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Stabilization of Lateritic Soil Using Coir Fiber as Natural Reinforcement

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Abstract

Stabilization of soil using fibers is one of the effective techniques to improve the strength of soils for engineering se. This paper aims to evaluate the effect of coir fiber as natural reinforcement in the stabilization of lateritic soil, which is classified as clayey silt. The performance of Coir fibers is separately analyzed for its impact on the strength of the soil. Tests were conducted on various fiber-soil ratios in six percentage levels such as 0, 0.2, 0.4, 0.6, 0.8 and 1.0 to determine the optimum fiber content. The index properties tests carried out on the natural soil samples (A and B) showed that the samples belong to A-6 and A-7-6 in the AASHTO classification system respectively and CL according to the Unified Soil Classification System (USCS). Compaction characteristics of the natural and treated soil samples were determined using the Standard Proctor method. Unconfined compressive strength (UCS) value of 58.59kpa and 87.89kpa obtained for the natural soil, increased to a maximum of 359.31kpa and 261.16kpa at 0.4% fiber content for samples A and B respectively. The California bearing ratio (CBR) values on the other hand increased with increase in fiber content from 14.52% to 23.28% and from 12.47% to 18.92% for soaked samples A and B respectively, and from 17.26% to 27.18% and 15.22% to 21.89% for unsoaked samples A and B respectively. The results indicate that, 0.4% coir fiber content are more optimal and efficient stabilizer for the laterite soil. This study also contributes to effective soil waste management as a befitting sustainable technique to solve current environmental crisis as well.

Keywords: ***laterite, Coir Fiber, Stabilization, Mechanical Properties***

1. Introduction

Lateritic soils are used as fill materials for various construction works. These soils are weathered under conditions of high temperatures and humidity. So, the properties of this soil easily change over dry and wet seasons resulting in poor engineering properties such as high plasticity and low strength, the effective use of these soils is therefore often hindered and can only be utilized after modification/stabilization. Plasticity index of this soil is found to be higher due to the presence of silt and clay in large percentage (Lokayath and Subha, 2015).

The process of improving engineering properties of the soil and thus making it more stable is known as stabilization of soil. There are various methods for soil stabilization like mechanical stabilization, cement stabilization, thermal stabilization, lime stabilization, electrical stabilization; stabilization by grouting, chemical stabilization, bituminous stabilization, etc. This is not only an economic solution, but also offers a potential use of industrial / domestic waste materials (Shriram et al., 2015). Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two (Sheerwood, 1993).

According to previous researchers, the use of industrial and agricultural wastes (iron ore tailing, fly ash, bagasse ash, locust bean waste ash, etc) for soil improvement is significantly beneficial to the environment. Previous investigations (Rajakumar and Meenambal, 2015) have shown that groundnut shell ash, coal ash and bagasse ash collectively improve the unconfined compressive strength and CBR of soil. Also, the use of coir in reinforcing laterite blocks will minimize the environmental problem of waste deposition in addition to reduction in the cost of building blocks. The conventional improvement of the soil with lime and ordinary Portland cement has been confirmed in its requirement for construction works (Balogun 1991; Matawal and Tomarin, 1996) but the cost of blending cement with the soil is usually very expensive (Osinubi and Oyelakin, 2012). However, the high cost of these products has induced intensive researches into the use of industrial, Agricultural and domestic waste for their potential use in improving marginal soils.

It is commonly accepted today in soil improvement work to examine the effects of local materials considered to be waste which actually do not connote worthless substances as they may be economically viable for construction purposes (Osinubi, 2000; Ghose and Sen, 2001). The major part of Nigeria is underlain by basement complex rocks, the weathering of which had produced lateritic materials spread over most of the area. It is virtually impossible to execute any construction work in Nigeria without the use of lateritic soils (Osinubi, 1998a). Therefore, there is need to investigate the effect of this waste material on the properties of lateritic soil when used as a road construction material.

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The volume of wastes generated worldwide has also increased over the years due to increase in population, socio-economic activities and social development. In other to minimize the effects of these wastes, one of the most attractive options is to look into the possibility of waste minimization and recovery. The exploitation of mineral resources promotes the development of economy and society, but it also generates massive overburden, mill tailings, silt, etc. that may pollute the environment. Effective management of these wastes is a global problem and of growing significance considering the cost of storing and transporting waste, along with the loss of revenue from not reclaiming waste materials, and also the possible associated risk of environmental hazards.

2. Location of Collected Samples

The lateritic soil sample used for this study was collected by method of disturbed sampling from a lateritic soil formation in Federal University of Technology, Akure (FUTA) (Longitude 5 °N 19ʺ E Latitude 7° 25ʺ N). The soil samples were collected at depths between 0.7 and 1.0 m corresponding to the B - horizon usually characterized by accumulation of material leached from the overlying A – horizon.

The coir fiber used for this study was collected from a village (Oni), Ogun Waterside Local Government Area of Ogun State, geographically located in South Western Nigeria. The fiber was then air dried and cut into pieces of about 30mm and having a diameter of about 0.2mm

3. Materials and Methods

The lateritic soil obtained from FUTA was wet washed on sieve 425µm. The retained sample was weighed and kept in the oven for 24hours at a regulated temperature of 1050C. The samples were then broken into smaller fragments, care being taken not to reduce the sizes of the individual particles. The Samples were prepared in accordance with BS 1377 (1990). The coir fiber collected from Oni, Ogun State was dried and cut into pieces of about 30mm length. The product, coir fiber was mixed in 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1% by mass of the soil sample with the oven-dried samples of lateritic soil.

The laboratory tests carried out include particle size analysis test, Atterberg limit test (liquid limit, plastic limit and plasticity index), Specific gravity, British Standard (BS) compaction test, unconfined Compressive test and California bearing ratio in accordance with BS 1377 (1990).

4. Results and Discussions

Properties of Natural Soil

The preliminary index properties tests conducted on the natural lateritic soil samples in accordance with BS1377 (1990) showed that the soil (sample A and B) is clayey, with a natural moisture content of 14.7 % and 14.55% respectively.

The summary of these properties is shown in Table 1. The particle size distribution curve is shown in Figure 1. The soil samples (A and B) are reddish brown in colour with liquid limit of 38% and 41%, plastic limit of 22.82 % and 20.85% and plasticity index of 15.18% and 20.15% respectively. The soil samples (A and B) are classified as CL soil in the Unified Soil Classification System, USCS (ASTM, 1992) or A-6 and A-7-6 respectively according to AASHTO soil classification system (AASHTO, 1986). The natural soil A and B also has linear shrinkage of 8.1 % and specific gravity of 2.21 and 2.01 respectively. The liquid limit curve is shown in figure 2.

Table 1: Properties of natural soil

Property Quantity	Sample A	Sample B
Percentage passing No. 200 sieve	44.56	49.80
Natural moisture content (%)	14.70	14.55
Liquid limit (%)	38	41
Plastic limit (%)	22.82	20.85
Plasticity index (%)	15.18	20.15
Linear shrinkage (%)	8.1	8.1
Specific gravity	2.21	2.01
AASHTO classification	A-6	A-7-6
USCS	CL	CL
Colour	Reddish Brown	Reddish Brown

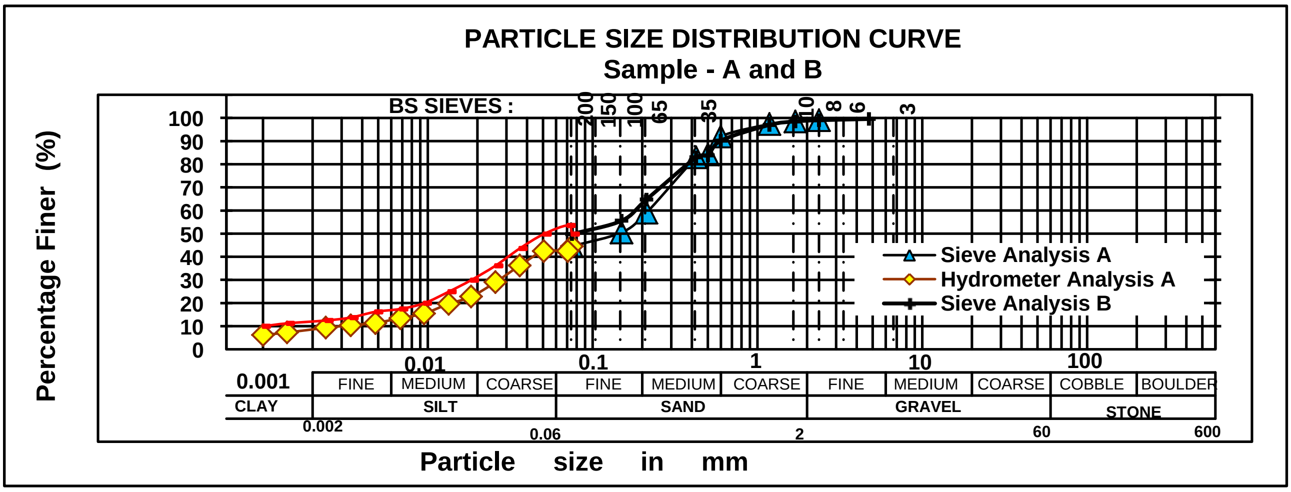

Figure 1: Particle size distribution of samples A and B

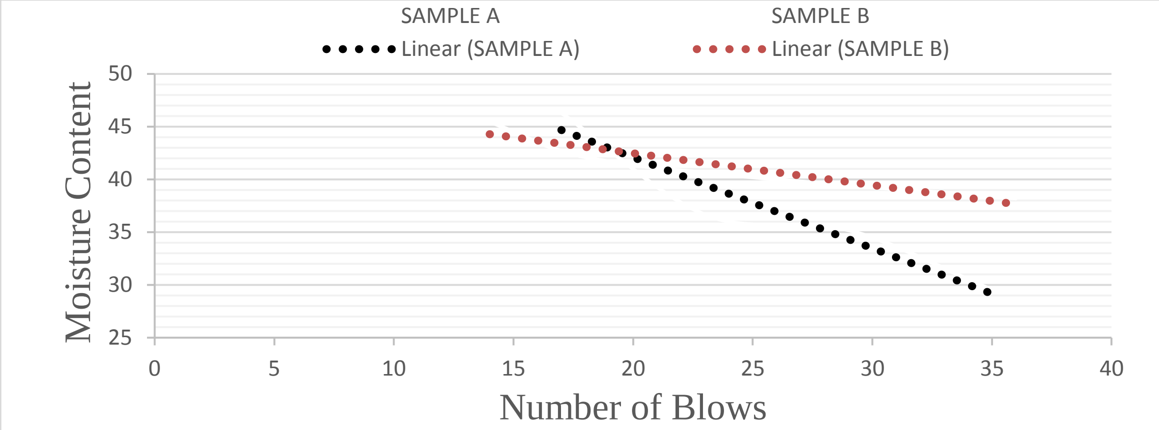

Figure 2: Liquid limit graph for Sample A and B

Compaction Characteristics

Many of the engineering properties of a soil are dependent on the moisture and density at which the soil is compacted. Therefore, it is necessary to achieve the desired relative density of 95 % or more on field relative to that obtained in the laboratory.

The variation of maximum dry density (MDD) of lateritic soil – coir fiber mixture is presented in Figure 3 for samples A and B respectively. It was observed for both samples (A and B) that MDD values increased from a natural value of 1.83 KN/m3 to a maximum value of 1.84 KN/m3 at 0.4% coir fiber and from 1.85 KN/m3 to a maximum of 1.87 KN/m3 at 0.4% coir fiber respectively (Figure 4) which is then followed by a reduction in MDD till 1%. The increase in MDD recorded for the comp active effort may be due to agglomeration of the clay particles caused by the reinforcing fibers and in addition, the fibers filling the voids within the soil matrix.

The variation in moisture content of lateritic soil – coir fiber mixture is shown in Figure 5. For the natural soil, OMC value of 17.46% was recorded for sample A, which then reduces to 14.09% at 0.4% coir fiber. A different trend was observed for sample B of which OMC value of 15.85% was recorded, which then increased to 17.89% at 0.4 % coir fiber. (Figure 5)

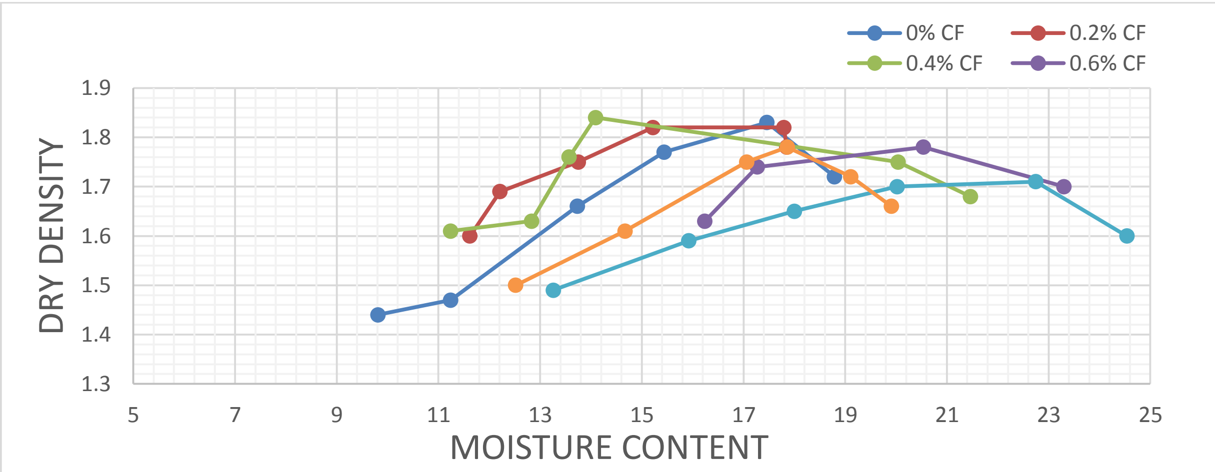

Figure 3: Graph of D.D against M.C for sample A

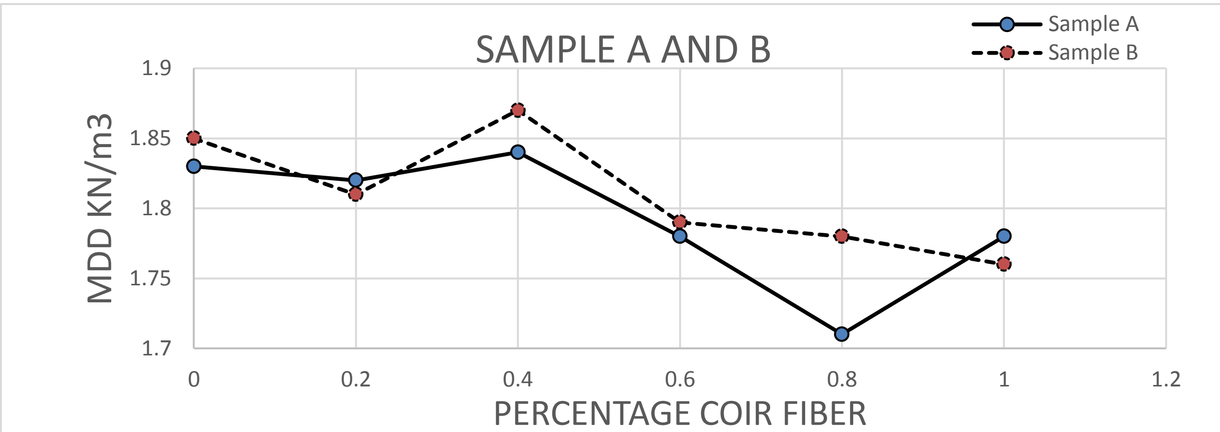

Figure 4 Graph of MDD against percentage Coir Fiber for Sample A and B

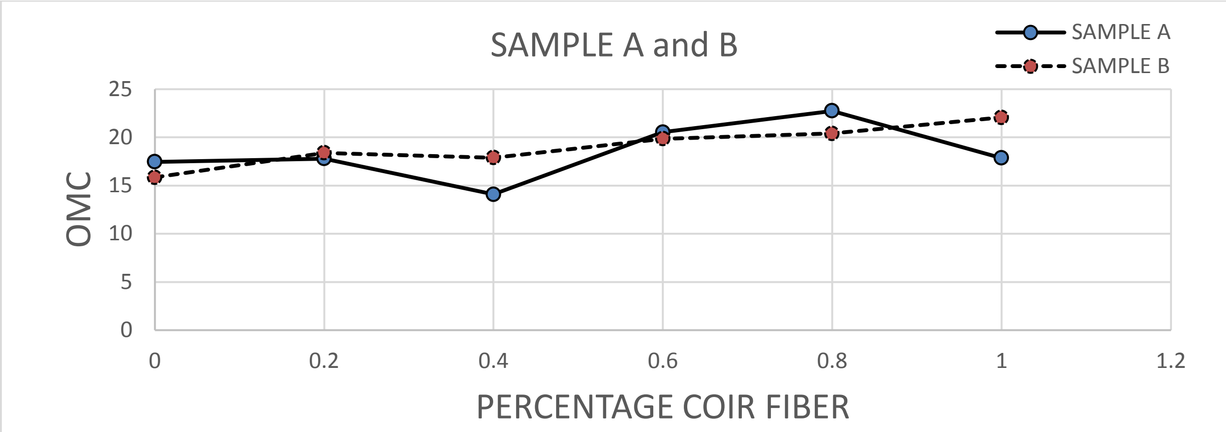

Figure: 5 Graph of OMC against percentage Coir Fiber for Sample A and B

Strength Characteristics

Over the years, unconfined compressive strength (UCS) test has been the most common and suitable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in the stabilization of soil (Singh, 1991). According to Ola (1983), it is an important factor in the evaluation of the design criteria for the use of soil as a pavement material.

The variation of UCS test on lateritic soil – coir fiber mixtures for sample A and B are shown in Figure 6. The UCS of lateritic soil – coir fiber mixtures increased up to 0.4 % coir fiber and thereafter decreased for both samples (A and B).

The California bearing ratio is a penetration test for evaluation of mechanical strength of road sub grades and base courses. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. It is an important parameter used to indicate the strength and bearing capacity for base and sub-base in pavement structure.

Figure 7 shows the variation of CBR (unsoaked) values of lateritic soil - coir fiber mixtures. The results showed an increase in CBR values for varied coir fiber contents from 0 % to 1% where it peaked for both soil samples. The values obtained were from 17.26% to 27.18% and 15.22% to 21.89% for unsoaked samples A and B respectively.

The variation of California bearing ratio (24 hours soaking) of lateritic soil- coir fiber mixtures is shown in Figures 8 the results showed an increase in CBR values for varied coir fiber contents from 0 % to 1% where it peaked for both soil samples. The values obtained were from 14.52% to 23.28% and from 12.47% to 18.92% for soaked samples A and B respectively.

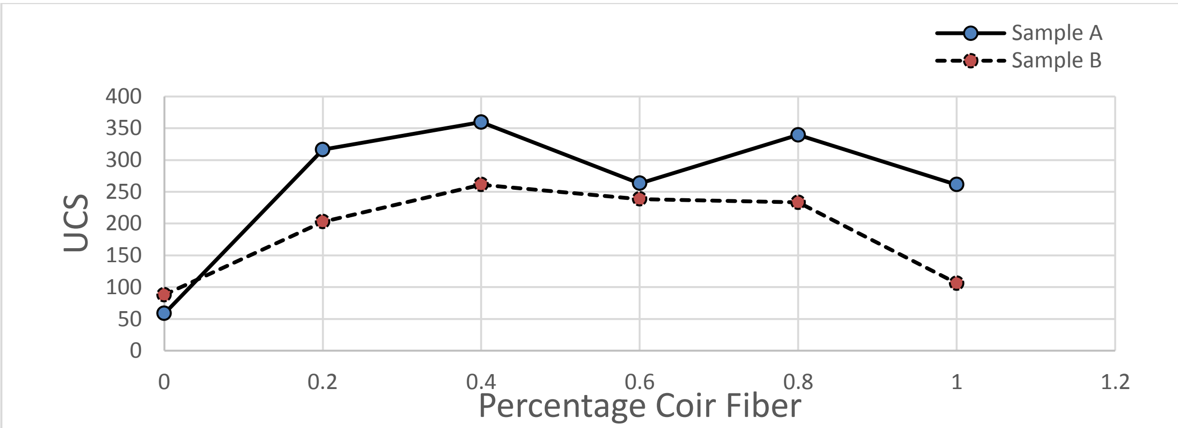

Figure: 6. Graph of UCS against percentage Coir Fiber for Sample A and B

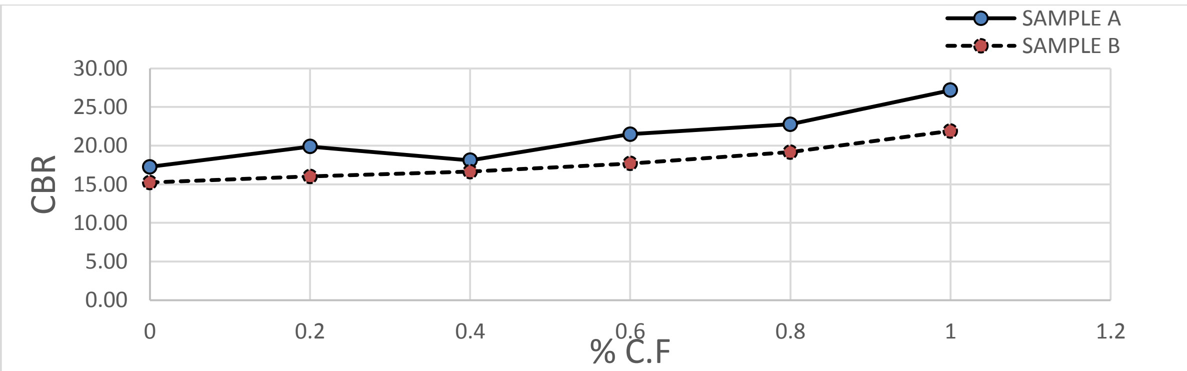

Figure: 7. Graph of CBR(UNSOAKED) against percentage Coir Fiber for Sample A and B

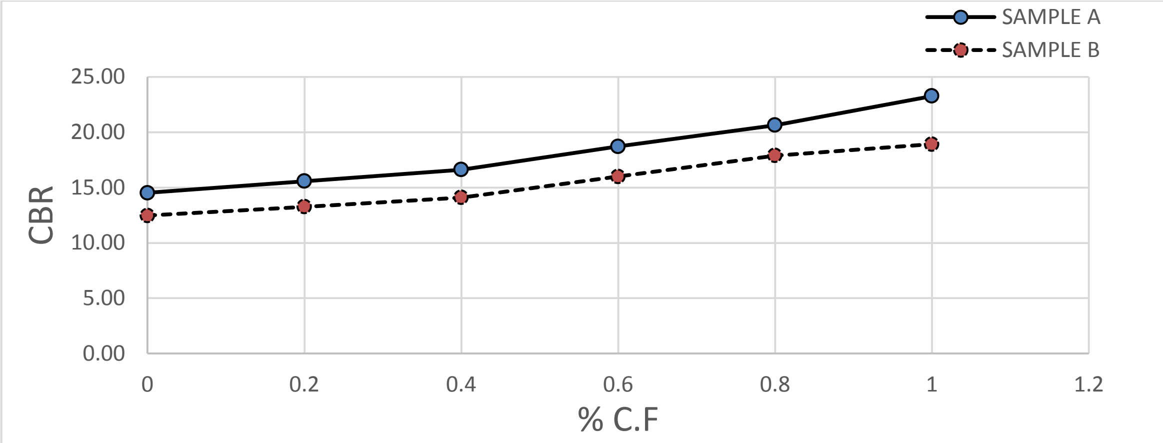

Figure: 8 Graph of CBR (SOAKED) against percentage Coir Fiber for Sample A and B

5. Conclusion

The soil samples A and B are found to contain high proportion of silt and clay fractions. They will be susceptible to swelling and cracking of road pavements. Their classification being A-6 and A-7-6 makes them unsuitable for road pavements without improvements.

Test results carried out have shown that 0.4% of the local stabilizer is best suited for the optimal improvement of the strength properties of the lateritic soil. With this local material, some of the unsuitable widely available soil materials could be improved and used for construction works.

6. References

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