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BUILDING IMPLICATIONS OF ADEQUATE SITE INVESTIGATION AND ANALYSIS: AN ARCHITECT'S POINTS OF VIEW

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ABSTRACT

This submission attempts to x-ray the underneath concept of site investigation and analysis with a view to revealing the implications of the choice site in terms of its general suitability for the intended use. This is examined considering the statutory building regulations in an area, physical contents as well as geotechnical data of the site. Hence, the information/data obtained are synthesized to serve as a veritable guide in the choice of site selection and its subsequent planning.

Key Words: *Bearing-capacity, Exploration, Foundation, Geotechnical, Subsurface*

INTRODUCTION

Prior to commencement of the design and construction of any building operations, the need to carefully consider the implications of its proposed physical context, the building site, could not be under-estimated (Francis 1975). All potential sites need to be investigated to determine their suitability for building, so also the nature and the extent of the preliminary works that will be required. This, which essentially involves gathering of both visual and geotechnical information about the proposed site, is largely determined by robust interactions of the design and construction teams (i.e. the client, the architects, the engineers, the contractors among others) as well as, with the officials of the local planning authorities. These interactions of the relevant professionals which reveal the site geotechnical location, topography, climate, orientation, soil behavioral pattern (before, during and after construction) as well as other site peripheral conditions would ultimately influence the choice of the site to be acquired and the building form (i.e. its orientation and relationship to the ground plane, its interior space design and layout, its structural system, materials and construction methodology) to evolve. It may also determine the correct sitting of a building with a view to controlling effects of natural light, heat, view, noise and other environmental elements by providing the building and its occupants with access to desirable elements and absorbing or shielding them from those elements considered otherwise.

Site Investigation and Analysis is considered an important preliminary activity before the site selection and commencement of building design and construction to ensure that:

- The prevailing statutory regulations in the area in respect of site acquisition and transformation are not contravened;
- The site conditions, especially the topography among others are adequately taken care of in the evolution of the design form;
- Overall stability of the proposed building form with regards to the prevailing climatic conditions as well as behavioral pattern of the soil before, during and after the construction works is achieved;
- If there are existing structures to be removed, the method of removal envisaged is appropriate and constitutes no hazard to anyone and;
- Speedy completion of project as it serves as an indicator for the types of problems to be expected with a view to solving them in advance (Obande 1990).

For any meaningful and effective Site Investigation and Analysis, information obtained must satisfactorily answer the following fundamental questions (Sidney 2001):

- Does a visual inspection of the site reveal any clues to the composition and consistency of the soil?
- Are there rock outcroppings? If so, what is the nature of the rock?
- Is there any indication of the presence of ground water close to the surface of the site?
- Do any remains of abandoned subsurface structures appear in areas where excavation will be required?
- Do any structures require demolition in areas where new structures are to be built or where underground utilities are to be installed?

- Are any utilities absent that might be required during construction (i.e. water, electric power, telephone lines, sanitary and storm sewers or gas mains)? Are any of these utilities in areas where new construction will be required are to be relocated?
- What do the soil test borings reveal?

FORMS OF SITE INVESTIGATION AND ANALYSIS

With the exception of high cost of land and planning controls, which frequently combine to prevent the acquisition of the ideal site, Site Investigation and Analysis in its pragmatic approach, entails obtaining information about the site in two major forms:

- (a) Visual inspection of the proposed site and;
- (b) Subsurface geotechnical investigation of the site.

Each of these is now considered in turn as follows:

a. Visual Inspection of the Proposed Site

This entails a reconnaissance visit to the site to investigate its physical features (especially the surface features). However, this is preceded with an initial visit to the local planning authorities to ascertain whether there are any special or significant restrictions, which could adversely affect the development of the site. Such facts finding visit should reveal information about details of the neighbouring development and the position with regard to facilities in the area, a study of Ordnance Survey maps to show the presence or otherwise of disused mines or former ponds or tips on the site which could have since been filled as well as knowledge of any restrictive covenants such as rights of way, light and drainage, which may restrict the development (Ivor 1987). Then, the actual physical site inspection follows. This is done in form of a visit to the site and its surroundings to record everything relevant to the proposed development. Usually done with two or preferably three categories of people inclusive of the architects, engineers and contractors with each taking his notes and discussing features as they come across them. In this case, careful observations should be made of the vegetation, evidence of marshy ground, signs of ground water and flooding, irregularities in topography, ground erosion and ditches and flat ground near streams and rivers where there may be soft alluvial soil. In line with this, records should be made of the foundations of old buildings on the site. Cracks and other signs of movement in adjacent buildings should be noted. When such site reconnaissance is being undertaken on contaminated land (Stephen and Christopher 2005), it must be ensured as far as possible that all hazards are identified and correct safety procedures are followed. In preparation for the site reconnaissance generally, all of the maps and records should be assembled, so that any differences or omissions found when walking over and observing the site can be recorded. A visual inspection of physical site boundaries should be made and compared with any legal documents that show boundaries.

In addition to all these, the following features with their possible interpretations should be noted on site:

- Any unusual steps on the surface which may be indicative of geological faults;
- Steps in mining areas may be consequent of subsidence. Other evidence of subsidence caused by mining may include compression as tensile damage to structures and roads, structures out of plumb; interference with the line of drainage patterns;
- Mounds and hummocks in relatively flat region in some cases often indicative of former glacial conditions (for example, glacial gravel);
- Where the ground is terraced and broken on hill slopes, this may be due to landslips, small steps and inclined tree trunks may be evidence of creep and ground movement;
- Crater type holes in chalk or limestones usually indicate swallow holes that have been filled with a soft material;
- Low-lying flat areas in hill country may be the site of a previous lake and can indicate the presence of soft silts and peat and;
- Nature of vegetation in relation to soil type and wetness of soil as unusual green patches, reeds, rushes, willow trees and poplars usually indicate wet ground conditions (Stephen and Christopher 2005).

b. Subsurface Geotechnical Investigation of the Site

Beyond the visit to the site for visual inspection of the features, details of the subsoil to include the soil type, consistency or strength, soil structure, moisture conditions and the presence of roots at all depths is very important. Information obtained from the nature of the subsoil would greatly assist to determine its bearing capacity, seasonal volume changes and other possible ground movements associated with the soil. Also,

conditions of ground instability such as geological fault, landslide, disused mines or unstable strata, which may affect a building, would be revealed. Essentially, information gathered in respect of the soil investigation includes the following (O'Flaherty 2002);

- *The depth, arrangement and nature of underlying strata:* the depth to the top of each underlying stratum and the thickness of each stratum, need to be determined. Also, the materials in each stratum need to be described and classified; in this context, the variability of each layer needs to be established, including the structure of the material (e.g. any fissures, laminations, interbedding, etc.). Particular attention should be paid to material changes that are near the ground surface as these may be associated with weathering or surface movement;
- *Strata Irregularities and features of special engineering significance:* This refers to natural or man-made discontinuities and distortions that might underlie the proposed site. Classical natural examples are fractures (including faults, fissures and joints), tilting and distortion of beds (including dipping, folds, contortions, cambering and valley bulging), cavities (including open fissures, solution cavities and swallow holes), and surface movements (including solifluction and instability). Typical man-made cavities include mines, adits, shafts and cellars
- *Hydrological Condition:* Ground hydrological information is required, in order to resolve many stability and settlement problems and for the design of measures to lower the groundwater level either permanently or as a construction expedient. Classically, appropriate information is gathered regarding water table levels and their seasonal and tidal variations, artesian pressures, strata permeability, wet and soft ground and peat, and springs, seepages and periodic streams;
- *Quantitative engineering characteristics of the strata:* The detailed engineering design may require the carrying out of special in-situ tests or the taking of disturbed and/or undisturbed samples for subsequent laboratory examination(s).

METHODS OF SITE INVESTIGATION: SUBSURFACE EXPLORATION

Many methods have been devised to securing information regarding the ground subsurface depending on the location and geotechnical features encountered. However, these various methods could broadly be divided into four main groups (O'Flaherty 2002):

- (i) **Exposures:** this involves direct observation through natural or existing adequate subsurface 'windows' e.g. outcrops, streambeds, quarries and surface deposits. However, care needs to be taken to ensure that these exposures are typical of the locale as otherwise, misleading interpretations may be made.
- (ii) **Accessible Excavations:** this provides an excellent way of examining and sampling soft rocks and non-cohesive soils containing boulders, cobbles or gravels. In this case, shallow test pits and trenches are dug above the water table (usually to a depth of 4-5m) to enable a direct visual examination and a photographic record of in-situ soil conditions.
- (iii) **Probing and Borings:** This is best adopted when another ground investigation method indicates a relatively thin layer of soft soil overlying a harder one and the thickness of the soft stratum needs to be checked quickly and economically; over a wide area e.g. to determine the depth of peat deposits. Essentially, probings which is also known as "soundings", involve pushing or driving sections of steel rod down through the soil; in its simplest form, it consists of a 25mm diameter pointed steel rod that is driven into the ground with the aid of a sledge hammer. However, one elaborate equipment has a pipe surrounding the rod, to eliminate side-friction and measures the resistance to penetration by recording the number of blows or force of a jack required to advance it a given distance. This may involve sinking boreholes. In this case, results are interpreted by comparing the readings with results from known profiles obtained with these penetrometers. Major types of equipment used include soil augers, shell and auger rigs, wash borings and rock drills (such as churn drills, diamond drills and shot drills-Whitney 1963). The choice of a particular type at a given site depends on a number of factors such as site accessibility, equipment availability, soil type, likelihood of rock, sampling requirements, depth of excavation and/or ground water conditions.
- (iv) **Geophysical Profiling:** This is an advanced form of subsurface investigation whereby specially developed instruments are used at the ground surface to obtain measurements of variations in the physical properties of subsurface materials. By correlating with the available geophysical data, the measurements obtained are then interpreted to provide information regarding the underlying materials. The speed and relative cheapness with which particular subsurface information can be obtained for a large site with reasonably uniform overburden conditions

make this method greatly advantageous. In this case, the digging of pits or the sinking of boreholes can then be restricted to control points where correlation testing is required and to locations where correlation testing is required as well as to locations where readings are obtained.

In addition, this method of site investigation is used in these four major areas of relevance:

a. Geological Investigation: This is used in;

- Mapping geological boundaries between layers;
- Determining the thickness of superficial deposits and depth to 'engineering rock head';
- Establishing weathering profiles;
- Study of particular erosional and structural features e.g. location of buried channels, faults, dykes etc.

b. Resource Assessment: This is used in:

- Locating aquifers and determining water quality;
- Exploration of sand and gravel deposits and rocks for aggregate;
- Identification of clay deposits etc.

c. Hazard Assessment: This is used in:

- Detecting voids and buried artifacts, location of buried mineshafts, natural cavities, old foundations, pipelines etc;
- Detection of leaks in barriers and pollution plumes on landfill sites.

d. Engineering Properties Assessment: This is used in:

- Determination of such properties as dynamic elastic moduli, rock rippability and quality;
- Soil corrositivity for pipeline protection studies etc;

SUBSURFACE EXPLORATION: CLASSIFICATION OF SOILS FOR BUILDING PURPOSES

Soils are grouped by reference to the size and nature of the particles as well as the density of the particular soil. Soils can conveniently be classified under five main headings as follows (Ivor 1987);

- Rocks which include igneous rocks, limestones and sandstones;
- Cohesive soils such as clays where the constituent fine-grained particles are closely integrated and stuck together;
- Non-cohesive soils such as gravels and sands, whose strength is largely dependent on the grading and closeness of the coarse grained particles;
- Peat, which is decayed vegetable matter of low strength with a high moisture and acidic content and;
- Made Ground, which may contain waste of one kind or another and can cause settlement problems.

The grouping above with individual corresponding bearing capacities is represented in Table I

BUILDING IMPLICATIONS OF SUBSURFACE EXPLORATION

With the knowledge of various categories of soil as revealed in the preceding section, their individual inherent properties vis-à-vis behavioral pattern under imposed building loads are now being reviewed with a view to understanding building suitability of a particular site, consequent upon the constituents of the underlying materials;

- a. Hard rock provides a good foundation but increases excavation costs and may cause difficulties in the disposal of sewage effluent on isolated sites (Ivor 1987);
- b. Cohesive soils: These are soils, the particles of which stick together, such as clays. Clay soils generally are subject to shrinkage and cracking in hot dry weather, followed by expansion in wet weather, they change in volume according to their water content. Unless adequate precautions are taken, such movements may cause considerable damage to buildings erected on subsoils of very soft clay especially. As the movement decreases with the depth below ground level, it is important that the foundations should be relatively deep. Hence, on shrinkable soils, it is recommended that the foundations of external walls should be of pile and beam type or of raft construction (McKay, 1992). In addition to the undesirable property of expanding and contracting, clay soils have a relatively low shear strength and a correspondingly small safe bearing capacity (refer to Table I).
- c. Non-cohesive soils which include gravels and sands. The strength or bearing capacity of such soils depends upon the grading, packing and average size of the particles. In general, the better the grading (as distinct from uniformity), the tighter the packing and the larger the grains, the higher will be the capacity for load carrying. Gravel is probably the ideal subsoil, being strong and drains well but if loose, could be subject to movement (Ivor 1987).

- d. Peat is decayed vegetable matter, black or dark brown in colour. It is highly compressible, thus unsuited to receive foundations, even those of light structures. If such a site must be used for a building project, it is necessary to support the foundations on piles, which are driven down to an underlying firm stratum.
- e. Made Ground or Fill. This is where soil or other fill has been deposited to make up levels and usually lengthy periods of time are needed for settlement. Owing to the possibility of unequal settlement and presence of injurious chemicals or unsanitary materials in the fill, it may be necessary to use raft or piled foundations (Mckay 1992 and Ivor 1987)

CONCLUSION

Having examined the relevance of visual inspection and subsurface exploration of any proposed site, it could be inferred that all potential building sites need to be investigated to determine their suitability for building as well as the nature and extent of the preliminary work that will be needed. Particular attention should be given to the nature of the soil and its probable load-bearing capacity by means of trial holes or borings, as there may be variations over the site. The level of the water table should also be established as a high water table may necessitate subsoil drainage and could cause flooding during raining season. In addition, there should always be robust interactions with the local building authorities to avoid unnecessary contravening of the prevailing restrictions in the area. These would indeed go a long way to ensure acquisition of good sites, which will be adequate for the desired purposes, physically and geo-technically.

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TABLE 1: SOIL TYPES WITH THEIR CORRESPONDING BEARING CAPACITIES

Group		Types of rocks and soils	Bearing capacity (KN/m ²)
I ROCKS	1	Strong igneous and gneissic rocks in sound condition	10000
	2	Strong limestones and strong sandstones	4000
		Schists and slates	3000
	3	Strong shales, strong mudstones and strong siltstones	2000
	4	Clay shales	1000
II NON- COHESIVE SOILS	5		
	6	Dense gravel or dense sand and gravel	>600
	7	Medium dense gravel or medium dense gravel and sand	<200 to 600
	8	Loose gravel or loose sand and gravel	<200
	9	Compact sand	>300
III COHESIVE SOILS	10	Medium dense sand	100 to 300
	11	Loose sand	<100
	12	Very stiff boulder clays and hard clays	300-600
IV	13	Stiff clays	150-300
		Firm clays	75-150
	14	Soft clays and silts	75
V	15		
	16	Peat and organic soils	Foundations carried down through peat to a reliable bearing stratum
	17	Made ground or fill	Should be investigated

Source: R.BARRY (1993) pp2