Nigerian Journal of Engineering Science Research (NIJESR).
Vol. 4, Issue 1, pp.25-33, 2021
Copyright@ Department of Mechanical Engineering, Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.
ISSN: 2636-7114
Journal Homepage: https://www.iuokada.edu.ng/journals/nijesr/

Compressive Strength and Cost - Benefit Analysis of the Hydroplast 200 Superplasticized Concrete

[1*] Ogheneochuko, D. O., [2] Onyeka J. O.

[1]*Department of Civil Engineering, Gen. Abdulsalami Abubakar College of Engineering, Igbindedion University, Okada, Nigeria*
(danielogheneochuko65@gmail.com, daniel.ogheneochuko@iuokada.edu.ng; +2348185585383)

[2]***Department of Civil Engineering, Faculty of Engineering, Imo State University, Owerri, Nigeria***
(juliusonyeka@yahoo.com)

****Corresponding Author: Ogheneochuko, Daniel Eguonor; danielogheneochuko65@gmail.com, daniel.ogheneochuko@iuokada.edu.ng (07068870937)***

Manuscript History
Received:
Revised:
Accepted:
Published: 30-06-2021

Abstract: *Several techniques have been discovered in the use of concrete to ensure its efficiency in construction work. In this direction, processes have emerged to obtain richer and stronger concrete at reduced cost. The strength gain and reduction in cost could be as a result of the addition of admixtures or reduction of construction time which also reduces the number of days spent on site, hence the cost of construction. This paper sought to analyze the compressive strength behaviour and cost-benefits in the use of hydroplast 200 superplasticizer for 7 days and 28days concrete strength. The compressive strength for Grade 25 concrete which stands out as one of the most common concrete grades used for construction was considered for each test duration with 0.5%, 0.7%, 1% and 1.5% of the superplasticizer and at a cement reduction of 5%, 10% and 15%. It was concluded that at 0.7% addition of the superplasticizer and 15% reduction in cement content, a 12.4% increase in compressive strength can be achieved. Thus, a metre cube of concrete can be produced at 12.1% reduced cost as compared to pure concrete without the superplasticizer.*

Keywords: *Concrete, Plasticizer, Fluidity, Superplasticizer, Compressive Strength, Hydroplast.*

INTRODUCTION

Construction and most other Civil Engineering works make use of concrete. In fact, according to Olufusi *et al.,* (2015), it is seen to be the most widely used construction material because of its property as one of the most versatile heterogeneous construction materials. The constituent materials such as fine aggregate, coarse aggregate, cement and water, affect the properties of the concrete produced. For instance, Bamigboye *et al.,* (2015) informed that concretes produced using washed gravel as coarse aggregate have been found to have compressive strengths higher than those of similar concretes produced using unwashed gravel. A significant parameter considered in the production of concrete is the water cement ratio. Malagavelli and Patune (2012) stated that water cement ratio has been found to have considerable influence on concrete properties especially the workability of concrete as the fluidity of the cement increases with increased water content per cubic meter of concrete. Concrete is said to share the similar chemistry that exists between cement and water as the adhesive property of cement is only activated when mixed with water. It has been said that concrete has found wide use in the industry where it has to be produced in a manner that can fit specific situations. In some instances, the ordinary concrete is not able to meet up with the expected performance in terms of quality. It is such conditions that necessitate the use of admixtures in order to alter the properties of the ordinary concrete to enhance its suitability for specific conditions.

Admixtures are materials, other than the basic constituents of concrete (cement, water and aggregates), infused into concrete just before or at the point of mixing (Bamigboye et al., 2015). These admixtures could be in the form of plasticizers, superplasticizers, retarders and accelerators. Among the plasticizers are water reducers which help to fluidify the mix and improve the quality of the concrete or mortar. On the other hand, superplasticizers are high range water reducers, more or less an improved version of plasticizers which can help reduce the water content up to 30 percent unlike the regular plasticizer that reduces water content by only 15 percent and they are powerful as dispersing agents (Shetty, (2010). Thus, the use of superplasticizers has been found to be very useful in achieving certain desired properties and it has been used to help reduce the water cement ratio of concrete considerably. It finds its widest application in the production of high strength and high performance concrete and in the production of self-leveling, self compacting and flowing concrete (Hammed, (2012). Superplasticizers in concrete have other beneficial effects such as acceleration, retardation, air entrainment, water reduction and plasticity, owing largely to their action on cement. They reduce shrinkage, improve workability and mechanical strength as well as affect the properties of the cement paste (Plank *et al.*, (2009) and Oladiran *et al.,* (2012). The type of superplasticizer such as Betocrete F-63, Hydroplast 200, etc has significant effect on the properties of concrete and production is based on the selection of synthetic polymers and organic substances used to reduce cement content. Many researchers, including Ede and Adegbite, (2014)., Kazeem *et al.,* (2015); and Ogheneochuko and Orie, (2016), showed that superplasticizers have been used to achieve better workability and compressive strength and reduced water-cement ratio. Estimating the appropriate quantity of superplasticizers and the relative cost advantage has posed a great challenge in time past hence analysis of the cost-benefit of the use of superplasticizers in the use of concrete as an engineering and construction material.

MATERIAL AND METHOD

The materials used for the study and the methods adopted include:

2.1 Materials

Ordinary Portland Cement (Grade 42), sharp sand as fine aggregate, 20mm granite stones as coarse aggregate, potable water free from contaminants as specified by BS 3148 and hydroplast 200 as superplasticizer were used in this research.

A. Mix Proportion and Curing

Two series of superplasticized mixes were compared with a conventional concrete as control mix to study the workability and compressive strength properties. A water - cement ratio (w/c) of 0.4 and 0% superplasticizer was used for the control mix, while the superplasticizer was varied at 0.5, 0.7, 1 and 1.5% for the superplasticized Concrete mixes. Hydroplast 200 superplasticizer was used to maintain high workability. The specimens were cast and cured in water until the test ages. The mix proportions are given in Table 2.

B. Mechanical Properties

The concrete was tested in the fresh and hardened states to determine the mechanical properties.

Workability Test

The workability was determined using slump test as specified by BS 1881-108,

Compressive Strength Test

Concrete specimens of 150 mm × 150mm × 150mm cubes were investigated for compressive strength at ages 7 days and 28 days. The compressive strength test was carried out as per BS 1881-105. The reported results are the average of three samples used.

RESULTS AND DISCUSSION

Table 1 presents the concrete mix design for the concrete grade considered. Table 2 presents the workability of the concrete using the slump test. The table revealed that the superplasticizer helped to improve the workability of the concrete.

Table-1 Mix Design for Control Mixes for Grade 25

Grade	w/c	Cement (Kg/m^3)	Water (Litre)	Fine Aggr. (Kg/m^3)	Coarse Aggr. (Kg/m^3)	SP (%)	Target Strength
25	0.40	380	152	558	1302	0	31.6N/mm^2
Per trial Mix of 0.05m^2	0.40	19	7.6	27.9	65.1		

Table-2 Slump Value Details for Batches

S/N	W/C	SP Content (%)	Workability (Slump -cm)
1	0.4	0	30
2	0.4	0.5	60
3	0.4	0.7	70
4	0.4	1.0	80
5	0.4	1.5	85

Table-3 Compressive Strength of Control Mix Concrete

Mix Proportion	W/C	Cement (kg)	F/A (Kg/m^3)	C/A (Kg/m^3)	SP (%)	Compressive Strength (N/mm^2)
7 Days Compressive Strength	0.40	380	558	1302	0	26.4
28 Days Compressive Strength	0.40	380	558	1302	0	32.2

Table-4 7 Days Compressive Strength of SP Concrete at 5% Cement Content Reduction

Mix Prop	W/C	Cement (kg)	F/A (Kg/m^3)	C/A (Kg/m^3)	SP (%)	Compressive Strength (N/mm^2)
7 Days Compressive Strength	0.40	361	558	1302	0	25.3
7 Days Compressive Strength	0.40	361	558	1302	0.5	20.7
7 Days Compressive Strength	0.40	361	558	1302	0.7	22.0
7 Days Compressive Strength	0.40	361	558	1302	1.0	19.3
7 Days Compressive Strength	0.40	361	558	1302	1.5	27.2

The 7 days strength tests showed that at cement reduction of 5%, the highest compressive strength is achieved at 1.5% addition of superplasticizer which produced a 7.5% increase in compressive strength as compared to the control mix. Similarly, the lowest strength is achieved at 1.0% addition of superplasticizer as seen in Table 4. Also, the 7 days and 28 days compressive strength of the control mix and experimental works are presented in Table 3 while those of the superplasticized concrete are presented in Tables 4 to Table 9. The results showed that with the reduction of cement content for all percentages considered (5%, 10% and 15%), normal concrete mix results in a slight decrease in the compressive strength.

Table-5 28 Days Compressive Strength of SP Concrete at 5% Cement Content Reduction

Mix Prop	W/C	Cement (kg)	F/A(Kg/m^3)	C/A(Kg/m^3)	SP (%)	Compressive Strength (N/mm^2)
28 Days Compressive Strength	0.40	361	558	1302	0	29.4
28 Days Compressive Strength	0.40	361	558	1302	0.5	38.2
28 Days Compressive Strength	0.40	361	558	1302	0.7	30.2
28 Days Compressive Strength	0.40	361	558	1302	1.0	24.2
28 Days Compressive Strength	0.40	361	558	1302	1.5	29.4

The proportion of superplasticizer added for each level of cement reduction affected the compressive strength. Table 5 shows that at 5% cement content reduction, only 0.5% of the superplasticizer gave an increase in the 28 day compressive strength. Other percentages of the superplasticizer brought about a reduction in the compressive strength.

Table-6 7 Days Compressive Strength of SP Concrete at 10% Cement Content Reduction

Mix Prop	W/C	Cement(kg)	F/A (Kg/m³)	C/A(Kg/m³)	SP (%)	Compressive Strength (N/mm²)
7 Days Compressive Strength	0.40	342	558	1302	0	24.7
7 Days Compressive Strength	0.40	342	558	1302	0.5	38.5
7 Days Compressive Strength	0.40	342	558	1302	0.7	36.8
7 Days Compressive Strength	0.40	342	558	1302	1.0	21.2
7 Days Compressive Strength	0.40	342	558	1302	1.5	21.8

Table 6 showed that at 0.5% addition of superplasticizer to the 10% cement reduced mix, the 7 days compressive strength is greater than that of the control by 56% with the lowest compressive strength obtained at 1.0% addition of superplasticizer.

Table-7 28 Days Compressive Strength of SP Concrete at 10% Cement Content Reduction

Mix Prop	W/C	Cement(kg)	F/A (Kg/m³)	C/A (Kg/m³)	SP (%)	Compressive Strength (N/mm²)
28 Days Compressive Strength	0.40	342	558	1302	0	29.2
28 Days Compressive Strength	0.40	342	558	1302	0.5	39.4
28 Days Compressive Strength	0.40	342	558	1302	0.7	40.5
28 Days Compressive Strength	0.40	342	558	1302	1.0	36.6
28 Days Compressive Strength	0.40	342	558	1302	1.5	37.6

For the 10% cement reduction, all percentages of the superplasticizer gave a compressive strength value greater than that obtained without the addition of superplasticizer. The highest value for this category was obtained at 0.7% of the superplasticizer and the lowest strength at 1.0% superplasticizer as seen from Table 7.

Table-8 7 Days Compressive Strength of SP Concrete at 15% Cement Content Reduction

Mix Prop	W/C	Cement (kg)	F/A (Kg/m³)	C/A(Kg/m³)	SP (%)	Compressive Strength (N/mm²)
7 Days Compressive Strength	0.40	323	558	1302	0	22.6
7 Days Compressive Strength	0.40	323	558	1302	0.5	19.2
7 Days Compressive Strength	0.40	323	558	1302	0.7	28.8
7 Days Compressive Strength	0.40	323	558	1302	1.0	24.1
7 Days Compressive Strength	0.40	323	558	1302	1.5	19.7

From Table 8, it is seen that at 15% cement reduction, the highest compressive strength is achieved at 0.7% addition of superplasticizer. This results in a 27% increase in the 7 days compressive strength as compared with the mix without superplasticizer and the lowest compressive strength at 0.5% superplasticizer content.

Table-9 28 Days Compressive Strength of SP Concrete at 15% Cement Content Reduction

Mix Prop	W/C	Cement (kg)	F/A (Kg/m³)	C/A(Kg/m³)	SP (%)	Compressive Strength (N/mm²)
28 Days Compressive Strength	0.40	323	558	1302	0	27.8
28 Days Compressive Strength	0.40	323	558	1302	0.5	21.5
28 Days Compressive Strength	0.40	323	558	1302	0.7	36.2
28 Days Compressive Strength	0.40	323	558	1302	1.0	30.6
28 Days Compressive Strength	0.40	323	558	1302	1.5	23.6

Table 9 shows that at 15% cement content reduction, the non superplasticized concrete produced a weaker concrete less than the control mix by about 13.7% and other proportions of superplasticizer produced lower compressive strength except 0.7% of the superplasticizer which produced a strength greater than the control mix by 12.4% and greater than its contemporary mix (15% cement reduction batch without superplasticizer) by 23.2%. This showed that as the cement content reduces to a certain level, the compressive strength of the concrete reduces despite the addition of the superplasticizer.

Table-10 Cost Analysis for 5% Cement Reduction and 0.5% SP Content

S/N	Material Description	Qty. (kg)	Unit Price (₦)	Amount (₦)
1	Cement	380	70	26,600
	Percentage reduction - 5%	361	70	25,270
	Difference			1,330
2	Superplasticizer	361	70	23,940
	Percentage addition - 0.7%	2.5	340	859
	Sum			24,799
	Difference (26,600 - 24,799)			1,801
	Percentage Savings			6.8%

Table-11 Cost Analysis for 10% Cement Reduction and 0.7% SP Content

S/N	Material Description	Qty. (kg)	Unit Price (₦)	Amount (₦)
1	Cement	380	70	26,600
	Percentage reduction - 10%	342	70	23,940
	Difference			2,660
2	Superplasticizer	342	70	23,940
	Percentage addition - 0.7%	2.4	340	816
	Sum			24,756
	Difference (26,600 - 24,756)			1,844
	Percentage Savings			6.9%

Table 12: Cost Analysis for 15% Cement Reduction and 0.7% SP Content

S/N	Material Description	Qty. (kg)	Unit Price (₦)	Amount (₦)
1	Cement	380	70	26,600
	Percentage reduction - 15%	323	70	22,610
	Difference			3,990
2	Superplasticizer	323	70	22,610
	Percentage addition - 0.7%	2.3	340	760
	Sum			23,379
	Difference (26,600 - 23,379)			3,221
	Percentage Savings			12.11%

The cost analysis is presented in Table 10. This table revealed the savings that can be made at 5% reduction of cement quantity and at 0.5% addition of superplasticizer. It also gives the highest 28 day compressive strength at the cement reduction level. Table 11 showed that the highest 28 day compressive strength when cement content is reduced by 10% can be achieved at a superplasticizer content of 0.7% with similar values for 15% cement reduction as seen in Table 12.

CONTRIBUTION TO KNOWLEDGE

This research has produced a modality for estimating the optimal content of superplasticized **concrete** with improved mechanical properties. Industries can adapt this approach to enjoy the benefits derived from the use of superplasticizers in concrete.

CONCLUSION

Based on the findings, it could be concluded that the comparative assessment of the compressive strength of conventional concrete and hydroplast 200 superplasticized concrete showed that the superplasticized concrete compares very well with the conventional concrete in addition to the great reduction in cost. Industries and relevant building agencies can adopt this model in the application of superplasticizers to concrete to help reduce construction cost.

RECOMMENDATION

Superplasticizers can be conveniently used in concrete technology with adequate test on the exact quantity required to save cost and obtain improved concrete quality.

CONFLICT OF INTEREST

I hereby state that no conflict of interest will arise in any form from the publishing of this study.

REFERENCES

BS 1881; Part 108, (1978). Methods for Making Cubes from Fresh Concrete. British Standards Institution

BS 1881; Part 115, (1983). Specifications for Compression Testing Machines for Concrete. British Standards Institution

Bamigboye, G. O., Anthony, N. E., Uwanabasi, E. U., Tajudeen, O. O., Oluwakele, A. O. (2015): Assessment of Strength Characteristics of Concrete Made from Locally Sourced Gravel Aggregate from South – South Nigeria. *British Journal of Applied Science and Technology*. Vol. 12, No 5, pp. 1-10

Ede, A. N., Adegbite, A. A. (2014). Effects of Limestone and Superplasticizer on the Fresh Properties of Self-Compacting Concrete. *Civil and Environmental Research*. Vol. 6, No 2, pp. 22 – 27

Hameed, A. H. (2012). Effect of Superplasticizer Dosage On Workability Of Self-Compact Concrete. *Diyala Journal Of Engineering Sciences,* Vol. 5(2), pp. 66-81

Kazeem, K. A., Wasiu, O. A., Idris, A. A. (2015). Determination of Appropriate Mix Ratios for Concrete Using Nigerian Portland Cement-Limestone Grades 32.5 and 42.5. *Leornardo Electronic Journal of Practices and Technologies*. Issue 26, pp. 79 – 88.

Malagavelli, V., Patune, N. R. (2012). Strength and Workability Characteristics of Concrete by Using Different Superplastizers. *International Journal of Materials Engineering.* 2(1), pp. 7 – 11

Ogheneochuko D. E., Orie O. U. (2016). Assessment of Superplasticized Concrete Using Taguchi's Optimization Approach. *Nigerian Journal of National Association of Mathematical Physics.* 37: pp. 347 – 354

Oladiran, A., Aderinlewo, O., Tanimola, M. (2012). Effects of Locally Sourced Water Reducing/Retarding Admixture on Concrete. *Journal of Civil Engineering and Urbanism.* Issue 5, pp. 170-175

Olafusi, O. S., Adewuyi, A. P., Otunla, A. I., Babalola, A. O. (2015). Evaluation of Fresh and Hardened Properties of Self-Compacting Concrete. *Open Journal of Civil Engineering.* 5: pp. 1 – 7

Plank, J., Schreofl, C., Gruber, M., Lesti, M., Seiber, R. (2009). Effectiveness of Polycarboxylate Superplasticizers in Ultra High Strength Concrete: The Importance of PCE Compatibility with Silica Fume. *Journal of Advanced Concrete Technology*. 7(1), pp. 5 – 12

Ran, Q., Miao, C., Liu, J., Wu, S. nasShen, J. (2006). Performance and Mechanism of a Multi-Functional Superplasticizer for Concrete. *Materials Transportations.* 47(6), pp. 1599 – 1604.

Shetty, M. S. (2010). Concrete Technology Theory and Practice. S. Chand & Company Ltd. ISBN:81-219-0003-4