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Impact on Cost by Reduction of Cement Content in Concrete by Application of Pce based Super Plasticizers

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Abstract:
The construction industry majorly depends on the use of various construction materials out of which cement is one of the majorly used ingredients in the concrete that is of utmost importance. Cement is the glue binding concrete together, and it plays a major role in the properties of fresh and hardened concrete. One of the majorly used construction chemical is SUPERPLASTICIZERS, which is not only responsible for the improving the compressive strength of the concrete but also helps in reduce the w/c content of it. This research focuses on the effect of poly-carboxylate based superplasticizers when used in the concrete mix. The goal is to investigate the possibility of reducing water/cement content in superplasticizer induced concrete mix designs while maintaining required specifications for fresh and hardened concrete.
Keywords: Cost Reduction; Cement Content; Superplasticizers;

1. INTRODUCTION

1.1. Need For Research

Concrete is the most heavily used construction materials in the entire world today. One of the important elements in concrete is Portland cement. Cement in a conventional concrete mixture is not only more costly than most other materials, but it also has significant environmental effects. Approximately 8% of the carbon dioxide (CO2) production worldwide is created in association with the production of cement.Graphenenanoplatelets (GNPs) are considered one of the most advanced nanomaterials that hold the promise of providing multifunctional characteristics to the cementitious matrix (Kumar et al. 2020, Kumar et al. 2019, Kumar et al. 2020).

In addition, the Environmental Protection Agency (EPA) designated the cement industry as the 3rd largest contributor to pollution in the world(U S Environmental Protection Agency, 2015).Thus, the findings detailed within this report have potential to offer substantial monetary and financial savings.

1.2. Objective

The objective of this paper majorly focuses on two aspects:

- Reducing the cement content by addition of superplasticizers into the concrete mix.

- Cost impact comparison between conventional concrete mix and superplasticizer induced concrete mix after reducing the cement content.

The first objective is pursued in order to identify the change in characteristic strength of the concrete if the cement content is reduced when the superplasticizerthat has the properties of improving the strength and cracking resistant is added into the mix.

The second objective however refers to the cost impact if w/c content is reduced when polycarboxylate based (PCE) superplasticizers are added to the mix design (Shukla et al. 2019). This objective can only be fulfilled when the first objective is achieved.

1.3Problem Definition

The annual cement production growth rate is 4 percent due to the rapid growth of construction in developing countries(BARKER, 1963). As the use of excessive cement content in concrete increases this demand further, the concrete industry aims to identify and use the most suitable cement content for a given application.

1.3.1Carbondioxide emission

During the cement manufacturing process at the portland approximately 80 percent of greenhouse gas emissions from concrete are emitted(Flower & Sanjayan, 2007). Furthermore, cement is the third-largest source of greenhouse gas pollution in the US(U S Environmental Protection Agency, 2015). There is therefore a pressure on the sector to reduce the environmental agencies ' carbon footprint.

1.3.2 Energyconsumption

The energy consumption cement of industry is 5 per cent of global industrial energy consumption(Atahan et al., 2009). Reduction of cement content is important if the environmental charge is to be reduced due to energy consumption [Singh et al 2020].

2. REVIEW OF LITERATURE

2.1Cement

Cement plays a major role within a concrete mixture and influences most important aspects of the mix, including: workability, compressive strength, drying shrinkage, and toughness. Cement particles react with water through the hydration process, binding the aggregate and the strength matrix develops(Robert et al., 2018). Recent research, however, has shed light on the relationship between cement content and cracking, and how over-designing can harm concrete. As the amount of cement in a mix increases, the compressive strength also increases. Nonetheless, due to the high cost of cement relative to other concrete materials, and the long-term effects caused by crack repair, costs often increase.

2.1.1. Cement content and workability

Cement material and cement fineness play important roles when it comes to influencing concrete workability. If there is too much cement in a mix in comparison to its water content, the mix would probably be hard to put. The mixture can segregate with too much water however, making it equally difficult to use on the job for the intended purpose(Barbhuiya et al., 2009).Therefore, choosing the amount of cement needed for a mix is crucial to the design of the concrete mixture, influencing its workability and overall construction costs.

2.1.2. Cement content and compressive strength

Increase of cement content typically results in arise in compressive strength, however with all other factors the w/cm has the greater effect on strength. There are limits to the linear relationship between compressive strength and cement content as provided See Fig.1. Found there was minimum cement content required to meet the 28-day strength. Once this value was achieved, the addition of cement beyond this amount did not significantly raise the compressive strength.

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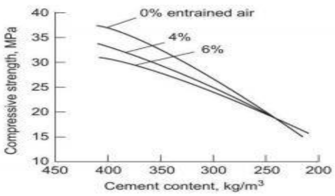

Figure.1. Relationship of concrete compressive strength and cementitious content

2.2Superplasticizers

Through analysis with the rotational rheometer, the effect of superplasticizers on the rheological properties of the mortar can be precisely calculated. On this basis, the compatible cement-superplastizing system can be selected and, from the point of view of operability, the composition of mortar and concrete can be optimised.

The results clearly demonstrate that superplasticizers of the PolyCarboxylate(pc) are more effective than superplasticisers of SNF. Used with the same dosage, they enable mortars with a significantly decreased and low workability loss to be obtained(Shukla, Gupta, & Kishore, 2020). The feature of mortars with PC superplasticizers is high, an advantage from the point of view of segregation and can cause certain practical difficulties In specific, good results for the low W / C mortar or concrete ratios can be predicted with the use of PC superplasticizers. The efficiency of these superplasticizers is similar to SNF super-plasticizers for simple concrete with a standard or high W / C ratio and is thus of no benefit for economic reasons.

3. RESEARCH METHODOLOGY

3.1Research Design

The purpose of this paper is to identify the minimum content of cement which is associated with an appropriate water-to-cement ratio (w/c) along with a constant superplasticizer dosage which results in optimum strength requirements at minimum cost for a concrete mixture.

3.2Materials and Methods

The materials used in this research and their properties are as follows:

3.2.1 Cement

Cement used was locally available in OPC. The physical properties of the cement are tested according IS: METHOD-10262-2009 & IS: 456-2000 are tabulated (Refer table 1).

Table 1 Physical properties of cement

	Properties	Value
Cement	Cement Type and Name of Brand	Shree OPC-43
	a) Density of cement (g/cc)	3.15
	b) Compressive Strength	
	3 days in N/mm^2	28.5
	7 days in N/mm^2	38
	28 days in N/mm^2	45.5

3.2.2Fine aggregate

Locally available sand of maximum size 4.75 mm was used. The physical properties of the sand tested according to the codal provisions of IS: METHOD-10262-2009 & IS: 456-2000 are given (Refer table2)

Fine Aggregate	Properties	Value

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	a) Specific Gravity	2.6
	b) Absorption of Water %	1.52

Table 2. Physical properties of fine aggregate

3.2.3Coarse aggregate

Coarse aggregate of size 20 mm was used. the physical properties of the ca tested according to the codal provisions of is: method-10262-2009 & is: 456-2000 are shown (Refer table 3). In the concrete mix, the ratio of weight of the ca of different size range (between 20 and 12.5 mm, 12.5 and 4.75 mm) is maintained.

Table 3. Physical properties of coarse aggregate

	Properties	Value
Coarse Aggregate	a) Specific Gravity	2.65
	b) Water Absorption in %	0.45

3.2.4*Fly ash*

Locally available fly ash is being used and tested in accordance with the codal provisions of IS 1727. Chemical properties of the fly ash are listed in table4.

Table4. Physical properties offly ash

	Properties	**Value**
Fly Ash	a) Density, g/cc	2.25
	Fly ash content (Kg)	80

3.2.5*Superplasticizer*

Based on the enquiries in the RMC plant in the nearby areas of Gurgaon, Haryana, Polycarboxylate based Superplasticizer was found to be majorly adopted in construction works. (Refer table5)

Table 5 Physical properties of super plasticizer

	Properties	Value
Superplasticizer	(a) Density of Admixture Brocrete C- 800	1.18
	(b) Dose (% of Cementeous Material)	0.8

3.2.6 Grading of aggregate

Aggregate grading is a calculation of the distribution of aggregates by particle size. Aggregate grading is an important factor in the construction of concrete mixtures. They influence both the strength of the concrete and its durability(Refer table 6 and 7).

Table 6 Grading of Coarse Aggregate

Coarse Aggregate- 20mm – I	
Sieve Size (mm)	% Passing by weight

40.0 20.0 10.0 4.75	100.0 96.4 4.2 Nil
Coarse Aggregate - 10mm – II	
Sieve Size (mm)	% Passing by weight
12.5 10,0 4.75 2.36	100 90.4 5.2 Nil

Table 7 Grading of fine Aggregate

I.S. Sieve Size	Fine Aggregate (% Passing)	Remarks Conforming to grading of Table 4 of IS: 383-1970, Zone-II
10 mm	100.0	100.0
4.75 mm	95.9	90-100
2.36 mm	80.6	75-100
1.18 mm	70.4	55-90
600 micron	43.7	35-59
300 micron	15.3	8-30
150 micron	4.7	0-10

3.3Mix Proportion

3.3.1 For M25 concrete with admixture (PCEsuperplasticizer)

Mix proportion implies the quantity of materials taken to prepare concrete of required strength relatively. (Refer table 8)

Table 8. Mix Design Ratio

Materials	Quantity in Kg/m^3
Cement (Shree OPC 43)	300
Water (0.46)	174.8
Fly ash	80
Admixture (Brocrete	3.04
C800)	736
Fine Aggregate	648
20mm aggregate	432
10mm aggregate	

Quantity of Coarse Aggregate = {1000-(300/3.15+80/2.25+4.18/1.18+174.8)}*2.65*0.59 = 1080.00 kg/m^3

Quantity of Fine Aggregate = {1000-(300/3.15+80/2.25+4.18/1.18+174.8)}*2.60*0.41 = 736 kg/m^3

Quantity of CA 20mm @ 60% = 648 kg/m^3

Quantity of CA 10mm @ 40% = 432 kg/m^3

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3.4Specimen Preparation

Mixtures were prepared in accordance with the IS Standards. Three concrete cubes of 150*150*150 were prepared each for Nominal M25 concrete mix design and after addition of superplasticizers in accordance with IS Standard. The samples were de-moulded after 24 hours and cured.

Concrete curing is a process by which the concrete is shielded from moisture loss needed for hydration and kept within the prescribed temperature range(Almutairi, 2017). Curing can increase the strength of hardened concrete and decrease its permeability. Curing also helps to reduce thermal and plastic cracks which can have a severe impact on structural durability.

After the test conducted on these specimens 18 more cubes were casted after reducing the cement content on the Mix design. The cement content was reduced from 7.5% , 10%, 12.5%and 15% respectively in order to determine the maximum cement content reduced to obtain optimum compressive strength of Conventional M25 concrete(Brooks et al., 2003).

3.5Compressive StrengthTesting

It is observed that a compression test is more difficult to perform than a tensile test as

- In order to withstand any buckling due to bending, the specimen must have a greater cross-sectional area,
- the specimen undergoing strain hardening as deformation continues
- With deformation, the cross-section of the specimen increases, resulting in a significant increase in the load required(Shukla, Gupta, & Gupta, 2020).

4. DATA ANALYSIS AND FINDINGS

The data analysis was done based on the compressive strength test conducted on the Six primary specimens of concrete. The test was conducted to determine variations in strength of the concrete when Polycarboxylic based Superplasticizers are added in to the concrete mix. This resulted in significant increase in the compressive strength of the concrete when Admixture (SP) was added in it. The Cement content was reduced in proportion of 7.5%, 10%, 12.5% and 15% respectively.

4.1Identification Of Variation In Compressive Strength Of Concrete

4.1.1 Results of compressive strength test on conventional M25 concrete

The results indicate that after 28 days of curing the concrete the average compressive strength obtained from the cubes is achieved to be 28.4 N/mm^2(Refer table 9)

Table 9. Conventional M25 concrete (Without superplasticizers)

Sr. No.	Load in KN	Compressive strength of concrete after 28 days (N/mm^2)
1	637	28.3
2	628	27.9
3	651	28.9
Average		**28.4 N/mm^2**

4.1.2 Result of compressive strength test on PCEsuperplasticizer based M25 concrete

The results indicate that after 28 days of curing the concrete the average compressive strength obtained from the cubes is achieved to be 34.8 N/mm^2 (Refer table 10). The result of these two specimens shows significant difference in the compressive strength of the concrete(Erdogdu, 2000).

Table 10.M25 Concrete with PCE based Superplasticizer

Sr. No.	Load in KN	Compressive strength of concrete after 28 days(N/mm^2)
1	801	35.6
2	767	34.0
3	781	34.7
Average		**34.8 N/mm^2**

4.2Reduction of Cement Content

Result of compressive strength test after reduction of 7.5%, 10%, 12.5% and 15% cement content: (Refer table 11)

Table 11. Compressive strength of PCE based concrete after reduction of 7.5%, 10%, 12.5% and 15% Cement content

Sr. No.	Reduction of 7.5% Cement Content		Reduction of 10% Cement Content		Reduction of 12.5% Cement Content		Reduction of 15% Cement Content	
	Load in KN	**Compressive strength of concrete after 28 days (N/mm^2)**	**Load in KN**	**Compressive strength of concrete after 28 days (N/mm^2)**	**Load in KN**	**Compressive strength of concrete after 28 days (N/mm^2)**	**Load in KN**	**Compressive strength of concrete after 28 days (N/mm^2)**
1	762	33.8	744	33.1	727	32.3	661	29.4
2	758	33.6	746	33.2	713	31.7	640	28.4
3	783	34.8	732	32.6	742	32.9	672	29.9
Average		**34.0 N/mm^2**		**32.96 N/mm^2**		**32.3 N/mm^2**		**29.2N/mm^2**

4.3Statistical Analysis of Data

In order to check the significance of the data obtained from the test conducted, ANOVA is to be applied on all the results cumulatively.

An ANOVA test is a means of finding out whether the results of a survey or experiment are significant In other words, they help you determine if the null hypothesis is to be rejected or the alternative hypothesis accepted(Bharatkumar et al., 2001). In fact, you are evaluating groups to see if there is any disparity between them.

4.3.1 Result of Anova

The null hypothesis would be:"There is no effect on mean strength of concrete after reduction in cement content."

This null hypothesis implicates that the strength would not vary even if the cement content is reduced in the concrete mix.

Now if the resulting P-value after the test turns out to be lesser than 0.05, then the above null hypothesis will be rejected indicating that the compressive strength of the concrete will vary with reduction in the cement content(Yazici& Arel, 2012).

The following data of the test concludes that:(Refer table 12). As P-value is < 0.05 therefore the null hypothesis is rejected. Thus the result shows that there is significant amount of difference between the data set. This means that the cement content reduction corresponds to the change in the mean strength of the concrete.

Table 12. Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
PCE BASED 7.5%	3	102.2	34.0667	0.41333333
PCE BASED 10%	3	98.9	32.9667	0.10333333
PCE BASED 12.5%	3	96.9	32.3	0.35999999
PCE BASED 15%	3	87.7	29.2333	0.58333333

ANOVA

Source of Variation	SS	Df	MS	F	P-value
Between Groups	38.6103	3	12.8701	35.2588	**0.0001**
Within Groups	2.9201	8	0.365		
Total	41.5304	11			

4.4 Observations

The following result shows that the minimal reduction in cement content in concrete does not majorly affect its compressive strength. The further data implicates that after reduction of about 10-12.5% of cement content, the optimum compressive strength of the concrete is achieved(Chang, 2004). This indicates that after the application of PCE based superplasticizers into the concrete, the cement content can be reduced upto 12.5% without compromising the strength or the concrete's workability.

4.5Cost Comparison

Based on the results, it is established that after the reduction of 12.5% of cement content in PCE based superplasticizer induced concrete, the concrete can achieve an optimum compressive strength of a Conventional M25 concrete without compromising with its durability and workability(Flower & Sanjayan, 2007).

In order to analyse the cost of preparing both the specimens, a rate analysis is to be done. The current market rates of all the constituents are to be accumulated to ascertain the difference in the cost of both Conventional concrete and PCE based concrete(Kapelko, 2006).

4.5.1 Rate analysis for conventional M25 concrete (Refer table 13)

Table 13. Rate analysis of conventional M25 concrete

Conventional M25 Concrete					
Material	Unit	Quantity	Unit	Rate	Amount
Cement (OPC-43)	Kg	300	Kg	7	2100.00
Fly ash	Kg	80	Kg	0.5	40.00
Fine aggregate	Kg	736	Cum	1235	568.10
Coarse aggregate 10mm	Kg	432	Cum	1050	318.54
Coarse aggregate 20mm	Kg	648	Cum	1050	477.81
	Ltr	174.8	Ltr	1	175.00

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Water	
Total	**3679.45**

The total cost for 1 cubic metre of concrete prepared by conventional method (without addition of any admixture any chemical compound) is summed up to be **Rs. 3679.45.**

4.5.2 Rate analysis for pce based M25 concrete (Refer table 14)

Table14 Rate analysis of PCE based M25 concrete with 12.5% reduced cement content

PCE based M25 concrete with 12.5% reduced cement content					
Material	Unit	Quantity	Unit	Rate	Amount
Cement (OPC-43)	Kg	262.5	Kg	7	1837.50
Fly ash	Kg	80	Kg	0.5	40.00
Admixture (PCE based superplasticizer)	Ltr	2.6715	Ltr	80	213.72
Fine aggregate	Kg	736	Cum	1235	568.10
Coarse aggregate 10mm	Kg	432	Cum	1050	318.54
Coarse aggregate 20mm	Kg	648	Cum	1050	477.81
Water	Ltr	155.5	Ltr	1	154.50
Total					**3608.17**

The total cost for 1 cubic metre of concrete prepared with addition of PCE Based Superplasticizer (Dosage: 0.78% of Cementitious material i.e. Cement + Fly ash) method is summed up to be **Rs. 3608.17.**

This Analysis of rate clearly indicate that the cost of construction of 1m3 of concrete is decreased by **Rs. 71.28**(Dhir et al., 2004). This does not only save construction cost, but also reduces cement content which is responsible for causing harm to the environment.

5. CONCLUSION

The following conclusions can be obtained from the research:

- It was observed that the compressive strength of the concrete increased with the application of PCE based superplasticizer into the mix.
- PCE based superplasticizer is very useful for providing strength to the pourable concrete while improving its durability and workability.
- With reduction of cement content in the concrete, the compressive strength of the pourable concrete decreases without compromising the durability.
- The cement content in SP influenced concrete mix can be reduced by up to 12.5 percent to achieve maximum compressive strength of conventional concrete.

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- Due to reduction in the cement content, the Emission of carbon dioxide shall substantially get reduced, thereby reducing the greenhouse effect.
- Due to the reduction in cement content, the water content reduces which helps in reduction of overall cost of construction.
- The cost of construction reduces up to Rs.70 for a $1m^3$ concrete which can help in reduction of cost of the project.

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