EFFECTS OF EXPANSIVE SOILS ON RURAL HOUSING AND INFRASTRUCTURAL DEVELOPMENT IN THE BENUE VALLEY AREA OF DEMSA, ADAMAWA STATE, NORTHEASTERN NIGERIA.

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Abstract:
Effects of expansive soils on rural housing and infrastructural development in the Benue valley area of Demsa LGA of Adamawa State have been investigated based on field observations and measurements, focus group interaction and geotechnical laboratory analyses of soil samples. Affected infrastructures have been carefully analyzed on the basis of cracks sizes and total collapse and soil profiles have been studied at sample sites. Coefficients of Linear Extensibility (COLE) and Atterberg limits of the soil samples were examined and assessed on the basis of standards provided by Singer and Munns (1999) and Ranjan and Rao (2000) respectively. Horizons of expansive clays ranging from 2m to 4m were obtained from soil profile studied. COLE values ranging from 0.05 - 0.16 (moderate to very severe) and mean plasticity index of 25.6 (high) were obtained, indicating high levels of shrink-swell of the soils as well as high destructive tendencies to infrastructure. The area has been found not suitable for infrastructural development within the residents' income range. Soil mapping and resettlement scheme, cheap modern wooden housing, lime stabilization and fly ash treatment of soils and underground wiring or solar panels for rural electrification projects have been recommended as alternatives for infrastructural development in the area.

Keywords: expansive soils, montmorillonite, rural housing, infrastructural development, shrink-swell potentials.

Introduction

The relevance of shelter over man's head could be traced back to early period of Neolithic revolution which turned man from a migratory hunter and gatherer to a sedentary farmer, where he has to settle in a particular place for a while and cultivate the land for food. This practice marked the dawn of housing and human settlement development, as group of people of common ties and interest constructed shelter over their heads in the vicinities of their agricultural lands. With the advancement in civilization and technology today, every local or rural settlement aspires for growth and development in terms of modernization in housing and land transportation as well as improvement in educational, health and recreational infrastructure among others. However, these aspirations can only be achieved where and when available land resources are adequate and qualitative enough to support the construction of relevant infrastructure.

One of the major land determinants for modern infrastructural construction is soil. Soil plays a vital role in terms of its resourcefulness and suitability to support settlement structures such as buildings, roads, sewage channels, bridges and pipelines among others.

While some soils are highly suitable for construction and support of human settlement infrastructure, others are less, not suitable or hazardous. A common soil type that depicts the later characteristics is the class of expansive soils.

Expansive soils are naturally occurring soils mostly found in low lying region and flood plains. They are fine grained soils, rich in expansive clay minerals which are subject to swelling when wet and shrinkage when dry (Ranjan and Rao, 2000). Montmorillonite, being the most common clay mineral in most expansive clay soils is composed of smaller particles called micelles. The clay mineral is characterized by a 2:1 expanding crystals lattices with two sheets of SiO_2 sandwiching a sheet of Al_2O_3, forming layers with inter-sheet spacing of about 14 Armstrongs (A^o). However this can vary from $11A^o$ to $19A^o$, depending on the amount of water and cations present (Thompson *et. al* 1986). Due to the smaller sizes of the micelles and the fact that ions can penetrate between the layers of the lattice, montmorillonite has a much greater surface area. Thus, it can become more plastic and cohesive by absorbing more water, swell on wetting and shrink on drying. In fact, when water is absorbed by its crystals it tends to swell to several times its original volume and its surface develops cracks when dry.

Expansive soils are common in Africa, Australia, India, South Africa, United States, Israel, Indonesia and Burma among others. They fall into the category of *Vertisols*- a soil order of USDA and FAO/UNESCO systems of soil classification (Esu and Lombin, 1988). In India, they are referred to as black cotton soils due to their coloration and propensity for growing cotton. However, by their shrink-swell characteristics, vertisols are often considered destructive to buildings and as such less or not suitable for structural foundations. This is based on their capability of causing damage to human settlement infrastructure by creating cracks and eventual damage of buildings and roads. Such cases have been recorded in many residential parts of Colorado, Texas, North Dakota, South Dakota, and Montana in the U.S.A (Sure Void Products Inc.1998).

In Nigeria, the larger proportion of expansive soils occur within the Sudan and Northern Guinea savannah zones of the north eastern part of the country (Kowal and Knabe 1972). This region is dominated by a large number of rural dwellings aspiring to develop into better human settlements in future. However, efforts towards achieving these aspirations have in most cases proved difficult due to so many factors among which is thorough understanding of geomorphic nature of the landscape and geotechnical properties of the soils. Therefore this study focuses on ascertaining the suitability of the Benue valley expansive soils for rural infrastructural development in Demsa Local Government Area of Adamawa State.

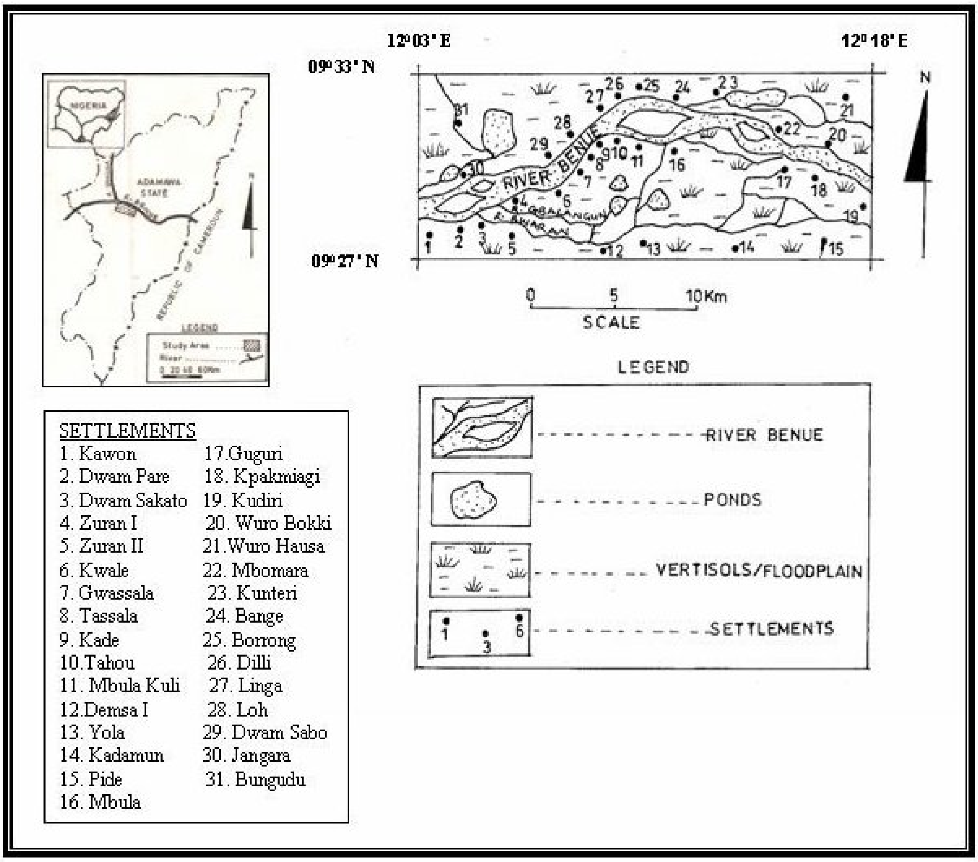
Study Area

Demsa Local government area of Adamawa state is a rural area made up of about 3,860 rural settlements occupied by a total human population figure of 180,251 (Federal Government's Extraordinary Official Gazette No. 4 of 19th January, 2007). A substantial proportion of these settlements are situated in the Benue valley floodable area, which falls into the zone of Numan expansive soils identified by Esu and Lombin (1988). However, the area delimited for this study lies between latitudes 9^0 27' N and 9^0 33' N, and between longitudes12^0 03'E and 12^0 18'E, and is comprised of about 31 major human settlements. With a mean elevation of 137 meters (450 ft) above sea level, the floodplain is characterized by slope angles ranging between 1^0 and 3^0. The main channel of the area's drainage system is the Benue River with Gbalagun and Bwarran streams as the major tributaries (see Fig 1.0). The area is predominated by vertisols, which are heavy cracking clay soils with more than 35 percent content of high clay expanding minerals; predominantly montmorillonite, characterized by vigorous swelling when wet and shrinkage when dry (Esu and Lombin, 1988).

Climate of the study area is typically tropical, marked by wet seasons from April to October and dry seasons from while the dry seasons form November to March. The hottest months of the year are mostly March and April with mean temperatures up to about 42.8^{0}C, while the coldest months are November and December, with means of about 18^{0}C. Relative humidity ranges from 20-30% between of January and March to 80% in August and September (Adebayo, 1999).

Cretaceous sedimentary deposits make up the area. The portion of the Benue valley within which lies the study area is characterized by continental conditions of Bima sandstones followed by marine conditions. The sediments which mark the change in these conditions make up a very variable sequence of sandstones and shales with thin limestones referred to as the Yolde formation (Bawden in Tuley 1972). Overlying this formation are recent alluvial deposits rich in expansive clay minerals.

Fig. 1.0 The study Area



Source: Yola Sheet 48. Edition 1, (1971)

Human settlements in the study area are rural in nature, predominated by mud buildings with thatch roofs, few concrete (cement) buildings, untarred roads and no sewage channels. The people are predominantly farmers and fishermen who also engage in small scale industrial commercial activities such as thatch and mat weaving, black smiting, calabash decorations and petty trading.

Materials and Methods

The effect of expansive soils on buildings and other infrastructure could be ascertained by apprehending the shrink-swell characteristics of the soils in relation to the level of hazard they could cause. This could only be achieved by field survey and geotechnical laboratory analyses which formed the methodological bases of this study.

Twelve (12) sample sites were randomly selected out of the 31 settlements in the study area. Twenty four (24) soil samples were collected (two samples from each site at depths of 100cm and 150cm respectively) for geotechnical laboratory tests. Two important shrink-swell tests were conducted on the soil samples to determine their Coefficients of Linear Extensibility (COLE) and Atterberg limits.

Coefficient of Linear Extensibility (COLE) is a measure soil's shrink-swell capacity expressed as:

$COLE = (L_w - L_d)/L_d$ …….(Equation 1)

Where L_w is the Length of wet soil sample and L_d is the Length of dry soil sample obtained from a standard geotechnical linear shrinkage test involving the use of shrinkage moulds, palette knives, flat glass plate, silicon grease, meter rule, 425 microns sieve and ovum. For building construction, COLE values in relation to Corresponding Hazard levels are interpreted as presented in table 1.0

Table 1.0 Coefficient of Linear Extensibility and Hazard levels.

Coefficient of Linear Extensibility	*Hazard Level*
<0.03	Low
0.03 – 0.06	Moderate
0.06 – 0.10	Severe
> 0.10	Very Severe

After Singer and Munns (1999)

From Atterberg Limits geotechnical test, Liqid Limits and Plastic Limits are determined. Plasticity indices (PI) are then obtained mathematically from the differences between Liquid Limits (LL) and Plasmits Limits (PL) of soil samples:

$PI = LL - PL$ …….(Equation 2).

The Swelling Potential of a soil is directly related to its plasticity index such that higher the plasticity index, the greater the quantum of water that can be imbibed within the soil structure and hence greater the swelling potential (Ranjan and Rao, 2000). See table 2.0.

Table 2.0 Relationship between Plasticity Index and Swelling Potential in expansive soils.

Plasticity index	*Potential for volume change*
< 15	Low
15-28	Medium
25-41	High
> 35	Very high

After Ranjan and Rao (2000)

From field survey, observable damage done to existing structures by the soils was studied. This involved taking into account the assessment of affected buildings in each sample site (settlement). Besides, the people's perceptions and responses to impacts of the soils on their infrastructure were obtained through Focus Group Interaction.

Results and Discussion

Shrink-Swell characteristics of the soils.

Table 3.0 shows the plasticity indices and Coefficients of Linear Extensibility (COLE) as well as the expansion and hazard levels of the soils at Twelve (12) sample stations. The soil at Dwam-Pare, having the plasticity indices of 29.7 to 26.2 and a COLE values of 0.18 to 0.14 possesses a high degree of expansion and a very severe to severe tendencies of hazard to building and other structures. Conditions at Zuran are similar to those at Dwam, while cases at Kwale, Mbula-Kuli and Tahau range form severe to moderate. Analyses revealed that the study area is characterized by expansive soils with a mean Plasticity Index of 25.6 and a mean COLE value of 0.08, indicating a high levels of Expansion and severe degrees of hazard tendencies to structures, thus making them not suitable for infrastructural development (see table 3.0).

Table 3.0. Shrink-Swell characteristics of the soils at sample stations.

Settlement	*Depth (cm)*	*Plasticity index (PI)*	*Degree of expansion*	*COLE*	*Degree of hazard*
Dwam-pare	100cm	29.7	High	0.18	Very severe
	150cm	26.2	High	0.14	Severe
Dwam-Sakato	100cm	22.3	High	0.07	Severe
	150cm	20.4	High	0.06	Moderate
Zuran I	100cm	26.5	High	0.14	Severe
	150cm	22.3	High	0.12	Severe
Zuran II	100cm	32.9	High	0.16	Very severe
	150cm	27.8	High	0. 14	Severe
Kwale	100cm	34.4	High	0.10	Severe
	150cm	30.2	High	0.08	Severe
Mbula-kuli	100cm	16.0	Medium	0.05	Moderate
	150cm	15.2	Medium	0.05	Moderate
Tahau	100cm	15.4	Medium	0.06	Moderate
	150cm	15.3	Medium	0.04	Moderate
Demsa I	100cm	18.6	Medium	0.07	Severe
	150cm	17.8	Medium	0.07	Severe
Kadamun	100cm	15.3	Medium	0.05	Moderate
	150cm	15.2	Medium	0.06	Moderate
Linga	100cm	9.2	Low	0.03	Moderate
	150cm	8.8	Low	0.04	Moderate
Loh	100cm	8.3	Low	0.03	Moderate
	150cm	8.0	Low	0.03	Moderate
Bange	100cm	7.8	Low	0.03	Moderate
	150cm	7.5	Low	0.03	Moderate

Source: Laboratory analyses, 2008.

Effects of the soils on infrastructure.

About 42% of the buildings in the area are affected by major cracks ranging from 50mm to 80mm or more, while 26% have collapsed due to expansive soils. Such cases are most common to structures at Dwam-Pare, Dwam-Sakato, Demsa I and Zuran I (see plate1 and 2). About 29% of the structures in the area are affected by minor to moderate damage with cracks ranging from 13mm to 55m in width. These were mostly found in Kwale, Mbula-kuli, Tahau, Loh and Linga where levels of damage range from moderate to severe. Structures with cracks 1mm to 12mm in width, most of which were new buildings constituted the remaining three percent (3%).

Source: Field Survey, 2008.

Plate 1. A Concrete building affected Expansive soils at Zuran II

Source: Field Survey, 2008.

Plate 2. A Mud Building damaged by Dwam-Pare.

People living in the area are aware that structural damage is a problem resulting from soil instability in the area but lack knowledge of the geotechnical properties of the soils let alone possible control measures. In addition to the general belief that mud housing is more durable in the area, 75% of the dwellers are low income earners (earning less than N100,000 per annum) who cannot afford the high cost of durable concrete structures. Besides, Clay profiles in the area range from 2m to 4m or more in thickness. Thus high and costly engineering technologies are required for road and drainage channels construction as well as for erection of durable concrete buildings which neither the dwellers can afford nor the government is willing to embark upon. Consequently, most settlements are cut off from the local government Head quarters (Demsa town) and other nearby central places during wet season. In addition, Electrification of some of the settlements could hardly be achieved through poles erection on the unstable soils. Respondents connect this problem to the non-electrification of Zuran I, Kwale, Tassala, and Kade settlements among others.

Conclusion and Recommendation

Expansive soils of the Benue valley area of Demsa LGA pose serious hazards to human settlement infrastructure in the area. This is a very serious and a major factor that have contributed to the stunted growth and development of human dwellings in the area. Therefore, the study strongly recommends resettlement of the residents to zones of stable soils for effective growth and development. Alternatively, modern wooden housing could be introduced to replace mud and concrete housing. In addition, treatment of the soils with lime and fly ash could be embarked upon to curtail Shrink-Swell effects; the removal of subsoil and replacement with laterite earth and stones during road construction should be encouraged. Finally, the use of underground wiring cables or solar panels for rural electrification should be pushed by the relevant agencies.

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