A Study on The Strength Enhancement of Weak Laterite Soil Using Metakaolin And Pofa

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Abstract- *Laterite is a soil and rock type rich in iron and aluminum, and is commonly considered to have formed in hot and wet tropical areas. Southern region of India forms a major tropical part, where lateritic soils are used as a road making material and they form the sub-grade of most tropical roads as either natural or formed. Most tropical laterite soils are composed predominantly of kaolinite clay mineral and in some cases they contain swelling clay mineral, montmorillonite. When lateritic soils contain swelling clay mineral type, they are known as problematic lateritic soils. The reason being they have reputation of being problematic in road construction. Numerous research works have been carried out on stabilization of laterites to make them suitable especially as a material for road construction. It is important to use innovative techniques by utilizing local available industrial waste material for the modification and stabilization of deficient soil. In the process of soil stabilization and modification, emphasis is given for maximum utilization of local material so that cost of construction may be minimized to the minimum extent. Palm Oil Fuel Ash (POFA) is a local agricultural waste material from Palm Oil Industry and and Metakaolin (MK) which is a pozzolanic material and is obtained by calcination of Kaolinite clay at temperatures from 700°C to 800°C. This paper presents the laboratory study carried out on the combined influence of Palm Oil Fuel Ash (POFA) and Metakaolin (MK) in improving the geotechnical properties of lateritic soil. To understand the performance of stabilized soil, its properties like Atterberg's Limits, Compaction Parameters, Swell Parameters and Penetration Parameters were studied.*

Keywords- Lateritic soil, Palm Oil Fuel Ash (POFA), Metakaolin (MK), Atterberg's limit test, CBR test, Un confined compression test, maximum dry density and optimum moisture content test.

I. INTRODUCTION

Today, due to the increasing population and also development of construction industry, having sufficient knowledge and information about the methods of improving the current surface soils for use in various construction projects is an essential issue for a Geotechnical Engineer. Laterite is a, residual soil found in tropical terrains which have pronounced wet and dry seasons. The soil is formed by the weathering of basalt, granite, gneiss, breccias and conglomerate. Laterites cover vast areas in the tropical countries with intermittently moist climate. The six main regions of the world in which laterites occur are Africa, India, South-east Asia, Australia, Central and South America. However, it should be noted that because of changes in climatic zone in the geological past, laterites could also be found in areas outside the tropics. Lateritic soils have found wide applications in such areas as pavements, embankments, low-cost houses, etc. However, weathered under conditions of high temperature and humidity with well defined alternating wet and dry season results in poor engineering properties such as high plasticity, poor workability, low strength, high permeability, tendency to retain moisture and high natural moisture content. As a result, the effective use of these soils is hindered by difficulty is handling especially under moist and wet conditions typical to tropical regions, therefore can be used after improvement of their performance characteristics by appropriate stabilization methods.

One of the most effective ways in terms of environmental benefits, product-type versatility and cost effectiveness in treating contaminated soils in order to make it suitable for engineering purposes such as the construction of road sub-grade (i.e. the natural foundation which receives load from pavement) is by using industrial wastes. Soil-stabilization is any treatment applied to a soil to improve its strength and reduce vulnerability to water.

Agriculture serves to be one of the most important sectors of production all over the world. Production of large quantity of agricultural wastes becomes a major problem of waste management. The improper management of such waste cause serious environmental problems like air pollution, water pollution finally influencing the local ecosystems. Disposal of large quantities of industrial by-products as fills on disposal sites adjacent to industries not only require large space but also create many geo-environmental problems. The disposal of the agro industrial wastes Metakaolin and palm oil fuel ash also faces these problems. However, these ashes were found to have pozzolanic properties, therefore have been used as stabilization agent in lateritic soils.

In this research work, the laboratory study carried out on the combined influence of Palm Oil Fuel Ash (POFA) and Metakaolin (MK) in improving the geotechnical properties of lateritic soil. The effects of the ash on geotechnical properties of the soil were investigated.

1.2 OBJECTIVES OF THE STUDY

The objectives of present experimental study are to develop correlations between engineering characteristics of lateritic soil. The study is focused on

- Improvement of locally available soil using some eco-friendly and cheap waste materials.
- Evaluation of strength characteristics of virgin as well as blended soil using Palm Oil Fuel Ash (POFA) and Metakaolin (MK)
- Determination of appropriate Palm Oil Fuel Ash (POFA) and Metakaolin (MK) content ratio co achieve the maximum gain in strength of soil.

II. LITERATUREREVIEW

2.1 **Studies on lateritic soil**

Recent research works conducted on stabilization of lateritic soil using different stabilizing agents were referred and their summary was listed below:

The common chemical compositions of laterites according to Gidigasu (1976), Ola (1983) and Osinubi (2003) are silica (SiO2), sesquioxide of iron (Fe2O3) and aluminum (Al2O3), and in some few cases, little quantities of manganese (Mn), titanium (Ti), chromium (Cr) and vanadium (V). Though silica is low in most laterite deposits, higher amounts are found in some few laterite deposits where the parent rock contains a lot of quartz.

M. Chittaranjan et al used agricultural wastes such as Metakaolin, rice husk ash and groundnut shell ash to stabilize the sub grade soil. The sub grade soil was treated with these waste materials separately at 0%, 3%, 6%, 9%,12% and 15% and CBR test was carried out for each per cent .The results of tests showed improvement in CBR value with the increase in percentage of waste up to a certain optimum content.
K.S.Gandhi (2012) worked on improving the sub grade soil using gasse ash. Metakaolin effectively dries wet soils and provides an initial strength gain, which is useful during construction in wet, unstable ground conditions. Various lab tests were performed with the percentage of Metakaolin varying from 0 % to 10%. It was observed that as proportion of Metakaolin increased in the soil sample, there was notable increment in engineering properties of the subgrade.

J. A. Sadeeq(2015) drawn a conclusion that the CBR values of soil samples treated with Metakaolin increased but reduced with used oil contamination. The unsoaked CBR values of soil – BA mixtures right from 4 %BA content and above met the minimum CBR value of 30% specified by (BS 1990) for materials suitable for use as base course material when determined at MDD and OMC.

George R. Otoko presents the experimental study on Soft Soil Stabilization Using Palm Oil Fibre Ash and the analysis shows that the palm ash is classified as class F according to ASTM C618. It is siliceous and aluminous with virtually little or no cementation value. Therefore for pozzolanic reaction it has to be combined into a little lime. An Optimum of 5% lime was obtained for pozzolanic reaction. This combines with 3% optimum palm ash to give best results of soaked and unsoaked CBR. Thus, the palm ash can successfully be used for soil subgrade stabilization

O. S Aderinola and E. S. Nnochiri studied stabilizing lateritic soil using Terrasil solution. Geotechnical tests such as compaction Test and California Bearing Ratio Test were performed on both the natural soil samples and the stabilized lateritic soil samples which were stabilized by adding terrasil solution in percentages ranging from 0% to 16% at 2% interval. The result indicated that between 0% and 12% terrasil solution, the MDD values and the unsoaked CBR values increased while the OMC values generally reduced. They concluded that the terrasil solution serves as a cheap and effective stabilizing agent for poor soil.

Based on the literature reports, the present is set out to evaluate the combined influence of palm oil fuel ash and Metakaolin in improving problematic lateritic soils. Different combinations of POFA and Metakaolin are added to the problematic soil to determine the optimum mix proportions. Further, the effect of curing period over the improvement in the strength properties is also studied to evaluate the long-term strength profile.

2.2 STABILIZATION

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils.. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

3.2 METHODS OF SOIL STABILIZATION

- Mechanical Stabilization.
- Soil Cement Stabilization.
- Soil Lime Stabilization.
- Soil Bitumen Stabilization.
- Thermal Stabilization.
- Chemical Stabilization.

III. METHODOLOGY

3 MATERIALS USED AND THEIR PROPERTIES

Laterite soil collected from Orissa region at 1.0m depth is used for the study. The lateritic soil was sealed in the air tight plastic bags and transported to the college laboratory for testing. After collecting the soil is dried for 2 weeks.

Metakaolin (MK) is a thermally activated aluminosilicate material, white in colour with a dull luster, obtained by calcining kaolin clay within the temperature range 6500-80000C. In the present investigation, Metakaolin marketed by Jeetmull Jaichandlall Pvt. Ltd. Chennai, Tamilnadu was used. The physical and chemical characteristics furnished by the manufacturer are moisture content of 0.18 %, specific gravity of 2.65, bulk density of 710 kg/m3 and pH of 7.0. Metakaolin consists majorly of SiO_2, Al_2O_3, and Fe_2O_3 contributing 53.7 %, 39.2 %, 3.84 %, of the total. The next most abundant component is titanium oxide, TiO_2 (5.97 %). According to ASTM standard specification (C 618 – 2012), the sum of SiO_2, Al_2O_3, Fe_2O_3 be ≥ 70 % for any material to be used as a pozzolana.

Palm oil trees are abundant in the Andhra Pradesh and the effectiveness of using its ash (waste from the process of burning the palm oil fiber) in soft soil stabilization was investigated. It exhibits high shear strength which is highly beneficial for its use as a geotechnical material. It has a good permeability and variation in water content does not seriously affect its desirable properties.. The dry density increased with the addition of Palm Oil Fuel Ash with attendant decrease in the optimum moisture content. The palm oil fuel ash is collected from Ruchi industries, Samalkot, A.P.

Different laboratory experiments conducted with different combinations of materials. Detailed discussion on the results obtained from various laboratory tests done on untreated and treated lateritic soil are presented in the results and discussions chapter.

TABLE 3.1 Properties of Lateritic Soil

Properties of Lateritic Soil		
S. No.	Property	Value
1	Specific gravity	2.66
2	Differential free swell Index (%)	68
3	Atterberg's Limits	
	i) Liquid limit (%)	30.8
	ii) Plastic limit (%)	17.6
	iii) Plasticity index (%)	13.2
4	Grain Size Distribution	
	i) Gravel Size Particles (%)	35
	ii) Sand Size Particles (%)	26
	iii) Silt & Clay Size Particles (%)	39
5	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.69
	ii) Optimum Moisture Content (%)	17.1
6	Penetration Parameters	
	i) CBR - Unsoaked (%)	10.3
	ii) CBR - Soaked (%)	4.5
7	Unconfined Compressive Strength (UCS) at OMC & MDD (kPa)	108

Table 2 Shows the Properties of Palm oil fuel ash

Properties of Palm Oil Fuel Ash		
S. No.	Property	Value
1	Specific gravity	1.96
2	Grain Size Distribution	
	i) Sand Size Particles (%)	71
	ii) Silt & Clay Size Particles (%)	29
3	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.3
	ii) Optimum Moisture Content (%)	14.1

IV. RESULTS AND DISCUSSIONS

In the laboratory, various experiments were conducted by combination of different percentages of Metakaolinand Palm oil fuel ash in the lateritic soil. Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of Metakaolin and POFA. CBR and UCS are conducted for curing studies.

Effect of combination percentages of METAKAOLIN + POFA in improving the compaction properties of laterite soil:-

By compaction of soil, the particles are mechanically constrained to pack more closely, by expelling part of the air voids. Proper compaction of fills, subgrade, sub-base and base courses are considered essential for proper highway construction. There is optimum moisture content for a soil, at which maximum dry density is attained for a particular type and amount of compaction. To assess the amount of compaction and water content required in the field, compaction tests are conducted. In the present study Standard Proctor Compaction test as per IS: 2720 (Part VII), 1980 was conducted on soil without cement. The test is conducted on soil alone, soil with combination of Palm Oil Fuel Ash (POFA) and Metakaolin. The compaction test is done immediately after treating it with the stabilizer. The test results of compaction test with soil alone, soil with combination of Palm Oil Fuel Ash (POFA) and Metakaolin dosages were shown in the graphs in fig 1, 2, 3, and 4.

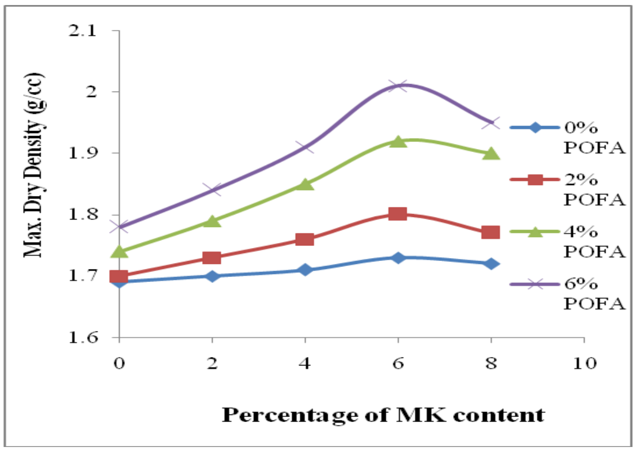

Fig1 shows the Variation in maximum dry density with percentage of Metakaolin content

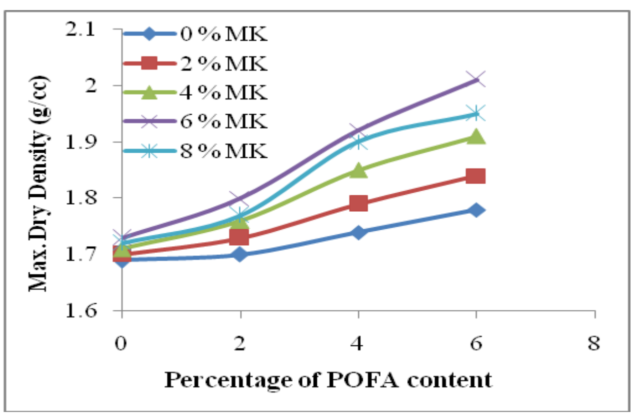

Fig2 shows the Variation in maximum dry density with percentage of POFA content

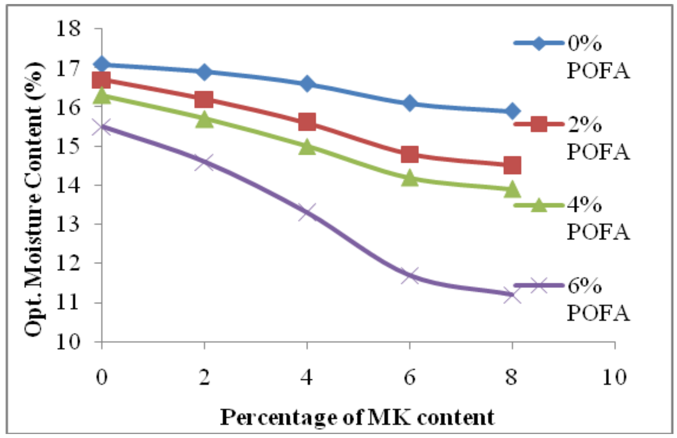

Fig3 shows the Variation in optimum moisture content with percentage of Metakaolin content

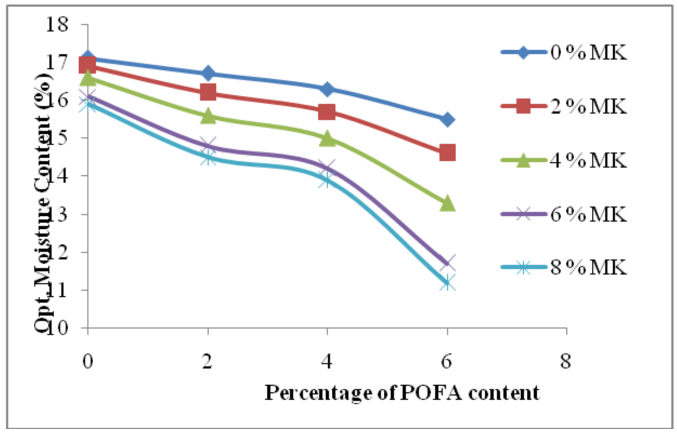

Fig4 shows the Variation in optimum moisture content with percentage of POFA content

Effect of combination percentages of METAKAOLIN + POFA in improving the penetration characteristics of laterite soil

CBR value for untreated soil remained constant for most of the time. When soil treated with palm oil fuel ash and Metakaolin as the combination dosage was increased CBR values also increased for all curing periods. The test is conducted on soil alone, soil with combination of palm oil fuel ash and Metakaolin. The test results of CBR test with soil alone, soil with combination of Palm Oil Fuel Ash (POFA) and Metakaolin dosages were shown in the graphs in fig 5 and 6.

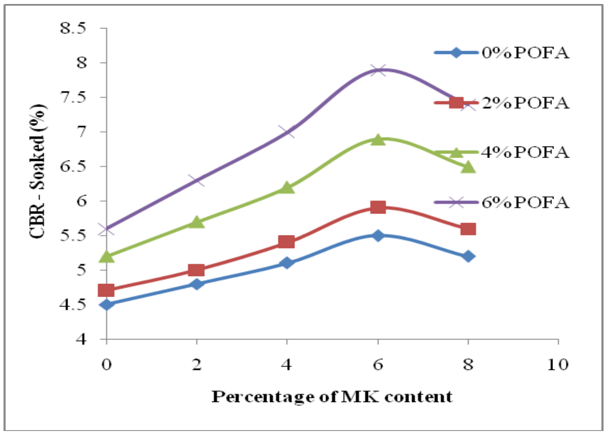

Fig5 shows the Variation in CBR Values with percentage of Metakaolin content

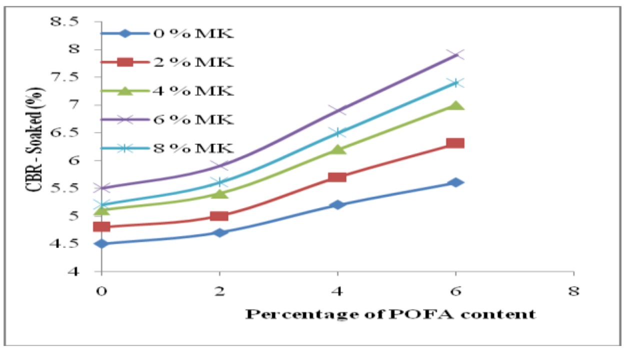

Fig6 shows the Variation in CBR Values with percentage of POFA content

Effect of combination percentages of METAKAOLIN + POFA in improving the unconfined compressive strength of laterite soil

Figure 7 and 8 shows the change of unconfined compressive strength with different percentage of combination of Palm Oil Fuel Ash (POFA) and Metakaolin. It is found that the unconfined compressive strength increases as we add on Metakaolin and palm oil fuel ash in combination and decreases after a particular percentage combination addition of Metakaolin and palm oil fuel ash.

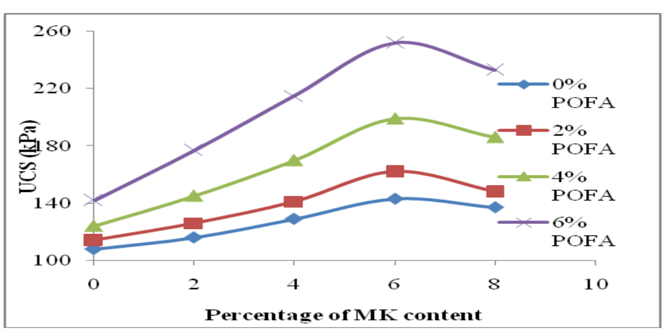

Fig7 shows the Variation in UCS Values with percentage of Metakaolin content

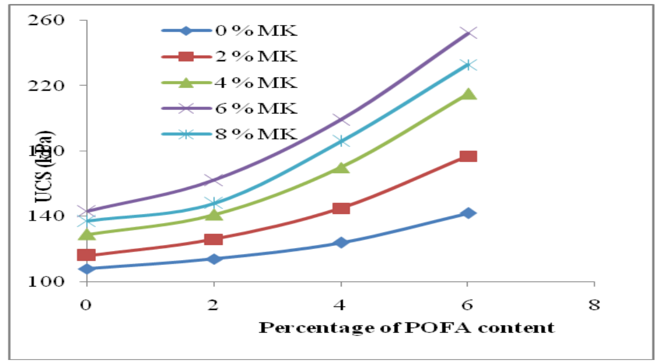

Fig8 shows the Variation in UCS Values with percentage of POFA content

From the above results the Combined Optimum Content of POFA + MK for improving the Weak Laterite Soil (WLS) is 6% POFA + 6% MK. Since the CBR requirement as per IRC 37-2012 which is Soaked CBR of 8% is not achieved for the optimum combination, the Curing study was done on the optimum combination samples.

Effect of curing on samples prepared with 6% Palm Oil Fuel Ash + 6% Metakaolin

Figure 10 and 11 shows the variation of penetration and shear characteristics for different curing periods. From above figures we can conclude that laterite soil when cured with 28 days had shown more pronounced improvement about 33.72% and 43.2% for CBR and UCS respectively.

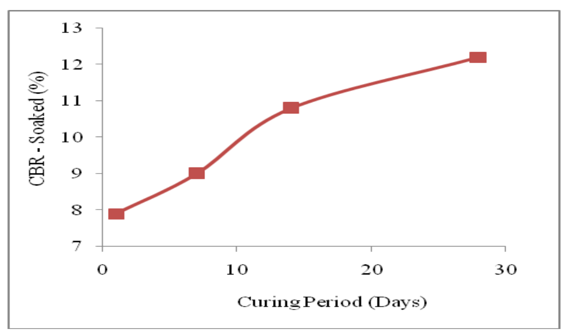

Fig9 shows the Variation in CBR Values with different curing periods

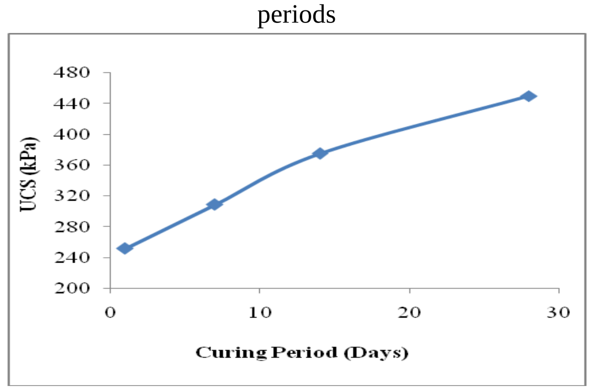

Fig10 shows the Variation in UCS Values with different curing periods

From the above results the outcome revealed that the potentiality of treated lateritic soil was established as a sub-grade soil with a combined optimum dosage of 6% Palm Oil Fuel Ash (POFA) and 6% Metakaolin.

Finally from the above discussions, it is clear that there is improvement in the properties of laterite soil stabilized with METAKAOLIN + POFA. It is evident that the addition of Metakaolin and POFA to the laterite soil showed an improvement in plasticity, compaction and strength properties. It can be summarized that the materials Metakaolin and POFA had shown promising influence on the properties of laterite soil, thereby giving a two-fold advantage in improving problematic laterite soil and also solving a problem of waste disposal.

V. CONCLUSIONS

An experiment was undertaken to investigate the effects of Metakaolin and palm oil fuel ash on some geotechnical characteristics of a lateritic soil. The following conclusions can be drawn from the results of the study.

- From the studies, it is observed that the laterite soil chosen was a problematic soil.
- It was observed that the soil with a combined optimum dosage of 6% Palm Oil Fuel Ash (POFA) and 6% Metakaolin has improved the properties of laterite soil.
- The maximum dry density of the soil increased with increase in both palm oil fuel ash and Metakaolin contents.
- It can be inferred from the graphs, that there is a gradual improvement in the maximum dry density by an amount of 16.37 % and it was about 79.16% for Soaked CBR and 135 % for UCS respectively.
- From the results the Combined Optimum Content of POFA + MK for improving the Weak Laterite Soil (WLS) is 6% POFA + 6% MK.
- Since the CBR requirement as per IRC 37-2012 which is Soaked CBR of 8% is not achieved for the optimum combination, the Curing study was done on the optimum combination samples.
- Curing studies done on the Metakaolin and palm oil fuel ash modified laterite soil. The optimum mix proportion blended with lateritic soil when cured for 28 days had shown more pronounced improvement about 33.72% and 43.2% for CBR and UCS respectively.

Finally it can be summarized that the materials Metakaolin and palm oil fuel ash had shown promising influence on the properties of laterite soil, thereby giving a two-fold advantage in improving problematic laterite soil and also solving a problem of waste disposal.

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