ARCHITECTURAL DESIGN CONSIDERATIONS FOR STABLE BUILDING STRUCTURES ALONG SLOPPY TERRAINS IN OKIGWE, SOUTHEASTERN NIGERIA

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ABSTRACT: Over the years, land-use planning has in the main, marginalized sloppy sites and areas with undulating topography as not good enough for housing development. Property developers and indigenes of areas blessed with sloppy terrains have frequently avoided erecting any durable structure on such sloppy sites for reasons associated with the topographic factor, erodibility, flood and erosion, slope failure, etc. Even property buyers scramble for plain table sites in preference for building development as against areas with sloppy terrain. This trend is not healthy for the Okigwe axis of the Eastern region of Nigeria since land is already a scarce commodity in this area owing to the seeming unfriendly topography of the region.

The benefits accruable from building along sloppy terrains are quite encompassing. However, it is the determination of this research to unravel treatments worth considering by the architect at the outset of any building design to be erected along sloppy terrains. These treatments shall measure environmental, geologic and topographic factors to arrive at an architectural result. The anticipated result is that; best landscape technique, foundation type, and water discharge/channelling mechanism will be specified for buildings to be sited along these terrains to avoid inducing erosion. Nevertheless, the application of these specifications shall be based on the percentage slope of the site under consideration.

Keywords- Architectural Considerations, Sloppy Terrains, Slope Failure, and Slope Stability.

1. INTRODUCTION

Architectural design, through a pre-conceived brief development and lines configuration, can contribute positively to the development of building stability parameters to be applied along sloppy terrains. It is in practice that the architect is often referred to as, “de premius enterperise”, that is, “the first amongst equals” in the building industry because he is the initiator of the project to which other members of the industry, and environmental managers are contributors. This premise lends credence to the conviction of this proposal that slope stability and building stability determination on slopes, should as a practice, be initiated right from the outset - on the architect’s drawing board.

Over the last hundred years, according to Montgomery (2000), it has become increasingly possible to incorporate geologic principles and considerations into architectural designs and construction plans. It should therefore be the paramount concern to the modern architect to take a site’s geology and erodibility factors fully into account in designing a building, so that the structure can be safe and stable (Abdulkarim, 2004). The purpose of architecture and land-use planning, according to Rahn (1986), is to make the best, most sensible, practical, safe, and efficient use of each parcel of land whether on a plain or sloppy terrain. Land management for building construction, particularly on slopes, entails decision-making and the implementation of such decisions about the land. The majority of such decisions are architectural and should begin on the Architect’s drawing board. Because such decisions are based in part, on geologic and environmental considerations – architecture, geology and land-use planning overlap (Dale and McLaughlin, 1990).
In its entirety, considering the three aforementioned and overlapping environmental professions as tools for explanation, this study intends to carry out all necessary tests and investigation pertaining to the development of stable building structures along sloppy terrains. One of such tests and investigations will centre on surface erosion, which is more identifiable on areas with sloppy terrains.

2. STATEMENT OF THE PROBLEM

Over the years, property developers and indigenes of areas blessed with sloppy terrains have frequently avoided erecting any durable structure on such sites for reasons associated with topographic factor, erodibility, flood and erosion, slope failure etc. Even property buyers scramble for plain table sites in preference for building development as against areas with sloppy terrain. This trend is not healthy for the Okigwe axis of Imo State, in the south-eastern region of Nigeria, where land is already a scarce commodity due to erosion and the seeming unfriendly topography of the region. Given the factors that influence slope stability, it is possible to see many ways in which human activities increase the risk of slope failure. One way is in the clearing away of stabilizing vegetation. Many types of construction and farming lead to over-steeped slopes. Construction of stepped home-building sites on hillsides are among the activities that can cause slope failure. Slopes cut in unconsolidated materials at angles higher than the angle of repose of those materials are by nature unstable, especially if there is no attempt to plant stabilizing vegetation. Carefully planned grading, terracing, and channel construction should be made to control the flow of runoff water, because water strongly affects the engineering behaviour of most soils, especially fine-grained soils. Water is also an important factor in most geotechnical engineering problems. When a soil deposit is loaded, for example by a structure, deformations will occur. The total vertical deformation at the surface resulting from the load is called settlement. Problems of settlement of structures and the stability of foundations and slopes also involve water to some extent (Holtz and Kovacs, 1981). The rate of settlement depends on the rate of pore-water pressure. Increase in pore-water pressure in saturated soil decreases the soils resistance to shearing stress, tending to cause faulting and/or sliding which is tantamount to slope failure (Montgomery, 2000).

In carrying out this research work, how to control and put checks on water force becomes imperative owing to the fact that water significantly reduce the strength parameters of soils, especially the friction strength parameter. Where strength criterion is given as:

\[ \gamma = C + \partial \tan \phi \]

Where

- \( \gamma \) = Shear strength
- \( C \) = Cohesion strength parameter of soil mass joints
- \( \partial \) = Applied normal stress on the soil medium
- \( \phi \) = Friction strength parameter of soil joint or soil mass

The presence of water in soil changes this equation to

\[ \gamma = C + (\partial - \mu) \tan (\phi - \mu) \]

Where \( \mu \) = pore water pressure – (Teme, 2002)

At this juncture, I make bold to state that, knowledge and application of these environmental forces which determine slope stability and/or failure are the basis of this research work which intend to unravel treatments worth considering at the conceptual stage of any architectural design of buildings to be sited on a sloppy terrain. All of this is geared
towards making sloppy terrains attractive for building development; and building development itself becomes a means of erosion control on slopes.

Bergsma (1986) in his analysis of the influence of relief on erosion outlined seven classes of steepness, which are related to those of soil survey.

- Nearly level 0 – 2%
- Gently undulating 2 - 4%
- Steeply undulating 4 – 6%
- Gently rolling 6 – 10%
- Steeply rolling 10 – 16%
- Hilly 16 – 25%
- Steep 25% and above

Whereas Brady and Weil (1999) advised that possible slope failure should be investigated particularly on a site with more than 15 percent slope (15 meters of rise over 100 meters of horizontal distance), on a site with much steeper slopes above or below it, or in any area where erosion is a recognized problem.

The Okigwe topography, which is steeply rolling and hilly, falls into the 5th and 6th classifications of Bergsma (1986); and from the hill summits and slopes the soil has continually been under the influence of erosion and slope failure (Jungerius, 1964). This range of topographic factor to which Okigwe belongs, forms the premise upon which this research work is founded. Nevertheless, the determination here is to pursue a change in the negative attitude towards building along sloppy terrains by focusing on requisite architectural design considerations that can be used to mitigate against natural contributors to building failures on slopes and make building on sloppy terrains be of interest.

To address these issues, this research intends to use the following questions as the guide:

1. What are the causes of slope failure and what architectural control measures can be utilized along the slopes?
2. How can architecture best utilize sloppy terrains for stable building development?
3. How can rainwater and surface erosion of sloppy terrains be controlled from building design to finish?
4. What building codes and standards should be maintained in designing for sloppy terrains?

3. STUDY OBJECTIVES

In sloppy areas, landslides are frequent and hazardous; it therefore becomes important that the stability of slopes with building loads be checked. However, it is the determination of this research work to develop architectural design considerations against sliding failure of slopes in view of building loads being transferred to the slope. Architecturally, the stability of slopes with differently configured buildings will be studied, while provisions will be made for soil test investigation and the determination of stepped foundation as a suitable foundation type for sloppy site buildings. If sloppy sites are indeed to be successfully developed, then these special factors have to be taken into account, understood and evaluated fully, before pen is put to paper in the preparation of any design.

All of these are geared towards achieving the following objectives through architectural design and specifications:

1. To identify factors worth considering at the conceptual stage of any architectural design of buildings to be sited on a sloppy terrain.
(2) To evaluate sites not more than 25% sloppy for stable building development.

(3) To ascertain the impact of landscape architecture in flood and erosion control along sloppy terrains.

(4) To assess the use of roof design, parapets, and duct service systems in checking rainwater discharges at headwater regions of slopes as a means of controlling erosion along slopes.

(5) To determine the most suitable foundation for giving stability to buildings along sloppy terrains.

4. JUSTIFICATION OF THE STUDY

Man, like all living creatures, is part of his environment: both as a product and a shaper of it. Like other creatures, he is totally dependent upon nature for his fundamental life support requirements. His vast capacity to use and adapt to these natural forces and resources differentiate him from other species even though he frequently takes them for granted. Man alters the environment in almost everything he does and ends up threatening his own corporate existence. One of such alterations made to our environment is in the area of construction and urban development, which changes the course of nature with attendant effects of flooding and erosion.

The relevance of this study is therefore related to the need to bring man closer to the natural environment – visibly manifest in the form of hills (slopes), greenery, water bodies, etc. The results obtained from this research will provide parameters for requisite architectural design considerations for housing developments on sloppy terrains.

The results will serve as handbook to architects and land-use planners; and could equally be enshrined in the building regulation policies of Local Government Areas with sloppy terrains. The long term relevance is that, it will help create awareness in the use of sloppy terrains for housing projects; and also prove housing on slopes as a better way of controlling rainwater induced erosion at head-water zones.

5. LITERATURE REVIEW

According to the United Nations Environmental Protection (UNEP) (2000), sustainable urban development requires considerations of the carrying capacity of the entire ecosystem supporting such development, including prevention and mitigation of adverse environmental impacts occurring in that urban area. Site slope angle, soil infiltration capacity, permeability, Erosion, and bearing strength of the soil, are among the considerations in alignment with UNEP specification with reference to this research. In the same vain, the only adverse environmental impact requiring prevention and mitigation in the sloppy area of Okigwe is, surface erosion. The prevention and mitigation of these, using design principles, are found in the requisite architectural design considerations, which this proposal intends to unravel.

Brady and Weil (1999) observed that the goals of preconceived architectural control on building construction sites are (1) to avoid on site damage, such as undercutting of foundations or finished grades and loss of topsoil needed for eventual landscaping; and (2) to retain eroded sediment on-site so as to avoid all the environmental damages that would result from deposition of sediment on neighbouring land and roads, and in ditches, reservoirs, and streams.

Architecture is perhaps one of the most potent forms of artistic expression in the building industry that encapsulates many forces of a geographical region. The natural forces of
geography and geology like soil strength, climate and abundant materials for construction; the socio-cultural forces like ethnicity, faith, folklores; economic factors like labour and materials; technological forces as various modes of energy and building systems, all affect and reflect in architecture (Ozkan, 2004).

The impact of landscaping and flood control in creating good architecture along slopes was emphasized by Lawal (2000) when he stated that an urban housing structure erected on hills without gardens and vegetation, where the only open spaces are roads, pavements and courtyards, is likely to be soulless and monotonous. If without an appropriate drainage and roof water control mechanism, inevitable erosion engendered by runoff and flooding, occurs. He further stated that the necessity for providing urban development with a larger proportion, and better location of open space and natural vegetation is one of the outstanding characteristics of modern architecture and planning practices.

Every landscaping attempt should be thought of in relation to the people who use it and as an integral part of the general architectural design, and not as an odd corner, which can be used as superficial trimming to the buildings. According to Lawal (2000), the uses to which open spaces are to be put become a ruling factor in location and architectural design to provide a setting for fine architecture.

6. METHODOLOGY

This research will be carried out primarily by on-the-site facts finding. In order to procure reliable data for this research, the methodology of data to be used is summarized into three broad headings:

(i) **Reconnaissance Survey**
(ii) **Primary Data Collection**
(iii) **Secondary Data Collection**

**Reconnaissance Survey** of the area involved a preliminary examination of the topographic angle of elevation of the sites, identification of the type of farming system applied on them, type of erosion prevalent in the area, and likely causes of the erosion. This was done in order to get acquainted with the sloppy sites and acquire the insight into the task ahead and how best to tackle them.

**Results:** The topography of Okigwe is hilly and undulating. A few hilltops reach 300 metres, while the average height of the crest lies between 120 and 180 m. The soils belong to the Ferro sols. They are deeply weathered red and yellowish brown. While their nature makes them easy to cultivate, they suffer from excessive internal drainage — engendering gully erosion. The structural stability of the soils is assured as long as they remain under dense vegetative cover (Areola, 1996).

**Primary Data Collection** constitutes the field survey of the study area and the direct field measurements of all the surveyed data within the study sites. The methodology includes:

(i) Survey plan showing contours, slope angle, and landmarks of the test and control sites.
(ii) Questionnaires administration
(iii) Measurement of sloppy terrains land-uses and erosion control measures
(iv) Measurement of soil infiltration capacity and permeability coefficient.
(v) Determination of soil bearing capacity
Measurement of sloppy terrain land uses:
On field exploration, the area used for site evaluation was subdivided into smaller units according to the following adopted land-use types which were measured in terms of percentage of usage:

Results:
(i) Built up area with landscaped and cemented surfaces (15%)
(ii) Open surface – land spaces in the built up area, which are not concreted, and has little or no grass (30%)
(iii) Tilled farmland – land surfaces with arable plants (35%)
(iv) Forest – land surfaces with bushes, shrubs and trees (20%)

The dimensions of the sloppy terrain land uses were measured using the land chains and a clinometer with the assistance of a trained surveyor. The land chain is a very good linear measuring equipment for field survey; it is easy to handle, and does not require much professional skill, unlike the theodolite transversing equipment. It is 20 metres long, graduated at 200mm intervals. The dimensions obtained will be used to estimate the surface area of each sloppy terrain land uses according to percentage of slope (survey plotting is not yet complete). The approximate angle of inclination of each slope under consideration was determined using only the clinometer, otherwise called the Abney level. The expected result will be the survey plan with angles of elevation of the research sites.

Measurement of soil infiltration capacity and permeability coefficient:
Measurement of soil infiltration capacity and permeability coefficient will be deduced from the results of soil test investigation carried out about the site. Cone penetration test was employed on the site, after which the soil samples collected by systematic random sampling will be analysed in the laboratory using falling head or constant head method; and results obtained. (Test result not yet available)

Determination of the soil bearing capacity:
Determination of the soil bearing capacity will also be by soil test investigation as already stated above. Auger boring made at a depth of 1.5 meters minimum (reference to point on the slope), was used to collect soil samples for laboratory tests and analysis, and for eventual foundation design and specification. (Test result not yet out)

Secondary Data Collection, on the other hand, will involve digging deep into past and present information obtained from various publications to supplement the primary data originated from field survey, in order to arrive at a wise decision. The Secondary data to be utilized in this study are:

(i) Rainfall data and flood information
(ii) Land-use development standards data
(iii) The historic erosion data in Okigwe
(iv) Population and Urbanization data

6.1 Sampling Technique

The Systematic Random Sampling technique was utilized for mapping out portions of the site for soil sample collection by means of auger boring. The procedure is such that one elementary unit was taken as a starting point on the site, from where subsequent samples would be thereafter measured and picked according to the plan based on transects.
The preferred transect I employed in this sampling design involved a set of criss-crossing straight lines at intervals of 3.5 metres running through the entire site under investigation. This was done so that the whole area in the case of bearing capacity of the soil, infiltration capacity, and the permeability investigation samples could be captured. Afterwards, the points of intersection of the criss crossing transect lines were picked (picking plan) for laboratory investigation.

Meanwhile, in administering the questionnaire, the stratified random sampling technique will be utilized. Okigwe as a town has been stratified into four strata with nomenclature as follows:

1. **Okigwe North** - (From Okigwe junction towards the new Okigwe cattle Market)
2. **Okigwe South** - (From Okigwe junction towards the old Okigwe cattle Market and beyond)
3. **Okigwe East** - (From Okigwe junction towards Abia-State University, Uturu)
4. **Okigwe West** - (From Okigwe junction towards Arondizogu)

It is proposed that one hundred (100) questionnaires will be administered in each stratum. Obtained results from collated questionnaires will be used for analyzing test of significance factors of existing building characteristics in Okigwe, such as:

- Land use and building character
- Sloppy terrain building characteristics
- Evaluation of building regulations

### 6.2 Research Design

This study will adopt the procedure of ex-post facto design survey in which simulated architectural design models will be used for comparing the in-situ effect of parapet gutters/duct service system (treatment) against the non para-petted roof design (control), for purposes of establishing the impact of parapets/duct service systems in erosion control. Effects of roof runoff from the non para-petted design, on the sloppy site, will be determined by analysis using erosion equations. All other parameters for erosion control (like, use of terraces, landscaping, etc) will likewise be established (Baridam, 1995; Sheppard, 1986; Simond, 1997).

### 6.3 Data Presentation and Analysis Method

The data obtained from field and laboratory investigations will be presented using tabulations and graphical techniques, which include line and bar graphs, the pie chart and the pictogram.

Test of significance of single variables measured in nominal and ordinal scale will be by way of t-test for correlation. The t-test statistical model is given as:

\[
t = r \sqrt{\frac{\mu-2}{1-Y^2}}
\]

Where,

- \(\mu\) = Number of scores
- \(Y\) = Correlation coefficient
Test relationship between the dependent and independent variables shall be determined using Pearson’s Correlation Regression Analysis. The nature of the relationship between the dependent variable (architectural and landscape design considerations (Y)) and five independent variables (site angle slope (x1); Soil infiltration capacity (x2); soil permeability (x3); soil erodibility (x4); and soil bearing capacity (x5) shall be examined using multiple regression model which states that the dependent variable (Y) is a function of the independent variables (Xi)

\[ Y = f(x_1, x_2, x_3, \ldots, x_n) \]

Where
- \( Y \) = the dependent variable
- \( f \) = function of \( n \) independent variables.

Assuming a linear relationship, the statistical expression becomes,

\[ Y = B_0 + B_1 x_1 + B_2 x_2 + B_3 x_3 + E \]

Where
- \( Y \) = the dependent variable
- \( x_1, x_2 \text{ and } x_3 \) = Independent variables
- \( B_0, B_1, B_2 \text{ and } B_3 \) = Constants
- \( E \) = Random error

In multiple linear regression models, random error term is assumed to be zero, i.e.

\[ E \approx 0 \]

The random error term, for each set of values for the independent variables, is normally distributed.

7. CONCLUSION:

The pursuit in drafting this thesis proposal is as simple as the need to bring man closer to nature without deterrents and impediments. Sloppy terrains, with the resultant effects of surface erosion and slope failure, nevertheless are not wastelands. They can equally be utilized for building structures, while at the same time providing better human and ecosystem interrelationship for sustainable development.

It is the quest of this research work, which is only in its middle stage, to determine requisite architectural do’s and don’ts in designing structures for sloppy areas, as well as update existing data. Presently it has received approval for continuation from the Rivers State University of Science and Technology, Nigeria. Application of the research methodology outlined in the body text for sampling and analysis, has already commenced this February. Outcome of test results will certainly guide the achievement of outlined research objectives.

However, if the present stage of this work meets your standard, please do give me a slot for presentation in the forthcoming 7\textsuperscript{th} International Postgraduate Research Conference in the Built and Human Environment.
8. REFERENCES


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QUESTIONNAIRE (APPENDIX I)

PART A: PERSONAL DATA
(1) Sex: (a) Male (b) Female
(2) Occupation: (a) Farmer (b) Self employed
(c) Business man (d) Civil servant
(e) Property developer (f) Others (specify) -----------

PART B: LANDUSE AND BUILDING CHARACTER
(3) Types of Land According to Usage:
(a) Sloppy (b) Plain (level) (c) Undulating (d) Fallow
(4) Types of Land use
(a) Farming (b) Building (c) Animal husbandry
(d) Erosion Control (e) Other (specify) -----------
(5) If answer to (4) is farming, indicate type.
(a) Erosion mitigation farming (b) Shifting cultivation
(c) Crop rotation (d) Just any type
(6) If answer to (4) is Building, indicate type of building according to usage:
(a) Residential (b) Commercial
(c) Industrial (d) Offices and institutional.

Indicate types of dwelling units or Houses:
(7) (a) Bungalow (b) Single storey (c) Block of flats
(d) Multi-family (e) Row House
(8) Tenure of House or dwelling unit:
(a) Owner occupied (b) Private rented (c) Publicly rented
(d) Service tenancy.

(9) **Age of building since completion**
(a) 1-2 years  (b) 3-5 years  (c) 6-9 years  (d) 10-15 years
(e) 16-20 years  (f) 20 and above

(10) **Has the building any formal Architectural Design?**
(a) Yes  (b) No

(11) **Has the building Runoff control elements?**
(a) Yes  (b) No

(12) **Indicate type of Runoff control element**
(a) Right-round roof gutter  (b) Roof gutter but not right-round
(c) Right-round parapet gutter with spout  (d) Right-round parapet gutter with ducts
(e) Terraced landscape  (f) Landscape areas

(13) **Has the building a good failure resistant foundation (deep concrete foundation):**
(a) Yes  (b) No

(14) **Indicate type of foundation:**
(a) Strip foundation  (b) Pad foundation  (c) Stepped foundation
(d) Combined strip-pad foundation  (e) Combined stepped-pad foundation.

(15) **The House is built of:**
(a) Cemented mud  (b) Cemented blocks  (c) Post and lintel with cemented blocks
(d) Dry-walls construction

(16) **Does the building immediate surrounding open space have landscaped land-use or others? Indicate:**
(a) Landscaped with erosion checks  (b) landscaped without erosion checks
(f) Farming  (d) Like building structures

(17) **Estimate cost of building this house now?** (a) #2,000,000  (b) #4,000,000
(c) #8,000,000  (d) #12,000,000  (e) Between #15,000,000 and #20,000,000
(f) Between #21,000,000 and #30,000,000  (G) other (specify)…………

(18) **Do you think it will cost more or less to build on a slope or on a level land?**
(a) Slope (more)  (b) Slope (less)  (c) Level land (more)
(d) Level land (less)

**PART C: SLOPPY TERRAIN BUILDING CHARACTERISTICS**

(19) **Why did you not build your house on the slope than farm on it?**
(a) Expensive  (b) Erosion prone  (c) Can’t handle the construction
(d) Not allowed by government  (e) Just don’t want to.

(20) **If you have all it takes would you like to build your house on a slope?**
(a) Yes  (b) No

(21) **If Yes to (20), indicate why:**
(a) Popularity of the place  (b) land shortage  (c) Low land price
(d) Luxury  (e) others (specify)  ------------------

(22) **Have you experienced any house built on a slope?**
(a) Yes  (b) No

(23) **Do you like it?**
(a) Yes  (b) No  (c) Indifferent

(24) **If Yes to (23), what do you like about it?** Indicate as applicable
(a) The building integration into the environment
(b) The drainage pattern  (c) Landscaping and erosion checks
(d) The view from the house  (e) others (specify)  ------------------

(25) **If No to (23), what don’t you like about it?** Indicate as applicable:
(a) Erosion threats (b) the roof style and uncontrolled runoff
(c) Cracks on the walls (d) Foundation washes off (e) Walls decolouration
(f) others (specify) ------

(26) For any little Rainfall do you have runoff from the roof forming pool of water on
the road and the environment?
(a) Yes (b) No

(27) Have you any means of checking roof runoff?
(a) Yes (b) No

(28) What effect of roof water runoff have you noticed about your building? Indicate
as applicable:
(a) Foundation exposure/ failure (b) Soil detachment
(c) Walls decolouration (d) flooding (e) Cracks on the wall
(f) Rill erosion (g) others (specify) ---------------

(29) Is the level of building failure on slope equal to the level of building failure on
plain land?
(a) Yes (b) No

(30) Rank the following factors as being responsible for building failure on slopes (5, 4, 3, 2, and, 1 mark to be assigned in order of preference).
(a) Uncontrolled roof-water runoff
(b) Poor Foundation setup
(c) Weak soil bearing capacity
(d) Loss of Topsoil needed for eventual landscaping
(e) Poor drainage mechanism.
(f) Natural effects

PART D: EVALUATION OF BUILDING REGULATION POLICIES

(30) Does Okigwe have Local Government Planning Regulations for new
constructions?
(a) Yes (b) No

(31) What are the required approval documents before commencement of
construction? Indicate as applicable:
(a) Architectural Drawings (b) Soil Test Report (c) Structural drawings for storey
buildings (d) Drainage design relative to building (e) Survey Plan
(f) Landscape plan. (g) Other (specify)………………

(32) What building types and structures are allowed on slopes?
(a) Bungalows (b) Storey buildings (c) any type

(33) What are the restrictions for heights and floor areas of any building to be erected
on slopes?
(a) One storey (b) Two storey (c) Three storey
(d) Not exceeding 4 storey (e) Not exceeding 6 storey
(f) No restriction.

(34) On what percentage of slope are building erections allowed in Okigwe? Indicate
as applicable:
(a) Nearly level (0 – 2%)
(b) Gently undulating (2 – 4%)
(c) Steeply undulating (4 – 6%)
(d) Gently rolling (6 – 10%)
(e) Hilly (16 – 25%)
(f) Steep (25 - ? %)
Do you think you can build a strong and stable structure on a site with 16 – 25 percent slope?
(a) Yes (b) No