Studies on workability and compressive strength of ternary blended concrete

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Abstract. With the increasing infrastructure across the world demand for concrete rising abnormally, to produce concrete, cement is the very vital element which binds the materials together. But primary issue arises to environment by the discharge of harmful gases like CO_2, Sulphur etc… at the time of production of cement. A mineral dmixtures, a type of cementitious substance, were employed as a partial or complete replacement for cement to aid with this problem. These materials not only reduced cement usage but also improved the durability of concrete. Partial replacement of cement in concrete is an inventive and elective development material delivered by substance activity of inorganic particles. This paper is mainly focus on compressive strength of a M40 grade Ternary blended concrete made with cement and cementitious materials like Fly ash and Wollastonite. Fly ash is a industrial bi-product materials used as binder material whereas wollastonite is a naturally occurring mineral grounded to fine powder can be exploited as partial replacement to cement. The mix design has been developed for conventional concrete of M40 grade with required workability. It has been observed that the compressive strength is increased slightly and the workability is decresed with partial replacement of cement by Wollastonite in combination of flyash. The workability is decreased with increasing fly ash and wollastonite, but it is in the required range at 50% cement, 30% flyash and 20% wollastonite.

Keywords. Ternary Blended Concrete, Wollastonite, Fly ash, Compressive Strength and Workability.

1 Introduction

Usually cement, aggregate, and water make up concrete. After water, concrete is the second-most-consumed man-made material worldwide. Concrete's key component, cement, bonds particles to create a sturdy building material. There are around 1.5 tonnes of raw ingredients required to create one tonne of cement. It emits 0.8 tons of CO_2 and is

responsible for environmental problems. In the manufacturing of concrete, additional cementitious ingredients are employed to cut down on cement use.
Using supplementary cementitious material and other additives such as admixtures, minerals and fibres have made the research field active during last few decades. Concrete's weakness in tension can be fixed by incorporating metal, mineral, or synthetic fibres, however doing so will increase the cost of the substance. Portland cement is primarily substituted by mineral admixtures as fly ash, silica fume, metakaolin, etc. to boost the strength and durability qualities.

Concrete is a delicate material with radically differing tensile and compressive strengths because it tensile strength is substantially lower than its compressive strength. Its resistance is largely determined by factors like cement, aggregate, and water cement ratio amounts. Although concrete's compressive strength was frequently emphasised, many buildings all over the world have deteriorated over the past 60 to 70 years. Blended cement is created for use in applications where the use of fly ash has been authorised, such as mortars, grouts, cement-based products, and general-purpose concrete. Like enhanced durability and improved later-age strength. Due to its improved performance, fly ash or slag-based concrete has gained popularity. Many research have been done, and it has also been found that exposure conditions significantly affect durability. In light of what has been discovered in other nations, this concept has been altered. This paper is mainly focus on compressive strength of a M40 grade Ternary blended concrete made with cement and cementitious materials like Fly ash and Wollastonite. Fly ash is a industrial bi-product materials used as binder material whereas wollastonite is a naturally occurring mineral grounded to fine powder can be exploited as partial replacement to cement.
The enhanced properties that are obtained due to blending of cement with different materials are,

- Improvement in workability and pumpability.
- Lessened water demand
- Improved bleed control
- Lower drying shrinkage and creep
- Improved resistance to sulphate attack and chloride penetration
- Reduced possibility for Alkali Aggregate Reaction

2 Literature Review

M.D. Gouse Mohiuddin et al. (2022) provided an experimental work on use of both wollastonite & GGBS as a mass-based partial substitute for cement in self-compacting concrete of the M30 grade. According to experimental data, wollastonite substitution levels up to 15% when combined with 20% GGBS content produced excellent outcomes. Maciej Dutkiewicz et al. (2022) presented research on fibrous concretes made using wollastonite, including concrete types like self-compacting, ultra-high performance and standard, engineered cementitious composites, and mortars. Studies have shown that wollastonite has an inert structure, and as a result, because of its acicular particle structure, it behaves like a fibre in cementitious composites. Supriya Xavier Lopes et al. (2020) presented the experimental investigation work contained wollastonite as partial replacement to cement. The obtained results shows that optimum percentage of wollastonite is in range of 14 to 16. Vijay Bhudiya et al. (2020) As a partial alternative for cement, experimental research is being done on materials such fly ash, GGBS, silica fume, wollastonite, and waste glass powder. The obtained results shows that optimum percentage of wollastonite is in range of 15 to 20%. Shubham Dahiphale (2018) presented an experimental study on replacing up to 30% of the cement in a concrete mix with wollastonite. The greatest rise was seen with a 15% replacement of wollastonite. S. Kant Sharma et al. (2017) reported a study comparing fly ash to SCC incorporating Wollastonite microfiber (WMF), a less expensive pozzolanic fibre, for permeability and drying shrinkage. According to the findings, drying shrinkage decreased by 49% for WMF reinforced concrete, whereas it increased by 1.25 percent for fly ash concrete. In both cases, the permeability coefficient reduced by 82 and 74%. Masthanvali. K et al. (2017) experimental investigation is done on concrete supplanted by 10% wollastonite and 15% fly cinder then compressive strength of 46.18 N/mm2 (M7), split tensile strength of 3.09N/mm2 (M7), flexural strength of 3.41 N/mm2 and when cement supplanted by 10% wollastonite and 10% silica fume then compressive strength of 47.20 N/mm2 (M10), split tensile strength of 3.19 N/mm2, flexural strength of 3.43 N/mm2. Based on test comes about, it is watched that there is essentialness change in the quality properties of cement with wollastonite and silica fume mix when contrasted with wollastonite and flyash remains.

3. Materials and Methodology

3.1 Materials

3.1.1 Cement: It is a structural binder, dries and bonds to other substances to create a bond. The primary binder in controlled concrete is regular Portland cement. Tests are performed in a lab on cement to determine general qualities and outcomes are displayed in Table-1.

Table 1. Physical Parameters of Cement

Name of Tests	Results	Limits	Code
Fineness	4%	<10% by weight	IS:4031-Part1
Specific gravity	3.15	3.0-3.15	IS:4031-Part11
Normal Consistency	30%	25-35%	IS:4031-Part4
Initial setting time	30 mins(7mm)	≥30mins	IS:4031-Part5
Final setting time	8hours	≤10hours	IS:4031-Part5

3.1.2 Fly Ash: Made from burning coal in a hot environment, fly ash shown in Fig 1 is a type of cement. According to IS:3812-2003, there are Class F and Class C categories of products.

3.1.3 Wollastonite: A naturally occurring mineral that is created when limestone or dolomite is subjected to extremely high pressures and temperatures. Wollastonite powder is shown in Fig 2. Table-2 displays the chemical compositions of wollastonite and fly ash.

Table-2. Chemical Compositions of Wollastonite and Fly Ash

Compound	**Wollastonite (%)**	**Fly Ash (%)**
Lime(Cao)	45	4
Silica (SiO_2)	47	60.11
Alumina (Al2O3)	4	26.53
Iron Oxide (Fe_2O_3)	1.1	4.25
Magnesia (MgO)	1.8	1.25
Sulphur Trioxide (SO_3)	0.2	0.35
K_2O, Na_2 O	0.04	0.22
Loss of ignition	0.85	0.88

Fig 1: Fly Ash **Fig 2:** Wollastonite

3.1.4 Fine aggregate: Fine aggregate that has passed through an IS 4.75 mm screen is used to cast the entire specimen. Fine aggregate from area III was used in this study, and tests were performed to ensure that it complied with IS: 2386 – 1968 Factor II and results were shown in Table 3.

Table 3. Fine Aggregate Physical Parameters

Name of Test	Results	Limits	Code
Fineness modulus	2.88	2.6-2.9	IS: 2386 Part-3
Moisture content	0.8%	Not more than 5%	ASTM C566
Specific gravity	2.64	2.1-3.2	IS: 2386 Part-3

3.1.5 Coarse aggregate: In the current investigation, it was successfully obtained domestically crushed granite rock accumulation of 20 mm devoid of life and maintained 10 mm for the study in accordance with IS 383-1970. The outcomes of general testing on coarse aggregate are displayed in Table 4.

Table 4. Coarse Aggregate Physical Pparameters

Name of Test	Results	Code
Fineness modulus	8	IS: 2386-1963 Part-3
Moisture content	0.7%	IS: 2386-1963 Part-3
Specific gravity	2.67	IS: 2386-1963 Part-3

3.1.6 Water: Cement, a structural binder, dries and bonds to other substances to create a bond. The primary binder in controlled concrete is regular Portland cement. The physical properties of cement complied with IS 269-2015 specifications.

3.1.7 Super Plasticizer (SP): Another name for it is a high range water reducer. Itis a component added to concrete to increase its strength. Superplasticizers are a class of chemicals that can lower concrete's water content by up to 20%.

3.2 Mix design

The mixture is manufactured in line with Table 5 and Indian Standard IS 10262-2019 for Conventional Concrete. By keeping the ratio of water to binder at 0.45 throughout experiment and percentages are maintained as cement 50%, remaining 50% mass is replaced with fly ash, wollastonite. Table 6 included a total of 5 different trail mix varieties. Materials quantities for the received experimental mixes were prepared, with specifics displays in Table 7.

Table 5. Mix Proportion of M40 grade.

1	Grade of Concrete	M40
2	Volume of concrete(m^3)	1
3	Cement (Kg/m^3)	390
4	Fine Aggregate (Kg/m^3)	671.1
5	CoarseAggregateKg/m^3	1155.6
6	Super plasticizer Kg/m^3	3.9
7	Ratio of mix proportion	1:1.72:2.96
8	W/C ratio	0.45
9	Water Content (Kg/m^3)	175.5
10	Workability (mm)	105

4 Experimental Investigations

General
The above mentioned mix proportions have been used to mix the conventional concrete, the required number of specimen are casted as per the codal standards to test the workability and compressive strength. The findings of experimental work using conventional concrete are presented below.

Test of workability:
Freshly mixed CC are put through a workability test to ascertain their capacity under filling and conformity with IS: 1199 part 6. Figs 3 and 4 show how the ingredients were mixed and how the slump test went.

Specimen casting and curing

Samples were cast in moulds with normal dimensions of cube 100 mm x 100 mm x 100 mm, as indicated in Fig. 4, and left at room temperature for 24 hours. Prior to the concrete pouring, the moulds were cleaned and lubricated. It showcases cast items that have been taken out of the moulds and cured for the recommended 3, 7, and 28 days in a water tank.

Test of compressive strength

After 3, 7, 28 days of water curing, cubic composites were put under compression using the compression testing apparatus depicted in Fig. 6 in granting with IS: 516-1959. Compressive strength is measured by the failure load given to an object's surface area and represented in (N/mm^2).

Fig 3: Materials before Casting Moulds

Fig 4: Experimental Setup of Slump Test

 https://doi.org/10.1051/e3sconf/202339101196

Fig 5 : Casting of Specimens for different Proportions

Fig 6 : Experimental Setup for Compression test

Table 6. Types of Mix and Composition of Mix

Types of MIX	Composition of Mix		
	C %	FA %	WOL %
MIX 1	100	0	0
MIX 2	50	50	0
MIX 3	50	40	10
MIX 4	50	35	15
MIX 5	50	30	20

Table 7. M40 Materials Quantity Represented in (Kg/m^3)

MIX	OPC	FA	WOL	Water	Binder	F.A	C.A	S.P
MIX 1	390	0	0	175.5	390	671.1	1155.6	3.9
MIX 2	195	195	0	175.5	390	671.1	1155.6	3.9
MIX 3	195	156	39	175.5	390	671.1	1155.6	3.9
MIX 4	195	136.5	58.5	175.5	390	671.1	1155.6	3.9
MIX 5	195	117	78	175.5	390	671.1	1155.6	3.9

5 Results and Discussions

- The compressive strength is determined following the customary curing times of 3, 7, 28 days. Fig. 7 and Table 8 both display the results graphically as results.
- Both fly ash and wollastonite were used as cementitious materials after them, and that these cementitious materials' functions and mechanisms were responsible for strength growth, allowing concrete to become denser. Wollastonite played a significant role in the strength growth by achieving high early strengths with the release of more CSH gel.
- The compressive strength is decreased with addition of half of flyash and then it is started increasing the strength with an addition of wollastonite and finally decreased. So an optimum percentage of mix proportion is chosen based on the target mean strength and required workability.

Table 8. Compressive Strength properties

Types of mixes	Compressive Strength in MPa			Slump (mm)
	3 Days	7 Days	28 Days	
MIX 1	24.11	34.62	50.24	102
MIX 2	20.64	31.43	46.92	93
MIX 3	22.94	32.68	47.65	88
MIX 4	24.72	33.74	49.24	82
MIX 5	23.52	32.14	48.15	76

6 Conclusions

The following conclusions are drawn from above results:

- The workability is decreased with increasing fly ash and wollastonite, but it is in the required range (75-100mm) at 50% cement, 30% flyash and 20% wollastonite, it may be due to more fineness of flyash and wollastonite.
- The mix 4 is confirmed as an optimum mix proportions as it has got the required target mean strength and workability.
- Compressive strength is decreased by 6.6% at 50% flyash, and then it is started increasing with an addition of wollastonite in place of flyash upto 15%, which may be due to high calcium oxide inwollastonite and again started decreasing due to more fineness of wollastonite.

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