

Experimental Study on the Proportioning and Strength Properties of Polymer Concrete with Mechanism Sand Flooring

Xiaonan Yang^{1*}, Jie Chen¹

¹*Building Technology Laboratory, Huzhou Vocational and Technological College, Huzhou, China*

**Corresponding Author. Email: 71971831@qq.com*

Abstract: Through the compressive strength and flexural strength tests on the specimen blocks of mechanism sand ground polymer concrete (GPC) at different mixing ratios, the effects of different fly ash and slag contents, mechanism sand contents and water glass contents on the strength of specimen blocks were analyzed. The research results show that: the strength of mechanism sand ground polymer mortar specimen with appropriate mixing ratio meets the engineering requirements; in the standard specimen, with the increase of fly ash and slag mixing and from 600g to 900g, the strength of specimen shows an increasing trend, and the critical value of fly ash and slag mixing and is 900g; with the increase of the mixing of water glass and alkali excitant (NaOH) and from 127g to 151g, the compressive strength of specimen For the overall trend of improvement, the critical value of the dosage of water glass and alkali exciter (NaOH) and is 151g.

Keywords: Mechanized sand, Geopolymer, mixing ratio, Compressive strength.

1. Introduction

Geopolymer is an environmentally friendly material with industrial waste as the main raw material. Under the strategic background of “Carbon Peak and Carbon Neutral” in the national “14th Five-Year Plan”, the research of geopolymer materials has gradually become a research hotspot in the field of new building materials [1-2]. Geo-Polymeric Concrete (GPC), which is prepared by using fly ash and industrial slag powder as raw materials, is a kind of green and environmentally friendly concrete made by using fly ash-based cementitious materials as binder, replacing the traditional silicate cement and adding fine aggregates. Fly ash-based cementitious material is a high-strength fly ash-based alkali-inspired cementitious material prepared by using fly ash and industrial slag as raw materials and sodium hydroxide, water glass and other alkali liquids as excitors. Since the raw materials used in the preparation of geopolymer such as fly ash and industrial slag can reduce the use of traditional silicate cement, it has a positive significance on energy saving and emission reduction.

The fine aggregate used for the preparation of GPM is generally natural sand and gravel, which is not renewable in the short term and is not conducive to long-distance transportation because it is a local resource. With the increasing development of China's infrastructure construction, many areas of China's natural sand resources are gradually short, and even the situation of no sand available, the contradiction between supply and demand of construction sand is particularly prominent; mechanism sand as a substitute for natural sand, greatly alleviating the state of natural river sand is on the verge

of depletion and the price of the state continues to rise, in recent years in the project has been more and more widely used [3]. And the national standard “sand for construction” (GB/T14684-2011), clearly stipulates the technical requirements of mechanism sand, which is of great significance to promote and standardize the engineering application of mechanism sand.

Mechanism sand GPC adopts mechanism sand as fine aggregate, compared with traditional concrete materials, GPC pollutes the environment less, and industrial waste residues such as fly ash in raw materials can be effectively utilized, the overall cost is low, which can effectively reduce the emission of greenhouse gases such as carbon dioxide and alleviate the pollution and destruction of the environment in the process of cement production; the use of mechanism sand instead of natural sand as fine aggregate can not only alleviate the contradiction between supply and demand in the current construction market, but also facilitate the application of mechanism sand in the project. The use of mechanism sand instead of natural sand as fine aggregate can not only alleviate the current contradiction between supply and demand in the construction market, but also benefit the national environmental protection requirements.

2. The test raw material parameters

2.1. Mechanism sand parameters

The mechanism sand produced by Huzhou Shangjian Material Products Co., Ltd. is used as the fine aggregate of mortar, and the source of the mechanism sand is granite flakes from local mountains in Huzhou. Sand sieve parameters are analyzed in Table 1.

Table 1: Sand sieve analysis table

Sieve size (mm)	Sieve weight mi (g)	Subtotal sieve residue (%)	Cumulative sieve residue (%)
5	10.1	2.02	2.02
2.5	167.4	33.48	35.5
1.25	135.1	27.02	62.52
0.63	86.9	17.38	79.9
0.315	45.4	9.08	88.98
0.16	26	5.2	94.18
Bottom of the sieve	28.9	5.78	99.96
Consider	499.8		

The raw materials of polymer silica-aluminum salt used in the test site are fly ash and slag powder produced by Henan Platinum Run Foundry Materials Co., Ltd, and the main chemical composition is shown in Table 2. Meanwhile, sodium water glass with a modulus of 2.31, a concentration of 42%, and a boehmian degree of 50 is used as the main excitatory agent of the ground polymer. NaOH flake solid with 99.0% purity and water were used to adjust the modulus and concentration of sodium water glass.

Table 2: Chemical composition of fly ash and slag

Materials	Al ₂ O ₃ (%)	SiO ₂ (%)	H ₂ O (%)	SO ₃ (%)	CaO (%)	Alkali content(%)	Iron content(%)	Loss on burn(%)
Fly ash	24.2	45.1	0.85	2.1	5.6	1.2	0.85	2.8
slag (mining)	-	99	0.1	0.1	-	0.56	-	0.8

2.2. Test ratio method

2.2.1. Test overview

In this test, it is proposed to use different concentrations of alkali excitors to configure alkali excitation cementitious materials with fly ash and mineral powder from a certain place instead of ordinary silicate cement; and use mechanism sand from a certain place instead of natural river sand, mixed with ordinary stones, and configured with different sand and stone ratios. Concrete specimens made from the above materials were utilized to test the developmental damage value of strength at different age states, modulus of elasticity and construction convenience, to explore the experience for new green building materials.

The design of the experiment for the alkali exciter solution concentration is divided into four concentrations, from 18% to 24%, every 2% as a sub-grade; the aggregate content is determined as 70% of the total percentage, which is the fine aggregate ratio, that is, the sand rate of the change in the value of the four grades, respectively, were set at 28%, 30%, 33%, 35%. In order to test the final strength of geopolymerized concrete, five strength grades of concrete with ordinary silicate cement were made at the same time as a comparison (C20, C25, C30, C35, C40).

2.2.2. Test materials

The specifications of the materials for this test are as follows:

The configuration ratio of alkali excitors is shown in Table 3. 0.1 mol/L solution of NaOH was used, which was produced from Beijing Beiweiye metering. Water glass with modulus of 2.25, density Be of 50, SiO₂ of 29.9% and Na₂O of 13.75% was produced from Jiashan Yurui Refractories. Fly ash and mineral powder were purchased from Henan Hengyuan New Materials Co. The chemical composition of fly ash and mineral powder varied from batch to batch, and the materials for this test were purchased in one batch and tested for chemical composition. The density of mineral powder is 3g/cm³ and the surface area is 465m²/kg, and the density of fly ash is 2.40g/cm³ and the surface area is 480m²/kg [4].

Table 3: Alkali exciter raw material mixing ratio

Alkali exciter concentration	Fly ash (g)	Mineral powder (g)	NaOH (g)	Water glass (g)	Water (g)
18%	1480	296	54	344	402
20%	1480	296	58	372	369
22%	1480	296	62	401	336
24%	1480	296	67	430	303

Mechanized sand was sourced from the raw material warehouse of Miaoxi Township, Wuxing District, Huzhou, Zhejiang Province, and crushed stone was sourced from a mine in Daoba Township, Wuxing District, Huzhou, Zhejiang Province [5]. Tested by Huzhou Construction and Testing Co., Ltd, the material testing report is shown in Table 4.

Table 4: Mechanized sand, gravel test report

Type	Mud powder content %	Content of needle and flake particles	Crushing index%	Apparent density kg/m ³	Continuous particle grading
Mechanized Sand	7.50	-	7.10	2750.00	5~16mm
Crushed stone	3.20	2.00	10.00	2660.00	0~4.75mm

2.3. Test block test method

Produce standard cubic test blocks with the size of 150X150X150mm, curing conditions for the standard conditions of 24H after curing using natural curing, age positioning 3d, 7d and 28d. as a comparison of the basic parameters, and the other preparation of natural sand ordinary concrete and mechanism sand ordinary concrete C20, C25, C30, C35, C40 specimen blocks of each of the 3 groups [6].

2.3.1. Fluidity test

According to GB/T50080-2016 ordinary concrete mix performance test method standard, after the concrete is made, it needs to have good fluidity to meet the needs of transportation and construction in most cases. Therefore, before making the test block after mixing, the test of collapse, cohesion and water retention is carried out, so as to find out whether the fluidity of the concrete is good or not.

2.3.2. Compressive strength test

According to the requirements of mechanical property test, measure the destructive load and compressive strength of three groups of specimens at 3d, 7d and 28d and obtain the average value as the strength value of a certain proportion, and verify whether it conforms to the standard curve of compressive strength of concrete.

2.3.3. Modulus of elasticity test

According to GB/T50081-2019 standard test method for mechanical properties of ordinary concrete, each proportion of 150X150X300mm cubic test piece, the use of NYL-2000 pressure tester, TM-2 elastic modulus tester to determine the cubic compressive strength of each test piece, axial compressive strength and modulus of elasticity. Used to analyze the mechanical properties of different ratios.

3. Three, test results and analysis

3.1. Mobility analysis

Figure 1(a) shows the collapse curves of natural sand and mechanism sand at different strengths. From the measured data, the collapsibility of mechanism sand and natural sand in the five kinds of strength concrete commonly used is not much different. And due to the mechanism sand in the particle grading on the particle size are less than 5mm, the degree of collapse of even slightly larger than natural sand about 20%. In addition, in the observation test of cohesion and water retention, the specimens made of two kinds of sand in the low strength grade (C20, C25), cohesion, water retention is general; in the medium strength grade (C30, C35), cohesion and water retention are better; in the high strength grade (C40), cohesion and water retention are very good. The experimental results are consistent with the actual performance of the same strength concrete in terms of its ease of performance and meet the criteria of the hypothetical reference.

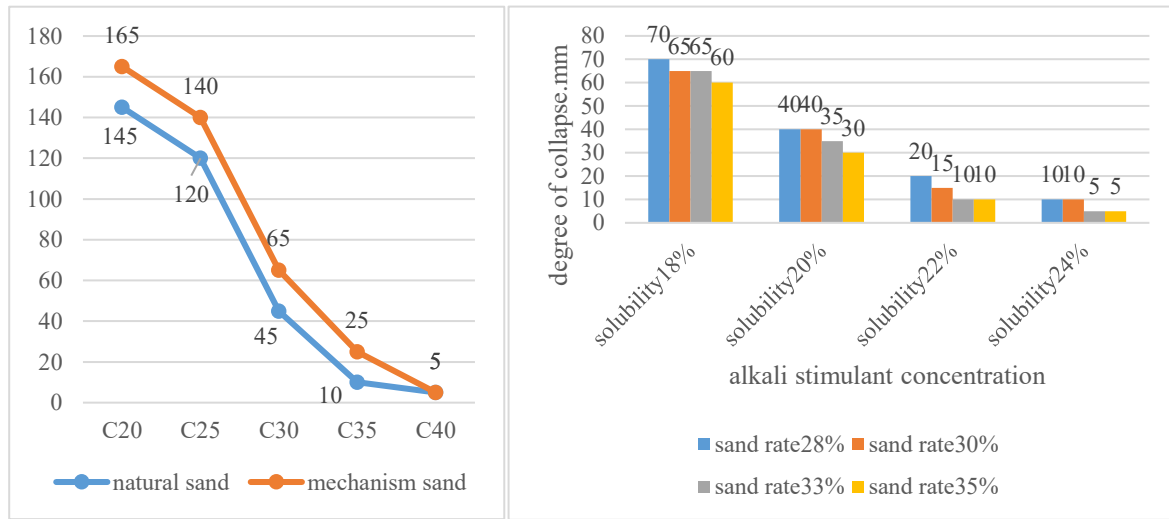


Figure 1: (a) Collapse degree of natural sand and mechanism sand unit mm. (b) Collapse curves of mechanism sand with different sand rates and solubility of different alkali exciter

Figure 1(b) shows the collapse curves of mechanism sand with different sand rates and different alkali exciter solubilities. There are two variables in this experiment (different sand rate, different alkali stimulant concentration), from the data observation in the figure, it can be seen that the change of sand rate and alkali stimulant will have an effect on the degree of collapse. Comparatively speaking, the change in sand rate has a smaller effect on the degree of collapse. As the sand rate increases, the degree of collapse decreases slightly, while as the concentration of alkali exciter increases, the degree of collapse decreases significantly. Compared with the first two ordinary concrete, the concentration of 18% is equivalent to the collapse degree of ordinary C30 concrete, and the concentration of 24% is equivalent to the collapse degree of ordinary C40. In the observation test of cohesion and water retention, the performance of different sand rates at 18% concentration is good, the performance of different sand rates at 20% concentration is good, the performance of different sand rates at 22% concentration is very good, and the performance of different sand rates at 24% concentration is very good. However, when making the test blocks later, after 20mins, the viscosity of the concrete with high concentration ratios was in full play and it was very difficult to make dense test blocks. Especially above 24% concentration, the time left for actual molding is only 10~15mins, which greatly increases the operational difficulty of the test. Therefore, according to the results of the concrete test of this 4 kinds of mix ratio. Our ranking according to the ease of good and bad is 22% concentration > 20% concentration > 18% concentration > 24% concentration.

3.2. Compressive strength analysis

Figure 2 shows the compressive strength of mechanism sand under different strength grades, and it is calculated that the strength of concrete with different strength grades reaches about 45% of the final strength at 3d, about 65% of the final strength at 7d, and basically reaches the final strength at 28d. Figure 3 shows the compressive strength at different ages with different sand rates and different alkali stimulant solubility. From the high and low positions of the bar graphs in the figure, we found that the effect of different sand rates on the compressive strength of the specimen is very small at different ages, which can be introduced as the effect of sand rate on the index of compressive strength can be negligible. The alkali exciter concentration has a very large effect on the compressive strength. The final compressive strength of 28d at a concentration of 18% is only 6MPa, which is equivalent to the strength of only C5, while the final compressive strength of 28d at a concentration of 24% can reach 51.1MPa, which is equivalent to the strength of C50. In addition, the age strength of alkali excited

agent concrete is also basically consistent with the strength curve of ordinary concrete. According to the inference of the test of 2.1 fluidity, the ease of concentration of 24% is very poor, and it is difficult to realize the actual construction, we choose the specimen with the best ease of concentration of 22% to analyze its destructive load again, see Figure 4.

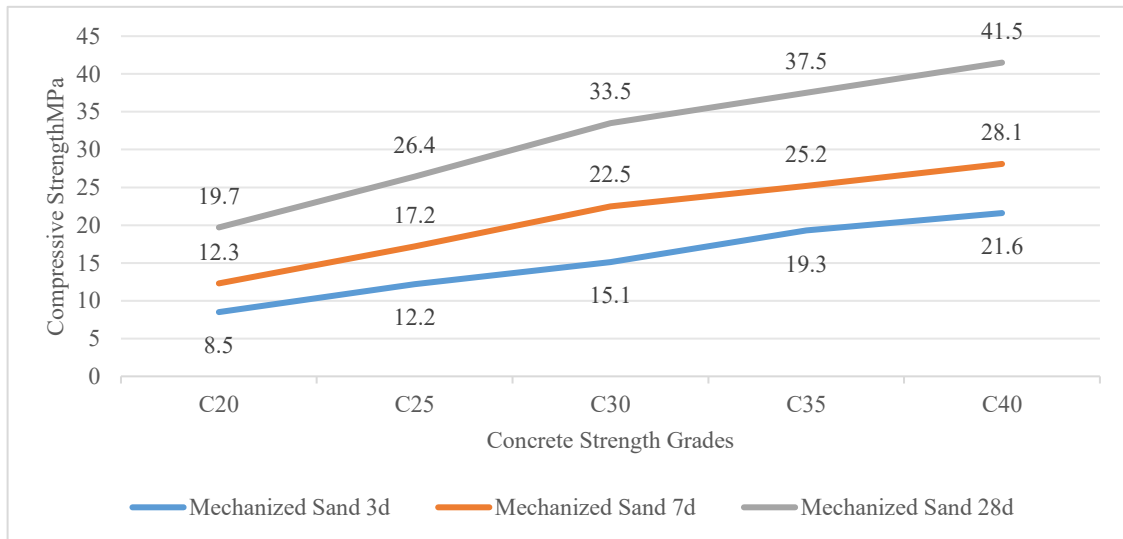


Figure 2: Compressive strength of mechanized sand at different strength grades

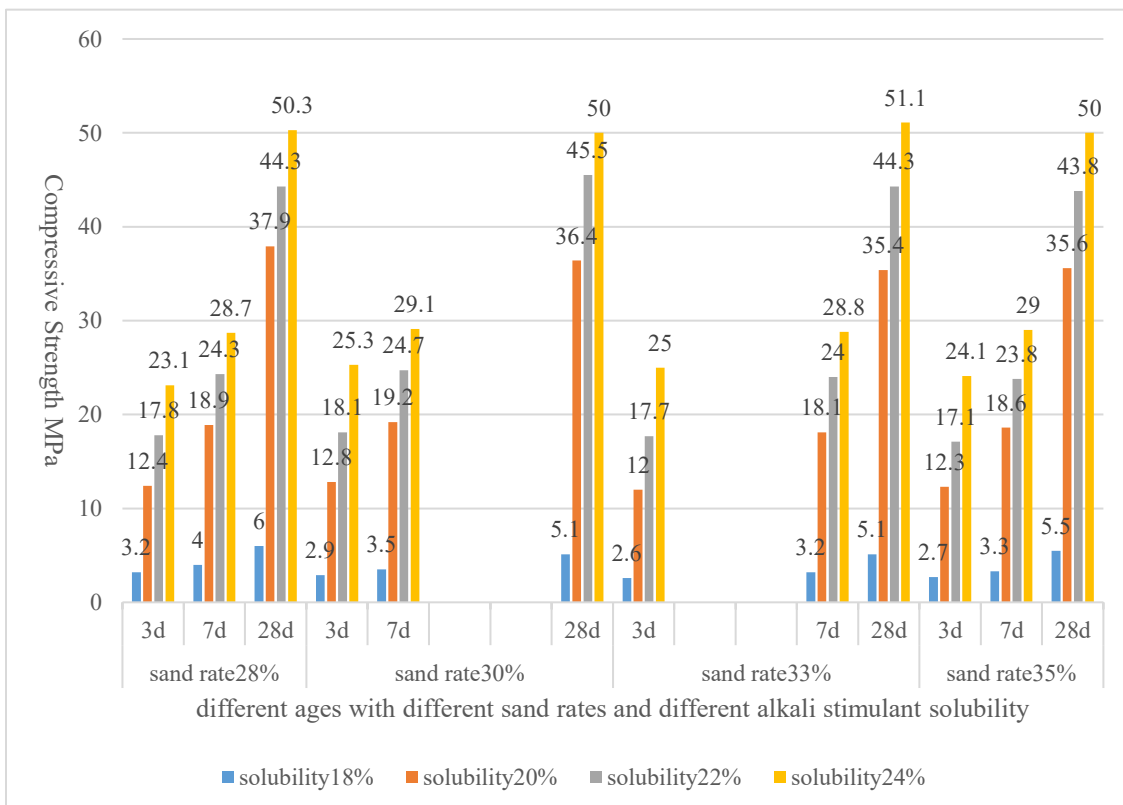


Figure 3: Compressive strength at different ages with different sand rates and alkali exciter solubilities

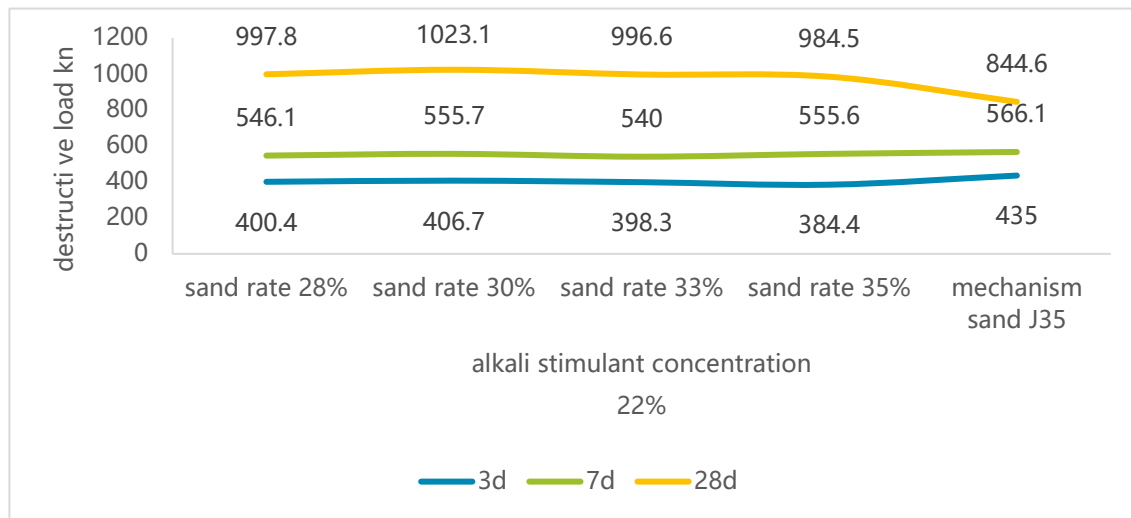


Figure 4: Breaking strength loads for different sand rates at 22% alkali exciter concentration, different ages

As can be seen in Fig. 4, the destructive load is similar to the compressive strength and is very little affected by the different sand rates. The destructive load value reaches 40% and 55% of the value at 28d at 3d and 7d, respectively, for the alkali exciter concentration of 22%, which is close to the variation curve of the strength value of ordinary concrete in Fig. 2. Upon comparison with the destructive loads of different strength classes of ordinary concrete, we found that the destructive load at a concentration of 22% approximates the destructive load of mechanism sand C35, and the final value at 28d is slightly larger than that of C35, which shows consistency with the change of compressive strength values in Fig. 3.

3.3. Modulus of elasticity analysis

According to the latest “concrete structure design code” (DG310-2020) to obtain the different strength of concrete modulus of elasticity table as Table 5.

Table 5: Modulus of elasticity table of concrete

Concrete class	strength	Modulus of elasticity $E_c(N/mm^2)$	Concrete Grade	Strength	Modulus of elasticity $E_c(N/mm^2)$
C20		2.55×10^4	C35		3.15×10^4
C25		2.80×10^4	C40		3.25×10^4
C30		3.00×10^4	C45		3.35×10^4

Due to the small number of samples in this test (one 150x150x300mm specimen for each proportion), it is not possible to measure the modulus of elasticity by the method of taking the average value of multiple loading, so the modulus of elasticity is obtained by empirical formulae according to the “Standard for Test Methods of Physical and Mechanical Properties of Concrete” (GB/T 50081-2019). And the axial compressive strength of concrete according to the specification requirements for, which when the concrete strength class is C50 or less, α_1 take 0.76, take 1.00. Thus, according to the measured natural sand and mechanism sand five strength class of the actual data, and the elastic modulus value of Table 3, after comparison, basically in line with the specification of the parameters of the strength class.

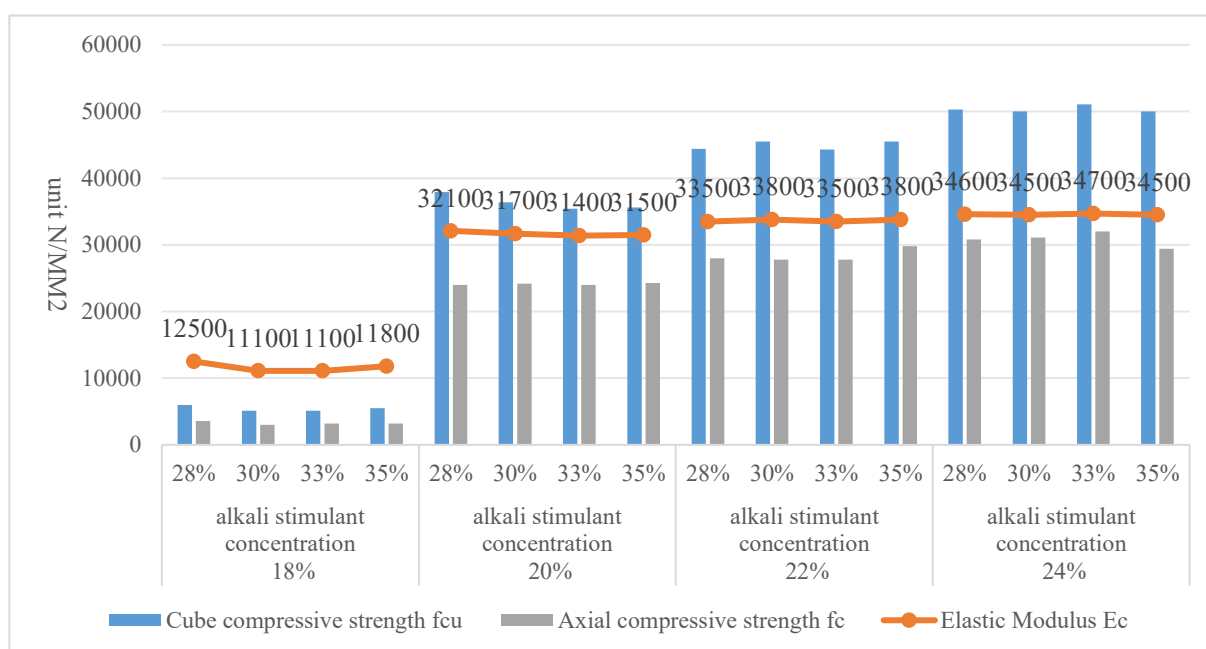


Figure 5: Modulus of elasticity of mechanism sand with different sand rate and solubility of alkali exciter

In 2.2 compressive strength test we have learned that the influence value of sand rate on the mechanical properties of the specimen is basically negligible. In Fig. 5, we verified this conclusion again in the test of elastic modulus with different sand rate and different alkali exciter concentration. The effect of alkali exciter concentration on the modulus of elasticity in 18%-20% of the qualitative change, 18% of both the compressive strength, cubic compressive strength and modulus of elasticity are extremely low, basically similar to the indicators of C5 strength ordinary concrete. And 20% when the three are greatly enhanced, indicators and C30 strength concrete indicators similar, and 22% and 24% concentration of elastic modulus growth and tend to slow down. 24% with C40 or C45 ordinary concrete indicators close.

4. Summary

The sand rate and the concentration of alkali stimulant solution have obvious correlation to the ease of concrete, fine aggregate sand in the aggregate proportion of 70% of the total value of the unchanged, the ease of sand rate in the range of 28%~35% with the increase in the range of the decrease. Alkali exciter concentration in the range of 18%~24% and the ease decreases with increasing concentration. The fluidity is great when the concentration is 18% and too low when the concentration is 24%.

The main mechanical properties of cubic compressive strength, destructive load and modulus of elasticity of different alkali stimulant concentrations are in line with the parameter values in the concrete design specification, and the effect of sand rate on the mechanical properties is negligible. Concentration in 20% below the strength index is too low, does not meet the needs of practical applications, concentration of 24% when the strength value is higher, equivalent to the performance of C50 ordinary concrete, but because of the poor compatibility, also does not meet the needs of engineering construction, so 20% to 22% concentration when the mechanical properties are the best.

References

- [1] Jia Dechang, He Peigang, Yuan Jingkun, et al. Research progress of aluminum silicate polymers and their composites[J]. *Journal of Silicates*, 2017,45(12):1721-1737.

- [2] LIU Jianfei,ZHANG Ying. *Experimental study on fly ash ground polymer mortar*[J]. *Comprehensive utilization of fly ash*,2018(2):46-49
- [3] YANG Jun. *Research on the application of siliceous mechanism sand and stone powder in ready-mixed mortar*[D],Beijing: Beijing Architecture University, 2018
- [4] Ministry of Construction of the People's Republic of China. *Standard of experimental method for basic performance of building mortar: JGJ/70-2009* [S]. Beijing: China Construction Industry Press,2010.
- [5] Jiang Zhenwu, Mei Shilong, Ren Qiang. *Mechanized sand high-performance concrete* [M]. Beijing: Chemical Industry Press, 2020.
- [6] Zhan Jianghuai, Li Hongbo, Fu Bo et al. *Effects of alkali equivalent, fly ash and slag admixture on mechanical properties and microstructure of alkali-inspired fly ash-slag geopolymer* [J]. *Science, Technology and Engineering*, 2021, 21(28):12218-12224.