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THE PLACE OF ENGINEERING GEOLOGY IN URBAN AND TRANSPORT PLANNING IN NIGERIA: A REVIEW OF LITERATURE

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OLAOGUN OLUSAYO BIMBO

The input of engineering geology into various elements of urban and transport planning considered in this paper are geological and geo-technical properties of materials at the emplacement of physical structures which include dams and other water supply facilities such as reservoirs, transportation routes, waste disposal sites" recreational facilities, housing estates, industrial estates and shopping complexes. Application of principles and methods of geology for the purpose of civil engineering operations during planning for urbanization and transportation infrastructure is a necessity for the understanding of the characteristics of residual soils at the immediate sites where such operations are to be carried out. The contribution of engineering geology is mainly based on the observation made on the site and laboratory investigations. Therefore, site investigation and laboratory analysis of residual soil samples collected from a site would yield results required to write a comprehensive report. Significance of engineering geology in urban and transport planning is a systematic approach to the organization and administration of land uses to the conveniences, comfort and safety of people or inhabitants. Negligence of detailed engineering geological investigation programme in any area of urban and transport planning may lead to rapid and frequent failure of infrastructures in place, which eventually causes many lives and substantial economic losses.

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Introduction

Urban and regional planning has to do with the organization and administration of land uses the convenience, comfort and safety of the inhabitants or people but geology is the study that deals with matters concerning the earth. The science of geology is concerned mainly with the description of the original materials that made up the earth. The earth is made up of rocks, and rocks are made up of mineral which are inorganic substances with a definite chemical composition and atomic structure.

Obateru, (1976) claimed that urban and regional planning attempts to solve the problems of urban and regional growth and decay. It deals with the future physical form and structure of towns, cities and by physical structure he meant the spatial pattern or arrangement of urban and regional land uses -on a functional basis. Therefore, the ultimate aim which urban and regional planning attempts to achieve through the creation of functionally efficient physical environments for living, working, circulation and recreation.

The main elements of urban and regional planning as stated by Ayeni (1984) are the residential, industrial, commercial, educational, health, public administration, transportation, public utilities and recreation areas. Enough spaces should be provided for these land uses in appropriate locations and it involves the employment of the technique of land-use zoning. In land-use zoning, an attempt is made not only to achieve functional relationships between the various land uses but also to achieve a balanced land (space) allocation between them that is to provide adequate land for the various land uses. In nutshell, land-use zoning aim at setting aside enough land for the various land-use activities in appropriate locations in the city. Transportation and traffic constitute one of the foremost problems in planning a city. According to Ajiboye and Olaogun (2006) and also high in the list is the expansion of the various basic city services and utilities especially water supply, drainage, including flood control.

According to Adebisi (1999) and Blyth and Freitas (1974), it is the characteristics of the earth material underlying its surface determine how land can be most effectively and safely used. This is a geologic factor and it ensures that land use will not conflict with the limitations imposed by natural

condition. The consideration in urban and regional planning mentioned above revealed two important facts:

- That urban and regional planning amounts to disturbance of the initial existing structure operating in the physical earth. However, the disturbance and the response of the earth depend on the geology of a particular area and the level of or extent of human activity; and
- Most of these considerations of physical planning which problems of geology and engineering. That is physical planning processes are based on a large degree of geologic and engineering principles and practice.

It helps the planner to divide these facilities into layouts, namely residential layouts, commercial layouts, public uses and industrial layout. Engineering geology on the other hand is an applied discipline of geology that relies heavily on knowledge of geologic principles and to the practice of civil engineering for the purpose of ensuring that geological factors affecting the location, design, construction, operation and maintenance of engineering works are recognized and adequately provided for. It is an interdisciplinary profession in which the geologist works with and must understand and respond to the needs of the civil engineer by being proficient with the properties and uses of earth materials outside those commonly encountered by the practicing geologist.

Engineering geology includes Geotechnics, which is an engineering geology, reinforced with useful information from other earth sciences. An adequate notion of engineering knowledge of basic properties of rocks and minerals constituting the earth's crust is a prerequisite for geo-technical studies according to Krynine and Judd (1998). Therefore, for a good background in engineering geology, the following subjects are essential and very important Petrology, Geomorphology, Geophysics, Hydrology, Hydrogeology, Soil and Rock Mechanics

There is a very close relationship between Geology and Civil engineering. Hence, engineering geology is the connecting link between civil engineering and geology and the most related discipline in engineering is civil engineering. Therefore, roles played by engineering geologist in civil engineering are enumerated below:

- Provision of detailed description of the geologic environment which is related to the project and the description of various earth materials, their distribution, general physical and chemical characteristics.
- Deduction of the history of related events affecting the earth materials as well as predicting , future events and condition that may develop; and

- Recommendation of ways to handle and treat various earth materials and processes.

To be able to perform these roles, physical engineering characteristics of the overburden materials and underlying bedrock are clearly defined during preliminary and explorative work because these characteristics are important factors in determining site for a specific construction and foundation. These physical characteristics include, shear strength, tensile strength, compressive strength, consolidation and swelling properties, porosity and permeability. From these characteristics, both - quantitative and qualitative parameters that can cause constructional problems can be known, they give indication of expensive soils especially montmorillonite, a form of clay which is a structural hazard because of its swelling nature. Compressible soils and high water table always call tedious and expensive foundation works in transportation structures, buildings, reservoirs, dams etc.

Research Methodology

In relation to urban and transport planning, the main aim of preliminary and exploratory work is to provide a thorough investigation and examination of site before construction. According to Fookes (1967) site investigation for both surface and subsurface environment can be divided into three stages or processes. These are preliminary Investigation; field investigation and laboratory investigation while large structures such as bridges, highways, commercial and recreational buildings, reservoir and dams require these stages of investigation.

Preliminary Investigation

This involves desk study of geology, geomorphology, history and relevant case histories aimed at isolating likely problems to facilitate accurate planning. Its main objective is to give insight into problems expected on the field. A venue for desk study includes the following: topographical maps, geological maps, aerial photography, satellite imageries, published and unpublished journal/report of the study area where urban and transport planning seems desirable. Advantage of this is that it shortens the time required for the project. In order to achieve success the following procedures are necessary:

- Locate and (if necessary) get any maps, papers, air photographs, satellite imagery, data relating to the site and interpret the geological conditions from these sources. In a complex area attempt on analysis of geology and preparation of geological sections are done.

- It is necessary to seek information from the relevant research institutions.
- Location of abandoned sewage, clay pits sand and gravel workings and quarries, and
- Changes in: (i) Surface level and resultant changes in drainage, stream and river courses, and (ii) Changes in coastline due to erosion or deposition.

Other information obtainable from geological and geo-technical maps include: dip of strata, location of buried channels, river terraces, description of depth, thickness and lithology. The above procedure is made to help in the examination of a new area where there is little information about subsurface conditions. Where it is not possible to get these information through this avenue, reconnaissance survey should be done.

Field Investigation

This is a detailed geological investigation that involves putting into practice the reports of desk study and reconnaissance survey. This is used to prove the geological and geo-technical characteristics of surface and subsurface materials and to accurately describe existing conditions. It entails careful examination of solid' rocks with their strike and dip recorded, superficial deposits and topographical features.

Advanced field investigation involves drilling a trial pits, logging cores and examining pits, taking disturbed and undisturbed samples for laboratory testing. The recent application in field investigation is geophysical technique and principles the objectives of geophysical prospecting include location and determination of nature of underground water supplies, the estimation of reserves of natural construction materials. Terzaghi and Peck (1957) illustrated various test that could be carried out in the field and the properties they measure as shown in the Table 1.

Laboratory Investigation

Laboratory investigations are normally searched for when suitability of a rock or subsurface material for a particular use need be assessed, and their composition evaluated which involve laboratory testing. Laboratory testing involves examination of both disturbed and undisturbed samples collected in the field by various equipments that are bulky and cumbersome or use on the fields. Type of tests and the properties they measure are illustrated in table 2 below as stated in B.S. (1957)

From the consideration given to each step involved in site investigation, it is clearly shown that engineering geology site investigation is indirectly of significant importance in urban and transport planning because it gives indication of various characteristics of naturally occurring materials at the site. The engineering geological characteristics of surface and subsurface environments are presented as guidelines for land use planning and location of possible areas for construction. Therefore, at an early phase in any urban and transport planning programme, routine engineering geological investigation should be conducted in the area, and very detailed engineering geologic investigations are highly necessary in more hazardous areas. By knowing the particular geological characteristic of an area a project can be successfully completed.

Table 1: Field-Tests for Soil geo-technical properties.

Properties	Test
Compaction Control	Moisture density relation
	Penetrometer needle
Shear strength (especially for soft soil)	Vane Test
Relative Density	Standard Penetrometer test
Permeability	Pumping test
Bearing capacity	California Bearing Ratio test
(For footing)	Plate Bearing
(Vertical load)	Load test
(For magnet)	Plate Bearing

Material Analysis

The input of engineering geology into urban and transport planning processes is mainly physical. Various elements (physical infrastructural facilities) in urban and transport planning that usually make life easier and ensures safety have a lot of engineering geological input, be it in transportation routes construction, dams and reservoir construction, water supply, disposal of wastes/land fill sites. The input and importance of engineering geology into each of these elements cannot be over emphasized.

Table 2. Basic geo-technical tests for residual soils.

Properties	Test
Grain size	Sieve analysis
Consistency plasticity index	Liquid limit, plastic limit,
Moisture	Natural moisture / water
Volume change	Shrinkage factor expansion
Pressure volume change. Compressibility	Consolidation test
Permeability	Permeability test
Compaction Characteristics	Compaction test Standard
Proctor test	Modified proctor
Bearing Capacity	California Bearing Ratio test

Transport Planning

Engineering geological work is required in determining the best possible locations of roads, railways, airfields, canals, pipelines, etc and engineering geologist must carry out a thorough study of any proposed site. The study grossly involves geological and geotechnical characteristics of the existing materials and some that are borrowed or procured for use in construction of the pavement and any other relevant facility. This is essential so as to ensure durability and the least possible maintenance of the intended infrastructure. The use of improper materials makes the structure in place sub-standard, thereby perform short of expectation.

Highways, airfields and railways have certain similar engineering requirements. The routes have level, smooth, and well-drained surfaces with sufficiently firm bases. Heavy aircrafts can extend stress deeper than one meter, therefore soil condition beneath a proposed airfield should be explored to a depth of at least two meters. Highways and airfields should be located over low water table and away from area of potential flooding. Knowledge of the engineering classification and properties of the soil is derived from the data gathered from exploratory work and forms the basis for the characteristics of road pavement design and construction. The sub grade materials are subjected to clarification test for liquid limit, plastic limit and particle size distribution, strength tests of compaction, California bearing ratio and consideration of water table, soil moisture and drainage. The materials that are identified to have high tendency to notably shrink eventually are often avoided in pavement construction. The existing unsuitable materials along the proposed path should

be removed and technically replaced by materials found suitable. The engineering geological study of road construction materials is an invaluable aid to road planners, designers and contractors.

Buildings Layout

The purpose of geological engineering investigation on a proposed site for building(s) is to gather sufficient geotechnical data from the field and laboratory. Professional recommendations are thereby made in respect of the data analyses. The recommendations are usually on suitable foundation type for the intended structure, permissible ground bearing pressure and formation levels, ground water table for water related matters, topography, naturally existing construction materials availability for use, foreseen hazardous occurrences such as landslide, earthquake etc.

Dam Construction

Well or boreholes should be sited where it is not likely to be polluted and where it is likely to meet water in reasonable quantity with minimum effort. Dams are constructed for the purpose of water storage for community, industrial, domestic use, agriculture, flood control, the development of hydroelectric power and silt and debris control. The type and size of dam constructed depend upon the need and the amount of water available, typography and geology of the site. Engineering geology is applied to look for the site of dam, which is the best place for the dam, taking into consideration the nearest source of suitable materials for construction. This involves studies of geology, lithology, hydrology / hydrogeology of the site and the determination of engineering properties of the lithologies represented in the geological sections along the possible lines for the dam. The nature of valley, the nature of the rock surface or rock across the valley is also taken into consideration. Engineering geologist field and laboratory investigation on sub-soils and rocks searches for the physical and chemical characteristics -of rocks and soils to determine their suitability.

Water Supply

Urban and regional planning makes provision or takes into consideration an access to good and safe water supply. The water supply in some cases in urban areas are in form of boreholes, the engineering geologist is actively involved in drilling of boreholes to harness underground water. Engineering geologist carries out site investigation to provide information on geology, hydrology, quality, and recoverability of water in the area. He also includes several series

of statistical reports on stream flow, floods, ground water levels in the area (United States Geological Survey, 1993). This site investigation determines where best to drill for ground water.

This involves both surface and subsurface investigations. Subsurface investigation involves searching for groundwater through drilling or boring into sub-surface strata, the hole is of small diameter called test hole or observation hole. Based on the engineering geologist sound knowledge and background in geophysics and hydrology / hydrogeology, the engineering geologist does the initial geophysical survey to determine the properties of the underlying rocks. These properties include the strength of the bedrock, porosity permeability and resistively. The proper analysis of the samples is done in the laboratory. From the result of resistivity survey and the geology of the area is evaluated and a well is sunk.

Other indirect investigation technique include geologic methods and involves collection of analysis and hydrological interpretation of the geologic map, topographical map and borehole/well logs of the area and other records. It also entails reconnaissance survey of the site. Here, rock or subsurface materials in the area, streams, vegetation, spring (water table) condition and well yield are greatly considered, rock type will be able to suggest the magnitude of water yield to be expected.

Remote sensing and GIS techniques involve the use of black and white photographs interpreted using stereoscope or computer processing of satellite imagery and overlay with maps and other information that could be geographically referenced. (Adebisi, 1999). The information that can be derived from the air photograph and imageries are drainage pattern, topography, geologic information, soil or rock, vegetation, secondary features like fault, joints, etc from these, engineering geologist detects the chances of getting water either for domestic, industrial or municipal use.

Recreational Facilities

The immediate concern in urban centers is the acquisition of appropriate sites for schools and recreational facilities. This is because urban areas harbour different categories of people including rich, the middle class and the poor. These recreational facilities include recreation centers like Trans Amusement Park, Lekan Salami recreation center in Ibadan, Oyo State, National stadium and National park, Abuja. Others include sport centers like Liberty stadium Lagos which consists of swimming pools football pitch, shopping complexes and so on.

The roles of engineering geologist in the provision of recreational facilities are:

- The determination of suitable sites for the location of various recreational facilities because these facilities cannot just be built anywhere. Their location is controlled by the characteristics of the underlying rocks or soil which are determinable by an engineering geologist and the type of recreational facilities based mainly on the amount of crowd it is required to pull. For instance, a football pitch cannot be built in a swampy area or a sloppy area unless necessary steps are taken to offset the conditions, which are within the area of professional competence of an engineering geologist because the extent of slope and digging required as well as material quantity and quality needed to meet the specification should be determined by relevant engineer and geologist.
- The location and recommendation of suitable materials that can be used in the construction of the facilities based on characteristics such as bearing, strength, plastic limit, liquid limit, compressibility etc of the materials. For instance construction material of a swimming pool are those that are resistant to water erosion.

Other basic infrastructural facilities include schools, hospitals, library and other important buildings like housing estates and market places. Their constructions must be supported by the materials that form the upper part of the earth's crust. These supports are called foundations and they give stability to building so as to avoid their collapse. According to Krynine and Judd (1998), there are two major categories of foundations. These are shallow foundation and deep foundation. The shallow foundations are those located just below the lowest point of these structures which they support. Examples are isolated footing, strip or raft. Deep foundations are considered when the soil is of poor quality to permit shallow foundation that is, when shallow foundation will be subjected to bearing capacity failure, vibration or excessive settlement. A common example is pile foundation.

The site and type of foundation suitable are determined by an engineering geologist after detailed preliminary and feasibility study followed by detailed site exploration. The last stage is foundation investigation which is based essentially on report of site investigation therefore a satisfactory foundation must meet these requirements:

- It must be placed at an adequate depth to prevent frost damage, undermining by scours or damage from future construction nearby;

- It must be safe against breaking into the ground; and
- It must not settle enough to disfigure or damage structure (George and George, 1970).

The organization of investigation programme is always treated according to the categories of building namely: residential buildings; commercial buildings; industrial buildings; and power or pumping plants. Engineering geological investigation in this regard should define grain size of the soil type or bedrock, their thickness and distance from the surface, porosity, permeability of the rock / soil that will bear the load, the partial and total settlement, compaction characteristic, bearing capacity of soil and on bed rock, shear strength of materials that will bear the load, consistency, slope stability, underground defect such as faults, groundwater conditions, depth of frost in temperate environment. These are necessary because;

- The ground conditions at proposed building site may be one of these three general types;
  - (i) Solid rock may exist below ground surface or so close to the surface that the building may be founded directly upon it;
  - (ii) Bedrock may exist below the ground surface but at a distance that may economically be reached so that the building load can be transmitted to it;
  - (iii) The nearest rock stratum may be so far below the surface that the structure will have to be founded upon the unconsolidated material overlying the bedrock.
- It is on these characteristics that the designs of specific building foundations are based.

In foundation design, an engineering geologist ensures that the foundation is properly located (in both vertical and horizontal orientation) so as not to adversely be affected by outside influence; the foundation and therefore the entire structure is safe from bearing capacity failure, the foundation is safe from excessive settlement after the post constructional work; the conditions predicted are confirmed.

Disposal of Wastes

An urban center must be planned in such a way as to make allowance for effective and safe disposal of waste without any danger of pollution of the environment and drinking water which is very much needed for human health. Safe waste disposal ensures that no dangerous product can travel far from their repository until they have degraded to a safe condition. To predict the rate of

migration of waste products that have been buried in the ground, it is necessary to study the geology of the disposal site and a special consideration must given to the movement of ground water (Todd, 1980). There are three places where wastes can be disposed into, the air, water or land. A safe method of refuse disposal is dumped in sanitary landfills. The domestic and building waste and certain industrial wastes degrade quite rapidly to safe by products and can be disposed off in surface excavations. Abandoned quarries and pits offer favourably sites or this waste which is used to fill them in and restore ground level to its former elevation, waste stored in this form is called landfill.

Groundwater suppliers in aquifers that extend beneath a land fill site, would be contaminated if the leachate were to reach them, therefore it is the work of engineering geologist to locate suitable sites and soil/rock type that is favourable to the construction of land fills depending on the pollution potential of the solid waste, while other methods of solid waste disposal are incineration, feeding of garbage to sucone composting.

Conclusions and Recommendations

The roles of Engineering Geology in urban and transport planning are fully discussed in this paper. Therefore at an early phase in urban planning routine engineering geological investigation which includes preliminary investigation, site investigation and laboratory investigation are necessary. As stated by Obateru (1976), there are basic principles of urban land uses in which the following physical environmental features should be given appropriate treatment. They are: steep

slopes; irregular and rugged sites or areas derelict quarried lands; rock outcrops, especially extensive ones; extensive sand tracts; wetlands; marshes and swamps; flood plains; surface water bodies; and wild-life - flora and fauna.

However, the importance of engineering geology in dam construction, transportation route, waste disposal, water supply and recreational facilities are fully discussed according to the above- mentioned physical environmental features in urban and transport planning. From the scope and definition of engineering geology and urban and transport planning as outline in this paper, it is obvious that engineering geology has a tremendous significance in urban and transport planning. In this case, at an early stage in urban and regional planning programme, routine engineering geological investigation should be conducted in the area and a very details engineering and geological investigations are highly important in more hazardous areas.

Therefore, negligence of very extensive and detailed engineering geological investigation, programme in urban and transport planning can be hazardous and. this can result in collapse of physical building structures such as St. Francis dam of California in 1928 and flood recorded in Oyo State where several buildings has collapsed across the country. For instance at Oremeji in 1980 and in River State in 1990. It is therefore recommended that detailed geological and geo-technical investigation must be carried out in an area where urban planning seems desirable.

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