GUIDELINE FOR SOIL BEARING CAPACITY AND GEOTECHNICAL INVESTIGATION FOR BUILDING-2014.

Department of Engineering Services
Ministry of Works and Human Settlement.

Foreword

When designing foundations for a structure there is a need to determine the bearing capacity of the underlying soil on which the foundations will be laid. This applies to all forms of foundations from a simple isolated footing to complex raft and pile cap foundations. This understanding comes from an appreciation of the distribution of the materials in the ground, and their properties and behavior under various influences and constraints during construction and lifetime of the structure.

The forms of structure proposed in this modern day demands taller and heavier structures, deeper depth of foundation and underground excavation. There are also structural forms and problems involving technical solutions dealing with complex actions from the ground.

The cost of the investigation varies according to the complexity of the project, the nature of the ground conditions and the level of acceptable risk. The risk to the project is increased by inadequate provisions being made for site investigation which is partly the result of failure on the part of clients and project managers to recognize the value of adequate geotechnical data and the risks posed by inadequate site investigation.

Bhutan being located in active seismic zone, need to incorporate the properties of underlying soil in the design to achieve the realistic designs to our buildings. The benefits of studying the soil properties far out-weigh from not studying in terms of planning the site, design of economical foundations, form of the structure, improvement of site conditions etc.

Department of Engineering Services, Ministry of Works and Human Settlement is pleased to bring forth the **"Guidelines for Soil Bearing Capacity and Geotechnical Investigation for Buildings".** It will also be useful for the designer, home owners to properly incorporate properties in the designs and submit them for scrutiny process and approval.

The Guidelines will be reviewed and updated periodically as and when required to suit our context. We would also appreciate your valuable comments and suggestions on this Guideline for consideration in its next Edition.

Tenzin

Director

Contents

1. Background

Bhutan lies on very fragile geology which is further compounded due do its' high seismicity. The safety and performance of structures depend on the profile and condition of the sub-surface beneath it; hence these conditions have to be investigated before and then incorporated in the design of the structures. Steep geographical terrain of our country aggravates the need for soil testing, bearing capacity tests and understanding soil conditions as well.

Currently in Bhutan, not much importance is given to the soil capacity in building design and construction by the designers as well as owners. On the other hand, there are no proper guidelines or regulations to address this issue. Usually the designer assumes the value of safe bearing capacity (SBC) of soil which might result in either unsafe or over-design of foundation structure. Since the soil properties vary at different sites and levels, adoption of some assumed value of SBC is not appropriate or correct. Thus it is imperative that proper investigation is carried out to determine the bearing capacity of the soil beforehand.

The most cost-effective way of doing this is to ensure that adequate geotechnical information is available to facilitate the selection, design, pricing, programming and execution of the works in the most appropriate way from the outset.

Failure to do so leads to either the adoption of conservative assumptions regarding the soil conditions or the adoption of inappropriate or unsafe solutions, both of which have severe cost implications. Clayton (1995) reports that in the 1940's the cost of site investigations "for fair sized works" was typically about 1% to 2% of the cost of the main work.

It is also observed that the amount of money spent on investigation, testing and professional fees after problems have occurred on a project frequently eclipse the amount spent on the original investigation. It is compounded by the mistaken belief that responsibility for unforeseen ground conditions can be passed on to the designer or the contractor simply by including necessary clauses or disclaimers in the contract documents.

This guideline is to inform and advocate the importance of carrying out the SBC in the construction industry. More importantly it will facilitate cost effective construction in particular. It will also guide engineers in making professional and correct decision in adopting realistic soil parameters in their designs.

2. Objective

1. To enable safe and economical foundation design.
2. To emphasize and create awareness on the importance of geotechnical investigation.

3. Scope

The scope of this guideline shall be limited to building and foundation systems requiring geotechnical investigations. This document will:

a. Assist government organizations and private individuals/house owners in carrying out the required sub soil investigation for foundation designs.

b. Provide guidance to the Approving Authorities.

4. Bearing Capacity of soil

The minimum investigation involves testing the bearing capacity of the supporting ground beneath a proposed building. This must be carried out by a suitably qualified professional or certified testing firm prior to the design of foundations. The method of testing varies depending on the sub- surface conditions. The type of ground and its bearing capacity determines the foundation requirements.

The design of the foundation, super structure and the characteristics of the ground are inter-related and should be studied as a whole. The study involves geotechnical aspects of the supporting ground and the structural aspects of the foundation material. The aim is to proportion the foundation size in such a way that the net loading intensity of pressure coming on the soil does not exceed its safe bearing capacity and maximum stress in foundation is within the permissible limits.

Visual examination of the soil exposed in suitably located trial pits at the site, combined with already established data for different types of soil is commonly used for deciding on the safe bearing capacity. While this procedure may be adequate for light or less important structures under normal conditions, relevant laboratory tests or field tests are essential in the case of unusual soil types and for all heavy and important structures.

5. Building requiring site investigation

5.1. Buildings

Soil tests are required for the following

a. All Proposed buildings.
b. Substantial horizontal extensions >50% of original area, or 150sqm whichever is more. However, if the existing building has shown

signs of movement or settlement, then any horizontal extensions will require soil tests.

c. Large (generally over 200 m^2) ancillary buildings
d. All structures which are prone (but not limited) to following hazards:
    - On or at the base of sloping land or on ridge tops.
    - Fill material/deposits.
    - Adjacent to water courses, drains or rivers.
    - Areas with high or moderate liquefaction threats.
    - Relic landslide areas.

Note: Foundation for buildings to be built on sandy soils requires liquefaction analysis.

5.2. Exemptions

Site investigations can be exempted for the following:

a. Timber frame structures.
b. Thatched houses.
c. Load bearing structures up to two stories in height with built up area less than 200m^2.
d. Ancillary building less than 200 m^2 in area.
e. Pole sheds.

f. For small to medium additions <50% of original area, or 100sqm (whichever is less) to an existing building showing no signs of differential settlement.

g. RCC structures up to 2 stories in height with column grid spacing up to 5m and built up area less than 200sq.m under normal conditions.

5.3. Geotechnical Report

5.3.1. Flat areas.

On a generally flat site, a 'Geotechnical Report' shall be submitted as part of the building application. This report must be prepared by a suitable qualified professional or a certified firm and may contain:

a. A site plan (to scale) showing the position of the proposed building 'on the lot' and accurate locations of the investigation sites.

b. Soil bearing capacity test results.

c. A description of the landscape and interpretation of the results, including recommendation for bearing capacity, depth of firm ground and reasoning how this was derived with pictorial evidences. Confirmation that the potential for differential settlement and liquefaction is either low, medium high and mitigation measures may be included.

d. Areas of high or moderate liquefaction potential.

e. Site location with respect to water course, drains or rivers.

f. Any special observations.

5.3.2. On slopes

In addition to the requirements outlined in the section 5.3.1 the report should also contain the following information:

a. Whether the building will be constructed on original profile of the slope or on a cut.
b. Recommend stability measures if necessary.
c. On cut or fill material.
d. Any special observations.

5. Testing specifications.

a. If your building footprint is 200m^2 or less and generally rectangular in shape:
   - At least three Trial pits or auger holes as deemed appropriate diagonally or any relevant geophysical studies.
   - Any soil bearing tests.

   To a minimum depth of:
   - Equivalent to the depth of foundation in case of trial pits
   - 2m below the underside of the proposed strip or bored pile footings in case of auger holes; or

Note: Where foundation depth may need to be deeper than the required testing depth, testing will need to be extended to allow for extra depth.

b. A penetrometer must be used in sandy soils and a vane shear in fine and medium grained soils.

c. If the building footprint is greater than 200m^2 or an irregular shape, additional test(s) will be required-1 extra test site per additional 50m^2.

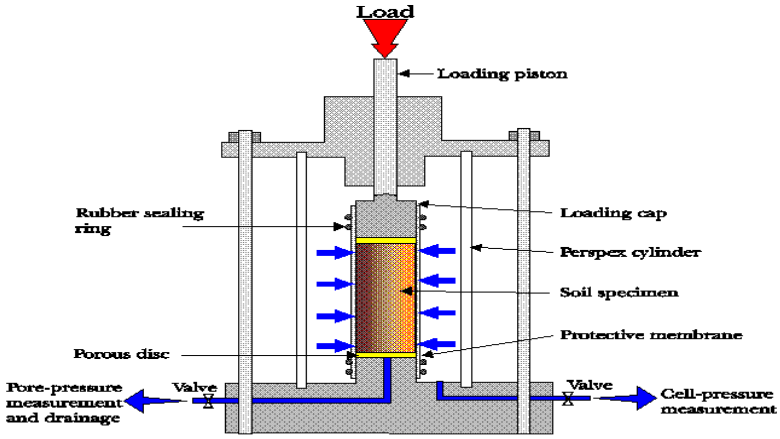
6. Tests for bearing capacity.

The following is a list of soil tests that can be conducted to determine the bearing capacity. Any one of the tests could be carried out but in some cases, a combination of two or more tests may be required to correlate and validate the data obtained. 7.1. Laboratory Tests.

7.1.1. Direct Shear test; IS 2720-Part (X).

Fig. Direct shear apparatus set up.

7.1.2. Tri Axial test; IS 2720-Part (XIII).



Triaxial apparatus

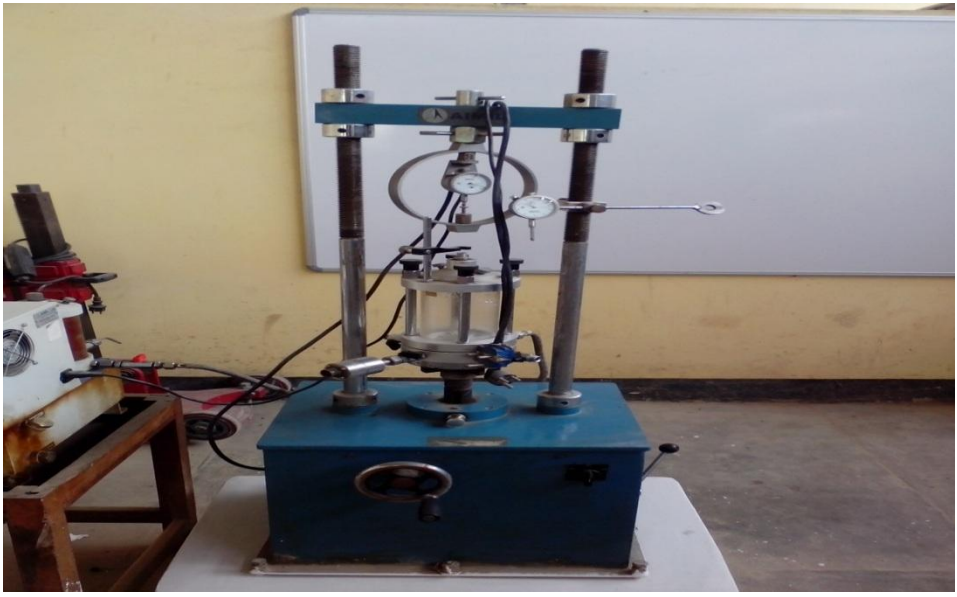


Fig. Tri axial apparatus set up.

7.2. Field Tests.

7.2.1. Plate Load test; IS 1888.

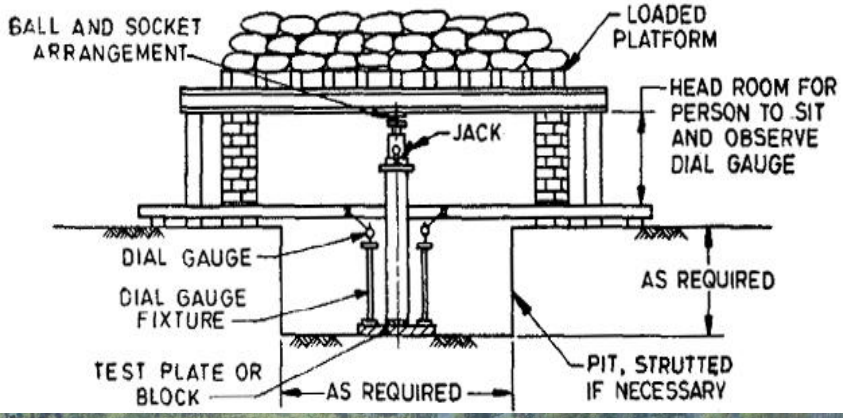


Fig. Plate Load test apparatus set up.

7.2.2. Standard Penetration test; IS 2131.

Fig. Standard Penetration Test set up

7.2.3. Static Cone Penetration test; IS 4968-Part (I).

7.2.4. Field Dynamic Cone Penetrometer; IS 4968-Part (II).

7.2.5. Vane Shear test; IS 4434.

8. Specific design solutions.

A suitably qualified or experienced engineer shall come up with the remedial measures for the following conditions;

- the allowable ground bearing capacity is less than 100 Kpa
- there is potential of ground liquefaction, or
- the ground consist of clays, expansive soils or loose gravels
- Slope stability remedial measures are required.

The design engineer is also required to give a professional guarantee through a 'Producer Statement' (PS) which must be submitted with the building application.

APPENDIX A

The following is a list of the testing facilities currently available within the country. However, one may avail the services from well certified facilities where deemed necessary.

Bhutan Standards Bureau.
Head office Thimphu: +975-2-325104/326905; Fax: +975-2-323712.
Regional office, Gyalpozhing, Mongar: +975-4-744315.

Department of Roads
Ministry of Works & Human Settlement
Thimphu
975-2324473

Department of Geology and Mines
Ministry of Economic Affairs
Thimphu
PABX: +975-2-323096/323349.

College of Science and Technology
Royal University of Bhutan
Rinchending, Phuentsholing,
Contact: 16551362.

Jigme Namgyal Polytechnic

Royal University of Bhutan

Dewathang, Samdrupjongkhar.

Contact; +975-4-260286/260305.

Advanced Geo-tech Engineering Testing Services

Changangkha, Thimphu

Contact: +975-2-325552/332911.

APECS Test House Thimphu

Contact: +975-2-332199;

Fax: 332201; Mobile: 17600313.

APPENDIX B

Definitions of key terms.

Liquefaction: This is the process where a saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid. This process is most often observed in saturated, loose (low density or un-compacted) sandy soils. Areas susceptible are often found along riverbeds, dunes and areas where windblown silt and sand have accumulated.

Liquefaction-induced lateral spreading: Lateral displacement of gently sloping ground as a result of liquefaction during an earthquake. Affects areas in close proximity to rivers and streams. The displacement appears as parallel cracks and the surface of the land can drop.

Differential Settlement: Uneven, downward movement of the foundation of a structure, usually caused by varying soil or loading conditions and resulting in cracks and distortions in the foundation.

Cone Penetrometer Test (CPT): CPT is an in-situ testing method used to determine the geotechnical engineering properties of soils, delineating soil

stratigraphy and gather pore water pressure data. CPT data is used for determining liquefaction and lateral spreading potential.

Slope Stability: Defined as the resistance of an induced surface to failure by sliding or collapsing. The main objectives of slope stability analysis are finding endangered areas, investigation of potential failure mechanisms, determination of the slope sensitivity to different triggering mechanisms, and designing possible remedial measures, e.g. barriers, stabilization and building setbacks restrictions.

Pole sheds: Is a structure that has framing system built of wood roof trusses connected to vertical columns (sidewall posts) and which also has secondary structural members such as wall headers, roof purlins and wall girts to support the exterior cladding (siding and roofing).

It uses large poles or posts buried in the ground or on a foundation to provide the vertical structural support and girts to provide horizontal support.

Allowable bearing capacity: In geotechnical engineering, bearing capacity is the capacity of soil to support the loads applied to the ground. The maximum permissible pressure on foundation soil that provides adequate safety against rupture of the soil mass or movement of the foundation of such magnitude as to impair the structure that imposes the pressure.

Safe bearing capacity: The maximum intensity of loading that the soil will safely carry without risk of shear failure is called safe bearing capacity of soil. This is obtained by dividing the ultimate bearing capacity by a certain factor of safety, and it is the value which is used in the design of foundation. The factor of safety normally varies from 2 to 3.

Ancillary Buildings: A building on the site of construction or civil engineering works, which is intended to be used only during the course of those works and contains no sleeping accommodation.

APPENDIX C
References:

IS 6403-1981: *'Code of practice for determination of bearing capacity of shallow foundation'.*

IS 1080-1985: *'Code of practice for design and construction of shallow foundations in soils'.*

IS 1892-1979: '*Code of practice for sub surface investigations for foundations'.*

IS 1904-1986: '*Code of practice for design and construction of foundation in soils. General requirement.*

New Zealand Building Code requirements Nov 2011, *Bearing capacity and Geotechnical investigation Requirements for buildings.*

2013 California Building Code, Chapter 18, *'Soils and Foundation'.*

SP-7 2005 National Building Code of India.

APPENDIX D

Technical team composition.

Technical working Core Group members

1. *Mr. Karchung, NHDCL.*
2. *Mr. Palden Khandu, Thimphu Thromde*
3. *Ms. Kezang Deki, ESD, DES.*
4. *Mr. Dhillip Thapa, DoR.*
5. *Mr. Sonam Yangdhen, EARRD, DES.*
6. *Mr. Dechen Norbu, ESD, DES – Team leader.*
7. *Mr. Choki Tashi, ESD, DES.*

Technical Review group.

1. *Mr. Tenzin, Director, DES, MoWHS.*
2. *Mr. Phub Rinzin, Chief Engineer, ESD, DES, MoWHS.*
3. *Mr. Karma Namgyel, Chief Engineer, EARRD, DES, MoWHS.*
4. *Mr. Karma Jamtsho, Chief Dzongkhag Engineer, Thimphu Dzongkhag.*
5. *Mr. Jigme Dorji, Executive Engineer, Thimphu Thromde.*
6. *Ms. Dago Zam, Executive Engineer, EARRD, DES, MoWHS.*

Cover page design Mr. Tshering Norbu, Architect, ESD, DES, MoWHS.