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# Experimental Analysis Using the Atterberg Limits On Soil around Ture-Mai Community to Identify the Causes of Cracks on Their Buildings

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**Abstract**
Cracks on buildings are a matter of urgent attention within the community of Ture-Mai in Kaltungo local government area ($9^o53^I$N $11^o26^o$E/$9.883^o$N $11.30889^o$E) of Gombe state, Nigeria. An experimental study was conducted on the soil around the affected community; the properties determined were the Liquid limit (LL), Plastic limit (PL) and the Shrinkage limit (SL). The plasticity index (PI) which is the numerical difference between the Liquid and Plastic Limits were calculated and found to be at the range of 16 to 40%, while the linear shrinkage fall within the range of 14 to 24%. Generally the results indicated that the plasticity index of the soil rose from medium to high and the soil have a low shrinkage potential because of its high clay content, that results in emergent expansion and contraction leading to differential settlement, which cause cracks and damages to buildings in the area.

**Keywords:** Experimental analysis, Ture-mai, soil, cracks, Atterberg limit, Shrinkage limit

## Introduction

Swedish scientist Albert Atterberg originally defined seven limits of consistency to classify fine-grained soils [1], but in current engineering field only two of the limit are commonly used which are the liquid and plastic limits, the third limits known as the shrinkage limit is used from time to time [1]. The Atterberg limits are based on the moisture content of the soil. The plastic limit is the moisture content that defines where the soil changes from semi-solid to a plastic state, the liquid limit is the moisture content that defines where the soil changes from a plastic to viscous fluid state, while the shrinkage limit is the moisture content that defines where the soil volume will not reduce further if moisture content reduced [1]. The foundation of a building is defined as the soil or rock upon which the footings are constructed, and the term soil in engineering refers to the sand, silt or clay material below the organic top soil layer [2]. There are various types of soil which can be distinguished by the size of the particles for instance Massachusetts Institute of Technology (MIT), classified soil size limits: > 2mm as gravel, 2 to 0.06mm as sand, 0.006 to 0.002mm as silt and < 0.002mm as clay. The United State department of agriculture (USDA), classified soil size limits: > 2mm as gravel, 2 to 0.06mm as sand, 0.05 to 0.02mm as silt and clay < 0.002mm. the American Association of State Highways and Transportation Officials (AASHTO), classified soil size limits: 76.2 to 4.75mm as gravel, 2 to 0.075mm as sand, 0.075 to 0.002mm as silt and clay <0.002mm. While Unified Soil Classification System (U.S Army Corps of Engineers; U.S Bureau of Reclamation; American Society for Testing and Materials) classified soil size limit: 76.2 to 4.75mm as gravel, 4.75 to 0.075 as sand, while fines such as silts and clays < 0.075mm.

Cracks formation is enhanced due to accessibility of clay [3]. The hydraulic conductivity tests conducted on compacted and saturated soils during wetting and drying cycles indicated that shrinkage strain is directly proportional to plasticity index and clay content and indirectly proportional to compaction effort and closeness to the optimal water content [4]. It was observed that in cracking activities of sandy and clayey soil mixtures, the shrinkage is directly proportional to the density of the mixture [5]. Cracking can either be as a result of the outcome of pressure exerted on the soil body or it can be a volumetric change in the soil body and is classified into two major types in line with the systems of their formation which include mechanical and physiochemical cracks [6]. Some of the major causes of cracks can be classified according to the stages of planning or during construction [2] stated as follows, (a) Site investigation; failure to conduct a proper soil analysis before construction or the investigation failed to reveal the potential problems on the soil. (b) Footing design; the designer may misinterpret the site investigation report or in the absence of the report, wrongfully assume certain soil properties. (c) Construction faults; faults in construction arise usually from poor workmanship, misreading of plans, and ignorance of the properties of building material. (d) Site drainage provision; drainage is an essential consideration to prevent excessive moisture movements and consequent heave or consolidation of soft or loose soils. (e) Post construction maintenance; in terms of moisture movements in reactive clays, the most common problems include location of trees too close to the building and neglect of other side drainage or maintenance plumbing lines [2]. Thus, this experimental study is aimed at using the Atterberg limits on soil around Ture-mai community to ascertain the major causes of crack formations on their buildings, and to suggest some of the preventive measures to avoid future occurrences of this problem.

## Materials and Methods

The soil samples were collected from 13 locations around the affected area with an interval of 150 meters in order to examine the variation of the plasticity properties of the soil. Test on liquid limit, plastic limit and shrinkage limit was conducted using standard test methods

### Determination of Liquid Limit

Liquid limit was determined using the record of the numerical difference between the wet and dry weight to obtain the weight of the moisture. The test was carried out in accordance with ASTM D4318-10 [8]. The liquid limit was calculated using equation (1)

$$L_L \text{ (No of blows)} = \frac{\rho m}{\mu f} \quad (1)$$

Where: $L_L$ = liquid limit
$\rho m$ = percentage moisture
$\mu f$ = correction factor

### Determination of Plastic Limit

The test was carried out in accordance with ASTM D4318-10 [8]. The plastic limit was calculated using equation (2)

$$PL = \frac{Wm}{Wds} \times 100 \quad (2)$$

Where: $PL$ = plastic limit
$W_m$ = weight of moisture
$W_{ds}$ = weight of dry soil

### Determination of Plasticity Index

Plasticity index of the soil is the numerical difference between the liquid limit and the plastic limit. The plasticity index was obtained in accordance with ASTM D4318-10 [8]. The plasticity index was calculated using equation (3)

$$PI = L_L - P_L \quad (3)$$

Where: $PI$ = plasticity index
$L_L$ = liquid limit
$PL$ = plastic limit

### Determination of Shrinkage Limit

Shrinkage limit test was carried out in accordance with ASTM D-427 [10]. The linear shrinkage of the soil is calculated as a percentage of the original length of the soil bar in the mound from equation (4)

$$SL = \frac{L - Ls}{L} \times 100 \quad (4)$$

Where; $LS$ = Soil Shrinkage limit
$Ls$ = longitudinal length of the dry soil bar (mm)
$L$ = length of the mound (mm)

## Results and Discussion

**Table 1:** Atterbergs Limit Soil test results

| Samples | Liquid limit % | Plastic limit % | Plasticity index % | Shrinkage limit % |
|---|---|---|---|---|
| | | | | |
| 1 | 47 | 11 | 36 | 19.6 |
| 2 | 53 | 21 | 32 | 11.5 |
| 3 | 52 | 34 | 18 | 14.1 |
| 4 | 53 | 37 | 16 | 15.0 |
| 5 | 54 | 27 | 27 | 10.0 |
| 6 | 64 | 24 | 40 | 18.6 |
| 7 | 68 | 39 | 29 | 12.0 |
| 8 | 53 | 20 | 33 | 12.1 |
| 9 | 56 | 24 | 32 | 11.9 |
| 10 | 59 | 35 | 24 | 14.7 |
| 11 | 60 | 39 | 21 | 9.7 |
| 12 | 38 | 19 | 19 | 15.0 |
| 13 | 47 | 25 | 22 | 8.3 |

**Table 2:** Classification of soil plasticity index (Burmister)

| Soil Plasticity index (PI) % | Description |
|---|---|
| 0 | Non plasticity |
| 1-5 | Slightly plasticity |
| 5-10 | Low plasticity |
| 10-20 | Medium plasticity |
| 20-40 | High Plasticity |
| >40 | Very high plasticity |

Source [9]

The shrinkage limit test and the plasticity index (which is the numerical difference between the liquid and plastic limit) presented in table 1 shows that sample 1 and 6 indicate a very high degree of expansion, sample 2, 7,8,9,10,11 and 13 indicate a high degree of expansion, while sample 3, 4, 5 and 12 indicate a medium degree of expansion according to [11]. The plasticity index (PI) of the soil range from medium at 16% to high plasticity at 40% as stated in table 2 according to [9], which is an indication of high clay content and essential swelling potential tendency in the soil [7]. Swelling and shrinkage of soil containing relative amount of clay may lead to severe damages and formation of cracks on foundation footings and walls. Consequently the swelling soil lifts up and crack lightlyloaded, continuous strip footings, and frequently causes distress in floor slabs.

**Conclusions**

Based on the Atterbergs limit test results obtained on the soil samples around Ture-mai community to analyse the major cause of cracks on their walls and other building structures, the following conclusion were made: The soil is weak due to high amount of plasticity which tend to possess a low bearing capacity to support the building structure. Most foundation footings around the affected area were not laid according to specifications and buildings were erected without conducting a proper soil test, which led to differential settlement that causes the soil beneath the structure to expand, contract or shift away which results to cracks in the structural foundations and interior walls. In order to avoid future occurrences of these peculiar problems, soil used on foundation footings has to be tested and analysed, so that a construction experts or engineer can determined the load bearing capacity of the soil and estimated settlement of the planned structures, make amendments to the soil before construction begins, in order to minimize the effects of differential settlement that causes cracks in buildings.

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