification	**Value**
Wire diameter (d)	0.6 mm (± 0.04 mm)
Fiber length (L)	30.0 mm (+2/-3 mm)
Aspect ratio (L/d)	50
Tensile strength of drawn wire	>1000 N/mm^2

1.2 FLY ASH

The usage of cement blended with mineral admixtures such as fly ash and slag is growing rapidly in construction industry due to the considerations of cost saving and sustainability. The addition of fly ash in concrete results in improvement of properties such as workability, later age strength development and durability characteristics. The major disadvantage observed in such concrete is the slower development of strength resulting in low early strength and increased setting time. Depending on its chemical composition, fly ash is classified into two via. Class C and class F. Class F fly ash has been used in this study.

II. EXPERIMENTAL STUDY

To begin the study, a control concrete mix of M20 grade was mix proportioned. The mix design procedure was according to the guidelines of IS 10262-2009 [5]. The fine aggregate confirming to zone II of IS 383:1970 and coarse aggregate of nominal size 20mm was used in the study [6]. The cement used was 43 grade OPC. The cement was replaced with percentage of 5%, 10%, 15%, 20% and 25% of fly ash. The detail of mix proportion for the various mixes is shown in table 2.1. The 28-day compressive strength and the workability of the different mixes measured by the slump test are summarized in tables 2.2 and 2.3 respectively.

Table 2.1 Details of mix proportion for M20 concrete with varying fly ash content

Serial Number	**Mix Type**	**Cement (kg/ m^3)**	**Fly Ash (kg/m^3)**	**Fine Aggregate (kg/ m^3)**	**Coarse Aggregate (kg/ m^3)**	**Water (kg/ m^3)**
1	Control Mix	380	Nil	693	1104	209
2	5% fly ash	361	19	693	1104	209
3	10% fly as	342	38	693	1104	209
4	15% fly ash	323	57	693	1104	209
5	20% fly ash	304	76	693	1104	209
6	25% fly ash	285	95	693	1104	209

Table 2.2 Compressive strength at 28 days of M20 concrete with different fly ash content

Serial Number	**Mix Type**	**Compressive strength (N/mm^2)**	**Percentage Decrease in Compressive Strength (%)**
1	Control Mix	27.22	NA
2	5% fly ash	26.98	0.9%
3	10% fly ash	26.89	1.2%
4	15% fly ash	26.73	1.8%
5	20% fly ash	26.40	3%
6	25% fly ash	25.31	7%

Table 2.3 Workability of M20 concrete with different fly ash content

Serial Number	**Mix Type**	**Workability (Slump in mm)**	**Percentage Increase in Workability (%)**
1	Control Mix	75	NA
2	5% fly ash	77	2.7%
3	10% fly ash	78	4%
4	15% fly ash	80	6.7%%
5	20% fly ash	95	26.7%
6	25% fly ash	105	40%

Hence, it can be seen that the early strength of concrete decreases with increase in the fly ash content. The maximum decrease was 7% at a fly ash content of 25%. For all the remaining mixes, the decrease in 28-day compressive strength was less than 5%. The workability increases with an increase in the fly ash content. The maximum increase of 40% was obtained for the mix with 25% fly ash content. From the consideration of both strength and workability, the mix with 20% replacement was chosen as the most optimum fly ash content. Although in this case, the increase in workability is only 26.7% compared to 40% in the 25% replaced mix, it has only a nominal decrease of 3% in the 28 day compressive strength.

In the second part of the study, the cement in the control mix was replaced with 0.5%, 1%, 1.5% and 2% of hooked end steel fiber. The details of the mix proportion are shown in table 2.4. The compressive strength and flexure strength of the different mixes are summarized in table 2.5 and 2.6 respectively.

Table 2.4 Details of mix proportion for M20 concrete with different steel fiber content

Serial Number	Mix Type	Cement (kg/ m3)	Steel Fiber (kg/m3)	Fine Aggregate (kg/ m3)	Coarse Aggregate (kg/ m3)	Water (kg/ m3)
1	Control Mix	380	Nil	693	1104	209
2	0.5% fiber	378.1	1.9	693	1104	209
3	1% fiber	376.2	3.8	693	1104	209
4	1.5% fiber	374.3	5.7	693	1104	209
5	2% fiber	372.4	7.6	693	1104	209

Table 2.5 Compressive strength at 28 days of M20 concrete with different steel fiber content

Serial Number	**Mix Type**	**Compressive strength (N/mm^2)**	**Percentage Increase in Compressive Strength (%)**
1	Control Mix	27.22	NA
2	0.5% fiber	27.46	0.9%
3	1% fiber	27.79	2.1%
4	1.5% fiber	28.11	3.3%
5	2% fiber	27.30	0.3%

Table 2.6 Flexure strength at 28 days of M20 concrete with different steel fiber content

Serial Number	**Mix Type**	**Flexure strength (N/mm^2)**	**Percentage Increase in Flexure Strength (%)**
1	Control Mix	5.75	NA
2	0.5% fiber	6	4.3%
3	1% fiber	6.25	8.7%
4	1.5% fiber	6.75	17.4%
5	2% fiber	6	4.3%

According to Mehta and Monteiro (1993), fibers impart considerable stability to a fresh concrete mass, and hence the slump cone test is not a good index of workability. For example, introduction of 1.5 volume percent steel or glass fibers to a concrete with 200 mm of slump is likely to reduce the slump of the mixture to about 25 mm, but the placeability of the concrete and its compactibility under vibration may still be satisfactory. Therefore, the Vebe consistometer test is considered to be more appropriate for evaluating the workability of fiber-reinforced concrete mixtures [7]. The workability of mixes with different steel fiber content measured by the vebe test is summarized in table 2.7.

Table 2.7 Workability of M20 concrete with different steel fiber content

Serial Number	**Mix Type**	**Workability (Vebe Time in Seconds)**	**Percentage Decrease in Workability (%)**
1	Control Mix	9.23	NA
2	0.5% fiber	11.15	20.8%
3	1% fiber	12.34	33.7%
4	1.5% fiber	13.74	48.9%%
5	2% fiber	15.13	63.9%

From table 2.5 and 2.6, it can be seen that the maximum compressive strength and flexure strength is obtained at the fiber content of 1.5%. The workability decreases with an increase in the fiber content. For the most optimum fiber content of 1.5%, the workability is drastically reduced by 48.9%.

In the last part of this study, a concrete mix is proportioned with the most optimum fiber content of 1.5% and a fly ash content of 20%. The detail of the mix proportion is shown in table 2.8.

Table 2.8 Details of mix proportion of M20 concrete with both fly ash and steel fiber

Serial Number	**Mix Type**	**Cement (kg/m^3)**	**Fly ash (kg/m^3)**	**Steel Fiber (kg/m^3)**	**Fine Aggregate (kg/m^3)**	**Coarse Aggregate (kg/m^3)**	**Water (kg/m^3)**
1	Control Mix	380	Nil	Nil	693	1104	209
2	1.5% fiber + 20% fly ash	298.3	76	5.7	693	1104	209

The compressive strength and flexure strength for mix with 1.5% fiber and 20% fly ash is shown in table 2.9 and 2.10 respectively. Table 2.11 shows the workability obtained for this mix.

Table 2.9 Compressive strength at 28 days of M20 concrete with both fly ash and steel fiber

Serial Number	**Mix Type**	**Compressive strength (N/mm^2)**	**Percentage Increase in Compressive Strength (%)**
1	Control Mix	27.22	NA
2	1.5% fiber + 20% fly ash	27.9	2.5%

Table 2.10 Flexure strength at 28 days of M20 concrete with both fly ash and steel fiber

Serial Number	**Mix Type**	**Flexure strength (N/mm^2)**	**Percentage Increase in Flexure Strength (%)**
1	Control Mix	5.75	NA
4	1.5% fiber + 20% fly ash	6.75	17.4%

Table 2.11 Workability of M20 concrete with both fly ash and steel fiber

Serial Number	**Mix Type**	**Workability (Vebe Time in Seconds)**	**Percentage Decrease in Workability (%)**
1	Control Mix	9.23	NA
2	1.5% fiber + 20% fly ash	11.08	20

III. CONCLUTION

1. When the cement in concrete is replaced with the percentage of 5 %, 10%, 15%, 20% and 25% by weight of fly ash, there was a decrease in 28 day compressive strength of 0.9%, 1.2%, 1.8%, 3% and 7% respectively. This decrease in early strength may be due to slower rate of pozzolanic reaction of fly ash.
2. The addition of fly ash increased the workability by 2.7%, 4%, 6.7%, 26.7% and 40% respectively. The increase in workability may be due to the smooth spherical shape of the fly ash particles.
3. From the consideration of both strength and workability, the mix with 20% replacement was chosen as the most optimum fly ash content. Although in this case, the increase in workability is only 26.7% compared to 40% in the 25% replaced mix, it has only a nominal decrease of 3% in the 28 day compressive strength.
4. When, cement in concrete was replaced with 0.5%, 1%, 1.5% and 2% by weight of steel fiber, the compressive strength increased by 0.9%, 2.1%, 3.3% and 0.3% respectively. The improvement in flexural strength was 4.3%, 8.7%, 17.4% and 4.3% respectively. Hence, it was concluded that the most optimum fiber content that gives the maximum compressive strength and flexure strength was 1.5%.
5. The addition of fibers however, drastically reduced the workability by 20.8%, 33.7%, 48.9% and 63.9% respectively.
6. The reduction in workability due to fiber addition can be compensated by the addition of fly ash. Finally, a concrete mix with a fiber content of 1.5% and fly ash content of 20% was tested. The improvement in compressive and flexure strength was 2.5% and 17.4% respectively. However, the workability of the concrete mix only reduced by 20%. This is because the reduction in workability due to addition of steel fiber was compensated by increase in workability due to the fly ash particles.

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