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# Acrylic Copolymer Stabilizer for Cost Optimization of Earthy Road Construction

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**ABSTRACT:** This study proposes an assessment of the utilization of acrylic copolymer as stabilizer in earthy road construction. The objective is to provide low-cost alternatives that reduce road maintenance annual cost and reduce the period between major rehabilitation. Conducting a suite of laboratory tests to evaluate the properties of soil and gravel mixture before and after the use of acrylic copolymer stabilizer and evaluating the cost feasibility by analyzing the test results. The soil engaged in this study was a local soil collected from borrow pit in Hadida oil field in west of Sudan, while the gravel soil was obtained from Altomat in west of Sudan too. The local soil was mixed with 30%, 50% and 70% gravel. Optimum moisture content and maximum dry density of the soil-gravel mixture were measured for each sample of proposed mixing percentage. CBR for each sample was measured before and after treatment by acrylic copolymer. The acrylic copolymer used in this study was obtained from Saudi Arabia provided by Sabco Co. and it is used for commercial purposes. The stabilizers amount used was 7% and it is in liquid formula. Remarkable improvement on compaction characteristics was obtained when 7% of liquid acrylic copolymer mixed with the soil-gravel. Addition of acrylic copolymer stabilizer to 50% soil and 50% gravel has increased MDD by almost 40%. The improvement on CBR when acrylic copolymer used is 180%. The results obtained from this experimental study evident the great effect of polymers on soil strength.

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## I. INTRODUCTION

A gravel road is a type of unpaved road with a harder surface made by addition of gravel that has been brought to the site from quarry or stream bed. They are common in less-developed nations and in the rural areas of the developed nations. Gravel road may be referred to as dirt road in common, but that term is used more for unimproved roads with no surface materials added. If well-constructed and maintained, a gravel road is an all-weather road. Soil roads constitute about 22% of the total road network in Malaysia,[1]. Many of earthy roads were constructed in rural areas in Sudan and they well served for many years in condition of well maintenance. Oil and gas operating companies also used gravel roads for their operations, and they constructed gravel road nets in their fields such as Baleela oil field in west of Sudan (Fig. 1).

Oil field operations need to remain efficient and cost-effective. Transportation of heavy drilling equipment and other facilities require stable and durable roads and extensive soil stabilization efforts. Road networks are important not just for oil extraction companies but also in the wider for local community surrounding oil field's areas as functioning road networks serving as vital arteries of transit. Road dust that is airborne primarily through the friction of vehicles and heavy equipment tires on unpaved roads require management and control. Managing road dust in oil fields is vital for vehicle safe traffic. Accidents due to obscuring vision on skipping are common on unpaved roads. Road dust ranges from fine through to coarse particulate and becomes airborne and has environmental impact for surrounding lo-

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cal community.

Oil field activities depend on functioning, safe and durable road networks. Weak gravel properties and harsh weather dramatically decrease efficiency of roads and cause frequently road damage and failure. In extreme cases when heavy rain hit, the road networks are closed for many days. This makes the operation reaching to well sites and other field facilities more difficult, unsafe, and costly. Road network damage or closure cause delays for movement of heavy drilling Rigs and consequently lost income for businesses. During rainy season movement of equipment, logistics support and vehicles flow may delay for days. Such a situation adversely impacts production activities and costs burden to companies. Therefore, it is necessary to employ techniques that improve the properties of the road's soil and consequently provide reliable performance and cost-effective maintenance of roads networks; In addition to control dust to improve environment and traffic safety.

Widely common techniques of improving poor soil properties are soil stabilization or soil treatment. Treatment of unsuitable soil is generally accomplished by modification, removal and replacement or stabilization. Modification refers to short-term soil treatment that is intended to provide a stable working platform during construction. Removal and replacement involve removal of the unsuitable soil and replacement with suitable material. Stabilization refers to a soil treatment intended to provide structural stability for improved long-term performance, and this is the main topic of this study.

## II. LITERATURE REVIEW

Soil stabilization is the process of creating or improving certain desired properties in a weak soil to render it stable and useful for a specific purpose[2]. The improvements in engineering properties caused by stabilization can include the following increases in soil strength (shearing resistance), stiffness (resistance to deformation) and durability (wear resistance), and other desirable characteristics. There are many techniques for soil stabilization classified into two groups, mechanical or chemical stabilization. Mechanical or granular stabilization is accomplished by mixing or blending soils to obtain a material meeting the required specifications. Chemical stabilization involves mixing or injecting the soil with chemically active compounds such as Portland cement, lime, fly ash, calcium or sodium chloride or with bitumen materials. For successful soil stabilizer applications, it is imperative to understand the mechanism of stabilization of additive[3,4]. As technology evolved, there have now emerged new types of chemical soil stabilizing techniques. Nowadays polymers are added to soils to further stabilize them. Their soil stabilization mechanism is little studied[5,6]. Soil stabilization using polymers has attracted considerable attention in the research arena with the aim of providing a more complete understanding of the expected properties of the polymer treated soils and the fundamental mechanisms governing the changes in engineering properties and performance[7]. The first-time polymers were used to stabilize soils was during World War II, when a water-soluble polymer was introduced to stabilize soils for road and runway construction for military vehicles[8].

Polymers are large molecules composed of repeating units called monomers. Polymer is usually formed through polymerization of monomers and exhibits physical and chemical properties that are different from the monomers. Both natural and synthetic polymers have reportedly been used to stabilize soils[7]. Several natural and synthetic polymers are marketed for soil stabilization, but the composition of these polymers is typically not accessible for commercial reasons. Nevertheless, it is known that polymers containing hydrocarbon chains act as a binder of soil matrix particles, reducing dust, and stabilizing the system as well[9]. Polymer treatments modify the size, shape, and cohesion of soil aggregates by changing the interactions between soil particles. The interaction between soil and polymer is highly dependent on the properties of the polymer (i.e. type and amount of surface charge, polymer configuration, chain length, molecular weight and size) as well as properties of the soil (i.e. type and percentage of clay content, ionic strength of the soil solution, type of ion in solution and PH value)[10]. However, effective interaction of soil particles takes place when polymers are adsorbed onto the soil particles, and the adsorption process is significantly affected by the type of polymer charge[11].

Acrylic Co-polymers are a type of synthetic polymer that is made up of two or more different monomers. The content of acrylic co-polymers can vary depending on the specific monomers used in their production. However, some common monomers used in acrylic co-polymer production include Methyl methacrylate (MMA), Butyl acrylate (BA), Styrene and Ethyl acrylate (EA). Acrylic co-polymer is used for soil stabilization. It is a water-soluble polymer that can be mixed with soil to improve its strength and stability. When added to the soil, acrylic copolymer forms a network of interlocking fibers that bind the soil particles together, forming hard crust and creating a stronger and more stable soil structure. Acrylic copolymer is particularly effective in stabilizing soils that are prone to erosion. It can also be used to stabilize soil in areas with high

FIG. 1: Gravel road in Hadida oil field.

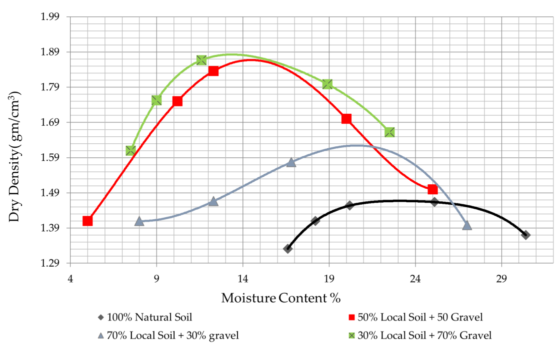


FIG. 2: Compaction result of local soil mixed with gravel.

traffic or heavy loads, such as roads and industrial sites. The benefits of using acrylic copolymer for soil stabilization include Improved strength and stability of the soil, reduced erosion and dust, increased load-bearing capacity, Improved resistance to water penetration, reduced maintenance costs. Soil stabilization using polymers can improve durability characteristics by making the soil resistant to the detrimental effects of water, such as volume changes.

In successful applications, polymers have proven to be more environmentally friendly compared to cement and lime in terms of emission of greenhouse gases and the consumption of natural resources and energy. Carbon dioxide emissions due to the production of Portland cement are the second largest contributor (i.e., single industrial emitter) to global greenhouse gas release from human activities, second only to the combustion of fossil fuels[12].

This paper provides a review of the existing research regarding polymers used in stabilization. The properties of polymers and their applications in areas other than soil stabilization are beyond the scope of this work. A laboratory investigation is carried out to evaluate the effectiveness of acrylic copolymer stabilizer (5-S Road) applied to the soil samples taken from Hadida and Altomaat. The standard engineering properties investigated include compaction tests and california bearing ratio (CBR). The aim of the study reported herein is to assess the levels of improvement of Hadida and Altomaat soil properties resulting from utilizing acrylic copolymer agent (5-S Road) as stabilization agent and the cost-benefit of the roads maintenance and rehabilitation annual expenditure in Block 6 oil field. Huge costs are obtained from gravel hauling from far distances such as Altomat. Location of Altomat is about 200 Km far from Hadida oil field. So, this study aims to use gravel mixed with local soil to reduce the amount of gravel transported. To use the local soil an improvement in soil strength is required which acrylic copolymer does.

## III. MATERIALS AND METHODOLOGY

Experimental work was undertaken to study the effect of acrylic copolymer as stabilization agent for soil mixed with different content of gravel. CBR tests were conducted on the natural soil mixed with gravel and the soil-gravel mixture mixed with different percentages of gravel (30%, 50% and 70%). The soil-gravel mixture

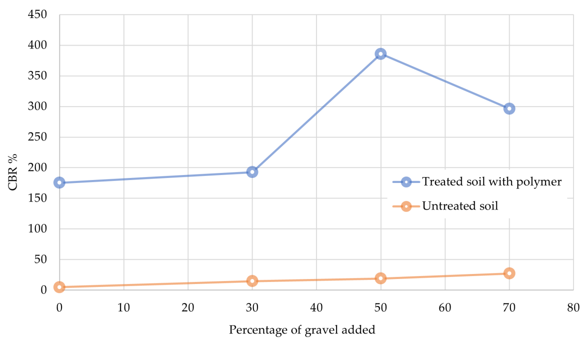


FIG. 3: CBR of treated soil versus percentage of gravel added.

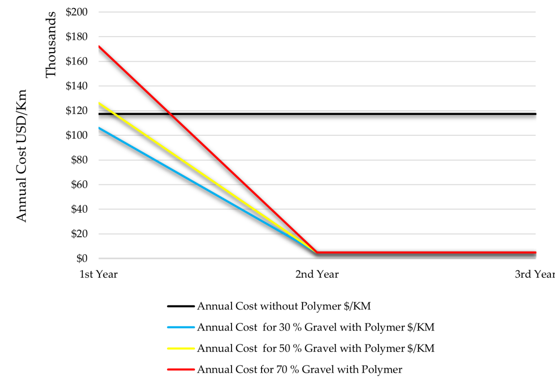


FIG. 4: Effect of acrylic copolymer and gravel on road upgrading and maintenance annual cost.

was treated by 5-S stabilizer (acrylic copolymer).

### A. Materials Used

The materials used for the laboratory testing include local soil, gravel and acrylic copolymer. These materials were collected from different region in west of Sudan, but the acrylic copolymer was brought from Saudi Arabia.

### B. Soil

The soil used for this study was collected from Hadida oil field in East Darfur. The soil was collected from a local borrow pit of depth between 1 and 3 meters below the ground. The soil that is used for construction of embankment of earthy road there. The soil appearance is white, soft and tends to be compressible if wet and tightened to grip in hand. The appearance of this soil indicates it is weak if used as road embankment.

### C. Gravel

The gravel used for this study was natural gravel obtained from Altomaat borrow bit. It is about 300 Km far from Hadida. The Gravel materials collected have brownish red look, hard and contain different particle sizes of fines and coarse.

### D. Acrylic copolymer

The soil stabilizer used in this study was acrylic copolymer brought from Saba Co in Saudi Arabia. It is an acrylic-copolymer based emulsion that has the commercial name as 5-S Road stabilizer. 5-S is designed to increase surface hardness and bearing capacity as a wear course in unpaved road applications. It provides outstanding performance and cost-effective maintenance of unpaved roads and surfaces in a range of applications from road construction to soil erosion and particulate emission control[13]. According to[13] 5S is non-combustible, non-reactive and stable under recommended storage conditions. 5S-Road stabilizers may contain low levels of VOC's or ammonia which evaporate during application and drying and therefore should always be handled in a well-ventilated space[13]. The chemical and physical properties of the 5-S Road stabilizer are shown in Tables I.

### E. Methodology

The local soil sample was initially air dried, manually crushed into small sizes and pulverized. Then prepared by sieving through sieve No.4 (4.75 mm). The fine soil passing sieve No.4 were used. The local soil samples and the gravel soil were oven dried at $105 - 110°C$ for 24 hours. The local soil was homogeneously mixed with different contents of gravel by weight. The content of gravel added to the local soil was 30%, 50% and 70% by weight. The prepared soil-gravel samples were divided into a couple of eight quantities. The first four quantities were untreated while the other four were homogeneously mixed with 7% of liquid acrylic copolymer. Modified compaction tests were performed to the local soil mixed with different content of gravel (0%, 30%, 50% and 70%) by weight. Figure 2 shows the compaction test result.

Un-soaked CBR tests were performed to the soil-gravel mixture before and after treatment by acrylic copolymer. For the measurement of CBR before treatment, four identical compacted soil samples at optimum moisture content (OMC) and maximum dry density (MDD) were prepared. The four samples were prepared as local soils homogeneously mixed with 0, 30,

TABLE I: Basic chemical and physical properties of 5-S Road stabilizer[13] (Saba Co.)

| Property | Value |
|---|---|
| Physical Form | Liquid |
| Color | White |
| Odor | Faint ester |
| Flash Point | Not applicable |
| Vapor Pressure | 23hPa@20°C |
| Relative Density | 0.9 - 1.1 |
| Solubility in Water | Insoluble but miscible in all proportions |
| pH | 5.5-6.5 |
| Viscosity | 100 - 1,000 mPa s |
| Total Solids | 61-63 % (ISO 3251) |
| Specific Gravity | 1.05 |
| Minimum Film Form Temperature | 0°C (32°F) |
| Particle Size | 0.4$\mu$ m |
| Glass Transition Temperature | 5°C (41°F) Onset 13°C (55°F) Midpoint |

50 and 70% of gravel. Another four samples were prepared as described above then mixed with 7% of acrylic copolymer for each sample before placed on the CBR penetration machine. The CBR testing machine was used to measure un-soaked CBR of each mixture. All introduced tests were conducted according to the standard procedures of BS (1990). These tests results were analyzed and further discussed.

## IV. RESULTS AND DESCUSSION

### A. Effect of Gravel and Stabilizer on Soil Properties

Table II shows the CBR values of local soil mixed with gravel untreated and treated with 7% liquid acrylic copolymer. Figure 2 illustrates the plotted compaction characteristics of the local soil and the local soil mixed with gravel as (30%, 50% and 70%). From the plot of the figure, it can be said that the addition of the gravel has enhanced the compaction characteristics. The maximum dry density of the local soil increased by almost 40% of its value when 50% or 70% of gravel was used. A remarkable reduction on optimum moisture content can be observed when gravel added to the local soil. The OMC was reduced by almost 50% when 50% or 70% of gravel mixed with the local soil. So that evidenced the improvements of local soil if mixed with gravel. However, the improvements in compaction characteristics a slight difference on MDD and OMC were recognized when 50% and 70% of gravel.

Figure 3 shows the CBR values of soil-gravel mixture untreated and treated with the polymer stabilizer. Considering the plot of Fig. 3. A remarkable increment in CBR can be observed when the soil-gravel is treated with acrylic copolymer. The CBR value has increased by 180% when the acrylic copolymer is used. The acrylic copolymer has a remarkable effect on CBR when 50% of gravel is added to the local soil. But almost the same increment values on CBR have been recognized when other percentages of gravel added to the local soil. The remarkable increment on CBR that recognized when treating the soil with acrylic copolymer are caused by the effect of acrylic copolymer that hardened the soil specimen which requires the CBR machine to represent more pressure to penetrate the specimen.

### B. Effect of Gravel and Stabilizer on Cost of road upgrading and maintenance

This study proposes the construction and maintenance of earthy road in Hadida oil field in Sudan as a probable case of using acrylic copolymer. Roads in Hadida oil field are 201Km far from the nearest borrow pit of gravel materials (Altomaat borrow pit). Roads in Hadida are under the role of Petro-Energy E&P Co.

According to data collected from Petro-Energy E&P Co, the cost of road upgrading with gravel surface layer is USD 42,656 per km and road maintenance is USD 2376 per km. The roads in Hadida are upgraded once a year but need maintenance (grading, watering and compaction) at least 6 times a year. The use of acrylic copolymer as stabilizer agent has a remarkable improvement in soil strength properties. Further improvement resulted when local soil blended with gravel (30, 50 and 70%) in the presence of acrylic copolymer as stabilizer agent.

The annual cost of work done on road upgrading and road maintenance in Hadida oil field for the last 3 years was obtained as almost USD 117 thousand per year according to Petro-Energy E&P Co. The initial cost of

TABLE II: CBR for local soil mixed with gravel untreated and treated with 5-S stabilizer.

| **Percentages of soil mixing** | **CBR (%) for untreated soil** | **CBR (%) for treated soil** |
|---|---|---|
| 100% soil with 0% gravel | 4.8 | 175.4 |
| 70% soil with 30% gravel | 14.7 | 192.6 |
| 50% soil with 50% gravel | 19 | 385.7 |
| 30% soil with 70% gravel | 27.2 | 296.4 |

acrylic copolymer is about USD 68 thousand. According to the improvement of strength properties of soil, it can be said that the use of acrylic copolymer and gravel will reduce the frequency of road maintenance (grading, watering and compaction) from 6 times a year to at least once a year. In addition, road upgrading can be reduced from one time a year to once every 3 years.

The plot of Fig. 4 shows that the use of acrylic copolymer and gravel for local soil treatment has a high initial cost. However, a remarkable reduction in cost can be obtained directly after the end of 1st year. The great reduction of cost that is clearly illustrated in the plot of figure 3 demonstrates the initial cost of acrylic copolymer. However, significant benefits of the use of acrylic copolymer can be obtained in the next two years.

## V. CONCLUSION

This study investigates the effect of acrylic copolymer when used as soil stabilizers for earthy road. The aim of the usage of acrylic copolymer is to increase the strength of the soil used as surface layer of earthy road in Hadida oil field in west of Sudan. Lack of strength of the soil used as surface layer causes serious damage on the road net in Hadida oil field. Gravel hauling from Altomat to Hadida causes huge budget on road construction and road upgrading. So, this study aims to use a mixture of Hadida local soil and gravel obtained from Altomat to reduce the cost of gravel hauling. The study investigates the improvements of soil-gravel strength by adding acrylic copolymer. A soil sample obtained from borrow pit in Hadida was engaged in this study. Gravel soil was obtained from Altomat. Acrylic copolymer was provided from Saudi Arabia. Hadida soil, which refers to local soil, was blended by the gravel soil. The blending process of the two soils were as 100% local soil with 0% gravel, 70% local soil with 30% gravel, 50% local soil with 50% gravel and 30% local soil with 70% gravel. OMC and MDD of each specimen were determined using proctor compaction test.

The blended soil samples were compacted at OMC and MDD and tested on CBR machine before and after treatment by 7% of liquid acrylic copolymer. Polymers as soil stabilizers have investigated in much previous research and they have shown very promising results. In this study acrylic copolymers have improved the strength of the soil used. The measured CBR of the tested soil was remarkably increased which evident the benefits can be obtained. Cost analysis has been conducted on road upgrading and road maintenance in Hadida oil field. The actual annual cost of road upgrading and road maintenance in hadida is almost USD 117 thousands. The high cost is relative to gravel transportation from far borrow pit. The use of acrylic copolymers admits the usage of local soil with 30, 50 or 70% of gravel. When using acrylic copolymers, high cost is obtained in the first year due to initial cost but in the next two years a remarkable cost reduction can be gained. Depending on the results of the experimental work performed in this study, it could be concluded that the use of acrylic copolymer as soil stabilizer agent is successful and economical.

## DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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