Development of A Thermal Expansion Crack Agent

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Abstract: With straw, coal-based carbon black, silica-alumina carbon black (produced with coal gangue), calcium peroxide, potassium perchlorate catalyst, and binder potato starch as raw materials, according to a certain ratio of 33.43:14.33:20:30:1:1.25, prepare a new cracking agent. The product preparation process is simple and adapts to the conditions of existing industrialized production equipment. Through the small displacement cracking test, it can be found that the right side rock cracking effect of the rock platform is significant, and the big stone is cracked by large blocks; the small-displacement well rock fracture test compares the effect of cracking stone before and after, it has good cracking effect and can be fixed point charge, oriented cracking and large displacement cracking stone test results show that the stones after the megalithic cracking can be easily removed and no gravel generated, and no gravel splash phenomenon occurs, which can confirm the development of thermal expansion cracking agent can be used in any large-area cracked rock structure. It is simple to calculate and easy to operate. It does not affect the selection and distribution of existing drilling positions, and can adapt to the existing environment and conditions for the use of thermal expansion cracking agent; cracking stone is fast and efficient. No excessive thermal expansion cracking agent was wasted during the process, which has a high research value.

1. Introduction
With the development of science and technology and social progress, safe and green mining concepts have gradually been taken seriously by industry professionals. Static cracking agents are injected (filled) into non-metallic hard and brittle objects, such as perforations of rocks, concrete, etc. Crack rocks using the expansion pressure caused by hydration [1]. There are two main types of static rip cracking agents [2]. One is limestone, silica and gypsum according to a certain proportion of ingredients, calcined into mineral powder, and added with water reducing agent; the other is prepared by adding a small amount of calcium aluminosilicate or ferroaluminate to quicklime. When it is used, add water and mix the slurry into the borehole of the cracked rock body. Compared with industrial explosives [3], static cracking agent [4] has become a research due to its advantages of being silent, controllable, non-debris, low economic cost, simple to use, construction and transportation safety, protection of resources and environment, etc. The hot points of application and application are gradually being widely used in the construction of stone cutting, rock crushing, trench caisson excavation, and demolition of concrete foundations. Although these static cracking agents have obvious advantages, they also show weaknesses in the long-term use of cracked stone in practical applications. Especially at low temperatures below 5°C, the hydration reaction of the quicklime is poor, and the cracking takes more than 2 days. The cracking efficiency and labor efficiency are low, and its application is restricted; the cracking agent is mostly powdery and granular and is not convenient for filling in boreholes. Need to use special tools to achieve the filling density requirements of cracked
stone, such as pneumatic picks and impact drills [5]; the main components of cracking agent are mostly quicklime. Due to the rapid hydration reaction and rapid heating, a large amount of water vapor is formed, causing shotcreting. It may cause the failure of cracked stone, and a danger of loss of personnel [6]; at the same time, the main raw material of cracking agent is high in energy consumption during the lime production process. Large amount of the reaction product strongly alkaline cracked stone, soil contamination and surface damage to the vegetation, water resource waste and environmental pollution phenomena significantly [7].

Developed a thermal expansion cracking agents in order to make up for the shortcomings of existing cracking agents, such as long breakage time and slow speed [8]. The effect is much better than the cracking agent, especially for the fast and safe cracking of rocks, concrete, bridge piers, buildings and so on.

2. Proportion scheme

The thermal expansion cracking agent is made from straw, coal-based carbon black, silica-alumina carbon black, calcium peroxide, potassium perchlorate and potato starch according to the following formula.

(1) Straw

Crop stalks in different regions have different combustion calorific values due to differences in growth and chemical composition, and integrate the situation of various crop production regions in the country. Corn cobs, corn stalks, wheat stalks, rice straw, and rape straw are selected as straw sources. The burning heat data of straw is the average value of crop heat value data in different producing areas. In order to ensure the stability of the burning raw heat value of straw raw materials, the final formula screening crop straw used for corn straw, corn stem, wheat straw, rice straw, rape straw five crop straw each 20% mixed, its combustion calorific value is 17064.3 kJ/kg.

| Table 1 Burning calorific value of several kinds of straw and its average value |
|-------------------------------|----------------|----------------|-----------------|----------------|
| Straw                        | Cor n cob | Cor n pole | Wheat stem | Straw straw |
| Heat of combustion(kJ/kg)    | 188       | 168        | 17177.5     | 15            | 16670         | 17064.3       |
|                               | 35        | 41         | 798          |               |               |               |

The main components of straw are cellulose, hemicellulose and lignin. The chemical elemental composition is mainly composed of five elements: C, H, O, N, and S. Among them, C, H, and O are the main elements. The content of each element is shown in the Table 2

| Table 2 Elements and Contents of Test Straw |
|--------------------------------------------|
| element | C       | H        | O        | N        | S        |
| range   | 35.21~5 | 4.74~    | 33.29~4  | 0.30~2   | 0.12~0.  |
|         | 1.43    | 9.95     | 5.69     | 0.68     | 68       |

(2) Coal-based carbon black

The chemical composition and content of coal-based carbon black are shown in Table 3.

| Table 3 The types of elements and their contents in different coals |
|---------------------------------------------|
| element | C | H | O | N |
|---------|---|---|---|---|
|         |   |   |   |   |
Coal-based carbon black contains various elements and their contents: C content is 93-95%, hydrogen content is 2.0-3.2%, oxygen content is 2-3%, and nitrogen content is 0.6-1.0%.

3. Silicon aluminum carbon black
Silica-alumina carbon black (produced with gangue) was used as an additive in the formulation. The main inorganic chemical composition of silica-alumina carbon black (produced with coal gangue): SiO$_2$, Al$_2$O$_3$, Fe$_2$O$_3$, CaO, MgO, etc. The main oxides are SiO$_2$, Al$_2$O$_3$. The average calorific value of pure vermiculite in coal gangue is calculated based on 2.51 MJ/kg. The heat amount of coal gangue in most of the mines in China is 5.02-10.45 MJ/kg. The carbon content of silicoaluminous carbon black (produced with coal gangue) used in this experiment is about 20%, combustion heat data is 9444kJ/kg, special treatment before use.

4. Calcium peroxide
The oxidant used in this test was granular calcium peroxide, with a particle size of 5 μm, and a special water-proof and moisture-proof treatment before use.

5. Potassium perchlorate
The catalyst used in this test was granular potassium perchlorate with a particle size of 5 μm.

6. Potato starch
The binder used in this test was a potato starch binder prepared with starch, preservatives, antistatic agents, and smoothing agents in water. The binder combustion heat data is 17572.8 kJ/kg.

According to the above formula, using straw, coal-based carbon black, silica-alumina carbon black (additive), calcium peroxide (oxidant), potassium perchlorate (catalyst) and potato starch (adhesive), according to 33.43:14.33:20:30:1:1.25 ratio, preparation of expanded (broken stone) agent, good dispersion, good antistatic property, can meet the requirements of the filling density of cracked stone, and does not require the use of water as a reaction raw material, it can be used in many fields such as rock fracture, trench caisson excavation and concrete foundation demolition.

3. Crack stone test
Follow the steps below to perform a crack test:

1. Small displacement crush test
In a quarry, a rock platform with an area of about 2m x 3m and a height of about 1.4m is selected (as shown in Fig 1).

![Fig 1 Rock platform used for small displacement rock test](image-url)
When the hole is filled with thermal expansion (broken stone) agent to the half depth, the ignition head is added and the thermal expansion agent is loosened until it is 15 cm away from the orifice, and the hole is filled and sealed with fine sand, and the hole is further sealed with stones (As shown in Fig 3).

Cracked stone test requires igniter ignition. There was no obvious sound 50 meters away, and there was a little muffled sound. The displacement of cracks between rocks was mostly between 1 and 5 cm, and the expected cracking effect was achieved. A comparison of the effects above the rock platform before and after the split rock is shown in Fig 4.

It can be seen from Fig 4 that the rock cracking is obvious and the fracture displacement is equivalent to the borehole diameter. Between 2 and 5 cm, there are black combustion residues at the crack, which are unburned vermiculite powder and some residual carbon residue.
Fig 5 Effect of the left side of the rock platform before and after the split rock
As can be seen from Fig 5, after the cracking, a crack with a displacement of about 0.5 cm appears on the left side of the rock platform.

Fig 6 Effect of cracked rock on the right side of the rock platform after split rock
It can be seen from Fig 6 that the right side of the rock platform has a significant effect on the cracking stone, and the large stone is cracked by large chunks. The distance between the two cracks in the vertical direction is consistent with the distance between the drill holes. The fracture displacement is 2~5 cm, the fracture is complete and no broken rock appears.

(2) Small-scale displacement well test
In a construction site, an artificial well with a diameter of 1.0 m encountered large blocks of rock during the excavation process and was difficult to handle. It was necessary to crack the rock before removing it. The rock was drilled with a spacing of 30 cm, a bore diameter of 38 mm and a depth of 30 cm. A borehole was charged, and the thermal expansion agent was loosely packed. When the distance was 6 cm from the orifice, the orifice was sealed with fine sand, and the cracking test was performed. The effect before and after the cracking was compared as shown in Fig 7.

Fig 7 Comparison of effects before and after rock cracking in a well
It can be seen from Figure 7 that there are cracks in the borehole in the borehole rock, the fracture displacement is about 5 cm, the stone cracking effect is good, and it can be fixed charge and oriented cracking.

(3) Large displacement crack test
In a quarry, a boulder that blocks quarry construction needs to be removed after it has cracked. The boulder platform measures approximately 4.2 x 2.5 m and has a height of approximately 1.4 m. In the platform above the boulders, six boreholes with a diameter of 58 mm and a depth of 1.1 m were drilled. The distance between the boreholes was 50 cm, and the boreholes formed a regular triangle arrangement. The hole is filled with thermal expansion cracking agent. The depth of the fine sand seal
is 20cm. After the fine sand is sealed, the hole is pressed with a mass of about 15kg to ensure the sealing effect. Ignite, crack stone. After the cracking stone began, the boulders were first cracked by a crack with a width of about 20cm. After the rock cracked, the stones were affected by their respective center of gravity, and a small area of rolling occurred. There was no sound coming out at the site 200m. The effect before and after the cracked stone is shown in Fig 8.

![Image](image_url)

Fig 8 before and after the effect of large displacement crack stone

As can be seen from Figure 8, due to the large amount of thermal expansive charges, a crack with a displacement of about 20 cm is first formed after the megalith has cracked, and since the boulders have no blocking space around the boulders, the boulders have a certain inclination angle on the ground and the post-cracking stones Affected by the center of gravity, rolling around a small area within 5m. After the cracks in the boulders have been drilled, the resulting stones are larger, free of gravel, and no gravel splashing occurs. The large-displacement cracking stone has the desired effect, and the stones after the megalithic cracking can be easily removed.

4. Conclusion

The researched thermal expansion cracking agent preparation process is simple and adapts to the conditions of existing industrialized production equipment; it can realize the conversion of thermal expansion cracking agent from laboratory research to industrial scale production, and the production process is safe and reliable. The product is granular and easy to drill and fill, and the filling density of cracked stone can be achieved without using special tools such as pneumatic pick and impact drill, and the thermal expansion cracking agent can be verified on the rock through the small displacement cracking test, the small displacement well test and the large displacement cracking test. The utility model can be used in many fields such as crushing, trench caisson excavation, and demolition of concrete foundations, and does not require the use of water as a reaction raw material, avoids waste of water resources and surface pollution, uses clean processes, is easy to use, safe and convenient, and has good quality and flowability. Good, good antistatic property, safe and stable storage; no "three wastes" emissions in the production process, no harm to the human body and the environment, clean and environmental protection without pollution; the use of water-free environmental protection, a wide range of raw materials needed, and low economic costs.

References

[1] Zhonghua Zhou. Low-temperature ultra-fast static cracking agent[J]Stone,2009(7):32-33
[2] Jiyu Chen. Development of an Efficient Static Cracking Agent[J]. Stone,2003(4):52-53
[3] Xuguang Wang. Technical Progress of Foreign Mine Explosives[J]Mining Engineering,1981(1):17-25
[4] Zhonghua Zhou. New Developments in Rapid Static Cracking Agents[J]. Stone,2005(5):41-41
[5] Zhonghua Zhou. Drilling efficiency and material-saving static cracking technology[J]. Stone,2005(11):38-38
[6] Youde Wei. Safe cracking stone and its application[J]Explosive materials,1984(1):19-21
[7] Jinjun Jiang. Research on Mechanism of Mining Marble by Static.[J]Blasting Technology.1984.6.
[8] Zhaowu Han, Kaijin Han, Zuoxing Di. Precise and controllable charge method for thermal expansion cracking agent. CN105004229A [P]. 2015.