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# Effects of mineral and superplasticizer admixtures on the mechanical behaviour of lightweight concrete

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## Abstract

This paper presents an experimental investigation of the combined effect of a superplasticizer admixture and metakaolin material on the mechanical behaviour of expanded clay lightweight concrete containing recycled glass aggregate. The optimum dosage of the superplasticizer admixture (type SNF) was adjusted and used by weight of cement. The short and long-term mechanical properties of concrete mixes were measured in accordance with the relevant British / EN standards. The obtained results were compared with the results of control concrete mixes (without superplasticizer).

The results obtained showed that the superplasticizer admixture exhibited a 20% reduction in mixing water content. All measured values of unit weight, compressive and splitting tensile strengths increased when the superplasticizer admixture and metakaolin material are used. The concrete mix containing 30% recycled glass revealed an increase in the mechanical strength compared with the mix of 15% recycled glass. However, the workability of the superplasticizer concrete mixes was degraded, reaching 44% reduction in slump value.

Keywords: Superplasticizer admixture, lightweight aggregate concrete, metakaolin, recycled glass, mechanical behaviour.

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## 1 Introduction

Improving the mechanical strength of lightweight concrete has recently been the subject of much published research into construction materials. The emphasis of much of this research has been on means of improving the density properties of the lightweight concrete for thermal insulation purposes as well as enhancing its load-bearing capability.

Environmental criteria have been also considered with regard to reducing the impact of waste disposal in land fill by reusing these waste and by-product materials as construction materials [Palacios et al., 2009].

One of the main techniques which has been used in developing the strength of concrete is the use of admixtures. The superplasticizer SP (also known as high range water reducer) is often used both in the concrete industry and on construction sites.

Different kinds of superplasticizer admixtures are available. They have similar conjunction roles in triggering dispersive action on the surface of hydration cement particles during the initial hydration reactions [Mollah et al., 2000]. The active ingredients of these products are commonly based on an anionic polymeric surfactant [Hsu et al., 1999]. The molecules of superplasticizer coat the cement grains and change their orientation, causing them to repel one another [Neville, 2000]. Two contrasting properties can be achieved with a superplasticizer admixture:

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either an increase in workability, combined with retention of the strength level, or the opposite. The superplasticizer action causes rearrangement of the cement particles, resulting in more regular and allowing better hydration.

The general benefit of this process is that the superplasticizer molecules enhance the propagation of ettringite crystals, which have a nearly cubic shape, instead of a needle-like geometry. This crystalline formation improves the performance of the concrete produced [Neville,1999].

Several models have been suggested to explain the effect mechanism of superplasticizer on the cement hydration process [Mollah et al.,2000]. One of these models is the adsorption mechanism which attributes the effectiveness of the superplasticizer to the adsorption behaviour of the admixture on the cement particles. It was proposed that the elementary processes were based on both adsorption and desorption [Mortimer, 1993]. Another study reported that the superplasticizer was capable of reducing the surface tension of water. This permits penetration of the molecules in between the solid particles and produces much denser mixes, which consequently reduces the tendency of permeable water [Morin et al.,2001].

The results of fluidising due to use of superplasticizer admixtures are affected by several parameters: for example, dosage of the superplasticizer; type and quantity of aggregate and cement used; mixing procedure and temperatures [Ramachandran et al., 1981].

A growing number of alternatives to the traditional ingredients of concrete mixes have surfaced in recent years. This is as a consequence of the need to reduce the demand on natural resources created by construction materials. One of these alternative materials is recycled glass aggregate. It has been used as an entire or partial replacement for the fine and/or coarse aggregate [Tung, Chi,2011; Andrea et al. ,2007; Chi et al.,2007; Farshad et al. ,2010; Miao,2011]. This approach is useful to mitigate the impact of waste glass which is produced in large amounts every year.

1 The inclusion of glass aggregate in concrete mixes causes an increase in the  
2 expansion phenomena due to the alkali-silica reaction (ASR) produced [Tung, Chi  
3 ,2011; Andrea et al. ,2007; Chi et al., 2007; Farshad et al., 2010; Miao, 2011; Chen  
4 et al. ,2006; Park et al., 2004;Topcu, Canbaz, 2004; Gerry et al, 2011]. However, this  
5 reaction can be reduced by using mineral additives [Tung, Chi, 2011; Gerry et al.,  
6 2011].

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12 Metakaolin (MK) is an example of such a mineral by-product materials. It has a  
13 higher pozzolanic ratio, used as a partial replacement for cement, and has received  
14 considerable interest for its applications to construction. The main effects of using  
15 metakaolin are the improvement of the strength and durability of concrete mixes  
16 [Parande et al.,2009; Rafat, Juvas, 2009; Dong et al., 2011; Paulo et al., 2010;  
17 Karoline, Arnaldo, 2010; Ganesh , Dinakar,2006; Frias,2006; Khatib,2008].

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Although much efforts has been paid to investigate the behaviour of sustainable concrete with different compositions, this study considers an attempt to develop the mechanical strength of a newly modified lightweight concrete using a superplasticizer admixture in conjunction with metakaolin was experimentally investigated. This type of lightweight concrete contains different ratios of recycled glass and uses expanded clay as a coarse aggregate.

## 2 Experimental details

### 2.1. Materials

The experimental programme described in this paper focused on exploring the influence of the addition of both superplasticizer and metakaolin admixtures on the mechanical behaviour of a newly developed lightweight concrete.

The main ingredients of the concrete mixes were ordinary Portland cement, natural sand, expanded clay, recycled glass, metakaolin and superplasticizer admixture.

1 Natural sand for building purposes was used as a fine aggregate with a grading  
2 which complied with BS EN 12620[BSI,2008].  
3

4 A medium-grade 8-5R of Techni Clay expanded clay was used as coarse aggregate;  
5 it was supplied by the Plasmor Concrete Product Company. The moisture content  
6 and particle density of the expanded clay were 20% w/w and 550 kg/m<sup>3</sup> respectively.  
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10 Recycled glass aggregate with particle sizes of 0.5-1 and 1-2 mm was used as a  
11 partial replacement for natural sand by volume with two levels: 15% and 30%. The  
12 recycled glass was provided by the Specialist Aggregate Ltd Company with a  
13 specific gravity of 2.52. MetaStar 501metakaolin material with a constant content  
14 (10%) was adopted as a partial replacement for ordinary Portland cement.  
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17 The Daracem SP6 superplasticizer admixture of the sulphonated naphthalene  
18 formaldehyde condensate SNF was used throughout this study, and its performance  
19 complies with BS EN 934-2[BSI, 2009a]. The maximum chloride and alkali contents  
20 were < 0.1% and 0.5% by mass respectively. Figure 1 shows the main components  
21 of the lightweight concrete mixtures investigated during this experimental work.  
22  
23

24 The mixing operation was carried out according to BS EN12390-2 [BSI, 2009c] using  
25 a 0.1 m<sup>3</sup> vertical portable mixer. The fresh concrete was cast in moulds in three  
26 layers. Each layer was completely compacted using a vibrating table until there was  
27 no further appearance of large air bubbles on the surface of the concrete.  
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30 After casting, the samples were kept in laboratory conditions and covered with a  
31 nylon sheet to ensure a humid atmosphere around the specimens. After 24 hours,  
32 the samples were demoulded, marked and immersed in a basin of water at a  
33 temperature of 20 ± 2 °C until the date of the test.  
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## 42 **2.2. Selection of the superplasticizer content**

43 In this experimental programme, the workability of the concrete mixes was kept  
44 constant, while the strength level was intended to be increased. On this basis, the  
45 content of the superplasticizer was adjusted based upon the fluidity features of the  
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reference lightweight concrete mix (0% G + 0%SP + 0%MK), which possesses a W/C of 0.45. In order to maintain a constant slump ( $50 \pm 5$  mm), multi-trial mixes were carried out and the W/C resulting from using the superplasticizer admixture was calculated each time according to the following equation [BS EN 5075-3, 1985]:

$$W/C \text{ of } SP_{mix} = W/C \text{ of } R_{mix} \times \frac{(100 - \text{percentagewaterreduction})}{100} \quad (1)$$

where  $SP_{mix}$  and  $R_{mix}$  are, respectively, the concrete mix containing superplasticizer and the reference concrete mix .

Since the experimental work scheme was concerned with improving the mechanical strength of the concrete mixes, it was found that 2% superplasticizer by weight of cement was the optimum admixture dosage. This dosage produced higher compressive strength (19.7 MPa at 28-day age) with a maximum water reduction of 20%, equivalent to a W/C of 0.36.

In accordance with these results the optimum superplasticizer content was chosen to produce two modified concrete mixes containing expanded clay, recycled glass and metakaolin materials (superplasticizer mixes). The measured mechanical properties of the former mixes were then compared with concrete mixes with the same constituents without superplasticizer (control mixes). The latter were previously studied and the results are presented in [Al-Sibahy, Edwards, 2012]. The details of the concrete mixes which were adopted in the experimental programme are shown in Table 1.

### 2-3. Test programme

The experimental programme tests included studying the fresh properties, unit weight, compressive strength, splitting tensile strength and stress-strain behaviour. All of these tests were conducted according to the relevant BS / EN standards [BS

1 EN 12350,2009; BS EN 12390-7, 2009;BS EN12390-3,2009;BS EN 12390-6,  
2 2009;BS ISO 1920-10,2009].  
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4 The short and long-term mechanical properties of the concrete mixes were  
5 experimentally measured. Except for the stress-strain behaviour test which was  
6 carried out using two cylindrical specimens, an average value of three specimens  
7 was taken for each test result.  
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### 16 **3 . Results and discussion**

#### 17 **3.1 Properties of fresh concrete mixes**

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22 The behaviour of the fresh status of the concrete mixes in terms of consistency was  
23 carried out using a slump test; the obtained results are shown in Figure 2. It can be  
24 seen that the workability aspect was degraded when the superplasticizer was used  
25 in producing the modified concrete mixes. A clear decrease in the value of the slump  
26 was recorded for both superplasticizer mixes, and further compaction work using a  
27 poker vibrator was required to overcome the drying condition of these mixes. This  
28 could be due to the accelerating effect of superplasticizer admixture, which becomes  
29 more effective in the presence of metakaolin material. In turn, this causes rapid  
30 hydration of the cement particles and reduces the fluidity time of the concrete mixes.  
31  
32 The same cannot be said for the control mixes, where the consistency was still found  
33 to be within the acceptable range of workable concrete (50±5 mm). However, the  
34 concrete mixes with a glass content of 30% showed a lower reduction in the  
35 workability aspect than that of the mixes with 15% glass content. Such behaviour  
36 can be attributed to the role of the glass particles in providing extra moisture content  
37 for the concrete due to their adsorbing the mixing water [Tung, Chi ,2011; Andrea, et  
38 al.,2007; Chi et al., 2007; Farshad et al., 2010; Miao,2011; Chen et al.,2006; Park et  
39 al., 2004; Topcu, Canbaz ,2004; Gerry et al, 2011].  
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### 3.2 Unit weight

Figure 3 shows the test results of unit weight for the control and superplasticizer concrete mixes at different test ages. The superplasticizer concrete mixes exhibited higher densities than the control mixes. This may be related to the penetration of the superplasticizer fluid and coating of the solid particles, thereby producing a denser mix [Morin et al.; 2001]. The concrete mixes containing 30% glass ratio showed higher densities than those of the samples with 15% glass ratio. This may be attributed to the capability of these mixes to hold the water particles due to the lower tendency of the glass aggregate to absorb the mixing water [Tung, Chi ,2011; Andrea et al. ,2007; Chi et al., 2007;Farshad et al., 2010; Miao,2011; Chen et al. ,2006; Park et al., 2004;Topcu, Canbaz ,2004; Gerry et al, 2011].

In general, except at 28 days' age, both the superplasticizer and the control lightweight aggregate concrete mixes exhibited a continuous decrease in density over time. This behaviour may be caused by two phenomena: the first is the consumption of water by hydration processes and the second is the reduction of free water inside gel pores by evaporation. The increase in density of the concrete mixes at age of 28 days compared with their density at 7 days could be explained by the greater level of hardness due to the pozzolanic reaction of the metakaolin material at this age. Furthermore, acceleration of the cement hydration process can be accounted by the presence of the superplasticizer which provides better water distribution for the cement particles.

### 3.3 Compressive strength

The compressive strength test results are presented in Figure 4. This figure indicates that the superplasticizer concrete mixes possess higher compressive strength values than the control mixes. This result is in agreement with previous studies [Palacios, et

1 al., 2009; Mollah, et al., 2000; Hsu, et al., 1999; Neville, 2000; Morin, et al.,2001].

2 Furthermore, the presence of metakaolin material, which is a mineral admixture  
3 plays a role in increasing the compressive strength in conjunction with the  
4 superplasticizer admixture. The main significance of the induction of metakaolin  
5 material is its role as a filler and, an accelerator for the hydration of Portland cement,  
6 as well as its pozzolanic properties [Parande et al., 2009; Rafat, Juvas, 2009]. For  
7 the superplasticizer concrete mixes, the concrete mix containing 30% glass  
8 produced a higher compressive strength value than that of the mix with 15% glass  
9 content. This can be explained by more water being available inside this mix which  
10 allows further hydration processes to take place.

11 For all of the concrete mixes, the compressive strength value increased with  
12 increased curing time. The percentage increases in compressive strength for the  
13 concrete mixes containing the superplasticizer admixture with 15% and 30% glass  
14 ratios at an age of 90 days relative to the control concrete mixes of the same age  
15 were 4% and 8.5 % respectively.

16 Figure 5 shows the cubic concrete samples after the compressive strength test had  
17 been conducted. Satisfactory failure modes were observed for all concrete samples  
18 which comply with BS EN12390-3[BSI, 2009d] mode-A. All four exposed faces were  
19 cracked approximately equally, with a little damage to the faces in contact with the  
20 platens without any explosive failure, as shown in Figure 6.

21 The pozzolanic reactivity of metakaolin material which, is described in BS EN 196-  
22 5[BSI EN, 2005] was measured according to the values of compressive strength as  
23 in [Paulo et al., 2010]. This was done by comparing with the results of reference mix  
24 (0%G + 0% MK + 0% SP) which was previously measured [Al-Sibahy, Edwards,  
25 2012]. The same approach also used to predict the pozzolanic reactivity of  
26 metakaolin in conjunction with the superplasticizer admixture on the strength of the  
27 concrete. The specific strength ratio  $R$ , which is an indicator of the contribution of the  
28

1 mineral admixture and/or the superplasticizer to the strength of the mixture, is  
2 defined as:  
3

$$4 \quad 5 \quad 6 \quad R = f_c/p \quad (2) \quad 7 \quad 8 \quad 9$$

10 where  $f_c$  is the compressive strength in MPa and  $p$  is the hydraulic cement of  
11 mineral and/or superplasticizer admixture percentage. The equivalent values of  $p$  for  
12 reference mix, the control mixes with metakaolin but without superplasticizer and  
13 control mixes with both metakaolin and superplasticizer are 100%, 90% and 88%  
14 respectively.  
15

16 By eliminating the reduction effect of the glass aggregate on the values of  
17 compressive strength, the contribution of the pozzolanic effect of metakaolin and/or  
18 superplasticizer  $R_p$  to the strength of concrete is given by Eq. (3).  
19  
20  
21

$$22 \quad 23 \quad 24 \quad R_p = R_M - R_C \quad (3) \quad 25 \quad 26 \quad 27$$

28 where  $R_M$  is the contribution of unit hydraulic cement when metakaolin and/or  
29 superplasticizer is used and  $R_C$  the contribution of unit hydraulic cement to the  
30 concrete strength without using metakaolin and/or superplasticizer.  
31

32 The index specific strength  $K$ , is the ratio of  $R_M$  to  $R_C$ . The contribution of  
33 pozzolanic effect and/or superplasticizer  $P$  to the concrete strength can be  
34 expressed as:  
35  
36  
37

$$38 \quad 39 \quad 40 \quad P = (R_p/R_M) \times 100 \quad (4) \quad 41 \quad 42 \quad 43$$

44 The values of  $R$ ,  $R_p$ ,  $K$  and  $P$  for the reference, control and superplasticizer concrete  
45 mixes at ages of 7,28, 90 and 180 days were calculated and are presented in  
46 Table 2.  
47  
48  
49

1 The contribution of metakaolin and the superplasticizer admixture to the  
2 compressive strength of the concrete was plotted in Figure 7. For both control  
3 concrete mixes, the improvement in compressive strength due to the pozzolanic  
4 effect of metakaolin exhibited a long-term duration (180 days). This is in agreement  
5 with the results of [Wild et al., 1996]. The optimum activity was recorded at 90 days  
6 age. The combined effect of metakaolin and superplasticizer was clearer in the  
7 earlier ages and reached its peak performance at 28-day age with a ratio of 30%  
8 contribution to the compressive strength. Thereafter, a reduced effect was observed.  
9

### 20 **3.4 Splitting tensile strength**

21 Figures 8 and 9 show the test results of the splitting tensile strength at sample ages  
22 of 120 and 180 days. These figures showed increases in splitting tensile strength for  
23 the superplasticizer concrete mixes relative to that of the controlled mixes. This could  
24 be attributed to an increase in compressive strength of these mixes, resulting from  
25 the positive action of superplasticizer admixture with metakaolin. Behaviour  
26 consistent with that of compressive strength was recorded for both test ages. When  
27 compared with the controlled concrete mixes, the percentage increases in the  
28 splitting tensile strength of the superplasticizer concrete mixes containing 15% and  
29 30% recycled glass at 120 days age were 9.4% and 11% respectively. The  
30 corresponding percentages at 180 days age were 7% and 21.3% respectively.  
31

32 BS EN 1992-1-1 [BSI, 2004] suggested the following expression to predict the  
33 splitting tensile strength of lightweight concrete according to its density and the  
34 characteristics of normal weight concrete:  
35

$$36 f_{lctm} = f_{ctm} \cdot \eta_1 \quad (5)$$

$$37 f_{ctm} = 0.3 \times f_{ck}^{2/3} \quad (6)$$

$$\eta_1 = 0.4 + 0.6\rho/2200 \quad (7)$$

where  $f_{lctm}$  and  $f_{ctm}$  are the mean splitting tensile strength of the light and normal weight concrete respectively in MPa ;  $f_{ck}$  is the characteristic compressive strength of normal weight concrete in MPa, and  $\rho$  is the density of lightweight concrete in kg/m<sup>3</sup>.

After statistical analysis had been performed, it was shown that Equation (5) was unable to match the results obtained for splitting tensile strength in this study. This is because a reasonable R squared value for the nonlinear regression analysis could not be achieved.

### 3.5 Stress- strain behaviour

The typical stress-vertical strain relationships of superplasticizer and control concrete mixes are presented in Figure 10. This test was conducted using dial strain gauges for the superplasticizer concrete samples at 28-day age. Lateral and vertical strain gauges were used to measure the stress-strain behaviour of the controlled concrete samples at 140 days age. If the difference in the test age of both concrete mixes was eliminated, it could be possible to compare between the global behaviour of these mixes and to explore the effect of superplasticizer admixture.

It can be seen that a tougher concrete had a larger post-peak branch in the stress-strain curve than the other mixes. The maximum vertical strain observed was 0.00187 for the mix of 15% glass with the superplasticizer admixture. This behaviour could be caused by aging, and the strain value may be decreased with an increase in the curing time.

In this test, lower stress values were observed for all concrete mixes, compared with the results of compressive strength test. This behaviour could be attributed to the different geometries of the samples used in these tests, where cylindrical concrete

1 samples were used in the stress-strain behaviour test, while cubic samples were  
2 used in the compressive strength test.  
3

4 According to the stress-strain curves, the static modulus of elasticity at the  
5 aforementioned test age was measured for both the control and the superplasticizer  
6 concrete mixes. The results are shown in Table 3. It can be seen that the highest  
7 value of modulus of elasticity was recorded for the control concrete mix containing  
8 30% glass at 16.25 GPa, while similar values were observed for the control concrete  
9 mix with 15% glass and the mix of 30% glass with superplasticizer admixture at 13.3  
10 GPa.  
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## 22 **4 Conclusions**

23 The results of this study highlight the effect of superplasticizer admixture when used  
24 in conjunction with metakaolin and glass aggregate on the mechanical behaviour of  
25 expanded clay concrete. The main conclusions of this paper can be summarized as  
26 follows:  
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- 34 • The superplasticizer admixture reduced the water content by up to 20%.  
35 However, the workability of the concrete mixes deteriorated with the use of  
36 superplasticizer when metakaolin existed
- 37 • An increase in the density values of the superplasticizer concretes was  
38 recorded compared with the controlled mixes, and the highest value was for  
39 the mix of 30% glass with 2% superplasticizer admixture for all test ages.
- 40 • A significant increase in the compressive strength values was achieved when  
41 the superplasticizer admixture was used in conjunction with metakaolin,  
42 especially at earlier curing ages.
- 43 • Increases in compressive strength due to the pozzolanic effect of metakaolin  
44 continued long- term (180 days) for both control concrete mixes.  
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- The contribution metakaolin and superplasticizer admixture to the compressive strength was clearer at the earlier stages and reached its peak performance at 28-day age with an enhancement of 30%.
- Consistent positive improvements in splitting tensile strength to that in compression features were observed at both short-term and long-term behaviours.
- The control concrete mix with 30% glass exhibited highest modulus of elasticity due to its lower strain value at the linear region of the stress-strain curve.

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### **List of Tables**

Table 1: Details of concrete mixes

Table 2: Calculated values of  $R$ ,  $R_p$ ,  $K$  and  $P$  for controlled and modified concrete mixes

Table 3. Static modulus of elasticity of concrete mixes

### **List of Figures**

Figure 1: The materials used in the experimental work: A- Superplasticizer container, B- Graduated cylinder with superplasticizer, C- Expanded clay, D- Waste Glass 1-2 mm, E- Waste Glass 0.5-1 mm and F. metakaolin material

Figure 2: The workability behaviour of various lightweight concrete mixes

Figure 3: The density of various lightweight concretes mixes.

Figure 4: Compressive strength behaviour of various lightweight concrete mixes

Figure 5: Cubic samples after compressive strength test

Figure 6: Satisfactory compression failure modes [35]: A- Cracks failure, B- Damage failure and C-Explosive failure

Figure 7: Contribution of pozzolanic effect and/or superplasticizer to the compressive strength of concrete mixes.

Figure 8: Splitting tensile strength of superplasticizer and controlled mixes at 120 days

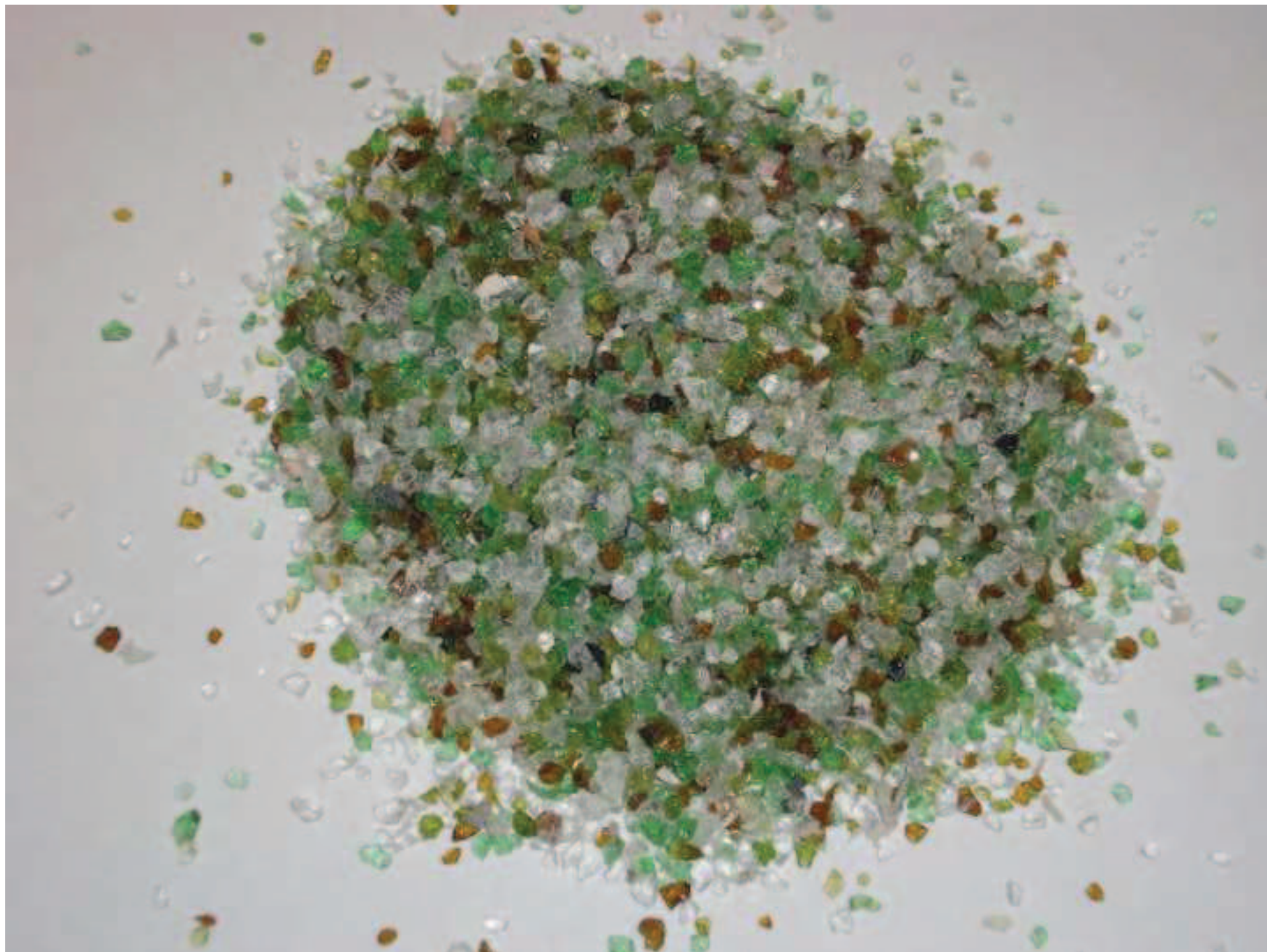
Figure 9: Splitting tensile strength of superplasticizer and controlled mixes at 180 days

Figure 10: Stress-strain curves of superplasticizer and control concrete mixes

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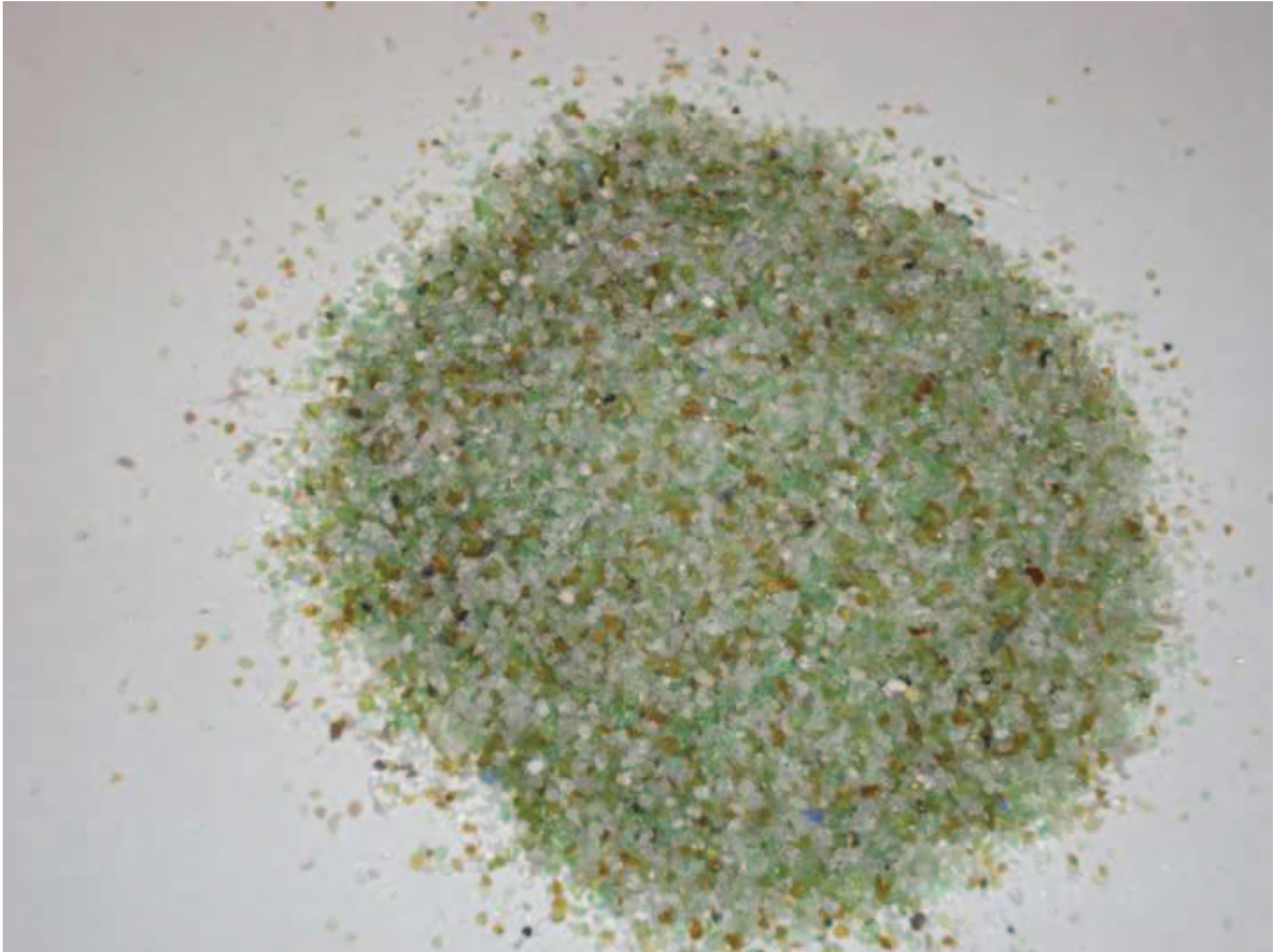






Figure-2

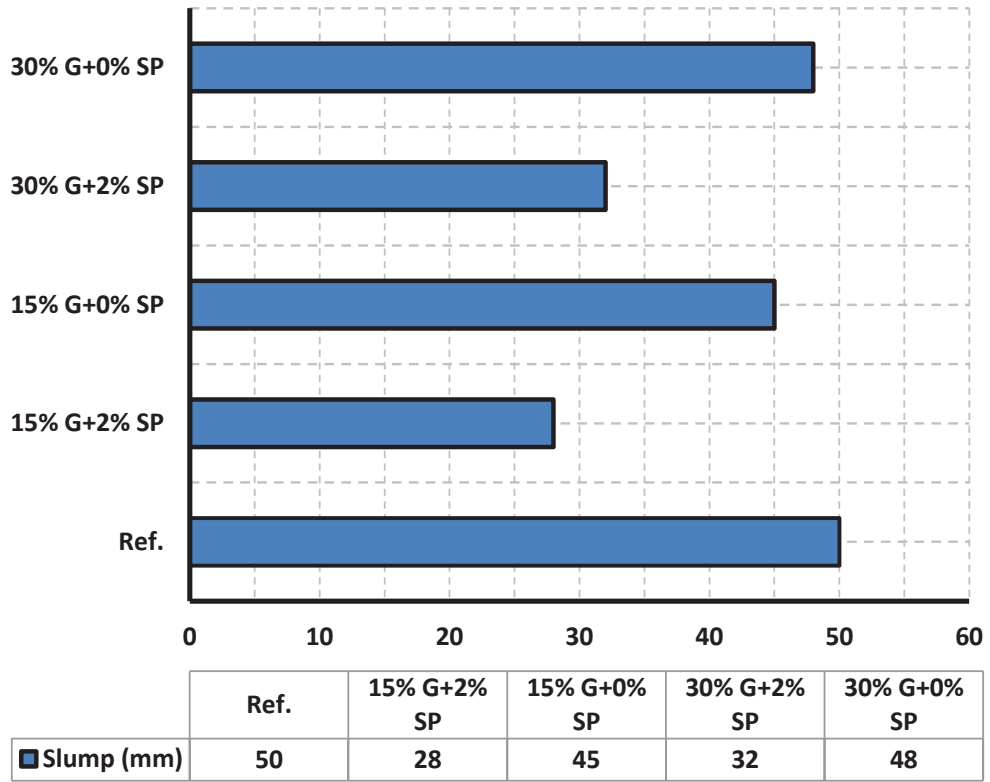


Figure 2 The workability behaviour of various lightweight concrete mixes

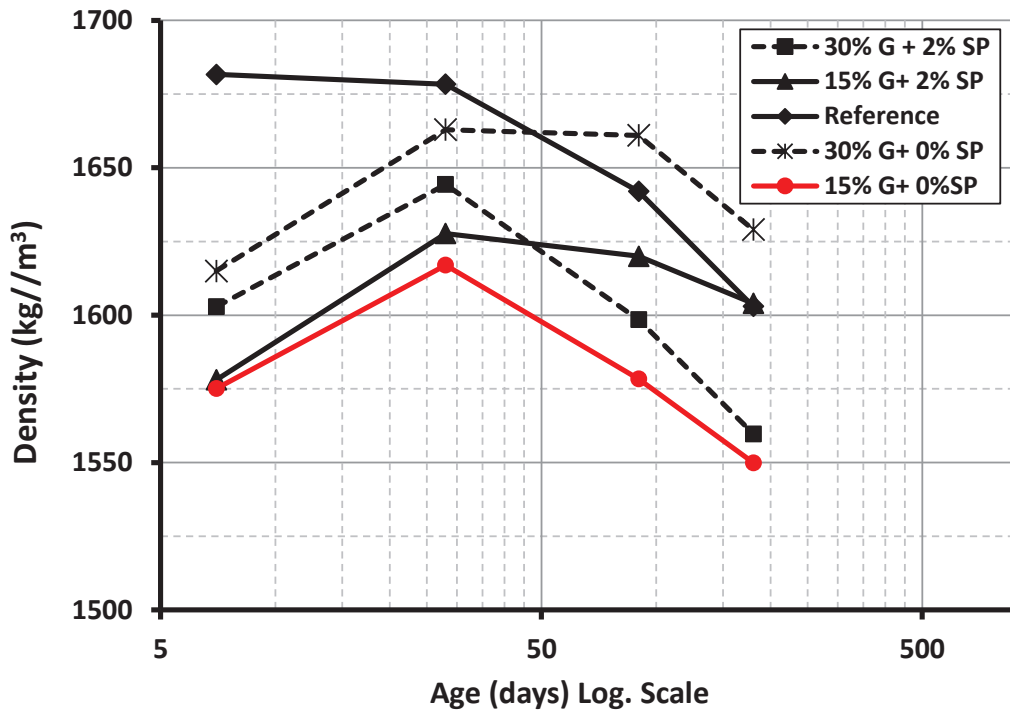


Figure 3: The density of various lightweight concretes mixes.

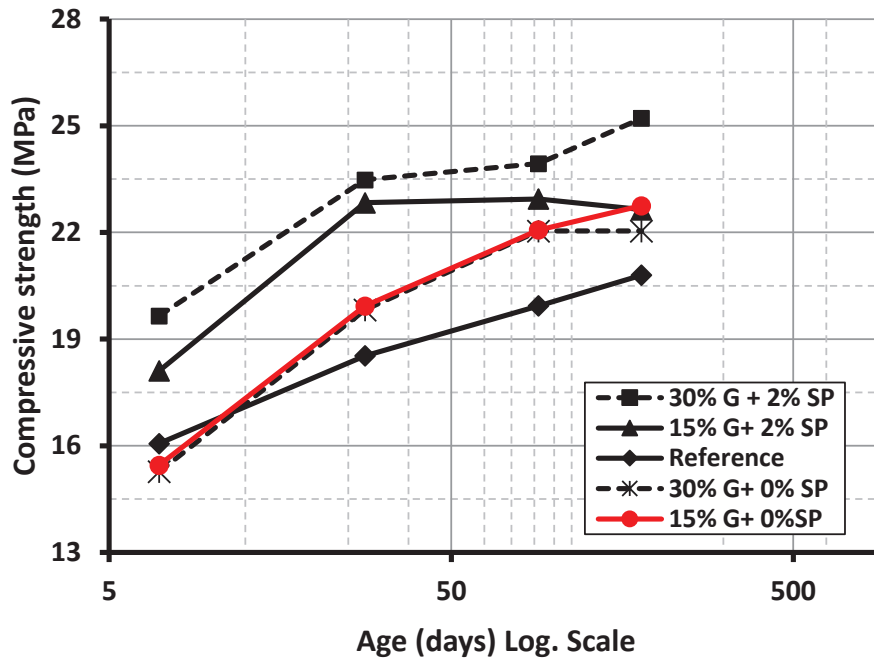


Figure 4: Compressive strength behaviour of various lightweight concrete mixes





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Figure-7

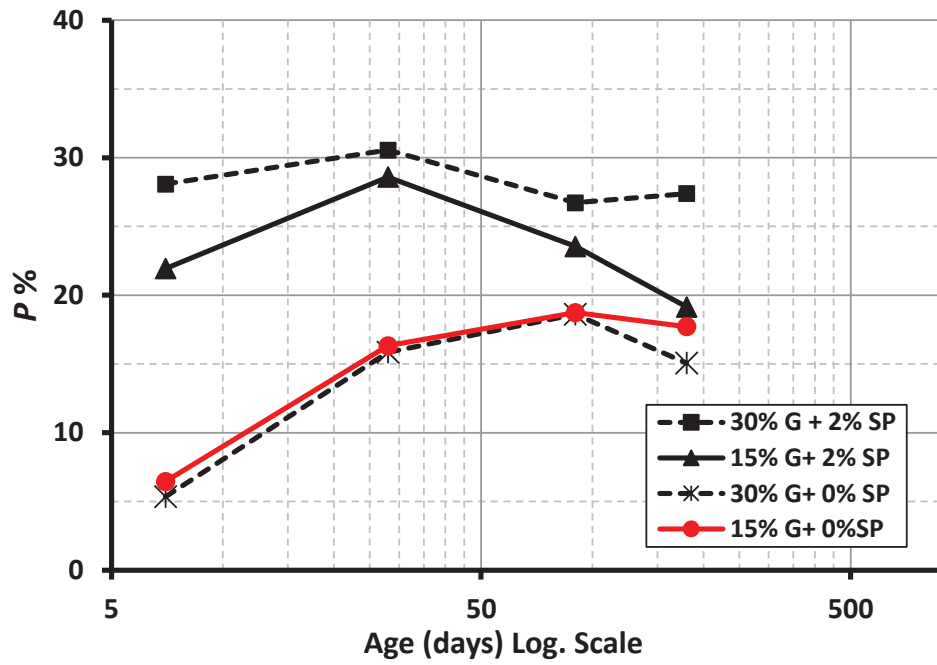


Figure 7: Contribution of pozzolanic effect and/or superplasticizer to the compressive strength of concrete mixes.

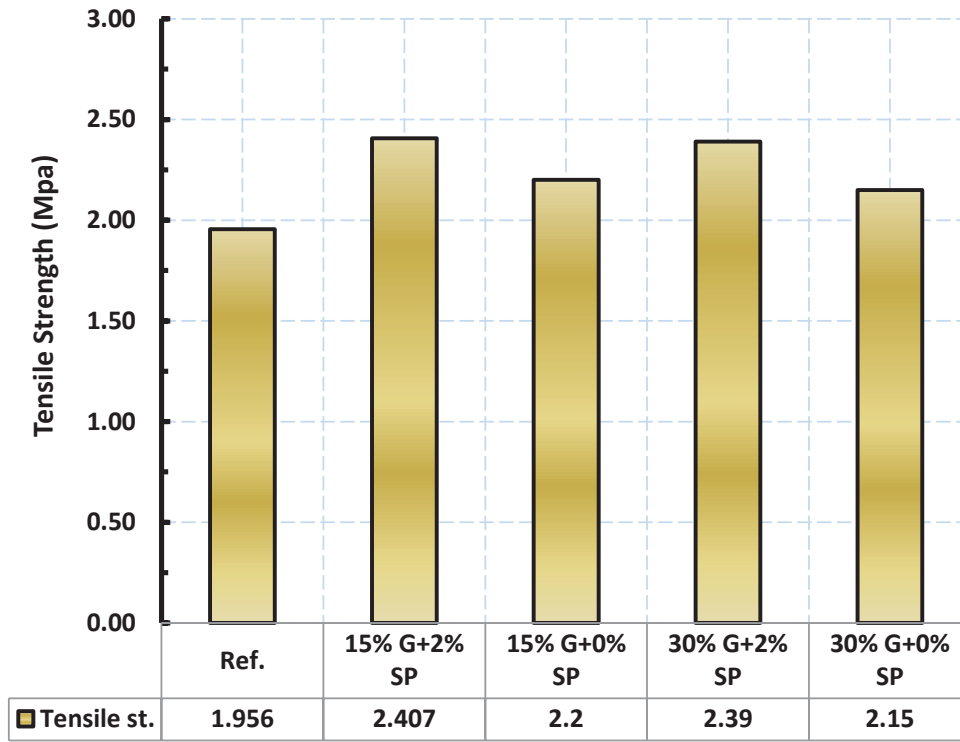


Figure 8: Splitting tensile strength of superplasticizer and control mixes at 120 days



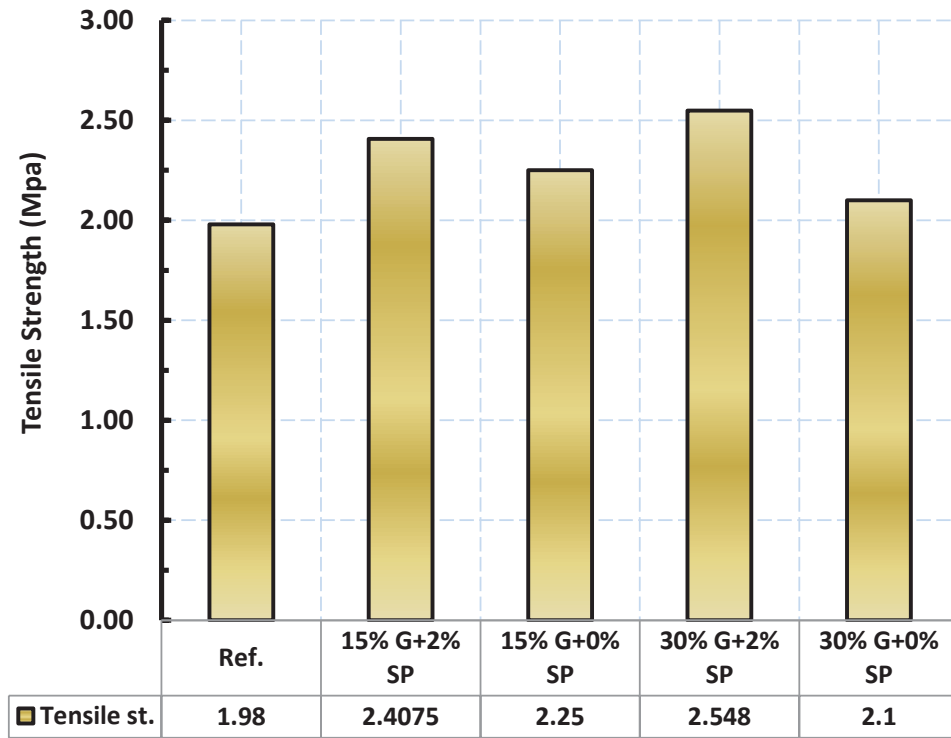


Figure 9: Splitting tensile strength of superplasticizer and control mixes at 180 days

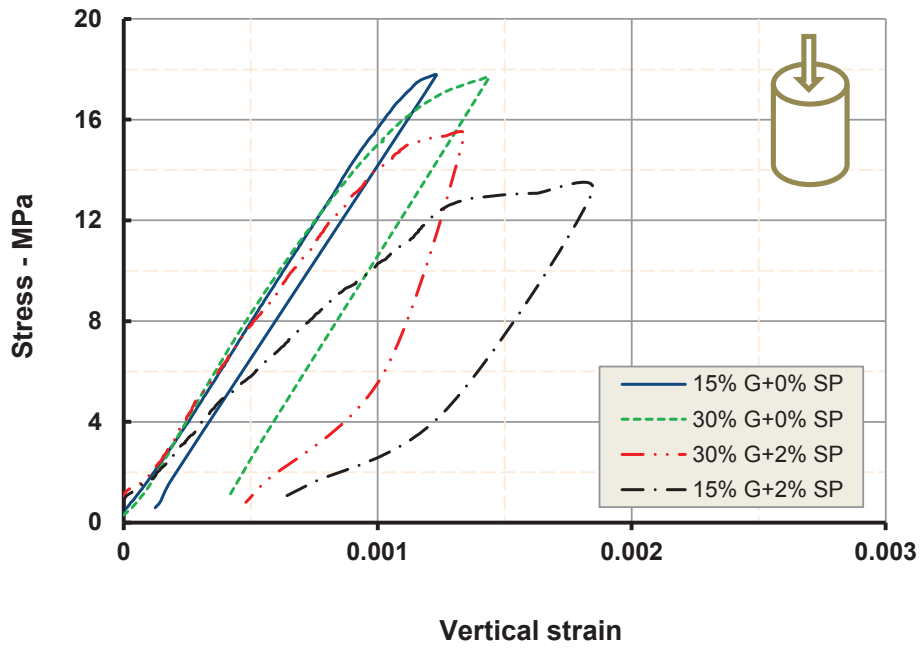


Figure 10: Stress-strain curves of superplasticizer and control concrete mixes

Table 1: Details of concrete mixes

Ingredient	Concrete mixes				
	Reference	Control mixes		Superplasticizer mixes	
		15% G+0% SP	30% G+0% SP	15% G+2% SP	30% G+2% SP
(OPC) cement	392.07	352.84	352.84	352.84	352.84
Metakaolin	0.00	39.20	39.20	39.20	39.20
Natural sand	598	508.28	418.59	508.28	418.59
Glass aggregate. 0.5-1	0.00	43.46	86.93	43.46	86.93
Glass aggregate. 1-2 mm	0.00	43.46	86.93	43.46	86.93
Expanded clay	247.50	247.50	247.50	247.50	247.50
Superplasticizer	0.00	0.00	0.00	7.05	7.05
W/C	0.45	0.45	0.45	0.36	0.36

Table 2: Calculated values of  $R$ ,  $R_p$ ,  $K$  and  $P$  for controlled and modified concrete mixes

Mix name	Age of test	$f_c$ (MPa)	$R$	$R_p$	$K$	$P(\%)$
Reference mix (0% MK+ 0% SP)	7 days	16.060	0.160	0.000	1.000	0.000
	28 days	18.530	0.1853	0.000	1.000	0.000
	90 days	19.930	0.1993	0.000	1.000	0.000
	180 days	20.800	0.208	0.000	1.000	0.000
Control mix 15% glass 10% MK+ 0% SP	7 days	15.450	0.171	0.011	0.962	6.446
	28 days	19.930	0.221	0.036	1.075	16.322
	90 days	22.070	0.245	0.045	1.107	18.726
	180 days	22.750	0.252	0.044	1.093	17.714
Control mix 30% glass 10% MK+ 0% SP	7 days	15.270	0.169	0.009	0.950	5.343
	28 days	19.820	0.220	0.034	1.069	15.857
	90 days	22.040	0.244	0.045	1.105	18.616
	180 days	22.040	0.244	0.036	1.059	15.063
Superplasticizer mix 15% glass 10% MK+ 2% SP	7 days	18.105	0.205	0.045	1.127	21.939
	28 days	22.835	0.259	0.074	1.232	28.590
	90 days	22.940	0.260	0.061	1.151	23.546
	180 days	22.640	0.257	0.049	1.088	19.151
Superplasticizer mix 30% glass 10% MK+ 2% SP	7 days	19.650	0.223	0.062	1.223	28.077
	28 days	23.480	0.266	0.081	1.267	30.551
	90 days	23.935	0.271	0.072	1.200	26.724
	180 days	25.210	0.286	0.078	1.212	27.393

Table 3. Static modulus of elasticity of concrete mixes

Mix name	Value of static modulus of elasticity ( GPa)	Age of test ( days)
15%G+ 0%SP	14.30	140
30%G+ 0%SP	16.25	140
15%G+ 2%SP	12.80	28
30%G+ 2%SP	14.38	28