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Characteristics of Foamed Concrete Containing Ultra-fine Drift Sand of the Yangtze River

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Abstract

The primary goal of this study was to evaluate the use of Ultra-fine Drift Sand from the Yangtze River (China) in place of natural sand in the production of foamed concrete. The experimental design included factors with varying levels: the proportion of Ultra-fine Drift Sand at four levels (0 percent, 30%, 60%, and 100%). Ultra-fine Drift Sand was substituted in proportion to the mass of material. Each factor's effect on compressive strength, density (dry and saturated), air voids, and water absorption was assessed. According to the results, all factors had significant findings. The compressive strength of concrete increased due to an increase in curing time; fly ash content up to 30%; increasing the percent of Yangzi river sand; and decreasing slag. The mixture of 10% SF (Silica Fume), 24% FA (Fly Ash) and 100% YS (Yangzi soil) gives the enhanced results in concrete strength, by which it reaches about 7 MPa compared with other findings. The remaining percentages of mixing benefit compression strength results. This method of treatment provides an economical way through providing a cheap material that enhances the mechanical properties of concrete, provides a light weight concrete, and a good isolator material to improve the building's thermal insulation to reduce ecological problems and save energy.

Keywords: Foamed Concrete; Ultra-Fine Sand; Compressive Strength; Drift Sand.

1. Introduction

To keep pace with changing construction, the world has advanced in a new direction in recent years, searching for materials that are lighter, more durable, practical, cost-effective, and environmentally friendly. With the increase of global warming, an alternative production sector to normal concrete is due to its high heavy weight and thermal conductivity. There are different ways, and it is lightweight at 300 to 1800 kg/m^3 [1]. Ultra-fine sand is periodically swept away in order to gain access to the natural activities of the Yangtze River Canal. Finding a new sand drift management solution becomes a challenge for channel managers [2]. The name foam concrete itself defines the nature of concrete as lightweight concrete made of a foaming agent that does not have coarse aggregate in it as an admixture, and it can also be called air slurry because it has air voids. The foaming agent is added separately to the cement paste, which is diluted with water in the foam formation when sprayed outside the pump [3].

The ultra-waste sand for houses found in electron microscopy and mercury penetration tests contains the highest concentration of FA products. These results verify the use of this project from a starting point of sand concrete [4]. The marine environment is greatly involved in the strict defense of marine disasters but causes severe damage to the ecological environment. An ecological material with great potential in the construction of ecological walls. Due to the

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difference between the equal properties of aggregate, its circulation and natural aggregate, the internal pore structure of porous concrete is different from that of ordinary concrete [5]. With the increase of the sand content, the tensile strength and compressive strength increase first, while maintaining its fluidity. When the sand content reaches 50%, the mechanical properties and workability are maintained [6]. The main factors were identified in terms of the ratio of ferromagnetic materials. Raw textures measured the characteristics of the new state of foam concrete, viz., (1) Stability of foam prices and (2) Estimated preliminary results. This will help in the hydro for the access mix as the timeline value has been suggested to get the arc chord [7].

It was found that replacing cement with 5 and 10% wt increases the compressive strength by 20% and 25%, respectively, when compared to control concrete. An image found during a moment was found in a generic vessel at 28. In general, it was found to be more effective than other conventional materials in improving the stability of a mixture [8]. Mixtures manufactured to prepare aggregate foam have been tested for thermal, mechanical, absorbent, and high temperature resistance [9].

This research aimed at the preparation mechanism and characteristics of lightweight foamed concrete based on ultra-fine drift sand in the lower Yangtze River. The ultra-fine drift sediment will be used to produce foamed concrete, and they will effect partial replacement of cement by slag, taking the ultra-fine drift sand of the Yangtze River waterway regulation as the raw material for insulation of buildings. The results of the tri-axial test of concrete showed that the residual stress of concrete under tri-axial monotonic loading was smaller than that under stable loading [10]. Fly ash and silica fume have been widely used for improved concrete durability and strength. Silica fume shows greater pozzolanic reactivity than fly ash, primarily because of its fine particle size [11].

An additive in the foam production process acts as a nucleate of crystallization, influencing the structure formation and hydration processes, leading to an increase in the crystalline hardened binding of material. The strength results showed a very large increase in the flexural strength and compressive strength of concrete [12]. The results of water absorption and density tests indicate that the suitable addition of graded sand can increase the strength of concrete, but excessive graded sand can increase the porosity and reduce the fluidity of concrete [13]. An investigation to study the effects of polyolefin fibers at a rarely low volume fraction on the flexural and compressive properties of foamed concrete. The foamed concrete was prepared to gain a target strength of 8.0-10.0 MPa with a density of 1590 kg/m^3 at the age of 28 days [14]. Both the compressive strength and flexural strength of concrete are modified when 30% crushed waste foamed concrete is added as partial sand replacement [15].

Foam concrete improves the thermal insulation of buildings, saving power and reducing ecological problems. It has characteristics and considerable potential as a promising material in construction applications, as well as improving the strength of foamed concrete and minimizing its absorption and porosity [16, 17]. It is also important to enhance eco-friendly materials as the environment has been affected by increasing construction activities. Using foam concrete is an imposed idea to gain the requirements [18].

2. Materials and Methods

2.1. Materials

The materials used in this research are the sand, which is brought from the Yangtze River shores in addition to natural sand, fly ash, silica fume, and slug. In order to simulate these parameters or materials in the practical work and graph, every material will be abbreviated as follows:

YS =Yangtze sand; NS=Natural sand; FA = Fly Ash; SF=Silica Fume; Slag

Cement and Fly Ash

The Ordinary Portland cement (OPC-PO42.5) of brand specifications was used in this study. Class F fly ash supplied by a local ready mix concrete plant. The details of chemical compositions for ordinary Portland cement and fly ash are given below in Table 1.

Table 1. Portland cement and fly ash properties

Property		Portland Cement	Siliceous Fly Ash
Proportion By Mass (%)	SiO_2	21.9	52
	Al_2O_3	6.9	23
	Fe_2O_3	3	11
	CaO	63	5
	MgO	2.5	—
	SO_3	1.7	—
Specific Surface (M^2/KG)^A		370	420
Specific Gravity		3.15	2.38

Water

Tap water supplied in the lab was used throughout the experiments. This is potable water which has less impurities.

Supper Plasticizer

High ranges water reducing agent the normal dosage for Glenium 51; Glenium 51 are (0.5–0.8) l/100 kg of cement. Table 2 shows the properties of the Supper plasticizer used in this research.

Table 2. Supper plasticizer properties

Main action	Superplasticizer
Color	Light brown
pH value	6.6
Form	Viscous liquid
Relative density	1.1 at 20 ºC
Viscosity	128º 30 cps at 20 ºC

Foam

Foam concentrate used in this experimental study is synthetic based type (Crete Foam CMX brand for example). In this research it is recommended to use the foaming agent of density 45 kg/m^3. The ratio of foam concentrate to water used was 1:30 as shown in Figure 1.

Figure 1. Foam output mixed with water

Natural Fine Sand

Natural sand is supplied and matched the requirements of BS 1985. The specific gravity of the sand is 2.6. Table 3 shows the grain size distribution for sand sieve analysis.

Table 3. Grain size distribution of natural fine sand

Sieve size (mm)	Passing recommendation passed on ASTM C33-03
2.36	100-85
1.18	100-75
0.6	60-79
0.3	12-40
0.15	0-10

Ultra-Fine Drift Sand of the Yangtze River

Ultra-fine Drift Sand of the Yangtze River was sieved to reach the grading exactly the same of natural fine sand.

P.P Fiber and Silica Fume

P.P fibers of 10 mm in length and 100 µm (Dia) were used. In laboratory mixing, the mixing ratio guide for ASTM C796 is followed. The mixing ratios of foam concentrate for this study are given below as shown in Table 4. The final mix ratios are determined through laboratory experiments to achieve the objectives.

Table 4. The mix proportions of foamed concrete

Run	Cement (kg)	Slag (kg)	Fly Ash (kg)	Silica Fume (kg)	Natural sand (kg)	Yangtze sand (kg)	water (kg)	P.P fiber (kg)	foam (kg)	Super plasticizer (kg)
0	500	-	0	-	850	0	200	7.5	60	3.1
1	450		50	-	-	850	270	7.5	60	3.1
2	400	-	100	-	-	850	270	0	60	3.1
3	350	-	150	-	-	850	270	7.5	60	3.1
4	500	-	-	-	595	255	270	7.5	60	3.1
5	500	-	-	-	340	510	270	7.5	60	3.1
6	500		-	-	595	255	270	7.5	60	3.1
7	450	50	-	-	-	850	270	7.5	60	3.1
8	400	100	-		-	850	270	7.5	60	3.1
9	350	150	-		-	850	270	7.5	60	3.1
10	350	0	100	50	-	850	270	7.5	60	3.1
11	350	-	120	30	-	850	270	7.5	60	3.1
12	350		140	10		850	270	7.5	60	3.1

2.2. Foamed Concrete Preparation and Design

Foam concrete is a type of porous concrete made by mixing cement paste with a foaming agent after hardening. The bulk density and compressive strength are 300~500 kg/m^3 and 0.5~0.7 MPa, respectively. It can be poured on site directly and is mainly used for insulating layers of roof panels. When foam concrete is produced, it is usually preserved by steam or autoclave. If it is kept under natural conditions, the cement strength grade should not be less than 32.5, otherwise the strength is too low [19, 20]. Foam concrete is prepared by adding a foaming agent to a mixture. Foam concrete is a non-structural vacuum filler that can be drilled with excavators. It is used for trench backfilling, the air content is more than half percent, compared to about 5% in air-packed concrete [21].

2.3. Compressive Strength

When the density of cement mortar is reduced by adding water, the amount of fixing material is also watered. Vacuum, voids, physical for foam concrete, those of conventional lightweight cement 2 to 4 pounds per meter/gallon (240 to 480 kg/m^3).

3. Result and Discussion

Several laboratory tests were conducted according to the specifications and mixing materials which are mentioned in the above sections. The program of laboratory tests is shown in the following diagram (Figure 2), which includes the program tests of compressive strength tests with periods of 7, 14 and 28 days.

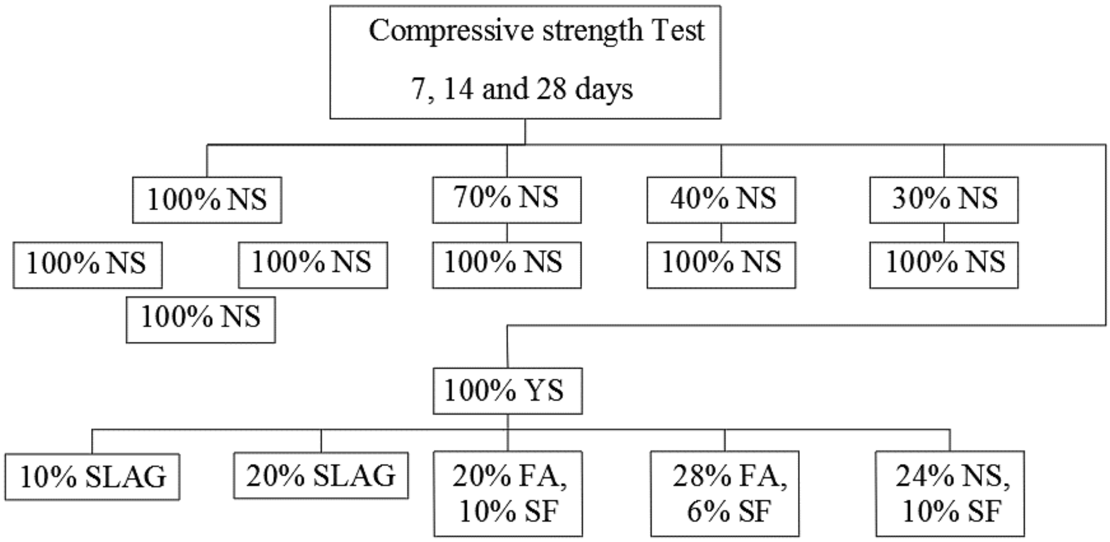

Figure 2. Laboratory testing program

Figure 3 shows the relationship between compressive strength and time at 100% NS for different periods of 7, 14 and 28 days. The results show that the compressive strength increased with an increase of curing time and the time of testing, but the compressive strength of 14 days is more than that of 28 days curing, this is may be attributed to the effect of water curing at this period (28 days) which will have an inverse effect on the compressive strength.

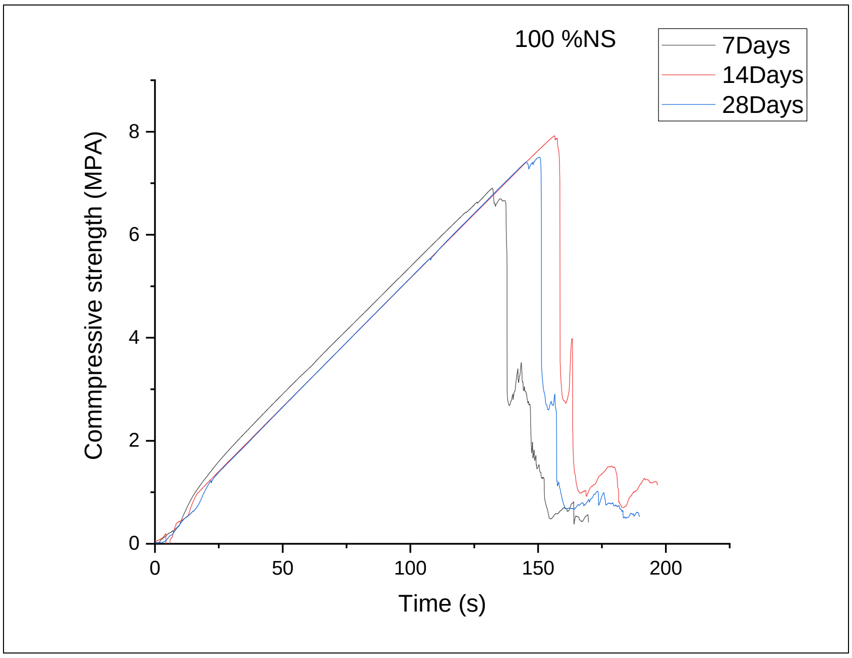

Figure 3. The relationship between compressive strength and time at 100% NS

Figure 4 shows the relationship between compressive strength and time at 100% NS and 10% FA, from which it can be seen that the results show that the compressive strength increased with an increase in curing time. The maximum values of compressive are maintained at 28 days of curing, which means the addition of 10% FA will modify the results and guide them for reasonable judgment. In the same manner, Figures 5 and 6 show the results behaving as the behavior in Figure 4, which means the increase of the percent of FA will have the same effect on the compressive strength as shown in Figure 6. The compressive strength will increase to 7 MPa with 30% FA for 28 days of curing compared with 4 MPa for 10% FA and 20% FA shown in Figures 4 and 5. The maximum compressive strength is maintained due to using 100% NS only, which reaches about 8 MPa as shown in Figure 2.

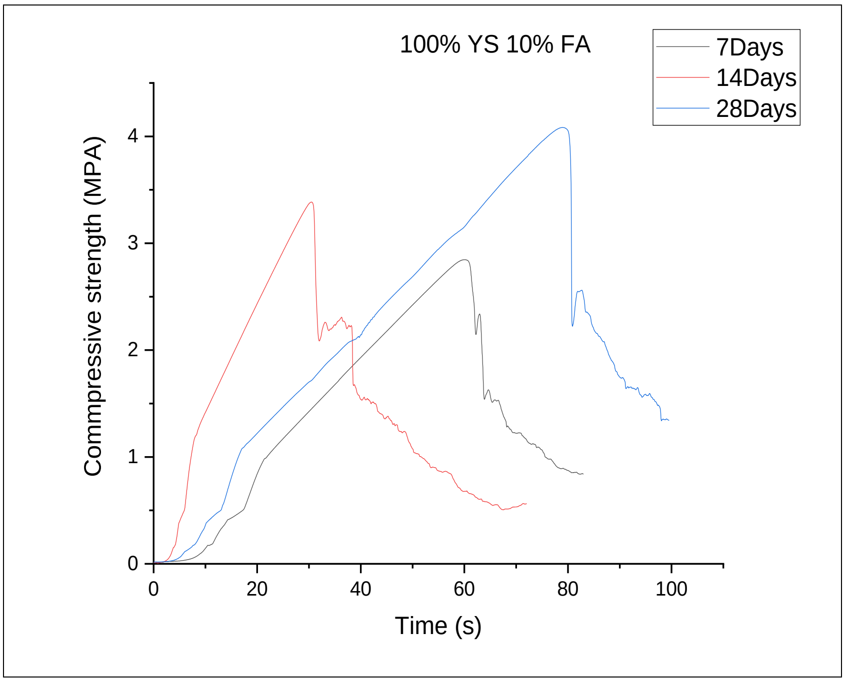

Figure 4. The relationship between compressive strength and time at 100% NS and 10% FA

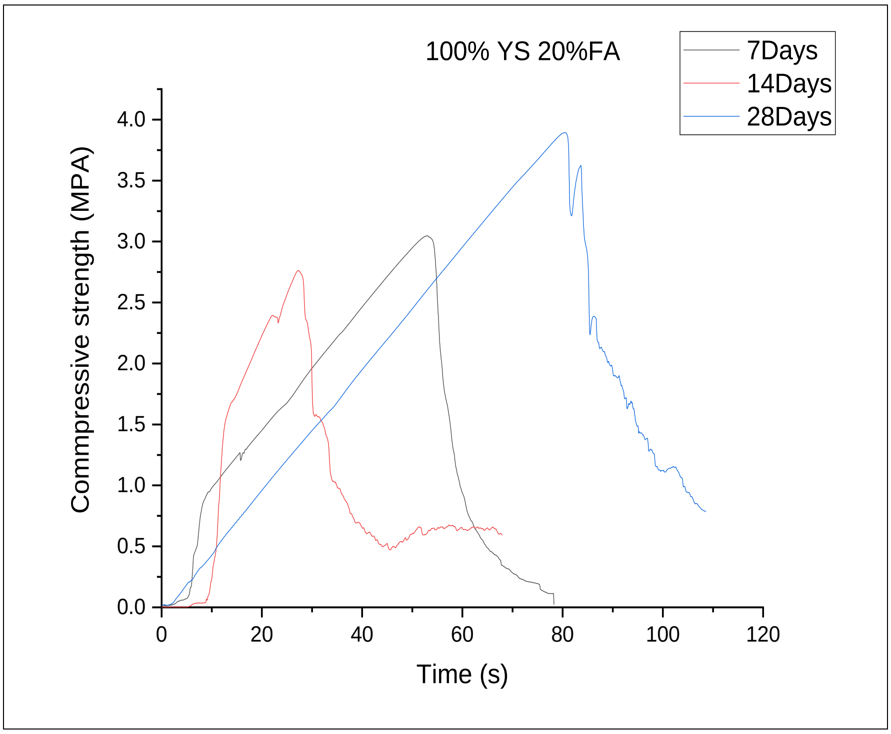

Figure 5. The relationship between compressive strength and time at 100% NS and 20% FA

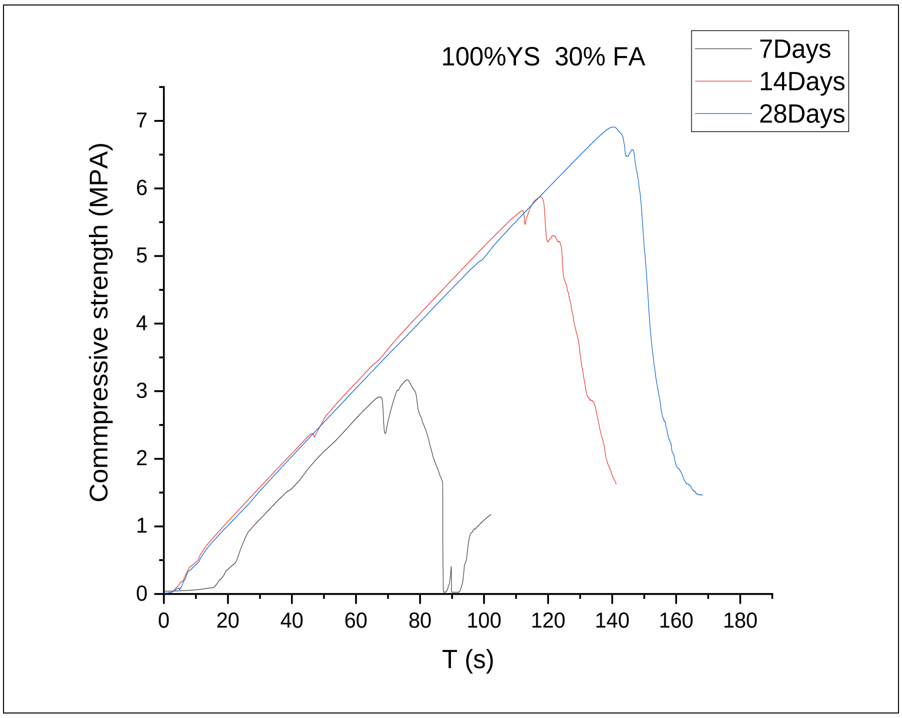

Figure 6. The relationship between compressive strength and time at 100% NS and 30% FA

Figure 7 shows the relationship between compressive strength and time at 70% NS and 30% YS, by which it can be seen that the compressive strength is increasing with time of testing and the periods of curing, the max. value of compressive strength is found at 28 days of curing. While Figure 8 shows the relationship between compressive strength and time at 40% NS and 60% YS but the results in Figure 7 are more reasonable compared with those in Figure 8. This may be attributed to the increasing percent of Yangtze sand (YS) will lead to this effect. This effect will be shown clearly in Figure 9 by increasing the YS to 70% compared with YS of 60%, so the increase of Yangtze sand percent will give a strange behavior for the compressive strength behavior. From the above, it can be concluded that variations in coarse aggregate content will significantly influence the strength of the concrete [22].

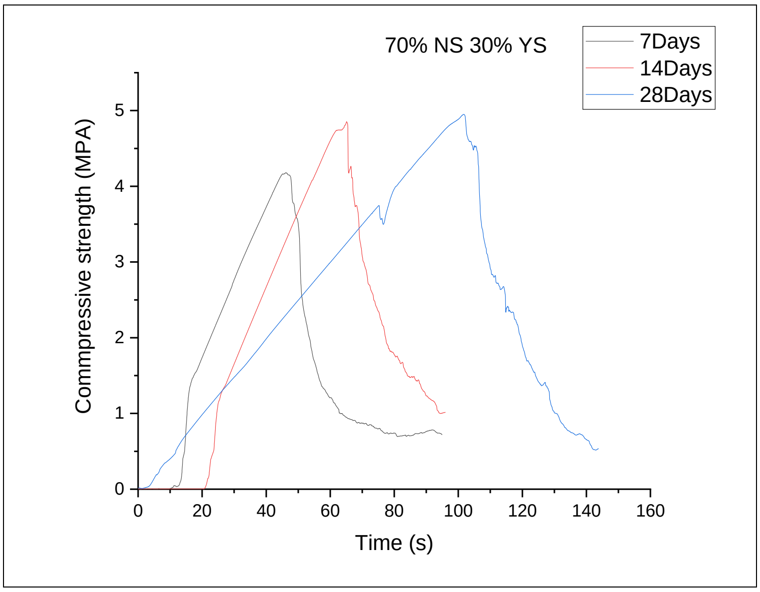

Figure 7. The relationship between compressive strength and time at 70% NS and 30% YS

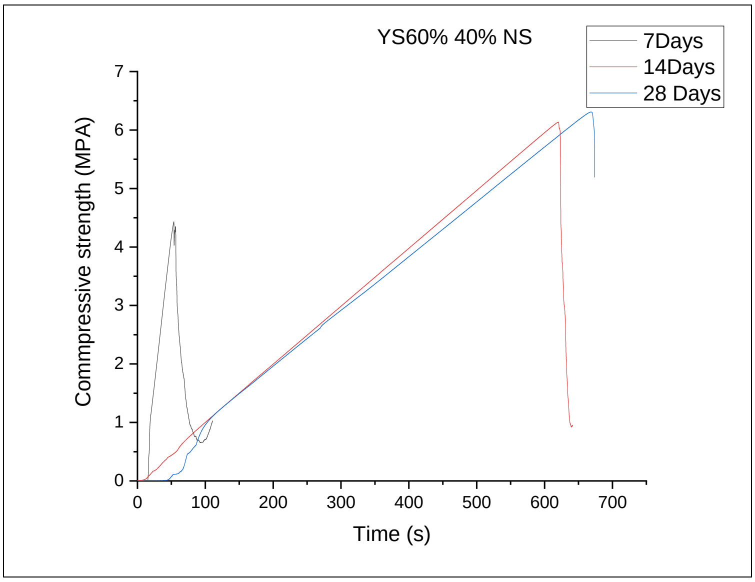

Figure 8. The relationship between compressive strength and time at 40% NS and 60% YS

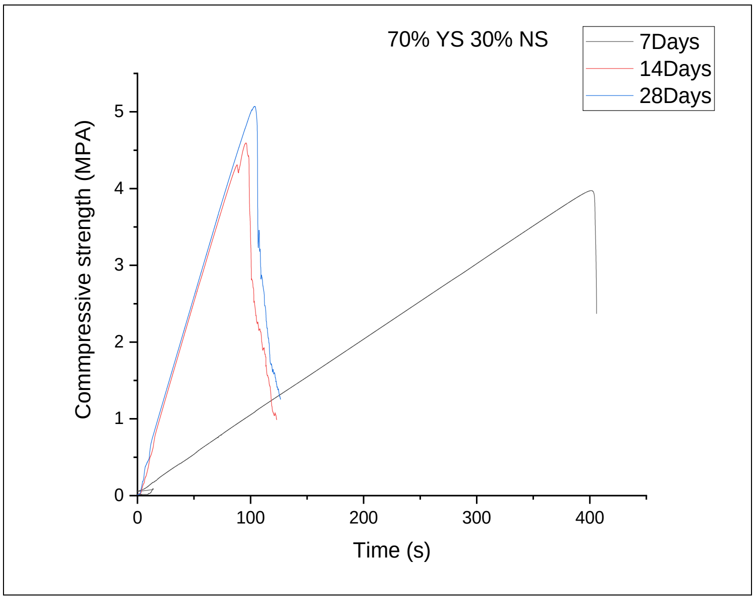

Figure 9. The relationship between compressive strength and time at 30% NS and 70% YS

Figure 10 shows the relationship between compressive strength and time at 10% slag and 100% YS. The compressive strength will be increased by increasing the time of testing and period of curing, the max. value will be reached at 6 MPa, which means the use of slag with 10% will improve the behavior of concrete and give higher strength. While the increase of slag percent will lead to the reverse effect, the compressive strength will decrease to 3.5 MPa at its max. value when the slag percent is 20% as shown in Figure 11. Concrete property can be obtained with advanced material admixtures such as blast furnace slag powder as an added partial replacement of cement of 5–30% [23].

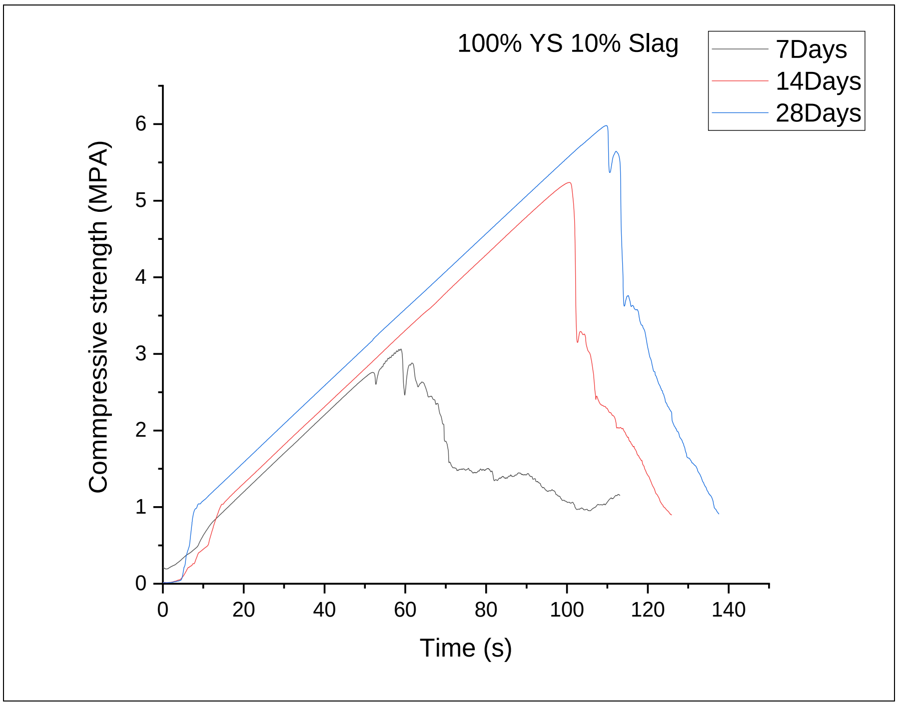

Figure 10. The relationship between compressive strength and time at 10% slag and 100% YS

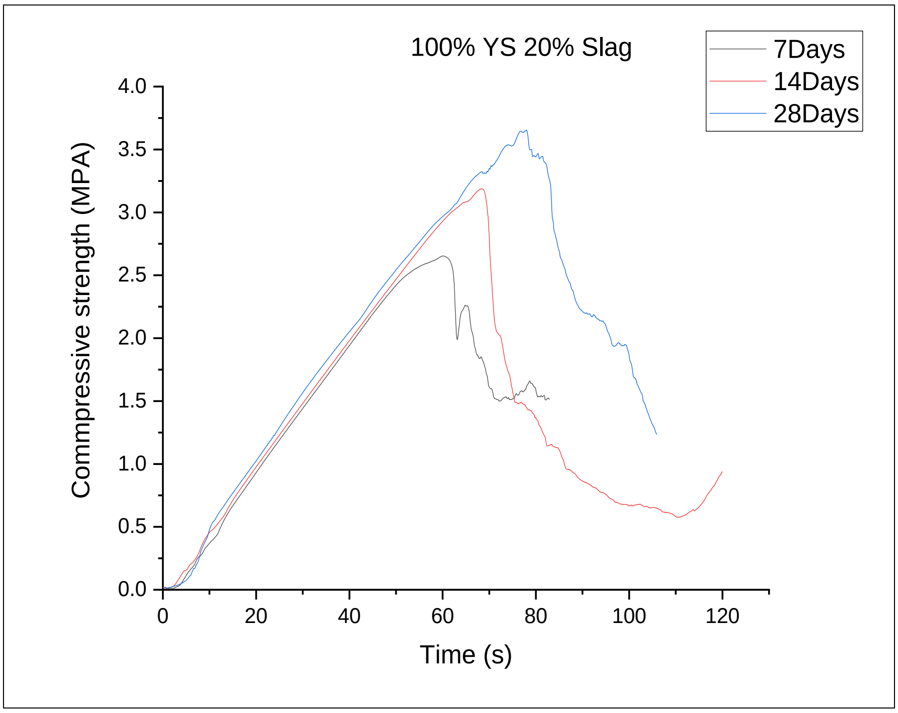

Figure 11. The relationship between compressive strength and time at 20% slag and 100% YS

Figure 12 shows the relationship between compressive strength and time at 10% SF (Silica Fume), 20% FA (Fly Ash), and 100% YS. The compressive strength at 28 days of curing shows the max. value at time 100 sec., about 4 MPa. By replacing of cement with fly ash in different percentages by mass of cement, the compressive strength increased a little for specimens with replacement of cement by 30% percent fly ash at age up to 91 days [24].

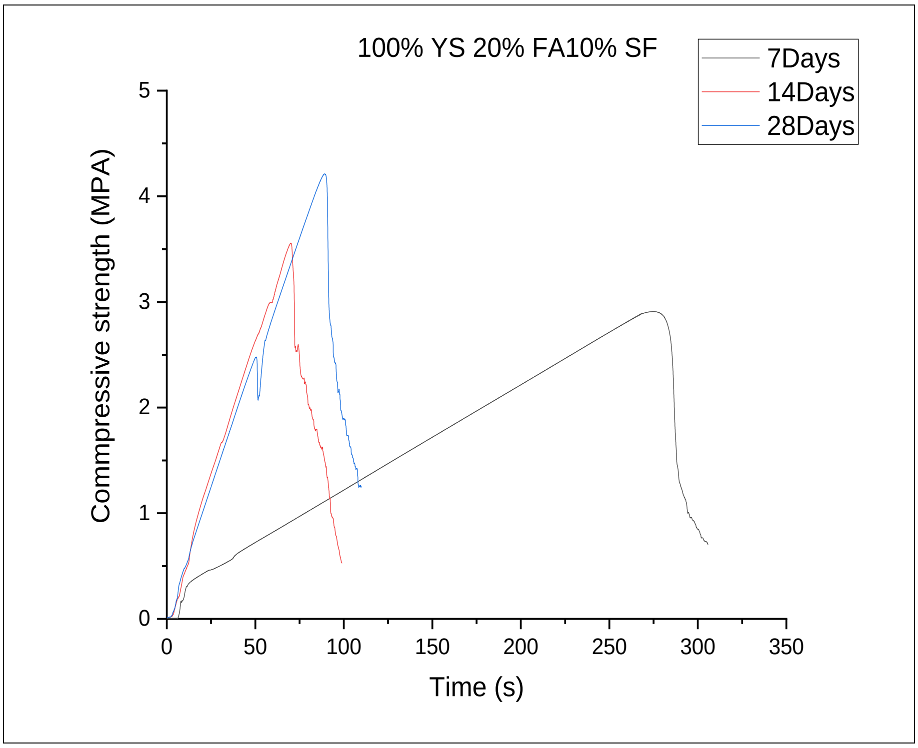

Figure 12. The relationship between compressive strength and time at 10% SF, 20% FA and 100% YS

By increasing the fly ash from 20 to 24% as shown in Figure 13, the compressive strength will increase from 4 MPa to about 7 MPa, which means the increase in FA percent will increase the compressive strength. The decrease of SF from 10% to 6% will decrease the compressive strength, as shown in Figure 14, which means the finding if SF in concrete mixtures with a large percent is necessary to get high strength. Silica fume can mainly be used with chemical admixtures, and it is normally used with a super-plasticizer. The admixture performance might depend on the properties of the individual sources of the cementation material, and tests were carried out to establish the suitable dosage levels [25].

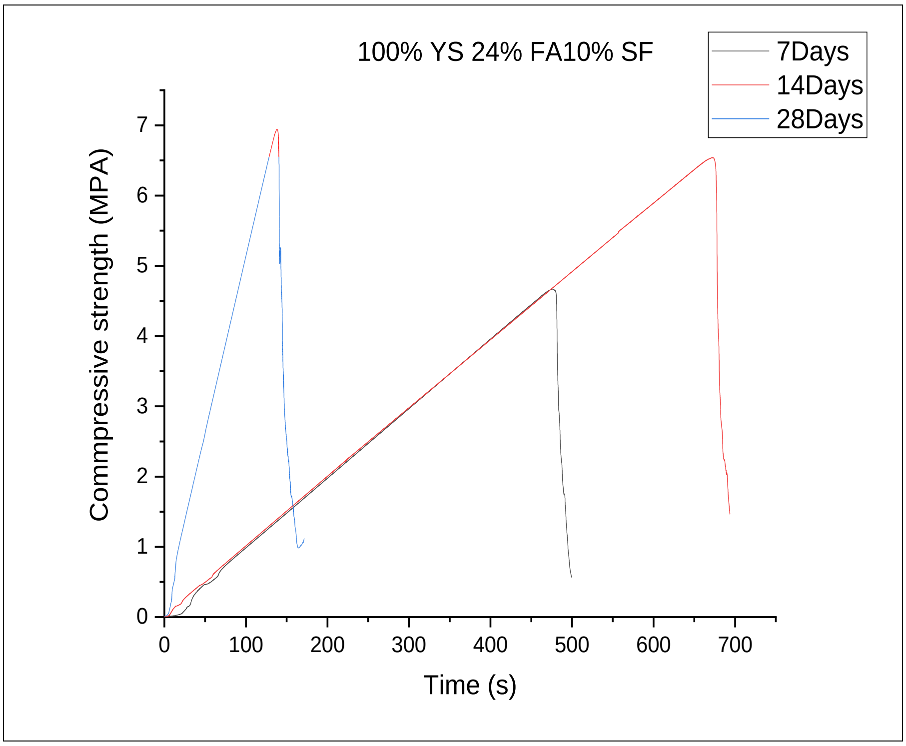

Figure 13. The relationship between compressive strength and time at 10% SF, 20% FA and 100% YS

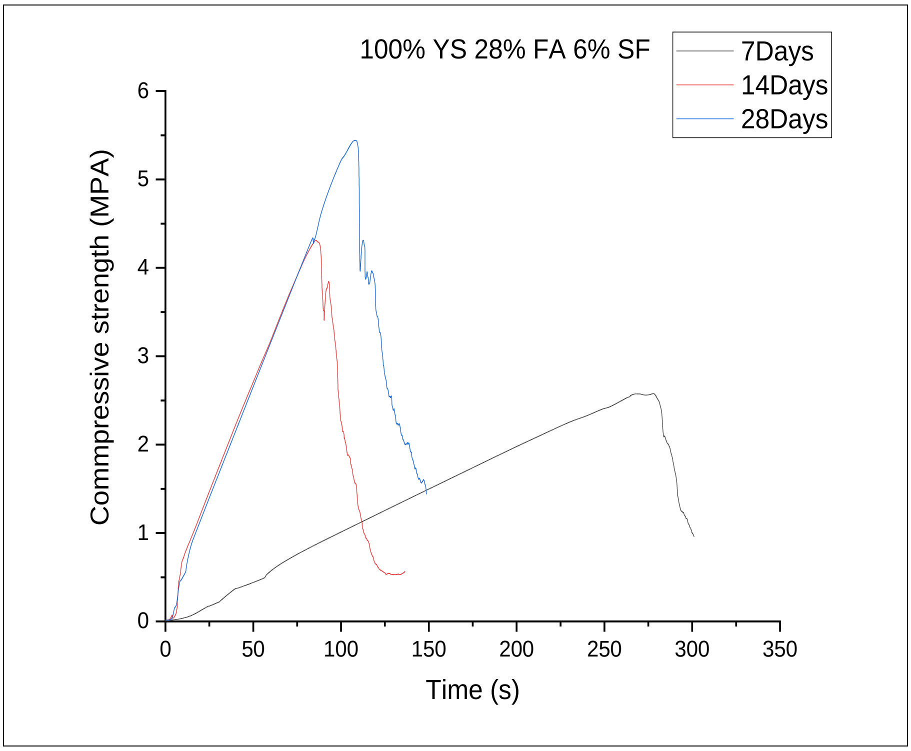

Figure 14. The relationship between compressive strength and time at 6% SF, 28% FA and 100% YS

It should be mentioned that the compressive strength tests were done in the compression machine and the samples were cubes with dimensions of (10×10×10) cm as shown in Figure 15.

Figure 15. The compression machine test used for testing

The failure of the cube samples can also be clearly shown in Figure 16. As shown from the cracks developed in the sample due to failure are nearly vertically, while the common failure should be inclined at an angle of 45°, this may be attributed to the distribution of treated material was not homogenous, which led to providing a resistance for the vertical cracks. By observing the compression test of a cubic specimen, the most severe compression in the inner central area does not match the damage side wedge peeling [26].

Figure 16. The failure of sample in the compression machine

4. Conclusions

- The compressive strength increased with the increase of curing time and the time of testing, but the compressive strength of 14 days is more than that of 28 days of curing;
- The compressive strength increased with an increase in curing time. The maximum values of compressive are maintained at 28 days of curing, which means the addition of 10% FA will modify the results and guide them for reasonable judgment;
- The increase in the percent of FA will have the same effect as increasing the compressive strength. The compressive strength will increase to 7 MPa with 30% FA for 28 days of curing compared with 4 MPa for 10% FA and 20% FA;
- At 70% NS and 30% YS, the compressive strength is increasing with time of testing and the periods of curing. The max. value of compressive strength is found at 28 days of curing;
- At 70% NS and 30% YS, compressive strength and time are more reasonable compared with those at 40% NS and 60% YS. The increasing percent of Yangtze sand (YS) will lead to this effect. This effect will be shown clearly by increasing the YS to 70% compared with YS of 60%, so the increase in Yangtze sand percent will give a strange behavior for the compressive strength behaviour;
- At 10% slag and 100% YS, the compressive strength will be increased by increasing the time of testing and period of curing, the max value will be reached at 6 MPa by which the use of slag with 10% will improve the behavior of concrete and give higher strength. While the increase of slag percent will lead to the reverse effect, the compressive strength will decrease to 3.5 MPa at its max. value when the slag percent is 20%;
- At 10% SF (Silica Fume), 20% FA (Fly Ash), and 100% YS, the compressive strength at 28 days of curing is approximately 4 MPa at time 100 sec.
- By increasing the fly ash from 20 to 24%, the compressive strength will increase from 4 MPa to about 7 MPa, which means the increase in FA percent will increase compressive strength. The decrease of SF from 10% to 6% will decrease the compressive strength.

5. Declarations

5.1. Author Contributions

F.A.A., C.J., W.X., and H.Y.A. contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors have read and agreed to the published version of the manuscript.

5.2. Data Availability Statement

The data presented in this study are available in the article.

5.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

5.4. Conflicts of Interest

The authors declare no conflict of interest.

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