



Laboratory Study on the Polymer Flexible Cement Slurry System

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Abstract

A polymer flexible cement slurry system has been developed because cement stone has poor deformability and can be destroyed easily in complex underground conditions and the subsequent construction of wells. A lot of laboratory experiments has been done to evaluate the properties of this slurry system and the emphasis was put on the properties of cement stone such as compressive strength, flexural strength, corrosion resistance and volume shrinkage. The result of study indicated, this polymer flexible slurry cement system had properties of resisting high temperature, salt endurance, low fluid loss, zero free liquid, the thickening curve emerged right angle with short transition period and anti-gas channeling. The compression strength of the cement stone was high, plasticity was strengthened, permeability was low, it was good to able to bear corrosion.

Key words: Oil well cement; Strength of cement; Flexibility of cement; Resistance to corrosion

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FOREWORD

Along with the technological progress in oil and gas field exploration and development, the amount of deep ultra-deep wells will continuously increase. It is very difficult

to make well cementing. At the same time, high quality cementing is urgently needed in various stimulation techniques and measures and subsequent construction of wells. The integrity of the cement sheath is easily destroyed leading to zonal isolation failure mainly because of the hard and brittle performance of the cement stone. So it becomes more and more important to improve the mechanical properties of the cement stone for extending well life and enhancing oil recovery. The cement stone with good mechanical properties has excellent flexible deformation capacity and cannot be easily destroyed by the stress concentration caused by the impact force^[1,2,3].

Based on this idea, the research on polymer flexible cement slurry system has been done in order to form a slurry system with properties of anti-gas channeling, the thickening curve emerged right angle, high rheological properties, low water loss and zero free water. After the cement setting the stone can bear corrosion and has strong flexible performance and unbreakable capacity.

1. LABORATORY METHODS AND EQUIPMENT

1.1 Main Laboratory Equipment

OWC-9360 cement slurry constant speed blender (Shenyang Tiger Petroleum Equipment Co., Ltd.), 2NN-D6 six-speed rotational viscometer (Qingdao Camera Factory), OWC-9850 normal pressure thickening apparatus (Shenyang Tiger Petroleum Equipment Co., Ltd.), OWC-9510 HTHP water loss meter (Shenyang Tiger Petroleum Equipment Co., Ltd.), 1,910 high-temperature curing autoclave (American CHANDLER company), 7,116 supercharging thickening apparatus (American CHANDLER company), Holland X'Pert Pro X-ray Diffraction instrument.

1.2 Laboratory Methods

Solid oil well cement additives conducted by GB6679, liquid oil well cement additives conducted by GB6680,

cement application performance test conducted by 10238-1998 well cement SY/T5546-1992, cement stone experiment by International Institute of Building Materials rock standards implementation manual.

1.3 Preparation of Cement Slurry System

The polymer latex SDJR optimized is an anionic latex and its solid content is between 40 and 45%. Optimizing latex matching treatment agent (such as stabilizer, antifoaming agent), fiber material SDXW and elastic particulate material SDXJ.

Table 1
Basic Properties of the Polymer Flexible Cement Slurry System at Different Temperatures

Temperature /°C	Fluid loss additive	Water loss /mL	Free water /mL	Initial consistency /Bc	Thickening time /min
75	J-1	78	0	5	85
95	TW1102	60	0	6	76

As can be seen in Table 1, the polymer flexible cement slurry has better physical properties. The reason of zero free water is that the latex used has a hydration capacity and the latex particles can be adsorbed on the surface of cement particles by means of a functional group in the molecule and the remaining groups may combine with water to form adsorbed water. Low water loss of the polymer flexible cement slurry is because of polymer latex and fiber joint action. Latex particles can inhibit the hydration of cement in the electrical repulsion and release the water wrapped in floc structure, thereby reducing the plastic viscosity slurry and improving fluidity of the slurry^[4].

Table 2
Thickening Time of the Polymer Flexible Cement Slurry System (75 °C)

Number	SDJR/%	SDXW/%	SDXJ/%	SDH-2/%	Thickening time /min
1	0	0.0	0.0	0.1	153
2	5	0.5	0.0	0.1	162
3	5	0.0	1.0	0.1	171
4	0	0.5	1.0	0.1	146
5	5	0.5	1.0	0.1	160
6	5	0.5	1.0	0.2	209

Note. Shengwei glass G 600 g, SWJ-1 0.6%, SWJZ 0.6%, appropriate amount of antifoaming agent.

As can be seen from Table 2, the polymer flexible cement slurry system has good thickening performance, you can adjust the dosage of SDH-2 according to cementing requirement thereby changing thickening time and ensuring cementing quality.

2.3 Temperature and Salt Tolerance of Cement Slurry

Figure 1 to Figure 3 are the supercharging thickening curves of the polymer flexible slurry cement system at different temperatures.

It can be seen from Figure 1 to Figure 3, this system not only has high temperature resistance but also has high

2. SLURRY PERFORMANCE OF POLYMER FLEXIBLE CEMENT SLURRY SYSTEM

2.1 Water Loss, Fluidity and Free Water of Cement Slurry

Main components of the slurry are Polymer latex SDJR, fiber material SDXW and elastic particulate material SDXJ. Its density range is between 1.80 and 1.88 g/cm³ and can be designed according to the requirements of down-hole conditions and construction work in order to meet the requirements of cementing. Its properties are shown in Table 1.

2.2 Thickening Time of Cement Slurry

Thickening time is the continuous measuring time of slurry consistency to reach 100 Bc under simulated well conditions^[5]. It must be carefully considered in slurry testing. If thickening time is short, it may cause “sausages” in cementing operations. On the contrary, if it is too long, it may lead to borehole fluid channeling and poor cementing quality^[6,7]. Thickening time of the polymer flexible cement slurry system as shown in Table 2.

salt resistance. It shows good stability and achieves the thickening curve emerged right angle. The reason is that the latex used in slurry system has anti-temperature salt group. The latex was designed and prepared by means of sulfonated modification, chain rigidity modification, zwitterionic modification and hydrophobic association modification. The anti-temperature salt group and other different functional groups have been designed into the latex molecules, thereby improving its anti-temperature performance and salt endurance^[8].

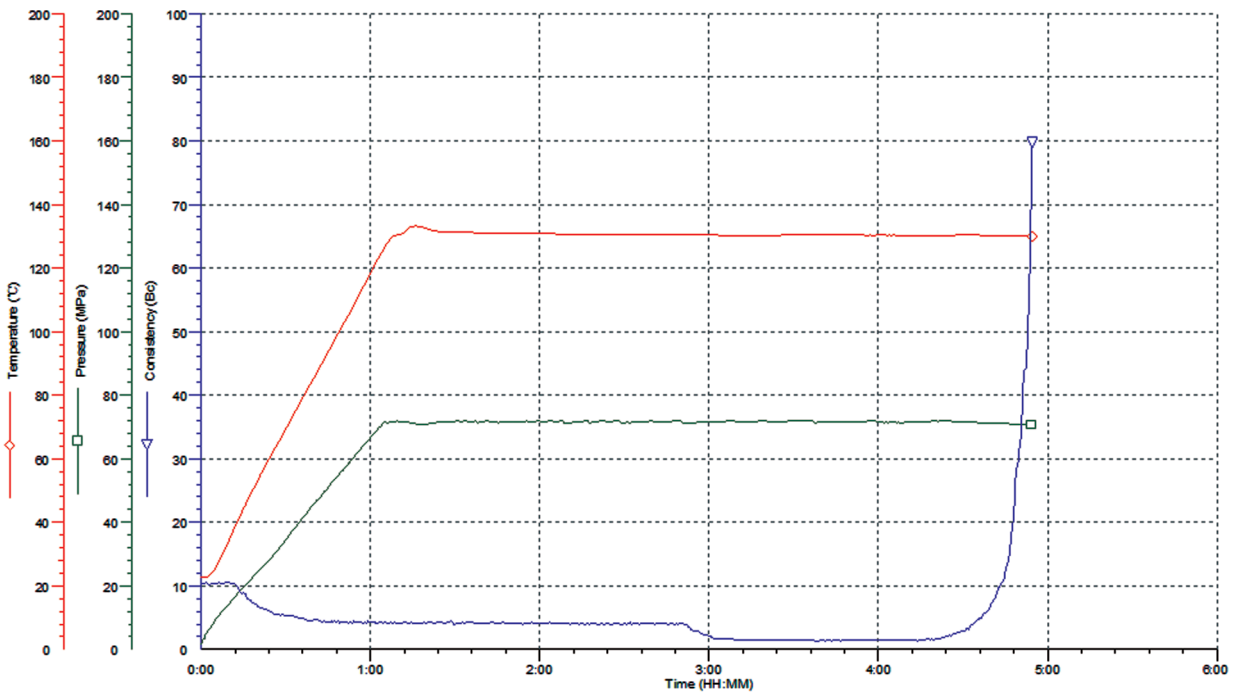


Figure 1
130 °C × 70 MPa Supercharging Thickening Curve

Note. Shengwei glass G 593 g + silicon powder 207 g + water 275 g + SWJ-3 24 g + SWJZ-1 3.2 g + SDJR 40 g + SDW 2 g + SWH-1 2.8 g + salt 33 g + antifoaming agent 2 g.

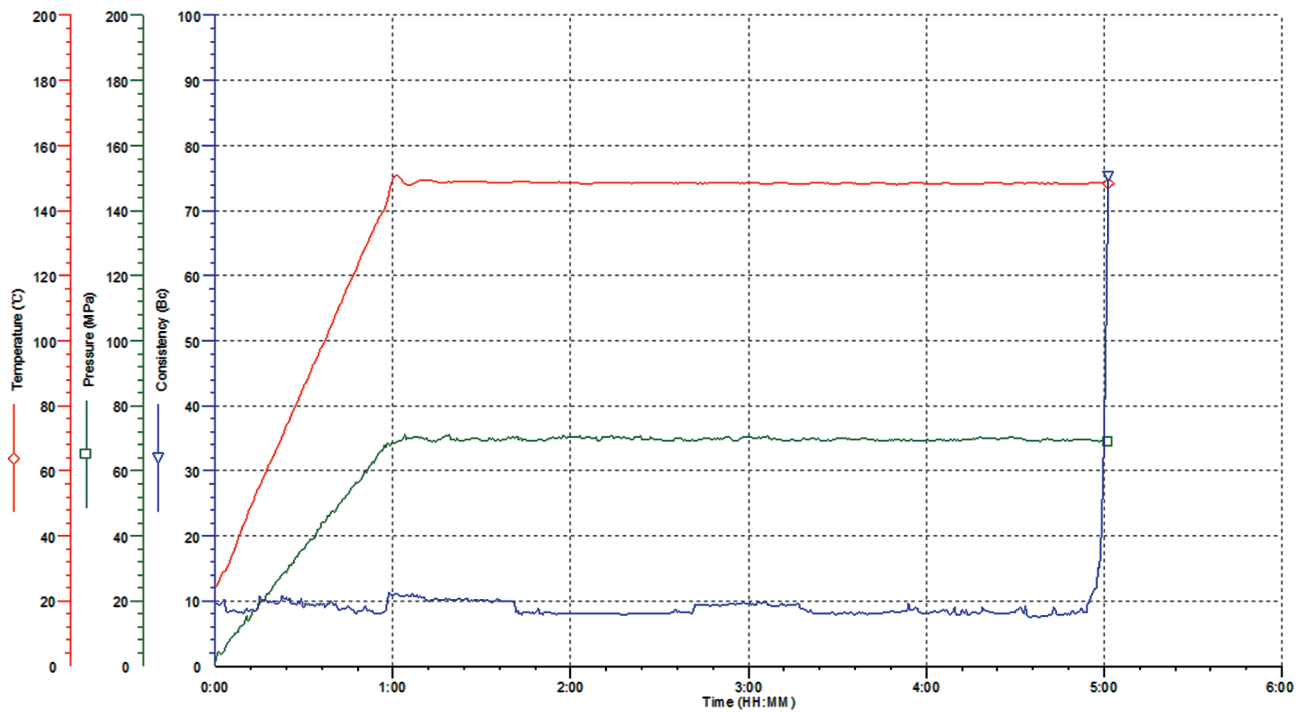


Figure 2
150 °C × 70 MPa Supercharging Thickening Curve

Note. Shengwei glass G 593 g + silicon powder 207 g + water 270 g + SWJ-3 32 g + SWJZ-1 3.2 g + SDJR 40 g + SDW 2 g + SWH-1 4.8 g + salt 48.6 g + antifoaming agent 2 g.

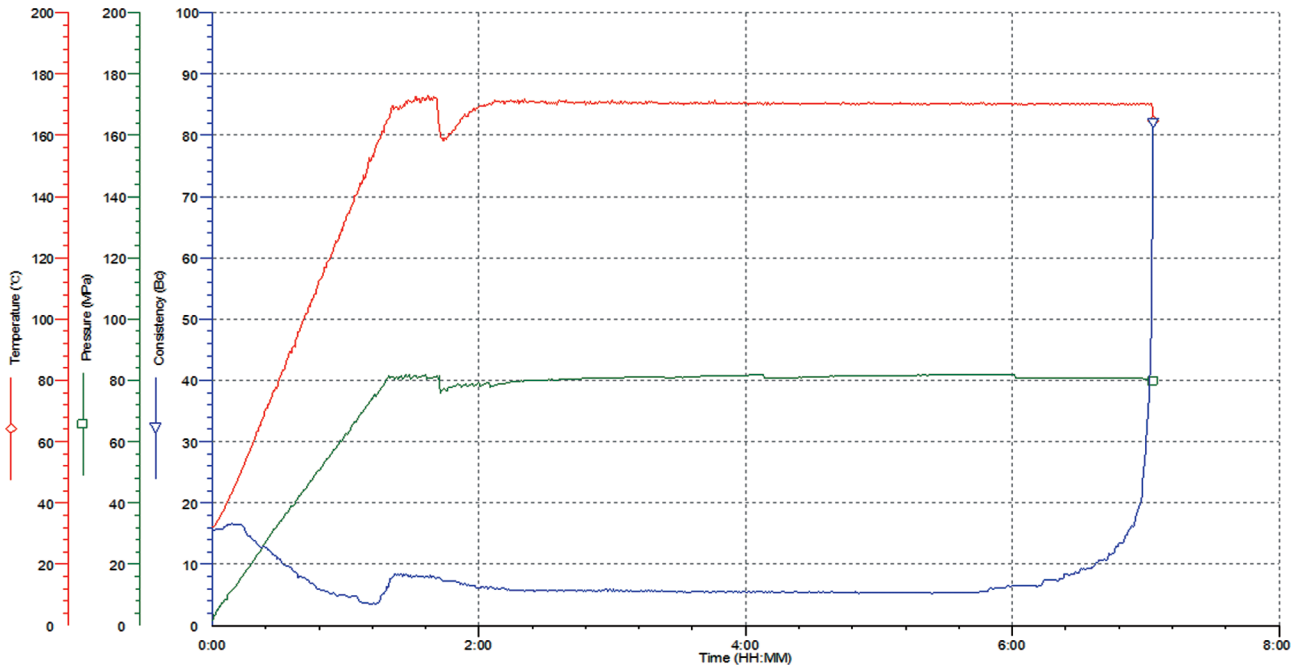


Figure 3
170 °C × 80 MPa Supercharging Thickening Curve

Note. Shengwei glass G 593 g + silicon powder 207 g + water 268 g + SWJ-3 40 g + SWJZ-1 3.2 g + SDJR 40 g + SDW 2 g + SWH-1 8 g + salt 32.6 g + antifoaming agent 2 g.

2.4 Anti-Gas Channeling Performance of Cement Slurry

This laboratory research was conducted by 7150-type gas channeling simulation analyzer of the United States CHANDLER company. Figure 4 shows a graph of gas channeling of the polymer flexible cement slurry system

at 95 °C. When the slurry liquid column pressure is smaller than the formation pressure, that is shown at five-star in the figure, the amount of gas channeling does not increased dramatically. So it can be seen that the slurry system has better anti-gas channeling performance.

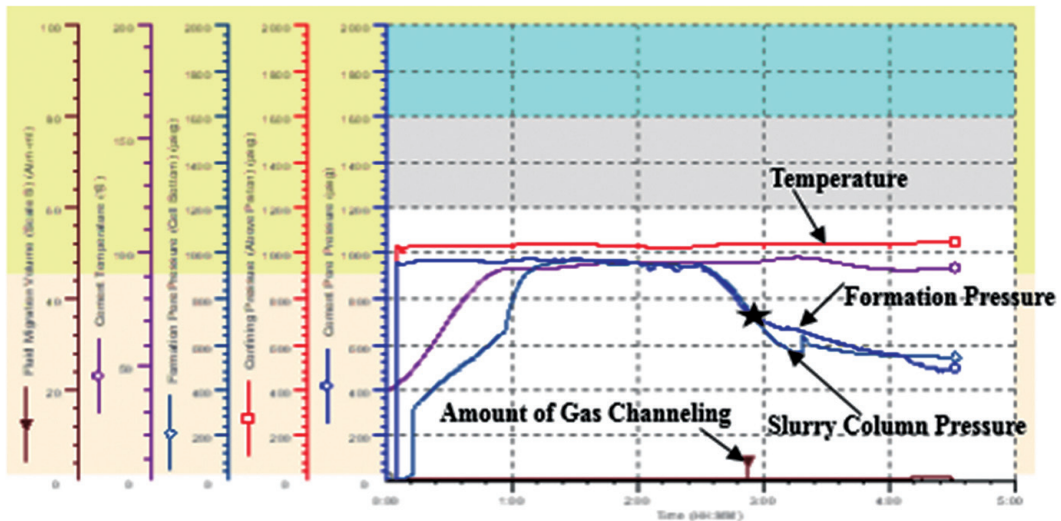


Figure 4
Graph of Gas Channeling of the Polymer Flexible Cement Slurry System at 95 °C

Note. Shengwei glass G 800 g + water 272 g + SWJ-1 1% + SWJZ 0.6% + SWH-1 0.1% + latex 10%.

3. PERFORMANCE OF THE POLYMER FLEXIBLE CEMENT STONE

3.1 Compressive Strength of the Polymer Flexible Cement Stone

Table 3
Compressive Strength of the Cement Stone

Number	SDJR /%	SDXW /%	SDXJ /%	SDJZ /%	Compressive Strength /MPa
1	0	0.0	0.0	0.2	44.8
2	5	0.5	0.0	0.2	8.2
3	5	0.0	1.0	0.2	8.2
4	0	0.5	1.0	0.2	29.3
5	5	0.5	1.0	0.2	12.7

Note. Shengwei glass G 600 g, conservation for 48 h at 75 °C water bath.

As can be seen from Table 3, pure cement (program 1) has high brittleness and its compression strength is 44.8 MPa, so pure cement is easily broken in perforating fracturing operations leading to reducing the cement ring seal and causing the interlayer cross flowing. On the contrary, compressive strength of the polymer flexible cement stone

(program 5) is only 12.7 MPa. This value can meet the requirements of oil field development and perforation. At the same time brittleness of cement has been improved due to the addition of latex, fiber and other materials, the cement stone is not easily broken in the perforation, thereby improving the sealing of cement ring greatly.

3.2 Flexural Strength of the Polymer Flexible Cement Stone

Table 4
Flexural Strength of the Cement Stone

Number	SDJR /%	SDXW /%	SDXJ /%	Flexural Strength /MPa	
				75 °C	95 °C
1	5	0.5	0.0	5.0	6.1
2	5	0.0	1.0	4.1	4.4
3	0	0.5	1.0	6.3	6.0
4	5	0.5	1.0	6.0	7.3

Note. Shengwei glass G 600 g, conservation for 48 h in water bath.

As can be seen from Table 4, program 4 the polymer flexible cement stone has the highest flexural strength and program 2 has the lowest. Compare these two programs can be seen, fiber can greatly improve flexural strength of cement stone. At 75 °C, the flexural strength increases from 4.1 MPa to 6.0 MPa, the rate of increase is 46.3%; at 95 °C, the flexural strength increases from 4.4 MPa to 7.3 MPa, the rate of increase is 65.9%. Thus SDXW has good toughness properties, its principle is that the length of SDXW material is much larger than the diameter of cement particles so that it can be effectively bonded with cement. When the crack width of cement internal micro is less than fiber spacing, fiber will play a role as a bridge across the crack and transfer load. This can make cement internal stress field more continuous and uniform and micro-crack tip stress concentration be passivated, so cracks are bound to further expand, thereby increasing the toughness and flexural strength of cement stone^[9].

3.3 Corrosion Resistance of the Polymer Flexible Cement Stone

3.3.1 Hydrochloric Acid Corrosion Test

After being soaked in HCl solution at 18% for 24h, X-ray diffraction experiments were carried out for cement stone before and after corrosion by XRD.

Comparing Figure 5 and Figure 6 can be seen, components of cement stone corroded by HCl solution remain unchanged. But the extent of corrosion of cement can be seen from the change of calcium hydroxide before and after corrosion. The amount of calcium hydroxide of the polymer flexible cement stone changes from 58% before corrosion to 51% after corrosion, this suggests that the polymer flexible cement is corroded by HCl to a lesser extent.

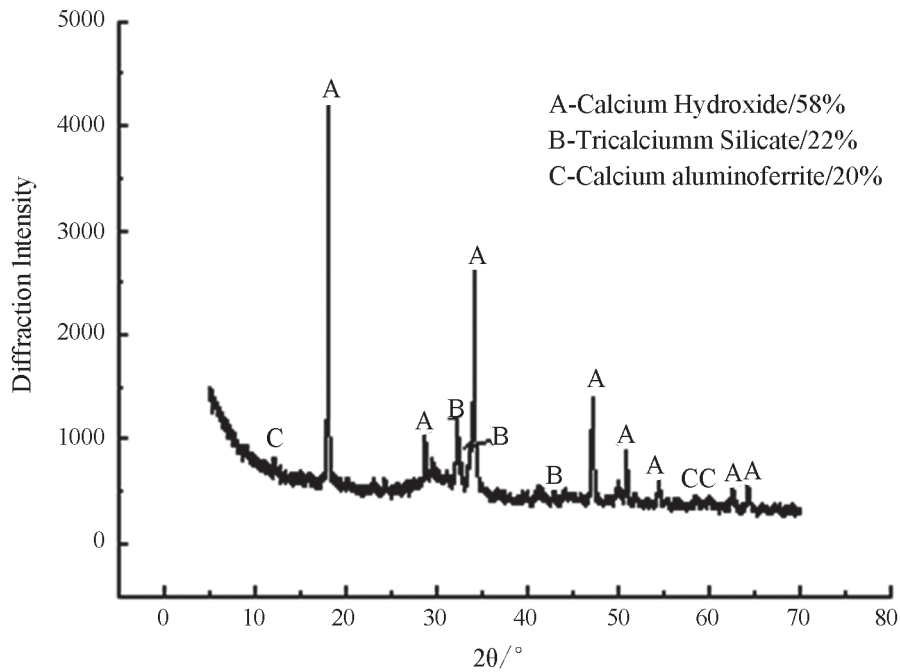


Figure 5
Component Diagram of the Polymer Flexible Cement Stone Before Corrosion

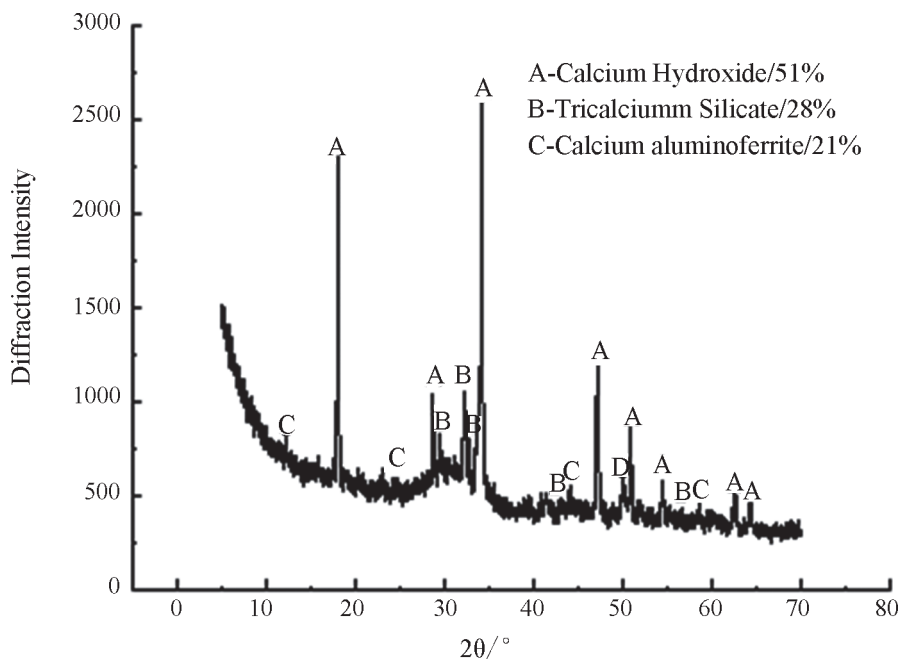


Figure 6
Component Diagram of the Polymer Flexible Cement Stone After Corrosion

3.3.2 Carbon Dioxide Corrosion Test

According to the corrosion mechanism of carbon dioxide for cement, the ability of cement stone to resist corrosion of carbon dioxide can be evaluated by XRD after being soaked in 10% sodium bicarbonate solution for 28 days.

It can be seen from Figure 7, there is the component of calcium carbonate after corrosion and the components of puree cement occurs significant changes. On the contrary, there is no calcium carbonate generated in the polymer

flexible cement stone after corrosion. The calcium carbonate is the main reaction product obtained by ion exchange after sodium bicarbonate corrosion, therefore, the capacity of corrosion-resistant sodium bicarbonate can be evaluated according to the amount of calcium carbonate in cement stone^[10]. So the ability of corrosion-resistant sodium bicarbonate of polymer cement is much stronger than puree cement.

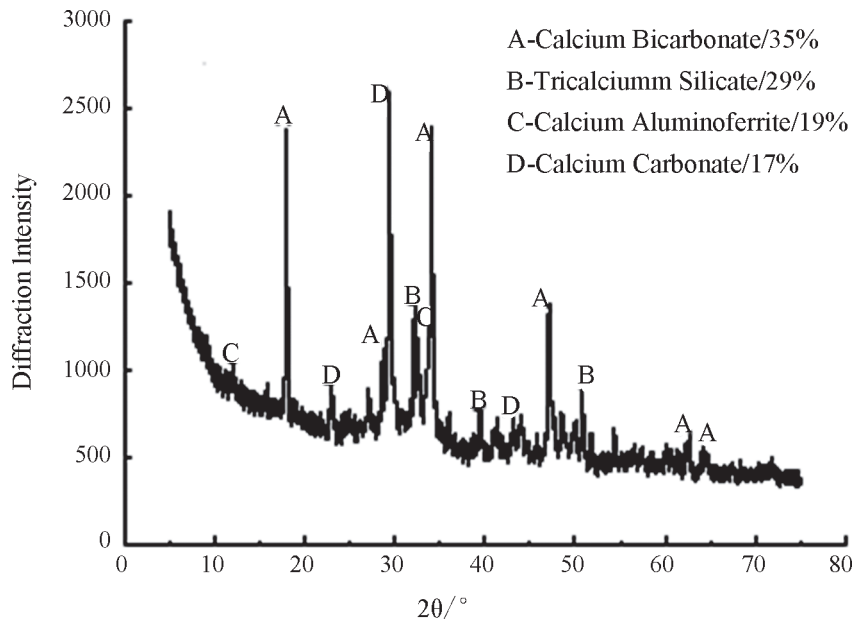


Figure 7
Component Diagram of the Puree Cement Stone After Corrosion

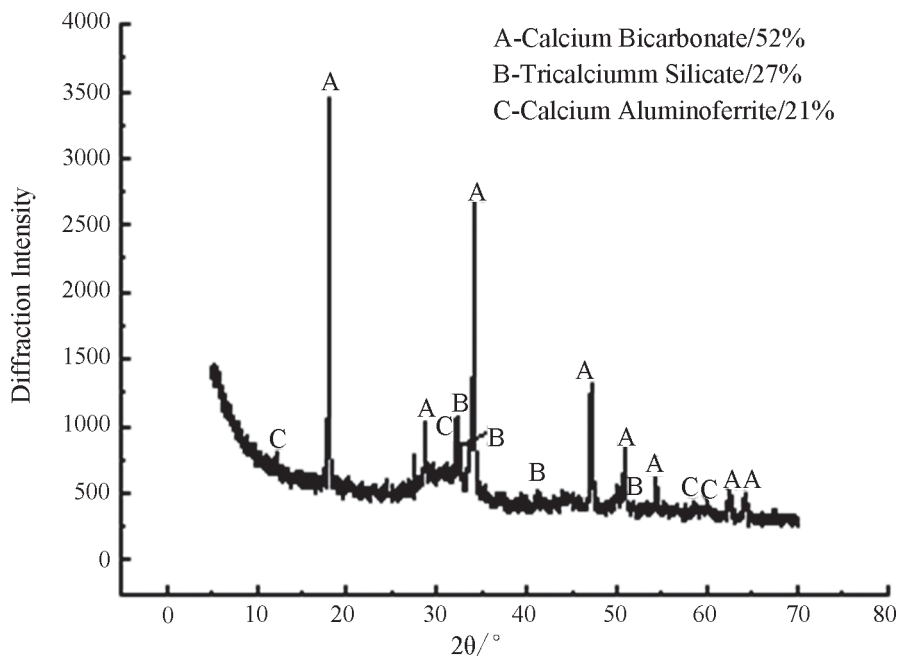


Figure 8
Component Diagram of the Polymer Flexible Cement Stone After Corrosion

3.3.3 Sulfate Ions Corrosion Test

Figure 9 is the X-ray diffraction comparison chart of the polymer flexible cement stone before and after being soaked in 10% sodium sulfate solution for 28 days. It can be seen, the peak value of diffraction pattern changes very little, that is to say, the components of the polymer flexible cement stone change a little before and after corrosion.

This is because the latex and other materials have been added in the polymer flexible cement stone. The addition of these materials can reduce the permeability of cement and the amount of sulfate intrusion into cement stone, thereby reducing the response probability of sulfate and calcium hydroxide and preventing cement stone from sulfate corrosion^[11].

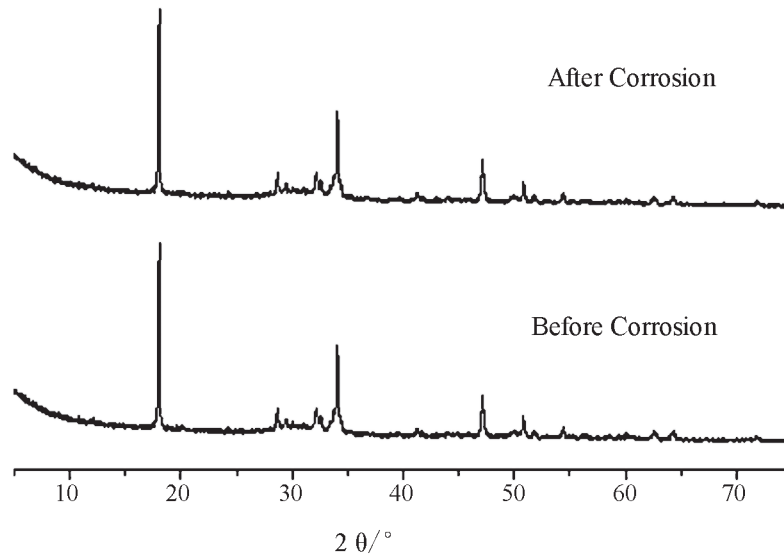


Figure 9
X-ray Diffraction Comparison Chart of the Polymer Flexible Cement Stone

CONCLUSION

(a) The polymer flexible slurry system optimized not only has properties of good rheology, zero free water, small water loss, the thickening curve emerged right angle and thickening time adjustable but also has high temperature resistance and high salt resistance. Laboratory evaluation temperature is up to 170 °C and salt concentrations is up to 12%.

(b) The polymer flexible cement stone has good mechanical properties, high compressive and flexural strength. The addition of polymer flexible materials greatly improves the flexibility of cement stone.

(c) The cement corrosion tests show that the polymer flexible cement stone has strong corrosion resistance so that well life will be extended effectively.

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