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Preparation of early-strength protective wall plugging cement for fractured geothermal deep wells

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ABSTRACT

The development of geothermal energy is progressing rapidly, but the solutions for well wall instability and leakage in fractured geothermal deep wells are not perfect. The existing protective wall plugging cement has a setting time of more than 24 hours, low early strength, and not much pumpable period. This paper prepared an early-strength protective wall plugging cement suitable for fractured geothermal deep wells. The results show that: a) Calcium formate is preferably used as a set-adjusting agent in cement components through the influence of setting time, uniaxial compressive strength compressive, and flow characteristics, Silica fume is used as the early strength agent component, and the naphthalene pumping agent is used as the pumping agent component. b) Through the orthogonal test, the cement formulations suitable for different depths are screened out. The compressive strength of the cement stone has reached 3.5MPa or more when the setting time is 16 hours, and the pumpable period can be adjusted from 40~120min.

1. INTRODUCTION

Geothermal is natural energy stored in the earth, and it is a precious environmentally friendly energy source. The natural heat stored within 5km of the shallow crust alone is as high as 14.2×1023kJ, which is equivalent to 5,000 trillion tons of standard coal, and the development potential is huge [1,2]. The annual exploitable resources of shallow geothermal resources in 336 cities above the prefecture-level can be equivalent to 700 million tons of standard coal; hydrothermal geothermal resources are equivalent to 1.250 billion tons of standard coal, and the annual extractable amount is equivalent to 1.865 billion tons of standard coal; the prospective resources of dry hot rock are equivalent to 856 trillion tons of standard coal [3,4].

Drilling is the only means to explore and develop geothermal energy. During the drilling of fractured geothermal deep wells, it is inevitable to encounter the development of stratum fissures and stratum fragmentation caused by the fracture zone, which brings problems of borehole wall instability and leakage to the drilling work. The problem of short length and limited scope of application reduces drilling efficiency and increases drilling costs. From the comprehensive consideration of cost, operation method, and environmental pollution, cement consolidation is generally used for treatment [5]. Cement grout is widely used in construction cement (ordinary Portland cement is the most widely used), sulfoaluminate cement (geological exploration cement), oil well cement these three. Ordinary Portland cement is one of the simplest and most widely used building cement. Ordinary Portland cement has a higher grade in common cement, relatively fast setting and hardening speed, and rapid early strength rise. Therefore, general wall protection and plugging engineering is used more, especially when the wall strength requirements are high [6]. The application cost of sulfoaluminate cement is too high, its price is 3-4 times that of construction cement, and the addition of water-reducing agent to prevent clog drill pipe; Oil well cement [7] emphasizes anti-permeability, high-temperature condensation, sulfate resistance, and other properties. At room temperature, the performance of compressive strength and setting time of the same curing time is not as good as ordinary Portland cement, and the price is more than 50% higher than ordinary Portland cement.

The purpose of this article is to evaluate the performance of existing wall-protecting and plugging cement, analyze the mechanism of cement-slurry wall-protecting and plugging, and improve its setting characteristics, strength characteristics, and pumping capabilities through setting modifiers, early strength agents, and pumping agents. In this research, we have developed a wall-protecting and plugging cement that can be applied to geothermal deep wells. It has the following characteristics. The 16-hour initial strength is 3.5MPa or higher. The setting time and pumpable period can meet the requirements of different depths of geothermal deep wells. Requirements for construction safety time.

2. MATERIALS AND METHODS

2.1 Experimental Materials

The cement adopts PO42.5 cement from Yangchun Cement, Zhucheng City, Weifang City, Shandong Province. The ordinary Portland cement mentioned in the following refers to the ordinary Portland cement (PO425) of the Yangchun brand.

The setting adjuster defined here is an admixture that plays a major role in adjusting the setting time of the cement slurry. Choose calcium formate produced by Chengqi Chemical. By consulting literature and investigating the application of early-strength agents on the market, silica fume, silica powder, and nano-calcium carbonate were selected as the comparative materials for this test. Therefore, we choose the naphthalene superplasticizer as the most comparative material.

2.2 Determination of the initial and final setting time

The initial setting time and final setting time of cement are determined in accordance with the GBT1346-2011[8] cement standard water consumption, setting time, and stability test method standards.

2.3 Compressive strength test

The test of compressive strength complies with the requirements of "National Standard GB/T 10238-2005 [9]" and "Oil and Natural Gas Industry Standard SY/T 6544-2010 [10]".A universal electro-hydraulic servo machine is used for testing at a loading speed of 17.1 kN/min. The tested specimen is a cube with a size of 50.8mm*50.8mm*50.8mm. Each group carries out three parallel tests, and the test results are the average of the test results.

2.4 Cement paste fluidity test

In the cement paste mixer, add 200 g of cement and mix with 200 g of water. Pour the stirred net slurry into the truncated cone circular mold, lift the truncated cone circular mold, and measure the maximum diameter of the cement slurry flowing freely on the glass plane [11].

3. RESULTS AND DISCUSSION

2.1 Cement paste fluidity

Calcium formate mainly increases the concentration of calcium ions in solution, accelerates the precipitation of calcium hydroxide, and the hydration of tricalcium silicate [12,13,14]. Through Figure 1 and Figure 2 the loss of slurry flow characteristics is not large, and the pumpable performance of cement slurry is not affected. The addition of silica fume weakens the pumpability of cement grout, but it still has a certain pumpability. This is because the silica fume is loose, the gap between particles is small, and it is easy to form a layer of adsorbed water film on the surface, which increases the flow resistance of cement grout and reduces the fluidity of cement grout. And silica fume in the reaction with water with small size effect, the contact area between particles is small, and the combination of free water increased chance, to some extent hindered the initial hydration of cement, and silica fume itself does not have gelling properties, greatly reduce the workability of cement paste, flow performance decreases, pumping possibility is also restricted by corresp onding; With the addition of silica fume, the initial fluidity of cement slurry is numerically smaller than that of base fluid, and the pumpable period decreases with the increase of the addition of silica fume. With the increase of the naphthalene pumping agent, the initial fluidity and pumpable period increase.

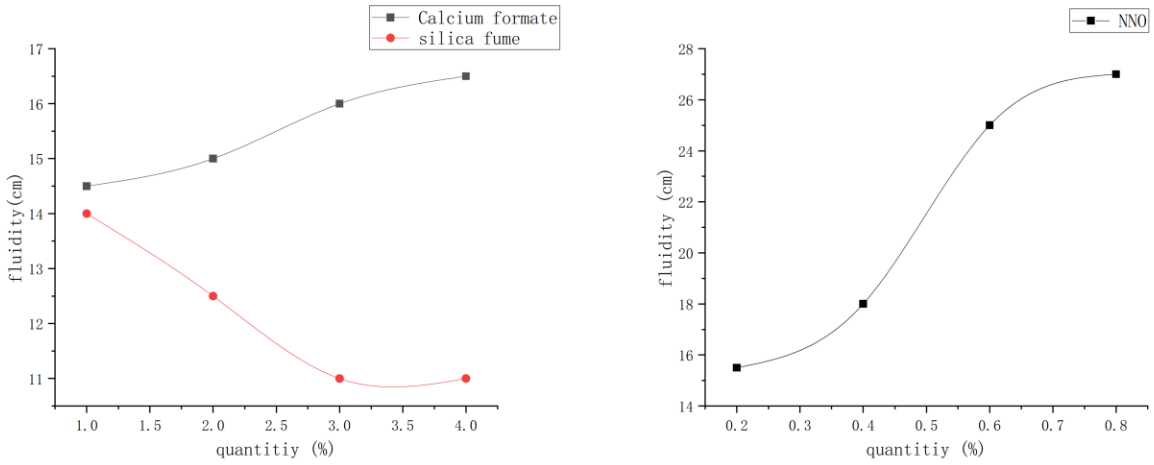

Figure 1 Relationship between fluidity and admixture

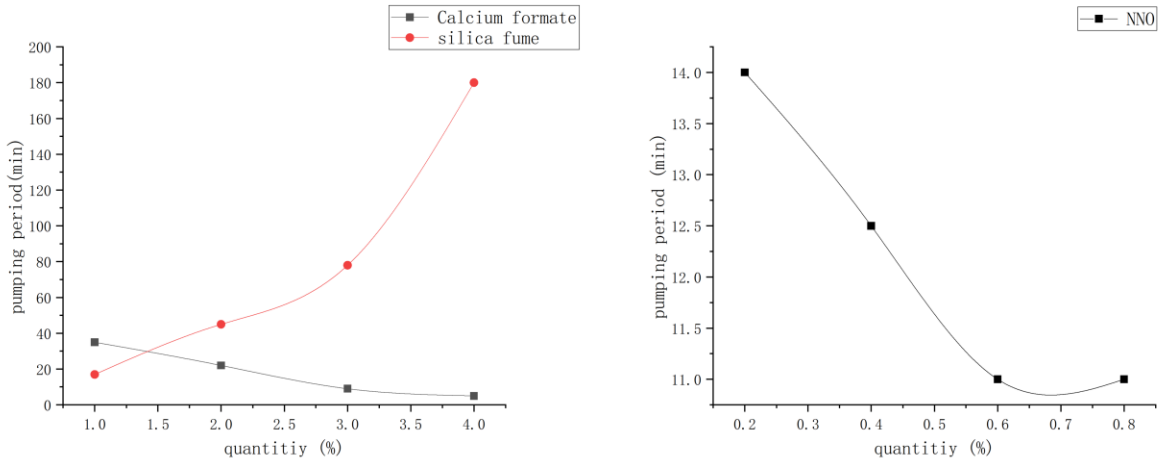

Figure 2 Relationship pumping period and admixture

2.2 Compressive strength

In the curing environment of 25℃ for 12 hours, through Figure 3, the compressive strength of cement stone increased with the increase of the proportion of calcium formate content, and the curing time was extended to 24 hours. With the increase of the amount of calcium formate, the amount of calcium formate reached a peak at 3% of the cement mass. The increasing effect of silica fume on the compressive strength of cement stone is significant, and the compressive strength of cement stone cured for 12h at 25℃ is more than 3.5mpa. The increasing effect of silica fume on the compressive strength of cement stone for 12h increases with the increase of dosage and reaches the peak value at 3% dosage. The increasing effect of silica fume on the compressive strength of cement stone for 24h increases with the increase of dosage and reaches the peak value at 2% dosage. As for the compressive strength of cement set after curing for 12h, the compressive strength decreases with the increase of naphthalene pumping agent, while for the cement set after curing for 24h, the compressive strength reaches the peak at 0.4% adding naphthalene pumping agent.

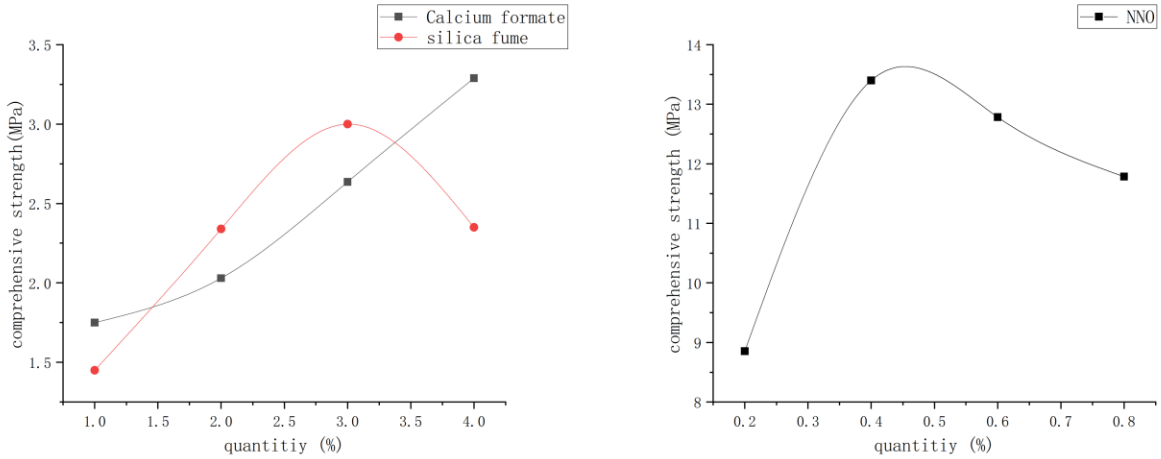

Figure 3: Relationship compressive strength and admixture

2.3 Setting time

The requirement of cement for sealing wall is not as small as possible, but as small as possible under the premise of greater than the complete pumping time and safety time, to plug the leakage layer more easily, reduce the waiting time, and strengthen the sealing wall of the formation prone to leakage. Through Figure 4, although calcium formate has weak coagulation promoting effect compared with aluminum sulfate, it can meet the construction requirements of well protection and plug to a certain extent, and the fluctuation of initial and final coagulation time is stable and controllable. The setting time of cement slurry with silica fume is gradually reduced. Proper shortening of setting time can improve the success rate of plugging cement slurry, and can also accelerate the initial strengthening effect of cemented rock formation. The retarding effect of the naphthalene pumping agent is basically proportional to the dosage.

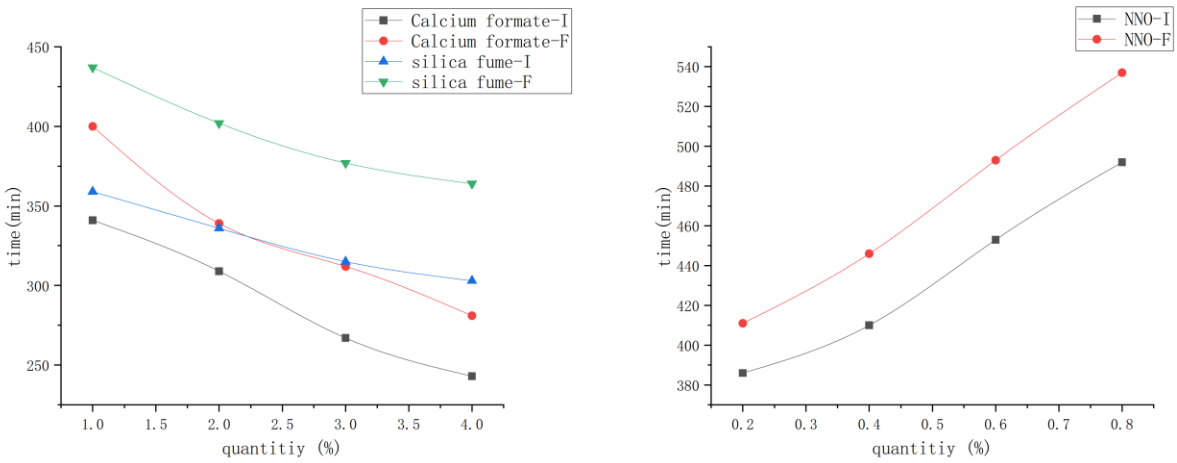

Figure 4: Relationship setting time and admixture

2.4 Orthogonal test results

Orthogonal experiments were conducted with water cement ratio, coagulant, early strength agent, and pumping agent as factors:

Table 1: Orthogonal test table

number	Water-cement ratio	Calcium formate	NNO	Silica fume
1	0.4	1	0.2	1
2	0.4	2	0.6	2
3	0.4	3	0.4	3
4	0.5	1	0.6	3
5	0.5	2	0.4	1
6	0.5	3	0.2	2
7	0.6	1	0.4	2
8	0.6	2	0.2	3
9	0.6	3	0.6	1

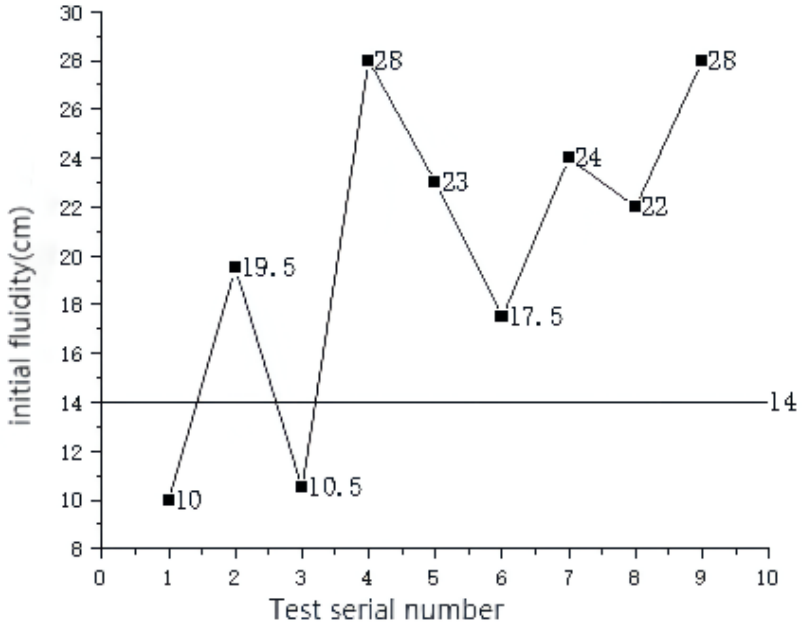

Figure 5: Orthogonal test results:initial fluidity

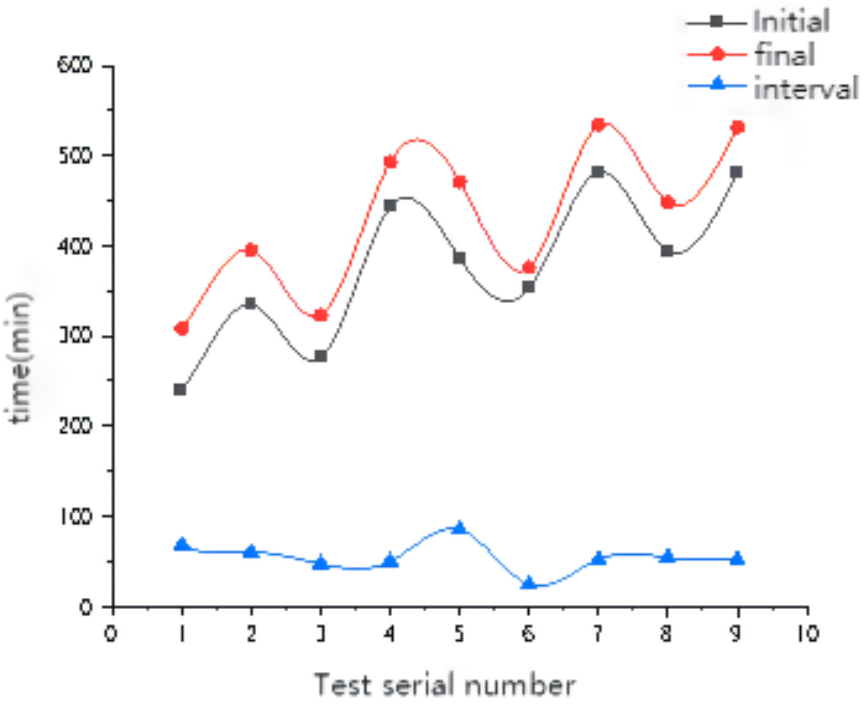

Figure 6: Orthogonal test results: setting time

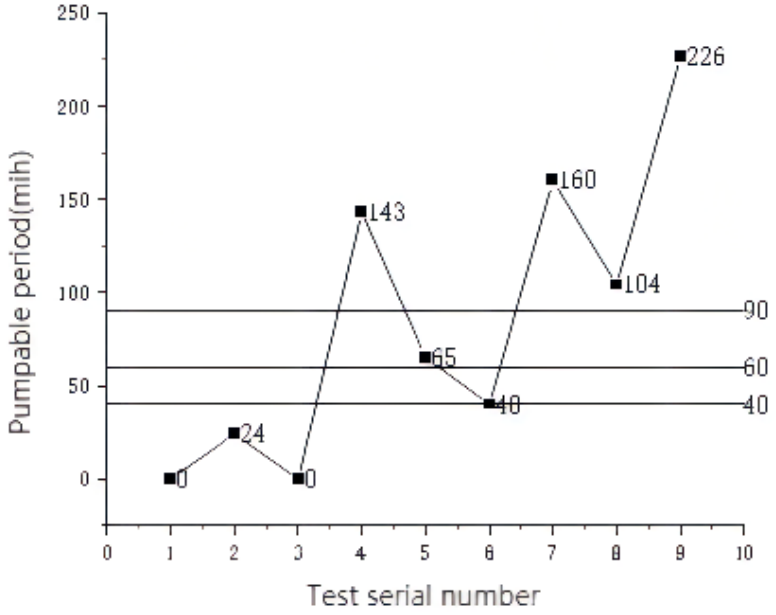

Figure 7: Orthogonal test results: pumpable period

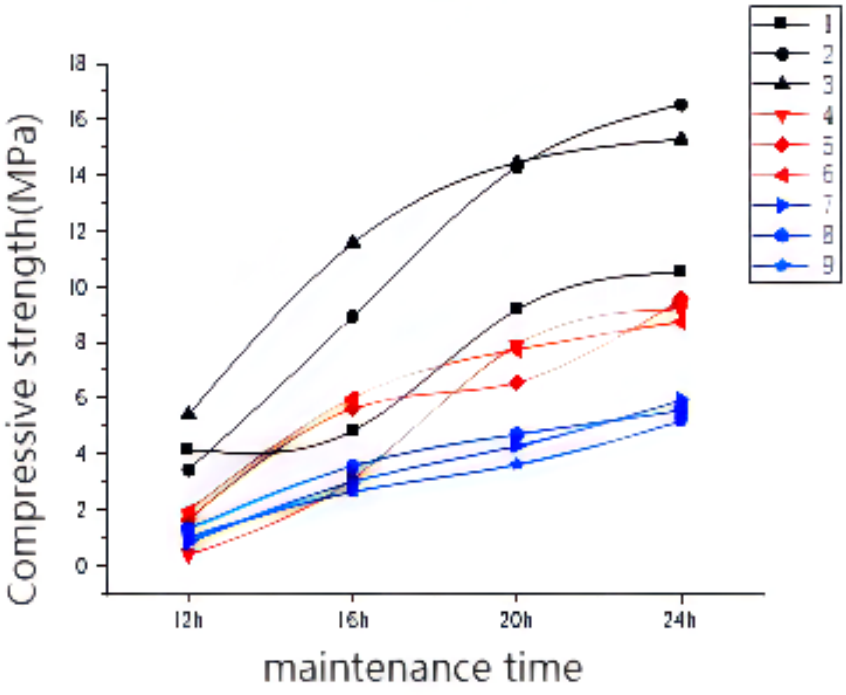

Figure 8: Orthogonal test results: compressive strength

The setting time is required to be more than 120min to ensure safe construction, and all formulations can meet the requirements. In terms of compressive strength, only formula 1 and 3 reached 3.5mpa after 12h curing, formula 1, 2, 3, 5, 6, and 8 reached more than 3.5mpa after 16h curing, and basically reached 3.5mpa after 20h curing. Combined with the orthogonal experiment results and the index requirements formulation screening, obtained for different depth of drilling grout formula, and protecting in 16 h cement setting time has reached more than 3.5 MPa, the compressive strength of the pump stage from 40 ~ 120 min is adjustable, the grout has can satisfy different depth and protecting drilling for plugging and protecting function, Improving drilling efficiency and reducing drilling costs.

4. CONCLUSION

A cement formula with 0.5 water-cement ratio +3% calcium formate +0.2% naphthalene pumping agent +2% silica fume shall be used within 500m depth, and a cement formula with 0.5 water-cement ratio +2% calcium formate +0.4% naphthalene pumping agent +1% silica fume shall be used within 500-1000m depth.From 1000m to 1500m, the cement formula of 0.5 water-cement ratio +1% calcium formate +0.6% naphthalene pumping agent +3% silica fume is used.It has a longer pumpable period, deeper service depth, higher early strength, and a shorter waiting time than existing cement formulations. To sum up, the cement formula can meet the sealing and plugging function required by drilling at different depths and achieve the effect of improving the sealing and plugging success rate, drilling efficiency, and reducing drilling costs.

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