Journal of Resources Development and Management www.iiste.org
ISSN 2422-8397 An International Peer-reviewed Journal
Vol.45, 2018

Effect of Plastcrete and Steel Fiber on the Mechanical Properties of Fresh and Hardened Concrete

Ali Tayeh* Eyad Haddad
Faculty of Applied Engineering and Urban Planning, University of Palestine, Gaza, Palestine

Abstract
Plasticizers and steel fibers are used in several fields in civil engineering. They have been widely used in concrete industry to produce concrete with specific fresh and hardened properties; such as high strength, workability, permeability...etc. The main objective of this research is to study the effect of Plastcrete which is one of many different types of plasticizers and steel fiber on the mechanical properties of concrete containing steel fiber in order to produce high strength concrete of about 37.19 MPa with good workability. The Plastcrete used in this research was not heavily used in the production of concrete. These materials are considered as filler materials which means they don't generally react to concrete components. The mechanical properties of fresh and hardened concrete have been studied for normal concrete without adding Plastcrete and steel fiber. Four dosages of Plastcrete were applied. These ratios were from 2% to 5% of Plastcrete and 2% of steel fiber for all samples. Also the current research studied using Plastcrete material and steel fiber with reduction of water by 27% of cement weight for all samples with different dosages ranging from 2% to 5% of Plastcrete and 2% of steel fiber for all samples. These materials were used to improve workability and compressive strength of fresh and hardened concrete .The slump test, compressive strength test were conducted for all specimens with and without adding Plastcrete and Steel fiber materials. The indirect tensile strength and flexural strength were carried out for concrete specimens having 3% of Plastcrete and 2% of Steel fiber for both with and without reduction of water.
Keywords: Superplasticizer, Plastcrete, Steel fiber, Concrete

1. Introduction
The repeated aggressive attacks on Gaza strip by the Israeli army left a large number of damaged buildings. These damaged buildings need strengthening with high quality concrete such as High Strength Concrete "HSC". This type of concrete cannot be produced in Gaza Strip economically. Therefore, normal concrete with normal strength has been used with adjusting workability by increasing the water to cement ratio and cement quantity. These adjustments will cause many problems such as larger cross-sections, segregation, honeycombing, bleeding, and shrinkage of concrete. Recent studies showed that using Superplasticizer 'SP' in concrete containing steel fiber have very strong effect on the properties of concrete. [1] [2]

This research will focus on the effect of Plastcrete (type of superplasticizer) on the properties of fresh and hardened concrete containing steel fiber to improve the properties of concrete.

2. Research Aim and Objectives
2.1 The Aim
The aim of this work is to study the effect of Plastcrete on the mechanical properties of fresh and hardened concrete containing steel fiber to reach higher strength of concrete as much as possible with optimum workability and good permeability at low cost.

2.2 The Objectives
The following objectives were identified to achieve the aim of the study:
- Identify the exact quantity of Plastcrete and steel fiber that will be used to enhance concrete mixes.
- Study the effect of Plastcrete and steel fiber dosage on the mechanical properties of fresh and hardened concrete.
- Identify the optimum mechanical properties of material used in the mix.

3. Literature Review
This section reviews the literature of the available previous studies which use superplasticizer material and steel fiber in concrete. The effect of these materials on the mechanical properties of fresh and hardened concrete is also reviewed.

3.1 Impacts of Superplasticizer on Concrete Properties
The impact of Superplasticizers on concrete was discussed in previous researches as follow:
- Santhanam (2013), was able to highlight evaluation of superplasticizer performance in concrete and he

noted that superplasticizers are an essential component in modern concrete, they improve workability and he tested superplasticizer in field in terms of evaluation of the influence of ambient conditions and studies the size of mix and speed of mixing on superplasticizer effectiveness. The test results revealed the complex nature of interactions between cement and superplasticizers in concrete. [5]

- Alsadey (2012) concluded that when concrete mixes with SP amounts, if the amounts levels are lower than the optimum dosage (must be 1%), an increase in admixture amount might help to enhance the concrete characteristics. [6]

3.2 Previous Studies of Using Steel Fiber in Concrete

Several studies have been conducted to study the effect of using steel fiber on concrete to enhance the mechanical properties of fresh and hardened concrete, the studies below explain that.

- Gencel et al. (2011) studied that Steel fibers change the properties of hardened concrete significantly, and addition of fibers to fresh concrete results in a loss of workability, he concluded that w/c ratio and cement and fly ash, superplasticizer contents were kept constant at 0.40, 400, 120 and 6 kg/m^3 respectively, and the fiber amounts were 15, 30, 45 and 60 kg/m^3, and they used J-ring and V-funnel tests were conducted for evaluating the fluidity, filling ability and segregation risk of the fresh concrete.Also, he found that no problems with mixing or workability while the fiber distribution was uniform and it increased to maximum compressive strength at 15 kg/m^3 by 3.2% and decreased to minimum compressive strength when the amount was equal to 60 kg/m3 by 1% . Moreover, he found that steel fiber can inhibit the initiation and growth of cracks. [11]
- Mohod (2012) studied the different types of fibers added in specific percentage to concrete and he found that they improve the mechanical properties, durability and serviceability of the structure. Also, he established that one of the important properties of Steel Fiber Reinforced Concrete (SFRC) is its superior resistance to cracking and crack propagation and he found the optimum fiber content while studying the compressive strength of cube is found to be 1% and 0.75% for flexural strength of the beam Also, it has been observed that with the increase in fiber content up to the optimum value it increases the strength of concrete. [12]

3.3 Application of Superplasticizer and Steel Fiber

3.3.1 Self-Compact Concrete (SCC)

Hameed (2012) found that by using the slump flow, L-box, U-box and V-funnel tests, SCC achieves consistency and self compactability under its own weight, without any external vibration or compaction. Also, SCC can be obtained in such a way, by adding superplasticizer dosage and very fine mineral admixtures. These two materials provide sufficient balance between the yield and viscosity of the mix. [19]

3.3.2 High Strength Concrete

Pandit and Wadekar (2015) studied that when adding steel fibers to concrete, it changes from brittle mode of failure into a more ductile one and improves the concrete ductility. Additionally, the compressive strength split tensile strength and flexural strength of concrete increase with fibers content as showed in Table 1 and Table 2. [20]

Table 1. Compressive Strength after 28 Days (after Pandit and Wadekar, 2015)

Sr. No	Fibers Volume Fraction Vf (%)	Compressive Strength at 28 days (N/mm²)	
		PF	FSF
1	0	82.5	82.5
2	0.5	83.16	82.67

Table 2. Flexural Strength after 28 Days (after Pandit and Wadekar, 2015)

Sr. No	Fibers Volume Fraction Vf (%)	Flexural Strength at 28 days (N/mm²)	
		PF	FSF
1	0	16.3	16.3
2	0.5	16.68	16.68
3	1	16.83	16.93
4	1.5	17.33	16.9
5	2	17.9	17
6	2.5	17.9	17.23
7	3	18.83	17.4
8	3.5	16.03	19.16
9	4	15.06	16

4. Design of Concrete Mix

4.1 Specification

The job mix will design according to Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91).

4.2 Design Criteria

The design criteria which are used in the current study are as following:

1. Compressive strength: The most strength of normal concrete for general use is 30 MPa for cubic strength and 24 MPa for cylinder strength so the mix will be designed for that strength.
2. Slump: The most slump of normal concrete for general use is between 25 to 100 mm as mentioned in Table 3.Thus; the mix will be designed with slump around 75 to100 mm.
3. Nominal maximum aggregate size: The nominal maximum aggregate size which is used in Gaza Strip is 19 mm. Therefore, we will assume the nominal aggregate size in the job mix as 19 mm.

Table 3. Recommended Slump Values for Various Types of Construction

Type of Construction	Slump
	(mm)
Reinforced foundation walls and footings	25 - 75
Plain footings, caissons and substructure walls	25 - 75
Beams and reinforced walls	**25 - 100**
Building columns	25 - 100
Pavements and slabs	25 - 75
Mass concrete	25 - 50

4.3 Job Mix Procedure

1. Choose the Water/Cement Ratio: From Table (4) and with Compressive Strength 23.5 MPa, water to cement ratio *"(w/c)" can be found which is equal to 0.61.*

Table 4. Relationships between Water/Cement Ratio and Compressive Strength

28-Day Compressive Strength in MPa	Water-cement ratio by weight	
	Non-Air-Entrained	Air-Entrained
41.4	0.41	-
34.5	0.48	0.40
27.6	**0.57**	0.48
20.7	**0.68**	0.59
13.8	0.82	0.74

2. Choose the approximate mixing water: From Table 5 and with maximum aggregate size 19 mm. It can be found that the approximate mixing water which is equal to 205 liter/m3 and the entrapped air is 2.0%.

Table 5. Approximate Mixing Water and Air Content Requirements for Different Slumps and Maximum Aggregate Sizes

Slump	Mixing Water Quantity in kg/m^3 for the listed Nominal Maximum Aggregate Size							
	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	75 mm	100 mm
Non-Air-Entrained								
25 - 50	207	199	190	*179*	166	154	130	113
75 - 100	228	216	**205**	193	181	169	145	124
150 - 175	243	228	216	202	190	178	160	-
Typical entrapped air (percent)	3	2.5	**2**	*1.5*	1	0.5	0.3	0.2
Air-Entrained								
25 - 50	181	175	168	160	148	142	122	107
75 - 100	202	193	184	175	165	157	133	119
150 - 175	216	205	197	184	174	166	154	-
Recommended Air Content (present)								
Mild Exposure	4.5	4.0	3.5	3.0	2.5	2.0	1.5	1.0
Moderate Exposure	6.0	5.5	5.0	4.5	4.5	4.0	3.5	3.0
Severe Exposure	7.5	7.0	6.0	6.0	5.5	5.0	4.5	4.0

3. Calculate the cement quantity: the cement quantity is equal to 205/0.61 = 336 kg/m^3.
4. Choose the Volume of Coarse Aggregate per Unit Volume: From Table 6, the fineness modulus of sand 2.504 and the nominal maximum aggregate size is 19 mm. Thus, the volume of coarse aggregate per unit volume is equal to 0.66.
5. Calculate the weight of dried coarse aggregate: the dried coarse aggregate weight is equal to the percent of CA* unit weight = 0.66*1827 = 1206 kg.
6. Estimate the mass of the fresh concrete: from Table 7 and with nominal maximum aggregate size 25 mm. The mass of fresh concrete can be estimated which is equal to 2345 kg/m^3.

Table 6. Volume of Coarse Aggregate per Unit Volume for Different Fine Aggregate Fineness Modules

Nominal Maximum Aggregate Size	Fine Aggregate Fineness Modulus			
	2.40	2.60	2.80	3.00
9.5 mm	0.50	0.48	0.46	0.44
12.5 mm	0.59	0.57	0.55	0.53
19 mm	**0.66**	**0.64**	0.62	0.60
25 mm	0.71	0.69	0.67	0.65
37.5 mm	0.75	0.73	0.71	0.69
50 mm	0.78	0.76	0.74	0.72

Table 7. First Estimate of Mass of Fresh Concrete

Nominal maximum size of aggregate	First estimate of concrete unit mass ,Kg/m^3	
	Non –air- entrained concrete	Air-entrained concrete
9.5	2280	2200
12.5	2310	2230
19	**2345**	2275
25	2380	2290
37.5	2410	2350
50	2445	2345
75	2490	2405
150	2530	2435

7. Estimate the fine aggregate weight " absolute volume method":
- Volume of trapped air= 2/100 = 0.02 m^3
- Volume of water=205/1000 = 0.205 m^3
- Volume of cement=336/3150 = 0.106m^3
- Volume of coarse aggregate=(642/2611+564/2623) = 0.461m^3

- Total solid volume of ingredients except fine aggregate = 0.792 m^3
- Volume of fine aggregate = 1- 0.792 = 0.208 m^3
- Weight of fine aggregate = 0.208* 2577 = 536 kg.

8. The water quantity must be modified to cover aggregate absorption as below: (642*0.512/100+564*1.472/100+536*0.316/100) = 13.28kg.
9. The final average weight for job mix is shown in Table 8:

Table 8. Total Weight and Volume of Different Materials

Material	Weight (kg)	Volume (m3)
Entrapped air	0	0.020
Water	218	0.205
Cement	336	0.106
Coarse aggregate	1206	0.461
Fine aggregate	536	0.208
Total	**2296**	**1.000**

10. The weight of material for batch with volume 0.015 m^3 to check the slump is shown in Table 9.

Table 9. Total Weight and Volume of Different Materials

Material	Weight (kg)	Volume (liter)
Entrapped air	-	0.300
Water	3.274	3.074
Cement	5.040	1.600
Coarse aggregate		
Type 1	9.627	3.688
Type 2	8.460	3.225
Fine aggregate "sand"	8.020	3.113
Total	**34.421**	**15.00**

11. The first trial aggregate gradation: the first trial weight of material mix and the graduation of aggregate as in Tables 10 and 11 and Figure 1 below.

Table 10. Weight of Material Mix

Material	Type 1 ¾" (ADDASIA)	Type 2 ½" (SOMSOMIA)	Sand #8	Cement	Water	**Total kg**
Weight (kg)	9.627	8.460	8.020	5.040	3.274	**34.421**

Table 11. Concrete Aggregate Gradation

Material	aggregate			
	Type 1 ¾" (ADDASIA)	Type 2 ½" (SOMSOMIA)	Sand #8	**Total**
Weight (%)	36.88	32.40	30.72	**100**

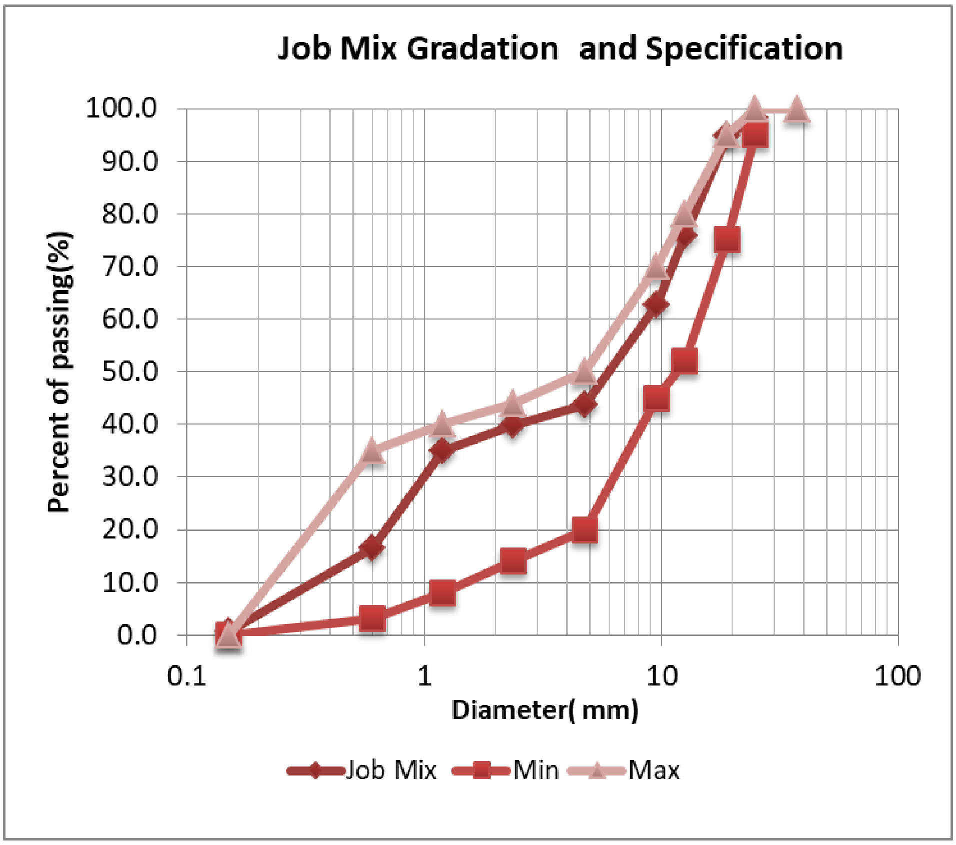

Figure 1. Concrete Job Mix Gradation and Specification.

12. Batching: After the first trial batching the slump value was 220 mm with segregation.

Notes: The value of slump is high with clear segregation. The main cause is the high quantity of water, so the quantity of water must be reduced by nearly 27 %. The quantity of water will become 150 liter without the water quantity for aggregate absorption. And will take the quantity of cement as 300 kg as used in Gaze Strip in construction.

5. Tests on Hardened Concrete

5.1 Concrete with Plastcrete and Constant Dosage of Steel Fiber without Reduction of Water

This mix is prepared by adding Plastcrete as Superplasticizer with different dosages (2, 3, 4, and 5) % and constant dosage of steel fiber (2%) without reduction of water. The effect in the mechanical properties of fresh and hardened concrete is explained as below:

5.1.1 Mechanical properties of fresh concrete "Slump"

While the slump value of mix was 7 cm, the slump of the Plastcrete from 7 to 20 cm. The slump values of mixes having 2%, 3%, 4% and 5% of Plastcrete material by cement content are shown in Figure (2).

Figure 2 represents a proportional relation between slump and the increasing percentage of Plastcrete. This proportional range was from 70 mm for the control mix to 200 mm for 5% of Plastcrete.

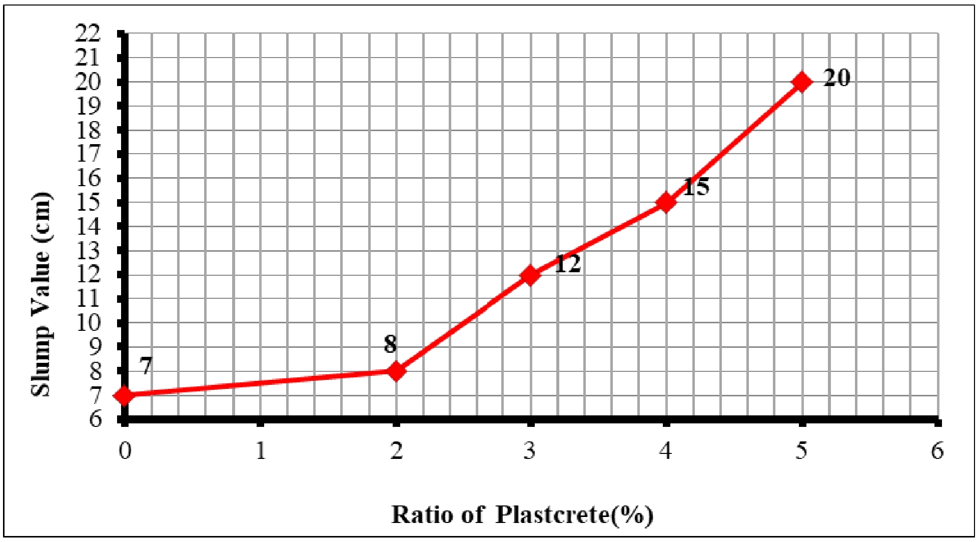

Figure 2. Relationship between the Ratio of Plastcrete and Slump Value.

5.1.2 Mechanical Properties of Hardened Concrete

1. Compressive strength for cube at 28 days

The 28 days compressive strength of concrete mixes having 0%, 2%, 3%, 4% and 5% of Plastcrete material by cement content are shown in Figure 3. Figure 3 reveal that there was a very slight increase in compressive strength from 29.36 MPa to 35.92 MPa from 2% to 3% respectively and decreasing from 35.92 MPa to 32.51 MPa when adding 4% and 5% respectively. Any addition of Plastcrete by more than 3% will cause decrease of strength. The increasing rate of compressive strength was explained in Figure 4.

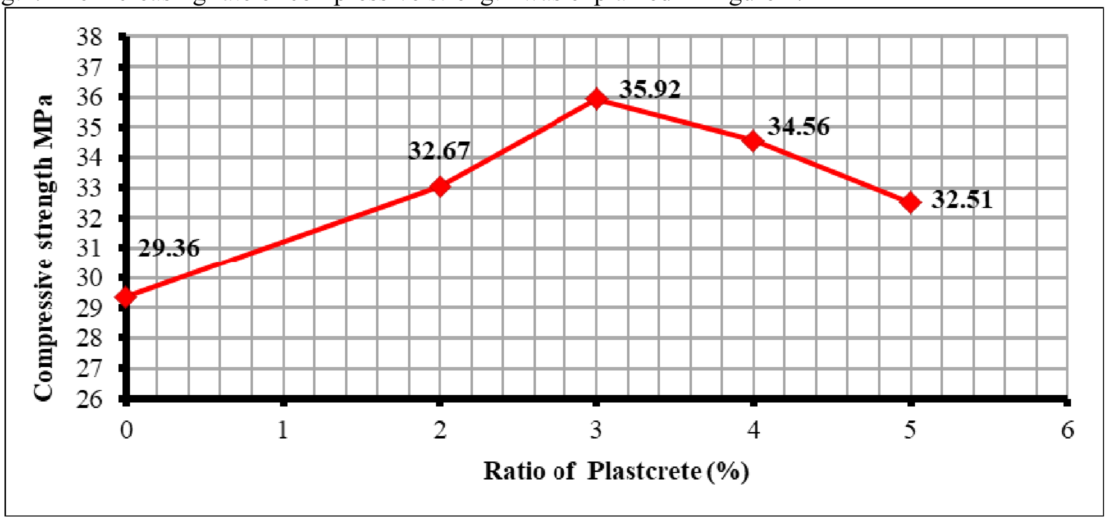

Figure 3. Relationship between the Ratio of Plastcrete and 28 Days Compressive Strength.

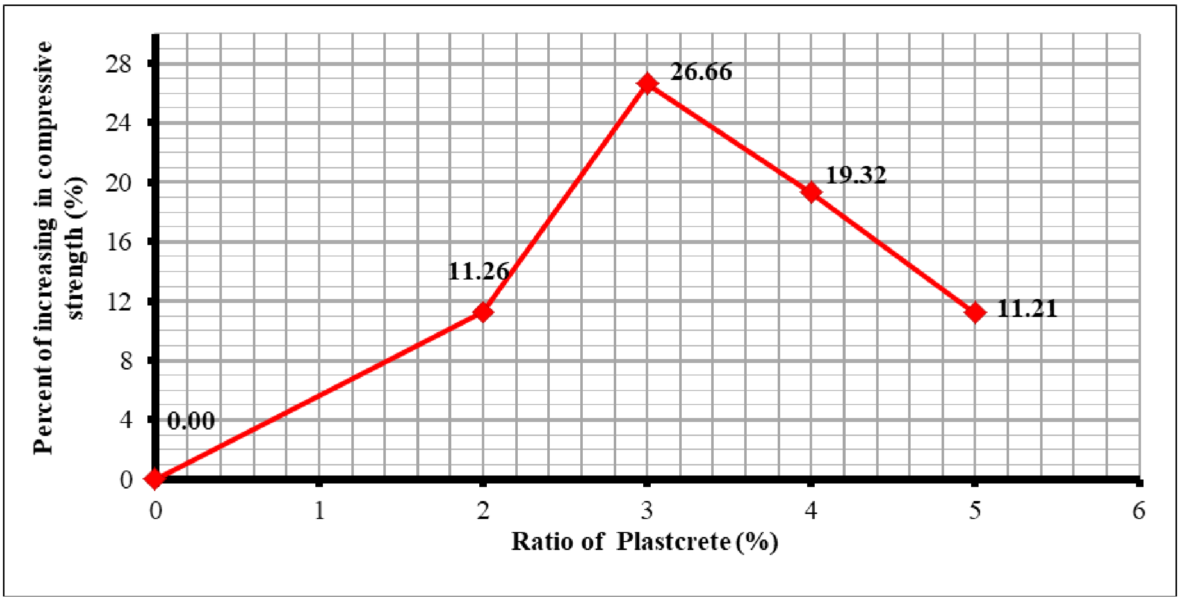

Figure 4. Relationship between the Ratios of Plastcrete and Increasing of 28 Days Compressive Strength.

Plastcrete is a solid material dissolved in water, so the increase in Plastcrete means increasing water in the mix, which leads to increasing w/c ratio, meaning that there are adverse relationship between w/c ratio and compressive strength.

From above Figures, it is found that the Plastcrete was effective at the beginning for increasing the compressive strength, until the excessive water decreases compressive strength. It is found that the percentage of compressive strength achieved by Plastcrete was increased, but the strength remained more than the original compressive strength.

6. Results and Discussion

6.1 Conclusion

The result of this research showed that Plastcrete material can enhance the mechanical property of fresh and hardened concrete as slump, compressive strength, indirect tension and flexural strength with different aspects of enhancing and steel fiber could enhance only the indirect tension. The Plastcrete and steel fiber used are considered as low cost material. The next concluding marks were obtained from experimental observation:

- Plastcrete give more workability with optimum slump value at 120 mm without reduction of water, but the optimum strength value could achieve with 3% of Plastcrete with reduction of water with slump value in this case 50 mm.
- Steel fiber has no critical effect in increasing compressive strength, or flexure strength, because of the 2% of steel fiber, but steel fiber works well in indirect tension and increases it by average 16.91 %.
- The optimum value of Plastcrete was 3% of cement weight with reduction of water and improves the compressive strength of normal concrete on 28 days from 29.67 MPa to 37.19 MPa by 25.34%
- Flexural strength and indirect tension tests of concrete show that the best results have been seen when using 3% of Plastcrete with reduction of water amount in mixing compared to normal concrete with fixed amount of steel fiber. Also, the percent value of each test increases the strength after 28 days by 34.71 % and 18.47 %, respectively.

References

[1] Boukendakdji, O. Kadri H. and Kenai, S. (2012) Effects of granulated blast furnace slag and superplasticizer type on the fresh properties and compressive strength of self-compacting concrete. *Cement and Concrete Composites,* 34(04), April, 583-590.

[2] Nuruddin, M. Demie, S. Ahmed, M. and Shafiq, N. (2011) Effect of Superplasticizer and NaOH Molarity on Workability, Compressive Strength and Microstructure Properties of Self-Compacting Geopolymer Concrete. *International Journal of Civil and Environmental Engineering,* 3(2): 122-129.

[3] Paillere, A.M. (2004) *Application of Admixtures in Concrete.* CRC Press.

[4] Yasmomisr (2014) *yasmomisr.* [online]. Available at: www.yasmomisr.com [Accessed 10 December 2014].

[5] Santhanam, M. (2013) ‘Evaluation of Superplasticizer Performance in Concrete’, *Sustainable Construction Materials and Technologies:* Coventry University and the University of Wisconsin Milwaukee Centre, 18-21 August. Kyoto: products Utilization, S. W2-2.

[6] Alsadey, S. (2012) Influence of Superplasticizer on Strength of Concrete. *International Journal of Research in Engineering and Technology, 0*1(03): 164-166.
[7] Dumne, S. (2014) Effect of Superplasticizer on Fresh and Hardened Properties of Self-Compacting Concrete Containing Fly Ash. *American Journal of Engineering Research,* 03(03): 205-211.
[8] Shah, S.N. Aslam, M. Shah, S.A. and Oad, R. (2014) Behaviour of Normal Concrete Using Superplasticizer under Different Curing Regimes. *Pak. J. Engg. & Appl. Sci,*15(2014), July, 87-94.
[9] Tamrakar, R. and Mishra, S. (2013) Experimental Studies on Property of Concrete due to Different Ingredient based Super Plasticizer. *International Journal of Science, Engineering and Technology Research,* 2(5), May, 1036-1040.
[10] Biswal, K.C. and Sadangi, S. (2011) 'Effect of superplasticizer and silica fume on properties of concrete', *Conference on Effect of Superplasticizer and Silica Fume on Properties of Concrete.* Trivandrum, 16 March. Kerela: ACEE.
[11] Gencel, O. Brostow, W. Datashvili, T. and Thedford, M. (2011) Workability and Mechanical Performance of Steel Fiber-Reinforced Self-Compacting Concrete with Fly Ash. *Composite Interfaces*, 18(2011): 169-184.
[12] Mohod, M. (2012) Performance of Steel Fiber Reinforced Concrete. *International Journal of Engineering and Science*, 1(12), December, 01-04.
[13] Akramuddin, S. Sutar, K. Nagure, S. and Subhash. (2015) Studies on Strength Properties of Steel Fiber Reinforced Concrete with Varied Percentage of Fiber Content. *International Journal for Innovative Research in Science & Technology,* 1(12), May, 170-174.
[14] Tanoli, W. Naseer, A. and Wahab, F. (2014) Effect of Steel Fibers on Compressive and Tensile Strength of Concrete. *International Journal of Advanced Structures and Geotechnical Engineering*, 03(04), October, 393-397.
[15] Dong, L. and Zhang, S. (2015) Effect of Steel Fiber on Comprehensive Performance of Concrete Materials. *Applied Mechanics and Materials*, 723 (January 2015): 440-444.
[16] Abdul Slam, L. (2015) Effect of Steel Fiber and Silica Fume on Hardened Concrete Compressive and Flexural strength. *Journal of Engineering and Development,* 19 (January 2015): 68-86.
[17] Vijayakumar, P. Ratnam, M. K. and RangaRaju, U. (2015) Influence of Aggregate Size on Steel Fiber Reinforced Concrete. *IJIRST –International Journal for Innovative Research in Science & Technology,* 1(11): 493-498.
[18] Khan, A. and Zahra, T. (2014) *Study of Properties of Steel Fiber Reinforced Concrete (SFRC) for Possible Applications in Pakistan*. Available at: http://www.researchgate.net/publication/264783515_Study_of_Properties_of_Steel_Fiber_Reinforced_Concrete_(SFRC)_for_Possible_Applications_in_Pakistan [accessed May 31, 2015].
[19] Hameed, A. (2012) Effect of superplasticizer dosage on workability of self compact concrete. *Diyala Journal of Engineering Sciences,* 05(September/November 2011): 66-81.
[20] Pandit, R . and Wadekar, A. (2015) Study of High Strength Fiber Reinforced Concrete by using Two Types of Fibers. *International Journal of Research in Engineering, Science and Technologies,* 1(2): 10-16.
[21] Mindess, S. S. Young, J. F. and Darwin, D. (2003) *Concrete.* 2nd Ed. New Jersey.
[22] ACI 301 (1999*) Specifications for structural concrete*. American Concrete Institute.
[23] Punmia, B. C. Jain, A. K. and Jain A. kr. (2003) *Basic Civil Engineering.* Firewall Media.
[24] Gambhir, M. L. (2013) *Concrete Technology: Theory and Practice.* Tata McGraw-Hill Education.
[25] Evaluation of Strength Test Results of Concrete (ACI 214R-02), *ACI Manual of Concrete Practice, Part 1*. American Concrete Institute, Farmington Hills, MI, 2014.
[26] Lemanod, J. F. (2006) *Significance of Tests and Properties of Concrete and Concrete-making Materials, part 4, N 169*. ASTM International, 2006.
[27] American Society for Testing and Material, (2004) *ASTM C39 Test Method for Compressive Strength of Cylindrical Concrete Specimens*. Philadelphia, Pennsylvania: American Society for Testing and Material.
[28] Garber, G. (2006) *Design and Construction of Concrete Floor*. 2nd Ed. Elsevier.
[29] American Concrete Institute. Committee 311. *ACI Manual of Concrete Inspection* American Concrete Institute, 2008.
[30] Kett, I. (2009) *Engineered Concrete: Mix Design and Test Methods.*2nd Ed. CRC Press.
[31] Riding, K. A. (2007) *Early Age Concrete Thermal Stress Measurement and Modeling.* The University of Texas at Austin: ProQuest.
[32] American Society for Testing and Material, (2002) *ASTM C469 Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*. Philadelphia, Pennsylvania: American Society for Testing and Material.
[33] Alexander, M. and Mindess, S. (2010) *Aggregates in Concrete*. CRC Press.
[34] American Concrete Institute. Committee 311. *ACI Manual of Concrete Inspection, part 2*. American

Concrete Institute, 2008.
[35] El-Reedy, M. A. (2013) *Concrete and Steel Construction: Quality Control and Assurance.*CRC Press.
[36] Chandigrah, T. (2001) *Civil Engineering Materials.* Tata McGraw-Hill Education.
[37] Shetty, M. S. (2005) *Concrete Technology (M.E.)* .S. Chand.
[38] Dabour, B. (2014) *The Effect of Nano Materials (NM) on The Mechanical Properties of Concrete.* IUG.