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Electro-Osmosis – An Experimental Study on Cochin Marine Clay Using Electrokinetic Stabilization

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Abstract

Electrokinetic stabilization (EKS) is an emerging technique which uses direct current (DC) or a low electric potential difference to an array of electrodes placed in the soil. Electrokinetic treatment is an effective soil improvement technique to increase shear strength. The objectives of this work include studying the influence of different arrangement of electrodes on the shear strength of soil. The various parameters that have varied throughout the test are voltage (20V, 30V), spacing (10cm, 15cm) and different arrangement of electrodes such as 3anode-1cathode (3C-1A), 2anode-2cathode (2A-2C), 1anode-1cathode (1A-1C), 3cathode-1anode (3C-1A). The shear strength of soil samples were studied by conducting unconfined compression tests (UCC) on samples taken out before and after electrokinetic treatment. The water content of the samples was also checked before and after the test. The variation of current and resistance were also studied.The test results indicate that the shear strength of soil samples improved considerably after electrokinetic treatment.

Keywords: Marine clay, Electrokinetic stabilization, Unconfined compression test.

Introduction

The soil found in the ocean bed and coastal areas is classified as marine soil. Marine or soft clays existing in these regions are characterized by high compressibility, low bearing capacity, and low shear strength. Several methods have been employed worldwide to improve the engineering characteristics of soils so as to increase shear strength and to reduce the compressibility. Such methods can be categorized into different classes of stabilization, namely mechanical, thermal and electrical. Electrokinetic is a soil improvement methods by supplying electric current to electrodes which are embedded in soil. Electro-osmosis technology is a proven stabilization technique on fine grained soils. When an electric field is applied to a mass of soil, the pore fluid moves from the region of anode to cathode along with the positive ions that move towards the negative electrode; the net effect being reduced water content and improved strength near the region of anode. It was established that copper and its alloys form the best electrode material for electro-osmosis and that a uniform increase of resistance in soil during the process increases the efficiency of the process. The applied electric current leads to electrolysis reactions in the electrodes. Oxidation of water at the anode generates an acid front while reduction at the cathode produces a base front by the following electrolysis reactions.

Anode : $2H_2O - 4e^- \rightarrow O_2 + 4H^+$
Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

The electrolysis reactions are then followed by H+ migration to the cathode and OH− migration to the anode, which is called electro migration, and the pore water migration from the anode to the cathode (electro osmotic). The pore water migration would strengthen the soil bearing capacity in the vicinity of the anode.

Materials and methods

Soil

Soil samples were collected from Panampilly Nagar, Cochin. The samples was air dired at room temperature and therafter soil lumps were powdered and sieved through 425micron sieve before the same is used for laboratory tests. The soil has 40% clay and 32% silt. The liquid limit and plastic limit are 80% and 27% respectively and the soil is classified as CH type.

Electrokinetic Cell

An electrokinetic cell (EK cell) was designed and fabricated which has components like square box, electrodes, voltmeter, ammeter, power supply. The square box is hollw, transparaent and one side opened, made of glass which can withstand temperature. Holes are provided at centre and at corner of box inorder to place the cathode pipes so

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that the cumulative volume of water can be collected in a measuring jar placed below that. The cathode is made of copper pipe(5mm dia) with perforations (2mm dia hole at 2cm spacing) to facilitate removal of water and the anode is made up of copper rod of 5mm in diameter. The voltemeter is provided to measure the voltage applied which is varied as 20 and 30V. An ammeter of 3A is used for measuring the current passing through the soil.

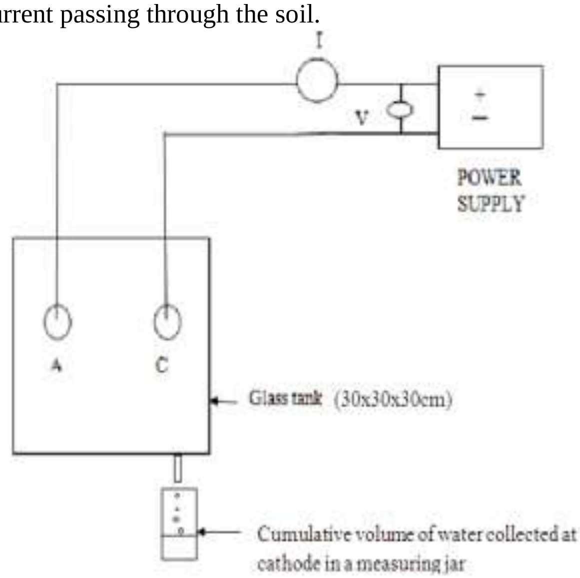

Fig.1 Schematic Diagram Of Fabricated Electrokientic Cell

Experimental Programme

The required amount of the soil was calculated from the volume of the tank and maximum dry density obtained from compaction test. The marine clay was mixed with 33% water content (OMC) in order to achieve a dry density of 13.2kN/m^3. The square glass tank was initially filled with remoulded marine clay sample. Prior to the start of the test, UCC test was cconducted on the soil sample (control sample) and it was found to be 8.2kN/m². The water content was also checked. The electrodes were fitted at suitable locations according to the layout of arrangements as shown in below figures. On applying the required voltage across the electrodes for a specified time(3hrs), the water was simultaneously collected at the cathode. At every 15mt intervals, the variation of current, resistance and cumulative volume of water collected at cathode are noted down. At the end of the test, the soil sample was tested for its final water content and unconfined compressive strength at different locations say at x/L ratio=0,0.5,1 (anode, middle, cathode).

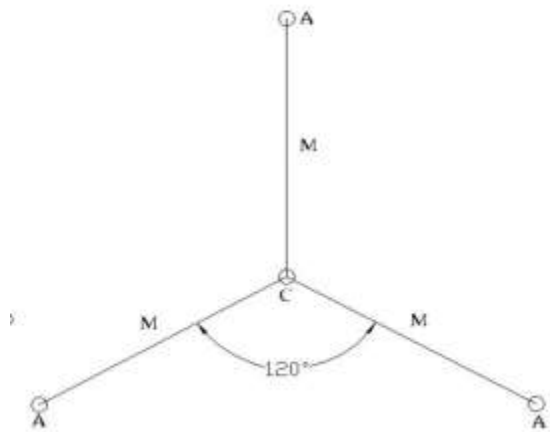

Fig.2 3anode-1cathode

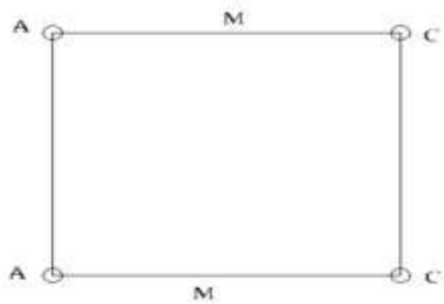

Fig.3 2anode-2cathode

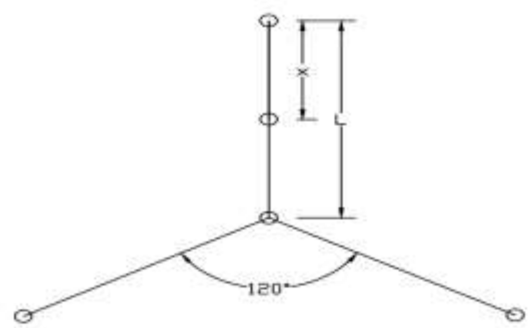

Fig.4 Configuration of electrodes in soil sample

Results and discussion

Comparison of Cumulative Volume of Water Collected at Cathode for Various Arrangements with Varying Spacing and Voltage

As the voltage increases, the cumulative volume of water collected at the cathode also increases. The below graphs show that cumulative volume of water collected also increases with increase in spacing.

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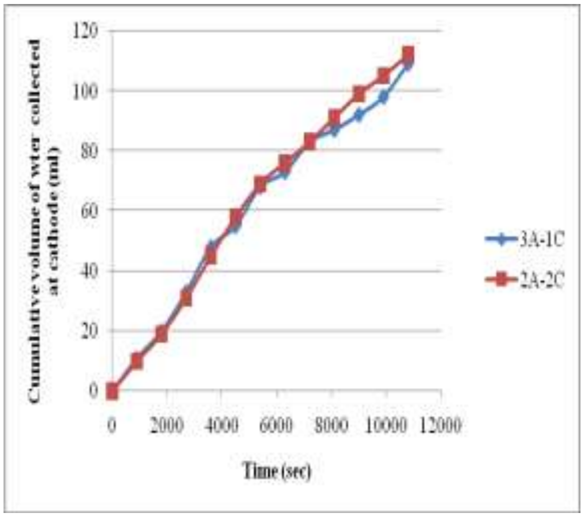

Fig.5 Cumulative volume of water collected at cathode (20V,15cm)

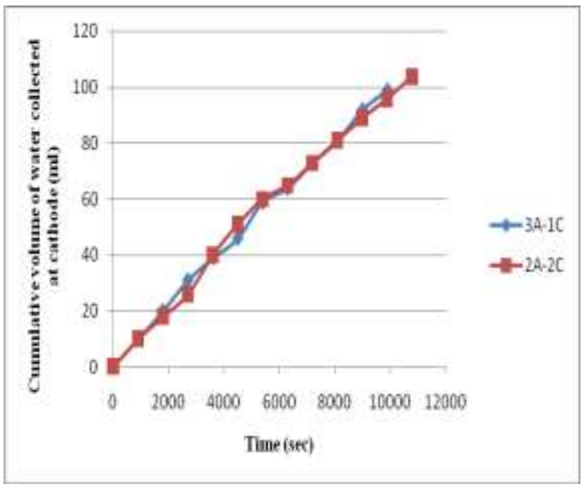

Fig.6 Cumulative volume of water collected at cathode (20V,10cm)

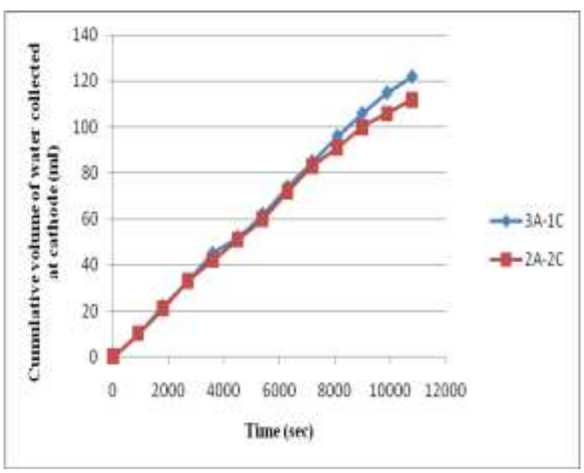

Fig.7 Cumulative volume of water collected at cathode (30V,15cm)

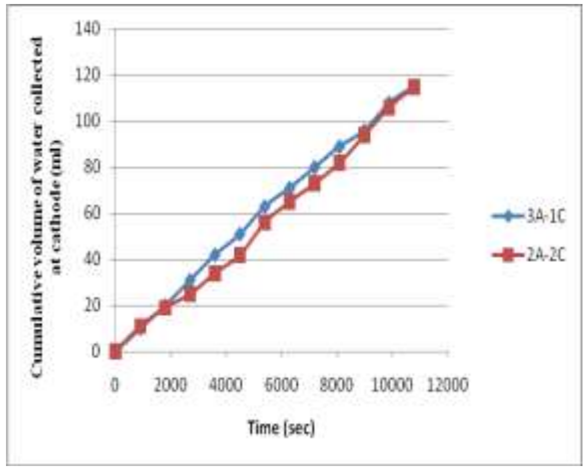

Fig.8 Cumulative volume of water collected at cathode (30V,10cm)

Variation of Current with Time

The current goes on decreases with time. In some cases, first there is an increase in current and after that it suddenly decreases, it may due to the discontinuity of current flow.

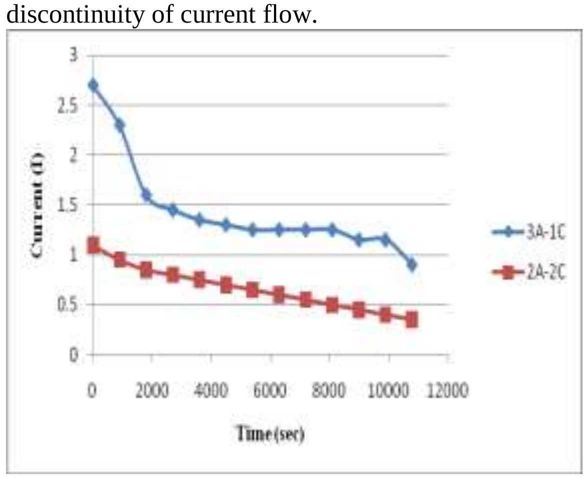

Fig.9 Effect of current with time (20V,10cm)

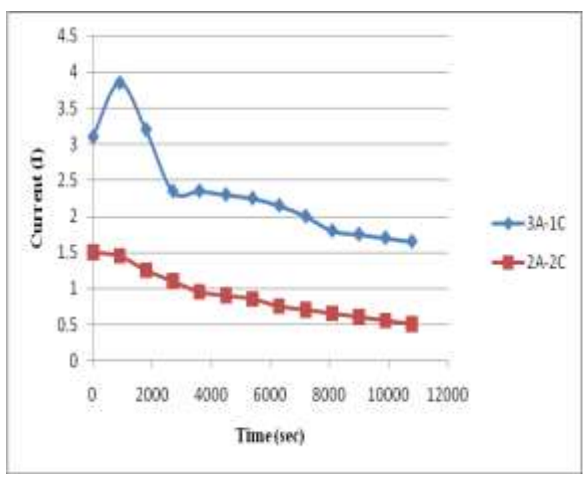

Fig.10 Effect of current with time (20V,15cm)

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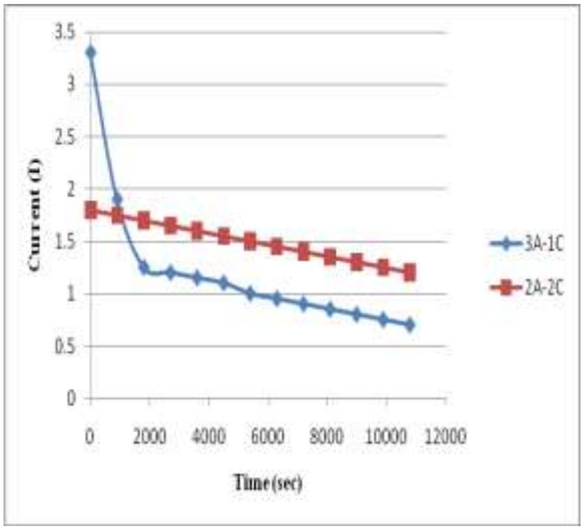

Fig.11 Effect of current with time (30V,10cm)

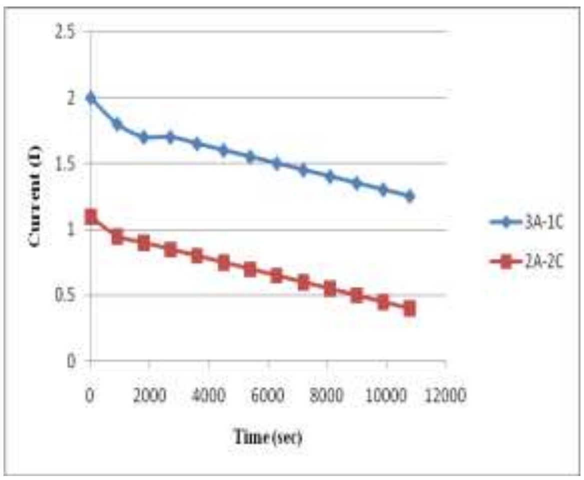

Fig.12 Effect of current with time (30V,15cm)

Variation of Resistance with Time

The resistance goes on increases with time.

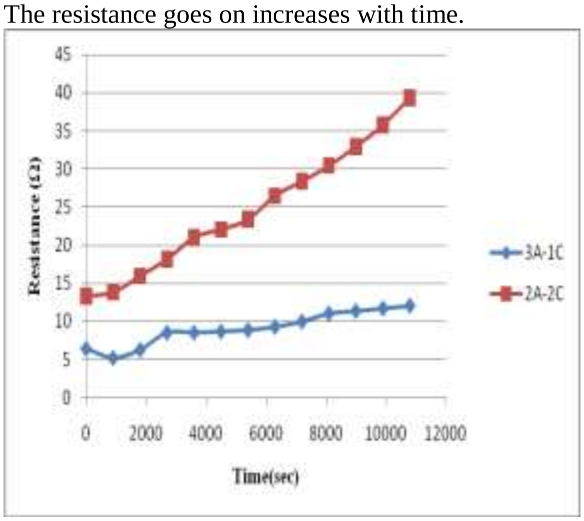

Fig.13 Effect of resistance with time (20V,15cm)

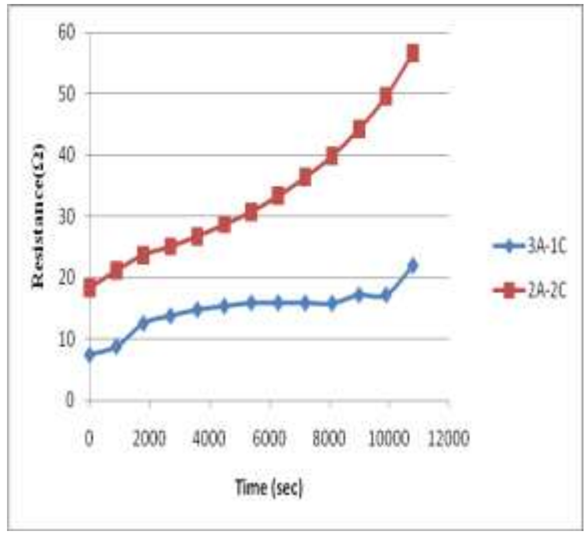

Fig.14 Effect of resistance with time (20V,10cm)

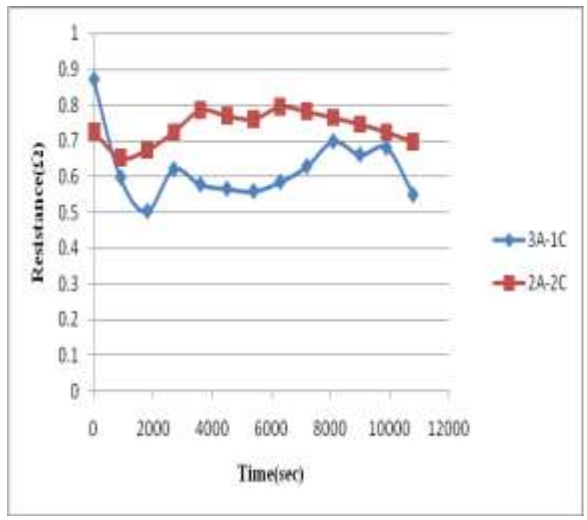

Fig.15 Effect of resistance with time (30V,15cm)

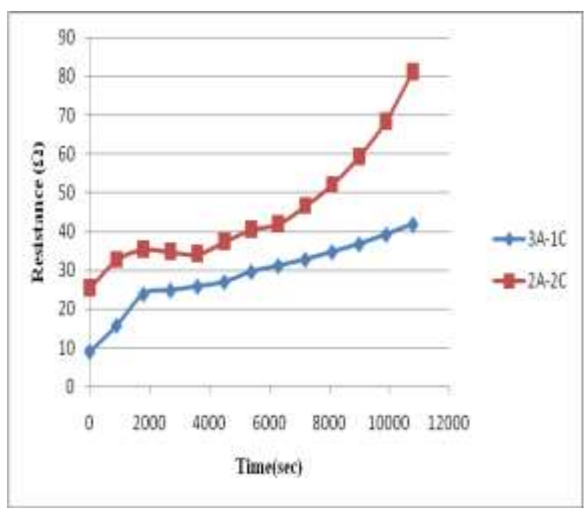

Fig.16 Effect of resistance with time (30V,10cm)

Influence of x/L Ratio on UCC Strength

The UCC strength increases with increase in x/L ratio. It also increases with decrease in spacings. The maximum UCC strength was found out in 3A-1C arrangement (28.64kN/m²). In case of 2A-2C arrangement, the UCC strength increases from 8.2kN/m² to 22.57kN/m².

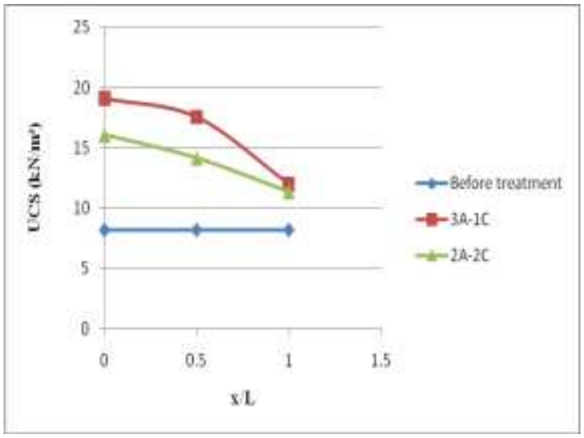

Fig.17 Effect of x/L ratio on UCC (20V,15cm)

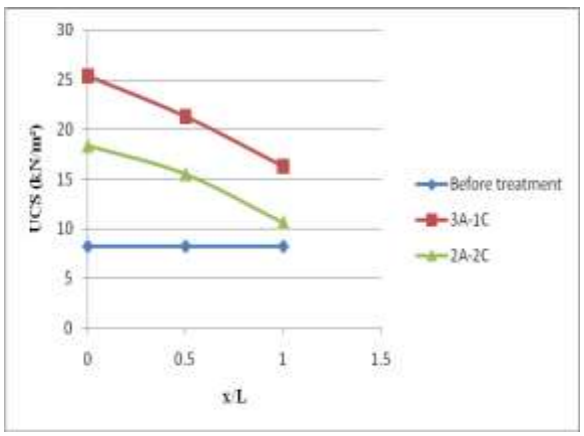

Fig.18 Effect of x/L ratio on UCC (20V,10cm)

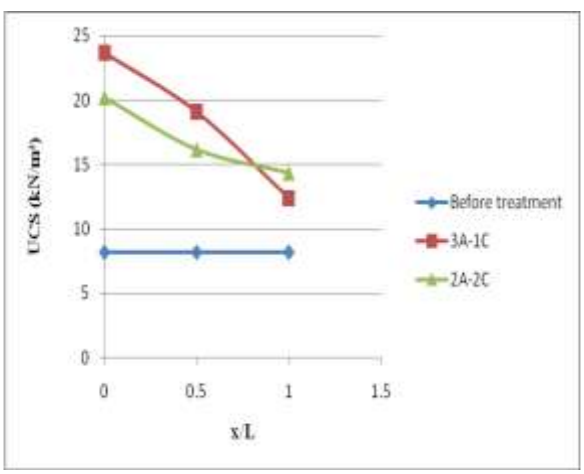

Fig.19 Effect of x/L ratio on UCC (30V,15cm)

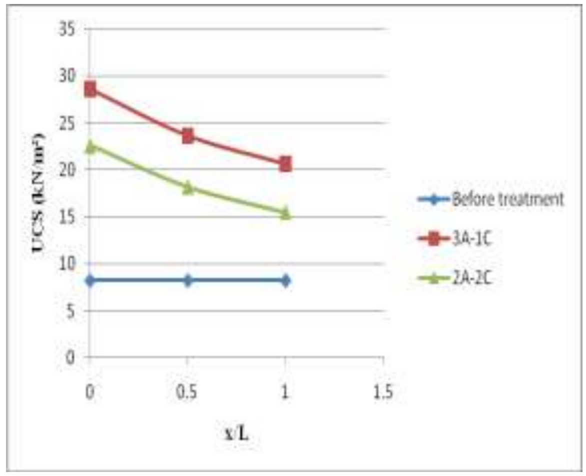

Fig.20 Effect of x/L ratio on UCC (30V,10cm)

Conclusions

In this experimental study, electrokinetic tests were conducted on the marine clay to investigate the effect of EK..The electric current density decreased steadily with time during EK treatment.

1. As the spacing increases not only the duration of dewatering process increases, the flow of current keeps decreasing drastically.
2. The UCC strength decreases significantly with increasing spacing of electrodes. This reduction is mainly attributed to discontinuity of current flow.
3. Electro kinetic process decreased the water content of soil surrounding the anode.
4. Tetrahedral spacing with cathode at centre shows the better strength characteristics by about 249%.

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