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S T A T U T O R Y   I N S T R U M E N T S

2019 No. ....

THE NATIONAL BUILDING (STRUCTURAL DESIGN) CODE, 2019

ARRANGEMENT OF PARAGRAPHS

PART I—PRELIMINARY.

Paragraphs

S T A T U T O R Y   I N S T R U M E N T S

2019 No. ………

The National Building (Structural Design) Code, 2019.

(Under section 46 of the Building Control Act, Act No. 10 of 2013)

In exercise of the powers conferred on the Minister responsible for building works by section 46 of the Building Control Act, 2013 and in consultation with the National Building Review Board, this Code is made this 2nd day of October, 2018.

Part I—Preliminary

1. Title.

This Code may be cited as the National Building (Structural Design) Code, 2018.

2. Interpretation

In this Code, unless the context otherwise requires—

"base plate" means a flat supporting steel plate fixed to the base of a column intended to distribute column loads over a greater area and to provide increased stability;

"basic stress" means the stress which can be permanently sustained by a member loaded in a direction parallel to one of its orthogonal axes;

"beam" means a structural member which supports loads primarily by its internal resistance to bending and shearing;

"block" means a walling unit which exceeds the size of a brick in overall dimensions;

"blockwork" means an assemblage of blocks interlocking or bonded together with mortar or grout to form a wall, pier or column;

"braced wall" means a wall where the reactions to lateral forces are provided by lateral supports;

"brick" means a common or standard basic building unit, made from wet clay hardened by heat, that supports vertical loads;

"brickwork" means an assemblage of bricks interlocking or bonded together with mortar or grout to form a wall, pier or column;

"building" means—

(a) any structure, whether of a temporary or permanent nature, and, irrespective of the materials used in its erection, erected or used for or in connection with—

(i) the accommodation or convenience of human beings or animals;

(ii) the manufacture, process, storage or sale of any goods;

(iii) the rendering of any service;

(iv) the destruction or treatment of refuse or other waste material;

(v) the cultivation or growing of any plant or crop;

(b) a swimming pool, dam, bridge, tower or other structure connected with it;

(c) a fuel pump or tank used in connection with a pump;

(d) an electrical installation or other installation connected with it;

(e) a gas supply installation or other installation connected with it;

(f) any other part of a building or of an installation connected to the building;

"bow" means the curvature of a piece of sawn timber in the direction of its length, whereby the plane of its face deviates from a straight line;

"cantilever" means a member which is fixed at one end and is free to deflect at the other;

"capacity" means the limit of force or moment which may be applied without causing failure due to yielding or rupture, or causing excessive deflection;

"characteristic load" means a load whose value has a probability of not being exceeded by 5%;

"characteristic wind speed" means the speed of the extreme gust of wind lasting a duration of two to three seconds occurring at a particular design height and having a return period of 50 years;

"characteristic strength" means the value of the strength of a material below which the probability of test results failing is not more than 5%;

"column" means a member with a ratio of height-to-least lateral dimension exceeding three, used primarily to support axial compressive load;

"compressive strength" means the resistance of a material to breaking under compression, and is measured as the maximum compressive stress that under gradually applied load a given solid material will sustain without fracture;

"concrete" means a material formed essentially from a mixture of cement, coarse aggregates, fine aggregates and water in specified proportions;

"connection" means the location at which two or more elements meet. For design purposes it is the assembly of the basic components required to represent the behaviour during the transfer of the relevant internal forces and moments at the connection;

"connector" means a device for connecting one or more members to one another, and capable of transmitting specified loads;

"cup" means the curvature of a piece of sawn timber across its width;

"dead load" means the load due to the weight of all walls, permanent partitions, floors, roofs, finishes and all other permanent construction including services of a permanent nature;

"design load" means the characteristic load multiplied by a partial safety factor for the load;

"design service load" means the design load for the serviceability limit state;

"design ultimate load" means the design load for the ultimate limit state;

"design strength" means the characteristic strength of the material multiplied by the appropriate partial safety factor;

"design working life" means the assumed period for which a structure or part of it is to be used for its intended purpose with anticipated maintenance but without major repair being necessary;

"disturbed sample" is a soil sample where the soil structure, water content and/or constituents have been changed during sampling;

"dynamic load" means a form of imposed load resulting from motion;

"effective depth" means the distance from the extreme compressive fibre to the centre of gravity of the tensile reinforcements in concrete at a section;

"effective height" means the height of wall, or column, between points of effective restraint, assumed for calculating the slenderness ratio;

"effective length" means the length between points of effective restraint of a member multiplied by a factor to take account of the end conditions and loading;

"effective thickness" means the thickness of wall or column assumed for calculating the slenderness ratio;

"elastic design" means a design which assumes no redistribution of moments due to plastic rotation of a section throughout the structure;

"empirical method" means a simplified method of design justified by experience or testing;

"factored load" means a specified load multiplied by the relevant partial factor;

"flat slab" means a slab with or without drops and supported, generally without beams, by columns with or without column heads. It may be solid or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions (waffle or coffered slab);

"footing" means that part of the building the function of which is to distribute loading directly to the ground;

"foundation" means that part of the ground immediately under the footing;

"freestanding" means a wall without top or side support which depends, for stability, on its base fixity or mass;

"hardwood timber" means timber obtained from trees with broad leaves, such as oak, teak, mahogany, walnut;

"H-section" means a section with one central web and two equal flanges, which has an overall depth not greater than 1.2 x width of the flange;

"imposed load" means the load assumed to be produced by the intended occupancy or use, including the weight of movable partitions; distributed, concentrated, impact and inertial loads; but excluding wind loads;

"I-section" means a section with central web and two equal flanges which has an overall depth greater than 1.2 x the width of flange;

"joint" means a zone where two or more members are interconnected and for design purposes, means the assembly of all the basic components required to represent the behaviour during the transfer of the relevant internal forces and moments between the connected members;

"knots" means a portion of a tree branch which has become embedded in the wood by the natural growth of the tree;

"lateral support" means an element able to transmit lateral forces from a braced wall to the principal structural bracing or to the foundations;

"load bearing wall" means a wall primarily designed to carry a vertical load in addition to its own weight;

"longitudinal" means the direction along the longer of the rectangular axes of the member;

"limit states" means the states beyond which the structure no longer satisfies the design performance requirements;

"masonry" means an assemblage of structural units, either laid in-situ or constructed in prefabricated panels, in which the structural units are bonded and solidly put together with mortar or grout which may be composed of brickwork, blockwork or natural stone as a structural material;

"masonry unit" means a preformed component intended for use in masonry construction;

"member" means a structural component such as a beam, joist, or column;

"modification factor" means a factor applied to the grade stresses, basic joint forces or calculated deformations, to allow for specific conditions or conditions under which a member structure will operate and which will influence its structural behaviour;

"moisture content" means the mass of water in a sample of material expressed as a percentage of oven-dry mass of that material sample as specified in the standard test;

"natural stone" means a natural product obtained by mining or by quarrying and made into masonry units by a manufacturing process and includes—

(a) magmatic or igneous rocks formed by the cooling and solidification of the magma such as granite, basalt, diorite, porphyry;

(b) sedimentary rocks formed by deposition, generally in water, and consolidation of organic or inorganic particles, such as limestone, sandstone, travertine;

(c) metamorphic rocks transformed by the action of heat or pressure or both, on the pre-existing rocks such as slate, gneiss, quartzite, marble;

"occupancy" means the use or purpose to which a building or site is normally put or intended to be put;

"panel" means an area of walling or floor slab with defined boundaries;

"permissible stress" means the maximum stress which can be permanently sustained by a member loaded in a direction parallel to one of its orthogonal axes;

"plain wall" means a wall containing either no reinforcement or the required minimum reinforcement;

"plastic design" means a design method assuming redistribution of stress within a cross-section;

"reinforced concrete wall" means a wall containing at least the minimum quantities of reinforcement;

"rubble" means broken stone of irregular size, shape and texture;

“serviceability limit states” includes limit states such as deflection and cracking which when exceeded can lead to the structure being unfit for its intended use and its specified service requirements no longer being met;

“shake” means a split, crack or deep check in timber;

“slenderness ratio” means the effective height or effective length divided by the effective thickness or the radius of gyration;

“slope of grain” means the deviation of the grain or fibres from the longitudinal axis of the timber, when the deviation is in the same direction throughout the depth of the piece;

“softwood timber” means timber derived from coniferous trees, such as pine, Douglas fir, spruce;

“specimen” means part of a soil or rock sample used for a laboratory test;

“split” means a longitudinal separation of the fibres which extends to the opposite face or adjoining edge of a piece of sawn timber;

“spring” means the curvature of a piece of timber in the plane of its edge, also known as edge bend;

“stability” means the resistance of the structure or part of the structure to overturning, sliding or overall failure;

“strength” means the resistance to failure by yielding or buckling or the mechanical property of a material indicating its ability to resist actions, usually given in units of stress;

“stress” means force applied per unit area of a material;

“stress grade” means the numerical value of the working stress in bending that can safely be sustained by timber under long-term loading conditions;

“structure” means an organised combination of connected parts designed to carry loads and provide adequate rigidity;

"structural member" means a physically distinguishable part of a structure such as a column, a beam, a slab, a foundation pile;

"structural steel" means a category of steel used for making construction materials in a variety of sections and capable of withstanding stresses;

"structural system" means load-bearing members of a building or civil engineering works and the way in which these members function together;

"structural unit" means, in the case of masonry structures, bricks or blocks or square dressed natural stone;

"strut" means a member of structure carrying predominantly compressive axial load;

"tensile strength" means the resistance of a material to breaking under tension, and is measured as the greatest longitudinal stress a substance can bear without tearing apart;

"transverse" means the direction perpendicular to the longer of the rectangular axes of the member;

"twist" means the spiral distortion of a piece of sawn timber;

"unbraced wall" means a wall providing its own lateral stability;

"undisturbed sample" is a soil sample where no change in the soil characteristics of practical significance has occurred;

"ultimate limit state" means that state, which if exceeded, can cause the collapse of part or whole of the structure or other similar forms of structural failure;

"wane" means the original rounded surface of a tree remaining on a piece of converted timber;

"wall" means a vertical member whose length exceeds four times its thickness;

"warehouse" means a building designed for use as go down, factory or for wholesale business;

"wind load" means the load due to the effect of wind pressure or suction; and

"yield stress" means the stress at which a material undergoes permanent deformation.

3. Symbols used for geotechnical reporting

In this Code, the symbols used for geotechnical reporting have the following meanings—

C_c	means	compression index;
c'	means	cohesion intercept in terms of effective stress;
c_{fv}	means	undrained shear strength from the field vane test;
c_u	means	undrained shear strength
c_v	means	coefficient of consolidation
c_α	means	coefficient of secondary compression
D_n	means	particle size such that *n* % of the particles by weight are smaller than that size e.g. *D*10, *D*15, *D*30, *D*60 and *D*85
E	means	yuoung's modulus
E'	means	drained (long term) Young's modulus of elasticity
E_{FDT}	means	flexible dilatometer modulus
E_M	means	ménard pressuremeter modulus
E_{meas}	means	measured energy during calibration
E_{oed}	means	oedometer modulus
E_{PLT}	means	modulus from plate loading test
E_r	means	energy ratio ($= E_{meas} / E_{theor}$)
E_{theor}	means	theoretical energy
E_u	means	undrained Young's modulus of elasticity
E_0	means	initial Young's modulus of elasticity
E_{50}	means	young's modulus of elasticity corresponding to 50 % of the maximum shear strength
I_A	means	activity index

I_C means consistency index
I_D means density index
I_{DMT} means material index from the flat dilatometer test
K_{DMT} means horizontal stress index from the flat dilatometer test
I_L means liquidity index
I_P or PI means plasticity index
k_s means coefficient of sub-grade reaction
N means number of blows per 30 cm penetration from the SPT
N_k means cone factor based on local experience
N_{kt} means cone factor based on local experience
N_{10L} means number of blows per 10 cm penetration from the DPL
N_{10M} means number of blows per 10 cm penetration from the DPM
N_{10H} means number of blows per 10 cm penetration from the DPH
N_{10SA} means number of blows per 10 cm penetration from the DPSH-A
N_{10SB} means number of blows per 10 cm penetration from the DPSH-B
N_{20SA} means number of blows per 20 cm penetration from the DPSH-A
N_{20SB} means number of blows per 20 cm penetration from the DPSH-B
N_{60} means number of blows from the SPT corrected to energy losses
$(N1)_{60}$ means number of blows from the SPT corrected to energy losses and normalized for effective vertical overburden stress
PL means plastic Limit
*p*LM means ménard limit pressure
q_c means cone penetration resistance
q_t means cone penetration resistance corrected for pore water pressure effects

q_u means unconfined compressive strength

w_{opt} means optimum water content

σ'_p means effective pre-consolidation pressure

σ_T means tensile strength of rock

σ_{v0} means total vertical stress

σ'_{v0} means effective vertical stress

Φ means angle of shearing resistance

Φ' means angle of shearing resistance in terms of effective stress

ρ_d means maximum dry density

ν means poison's ratio

4. Units

The units of measure used in this code have the corresponding meaning as follows—

kg/m^3 means mass density

kN means force

kNm means moment

kN/m^3 means weight density

kPa means stress, pressure, strength and stiffness

m means length

m/s means coefficient of permeability

m^2/s means Coefficient of consolidation

m_v means Coefficient of compressibility

5. Abbreviations and acronyms used for geotechnical reporting

The abreviations and acronymns used for geotechnical reporting have the corresponding meaning as below—

BH - Borehole

BS - British Standard

C - Cohesion

CH - Sandy fat clay

Cl - Chlorides

CL - Sandy lean clay

CPT - Cone penetration test

CPTU - Cone penetration test with pore water pressure measurement

D	-	Position of disturbed samples
DMT	-	Flat dilatometer test
DP	-	Dynamic probing
DPL	-	Dynamic probing light
DPM	-	Dynamic probing medium
DPH	-	Dynamic probing heavy
DPSH-A	-	Dynamic probing superheavy, type A
DPSH-B	-	Dynamic probing superheavy, type B
EN	-	Euro Standard (NORME EUROPÉENE)
FDP	-	Full displacement pressuremeter
FDT	-	Flexible dilatometer test
FVT	-	Field vane test
ISO	-	International Organization for Standardization
LL	-	Liquid limit
MH	-	Elastic silt
MPM	-	Ménard pressuremeter
N -value	-	Field blow count based on standard penetration test by free falling hammer (blows/450mm)
N_c, N_γ,N_q	-	Bearing capacity factors
NMC	-	Natural moisture content
PBP	-	Pre-bored pressuremeter
PLT	-	Plate loading test
PMT	-	Pressuremeter test
q_{all}	-	Allowable bearing capacity
q_{ult}	-	Ultimate bearing capacity
RDT	-	Rock dilatometer test
SBP	-	Self-boring pressuremeter
SC	-	Clayey sand
SDT	-	Soil dilatometer test
SM	-	Silty sand
SO_4^{2-}	-	Sulphates
SPT	-	Standard penetration test
U-100	-	Position of undisturbed samples
USCS	-	Unified soil classification system
WST	-	Weight sounding test

6. Objectives

The objectives of this Code are—

(a) to ensure that every building is designed in a manner that -

   (i) achieves an acceptable level of probability that it shall perform satisfactorily during its intended life;

   (ii) sustains all loads and deformations of normal construction and use; and

   (iii) affords adequate durability and resistance to the effects of misuse and fire;

(b) to ensure that due regard is given to economy in design, structural safety, serviceability and durability;

(c) to ensure that a building is designed and constructed in such a way that it is not unreasonably susceptible to damage by effects of fire, explosion, impact or consequences of human error;

(d) to ensure that for every building, suitable materials, quality control and good supervision are complementary to design calculations to produce safe, serviceable and durable structures;

(e) to provide for standards for materials, production, workmanship, maintenance and use of buildings to be complied with to ensure that the design objectives are realized;

(f) to ensure that potential damage is avoided by appropriate choice of one or more of the following—

   (i) avoiding, eliminating or reducing the hazards to which the structure can be subjected;

   (ii) selecting a structural form which has low sensitivity to hazards considered;

   (iii) selecting a structural form and design that can survive adequately the accidental removal of an individual member or a limited part of the structure, or the occurrence of acceptable localised damage;

(iv) avoiding, as far as possible, structural systems that can collapse without warning; and

(v) tying the structural members together.

Part II—Basis of Design

8. Limit states

(1) The design for a structure shall be based on—

(a) the ultimate limit states; and

(b) the serviceability limit states.

(2) The design shall be based on the most critical limit state and a check shall be conducted to ensure that the other limit states are not exceeded.

9. Ultimate limit states

(1) The ultimate limit states shall be in respect of—

(a) the safety of the structure and its contents; and

(b) the safety of people.

(2) The ultimate limit states which may be considered are—

(a) loss of equilibrium of the structure or any part of it, considered as a rigid body;

(b) failure by excessive deformation, transformation of the structure or any part of it, including supports and foundations;

(c) failure caused by fatigue and other time-dependent effects; and

(d) failure caused by the effect of earthquakes, segmental and overall robustness of the structure.

(3) Limit states prior to structural collapse which are considered in place of the collapse itself shall be treated as ultimate limit states.

10. Serviceability Limit States

(1) The serviceability limit states shall be in respect of—

(a) the functioning of the structure or structural members under normal use;

(b) the comfort of people; and

(c) the appearance of the construction works.

(2) The serviceability limit states which may require consideration are—

(a) deformation and displacements which affect the appearance or effective use of the structure or cause damage to finishes or non structural elements;

(b) vibrations which cause discomfort to people, damage to the structure or to the materials it supports, or which limit its functional effectiveness;

(c) damage, including cracking, which is likely to affect appearance, durability or the function of the structure adversely;

(d) observable damage caused by fatigue and other time-dependent effects; and

(e) damage caused by earthquakes.

11. Design approach

(1) The design approach of a structure shall primarily be based on—

(a) idealization of the structural elements or the structure, their connectivity and their load path;

(b) boundary conditions that are to be imposed onto the structure and to the individual structural elements;

(c) material properties;

(d) weather conditions;

(e) probability of change of use of the structure;

(f) determining which method of analysis or analysis software is suitable;

(g) determining which method of design or design checks to adopt;

(h) method of construction likely to be used; and

(i) the temporary works and quality of workmanship to be used.

(2) A limit state design shall be carried out by—

(a) setting up structural and load models for relevant ultimate and serviceability limit states to be considered in the various design situations and load cases; and

(b) verifying that the limit states are not exceeded when design values for actions, material properties and geometrical data are used in the models.

(3) A design value shall be obtained—

(a) by using the characteristic or representative values in combination with partial and other factors; or

(b) in exceptional cases, directly except that the values obtained directly should correspond to at least the same degree of reliability for the various limit states.

12. Partial safety factors

(1) The reliability, according to the limit state concept, shall be achieved by application of the partial factor of safety method.

(2) In the partial safety factor method, the designer shall verify and ensure that in all relevant design situations, the limit states shall not be exceeded when design values from actions, material properties and geometrical data are used in the design models.

(3) In particular, the designer shall verify that—

(a) the effects of design actions do not exceed the design resistance of the structure at the ultimate limit state; and

(b) the effects of design actions do not exceed the performance criteria for the serviceability limit state.

(4) The selected design situations shall be considered and critical load cases identified.

(5) For each critical load case, the design values of the effects of action in combination shall be determined.

(6) A load case shall identify compatible load arrangements, sets of deformations and imperfections which should be considered simultaneously for a particular verification.

(7) A load arrangement shall identify the position, magnitude and direction of a free action.

(8) Possible deviations from the assumed directions or positions of actions shall be considered.

(9) The design values used for different limit states may be different.

(10) The design values shall be derived in accordance with Schedule 1.

Part III— Loads

13. Self-weights and imposed loads.

(1) The loads that shall be used in the design of buildings are—

(a) self-weight or dead load; and

(b) imposed load.

(2) The loads in sub-paragraph (1) shall apply to new structures, alterations, additions, and existing construction upon change of use of the structure.

(3)For purposes of sub paragraph (1)_

(a) "self-weight or dead loads" means the loads arising from the weight of all walls, permanent partitions, floors, roofs, finishes, services and other permanent construction; and

(b) "imposed loads" shall be the loads arising from the particular occupancy or use of the building and shall include the weight of movable partitions and impact except wind and seismic.

(4) The general occupancy classes causing imposed loads shall be residential, institutional, educational, public assembly, offices, retail, industrial, storage and vehicular.

(5) The minimum imposed loads for the occupancies referred to in sub-paragraph (4) are specified in Schedule 2.

14. Wind loads

(1) The wind design forces shall be a co-efficient of characteristic wind speeds determined for the location of the buildings and factored to take into account the mean return periods, terrain categories, heights above ground and shapes of the structures.

(2) The characteristic wind speed shall be converted to the free stream velocity pressure using the formula prescribed in Schedule 3.

(3) For roofs, the design pressure on the surface of a roof, shall be determined in accordance with Schedule 4.

15. Other design loads

The other design loads that shall be provided for, appropriately, in the design of the building structures include—

(a) impact or vibrations due to plant producing significant dynamic loads;

(b) lifting or handling equipment such as forklifts, trolleys or cranes operating on the floors of buildings; and

(c) lateral and uplift forces due to retained soils or ground water inertia sway forces in grandstands.

Characteristic Properties of Structural Materials

16. Structural materials

(1) Properties of materials, including soil and rock, or products shall be represented by characteristic values which correspond to the value of the property having a prescribed probability of not being attained in a hypothetical unlimited test series.

(2) For a particular material, its properties shall correspond to a specified fractile of the assumed statistical distribution of the properties of the material in the structure.

(3) Unless otherwise stated, the characteristic values shall be defined as the 5% fractile for strength parameters and as the mean value for stiffness parameters such as modulus of elasticity and creep coefficients.

(4) The material property values shall be determined from standardized tests performed under specified conditions and a conversion factor shall be applied where it is necessary to convert the test results into values which can be assumed to represent the behaviour of the material in the structure or the ground.

(5) A material strength may have two characteristic values, an upper and a lower value.

(6) The characteristic values in sub paragraph (5) shall be used as follows—

(a) in most cases only the lower value will need to be considered;

(b) in some cases, different values may be adopted depending on the type of problem considered; and

(c) where an upper estimate of strength is required such as for the tensile strength of concrete for the calculation of the effects of indirect actions, a nominal upper value of the strength should normally be taken into account.

(7) Where there is a lack of information on the statistical distribution of the property a nominal value may be used but where the limit state equation is not significantly sensitive to its variability, a mean value may be considered as the characteristic value.

(8) Natural stone, clay bricks, structural timber, structural steel, concrete blocks and plain or reinforced concrete form the main construction materials for the structures commonly referred to as permanent.

(9) The main structural materials in sub paragraph (8) have varying characteristic strengths and the chosen allowable design stresses, shall depend on the components to be designed as well as the sizes and types of building structures involved.

Part IV—Foundations And Footings

17. General

(1) Foundation, footings or bases shall be designed and constructed in such a manner as to sustain the combined dead and imposed loads and transmit these loads to the ground without causing failure which may impair the stability of structures.

(2) The foundation, footings or bases in sub paragraph (1) shall be at depths equal to or greater than 1.0 metre to safeguard the building against damage due to swelling, shrinking or erosion of the sub-soil.

(3) Notwithstanding conditions in sub paragraph (2), where soil is rocky, the footing may be positioned at a depth less than 1m.

(4) The knowledge of the soil conditions on the building sites through soil investigations and the study of the available geological and soil engineering maps shall be a prerequisite in the design for stability and safety of buildings and a guide to the classification and bearing capacities of sub soils is shown in Schedule 5.

(5) Foundation, footings or bases shall be strip footings, isolated pads, rafts, piles independently, in combination or in their modified forms.

(6) Foundation, footings or bases shall be constructed in concrete with a characteristic compressive crushing strength not less than C12/15 at 28 days if unreinforced, or concrete with characteristic compressive crushing strength equal or greater than C20/25 at 28 days if reinforced.

(7) All foundations other than those in aggressive soil conditions shall be considered to be in moderate environment, in which case cover to all reinforcement shall not be less than 50 mm.

(8) The sizes of foundations shall be in proportions such that the pressure due to all the forces transmitted to the soils does not exceed the bearing capacities of the soils.

(9) Geotechnical investigations shall be carried out before any deep excavation is undertaken to determine the soil characteristics in order to design the most appropriate foundation and footing for the building.

18. Design of isolated footings or bases

(1) The depths of axially loaded unreinforced footings shall be equal to or greater than 300 mm and the projections from the columns or faces shall not be less than the foundation thickness.

(2) For axially loaded reinforced pad footings, the depth of the pads shall be determined in accordance with Part I of Schedule 5 from which also reinforcement percentages shall be obtained.

(3) The design shears at faces of columns shall be checked using the procedure indicated in Part II of Schedule 5.

19. Design of strip foundations

(1) A strip foundation shall be designed as a pad footing in the transverse direction and considering a linear metre in the longitudinal direction.

(2) For a rigid foundation, the bearing pressure may be assumed to be distributed linearly except that detailed analysis of soil-structure interaction may be used to justify a more economic design.

(3) For a flexible foundation, the distribution of the contact pressure may be derived by modelling the foundation as a beam or slab resting on a deforming continuum or series of springs with appropriate stiffness and strength.

(4) The serviceability of strip foundations shall be checked assuming serviceability limit state loading and a distribution of bearing pressure corresponding to the deformation of the foundation and the ground.

(5) For design situations with concentrated forces acting on a strip foundation, forces and bending moments in the structure may be derived from a sub grade reaction model of the ground, using linear elasticity.

(6) The moduli of sub grade reaction shall be assessed by settlement analysis with an appropriate estimate of the bearing pressure distribution.

(7) The moduli shall be adjusted so that the computed bearing pressures do not exceed values for which linear behaviour may be assumed.

20. Design of raft foundations

(1) Raft foundations may be used –

(a) where the building is on soft natural ground or fill or on subsurface strata containing compressible soils; and

(b) where the level of the base of raft foundations shall be near the surface of the ground and the ground under a raft near the surface shall be protected from deterioration due to weather conditions by extending the raft or providing a protective apron beyond the effective foundation area.

(2) The design of raft foundations shall be analogous to that of inverted flat slabs, with the column loads known but the distribution of ground pressure unknown.

(3) Where the disposition of the column loads and columns on the raft is regular, the soil pressure distribution under the raft can be considered uniform.

(4) In case column loads vary significantly from one column to another, the soil pressures under the raft can be estimated using the influence area of the raft of respective columns, and these pressures will then be compared with the safe bearing capacities of the soil.

(5) For a more pragmatic approach, a design software or raft finite element model having column loads will be required.

(6) The serviceability of raft foundations shall be checked assuming serviceability limit state loading and a distribution of bearing pressure corresponding to the deformation of the footing and the foundation.

(7) For design situations with concentrated forces acting on a raft foundation, forces and bending moments in the structure may be derived from a sub grade reaction model of the ground, using linear elasticity.

(8) The moduli of sub grade reaction shall be assessed by settlement analysis with an appropriate estimate of the bearing pressure distribution except that the moduli shall be adjusted so that the computed bearing pressures do not exceed values for which linear behaviour may be assumed.

21. Design of pile foundations

(1) The design of pile foundations shall be based on the following approach—

(a) the results of static load tests which have been demonstrated, by means of calculations or otherwise, to be consistent with other relevant experience;

(b) empirical or analytical calculation methods whose validity has been demonstrated by static load tests in comparable situations; or

(c) the results of dynamic load tests whose validity has been demonstrated by stated load tests in comparable situations.

(2) Static load tests may be carried out on trial piles, which are installed for test purposes only before the design is finalized or on working piles which form part of the foundation.

(3) Pile foundations for small and relative simple structures may be designed from comparable experience, without supporting load tests or calculations, provided the pile type and ground conditions remain within the area of experience and the ground conditions are checked and the installation of the pile is supervised.

(4) In the design of pile foundations, the behaviour of individual piles and pile groups and the stiffness and strength of the structure connecting the piles shall be considered.

(5) The design of pile foundation shall demonstrate that the following classes of limit states are sufficiently improbable—

(a) ultimate limit states of overall stability failure;
(b) ultimate limit states of bearing resistance failure of the pile foundation;
(c) ultimate limit states of collapse or severe damage to a supported structure caused by displacement of the pile foundation; and

(d) serviceability limit states in the supported structure caused by the displacement of the piles.

(6) In selecting design methods and parameter values and in using load test results, the duration and variation in time of the loading shall be considered.

(7) The spacing of piles shall be considered in relation to the nature of the ground, the behaviour of piles in-groups and overall cost of the foundation which includes pile cap or restraining beams and may be as follows—

(a) for friction piles the centre to centre spacing shall not be less than the perimeter of the pile, or for circular piles, three times the diameter;

(b) for end bearing piles passing through relatively compressible strata, the spacing shall not be less than 2.5 times the diameter of the pile;

(c) for end bearing piles passing through relatively compressible strata and resting on dense sand or stiff clay, the spacing shall not be less than 3 and 3.5 times the diameter of the pile, respectively;

(d) for driven cast in-situ piles, the spacing shall not be less than 2.5 times the diameter of the pile;

(e) for bored cast in-situ piles, the spacing shall be at least 3 times the diameter of the pile, but not less than 1.10 metres; and

(f) for under-reamed piles, the spacing shall not be less than 2 times the diameter of under reamed pile base.

Part V—Concrete Structures

22. Reinforced concrete

(1) Both fine and coarse aggregates shall be from natural sources and shall be graded such as to produce a concrete of specified proportions which shall work readily into position without segregation and without excessive water content.

(2) The mean strength of the designed mix shall exceed the specified values by 1.64 the expected standard deviation so as to take into account the inevitable variation.

(3) The mix proportions which are appropriate for grades C12/15 to C25/ are specified in Part 1 of Schedule 7.

(4) Cement for concrete shall be common cement that conforms to standard US 310-1: 2016 prescribed by the bureau.

(5) The reinforcing steel shall be in accordance with—

(a) in case of ribbed bars, standard US EAS 412-2: 2013 prescribed by the bureau; and

(b) in case of plain bars, standard US EAS 412-1: 2013 precribed by the bureau.

(6) For all reinforcing steel, the manufacturers certificate shall be required as proof of the characteristic strength.

(7) The strength of reinforced concrete shall be related to the value of the cube or cylinder strength of concrete, the yield or proof strength of reinforcement, or the ultimate strength of pre stressing tendon.

(8) The design strength shall be derived from the characteristic strength divided by a partial factor of safety, thereby taking into account the difference between actual and laboratory values, local weaknesses and inaccuracies in assessment of the resistance of sections.

(9) The partial factors of safety for the various reinforced concrete ingredients shall be as specified in Part II of Schedule 7.

(10) The design properties and strength classes for concrete, including characteristic compressive strength of concrete for the various grades are prescribed in Schedule 8.

23. Control of deformation of structural concrete

(1) Prediction of deformation of structural concrete shall be derived from the assessment of elastic, creep shrinkage and thermal strains, humidity and temperature.

(2) The final deflection, including the effects of temperature, creep and shrinkage of all horizontal members shall not, in general, exceed the value -

$$\delta = \frac{L_e}{200}$$

where,
L_e = the effective span

(3) For roof or floor construction supporting or attached to non-structural elements including partitions and finishes likely to be damaged by a large deflection, that part of the deflection which occurs after the attachment of the non-structural elements shall not exceed the value

$$\delta = \frac{L_e}{350} \leq 20 \text{ mm}$$

(4) The minimum effective depth obtained from the equation below shall be provided unless computation of deflection indicates that smaller depth may be used without exceeding the limits referred to in sub paragraphs (2) and (3)

$$d = (0.4 + 0.6\frac{f_{yk}}{400})\frac{L_e}{\beta_a}$$

where,
f_{yk} is the characteristic strength of the reinforcement in MPa;
L_e is the effective span; *and*, for two-way slabs, the shorter span;
b_a is the appropriate constant from table in Schedule 9, and for slabs carrying partition walls likely to crack, shall be taken as $b_a < 150L_{o;}$
L_o is the distance in metres between points of zero moment; and for a cantilever, twice the length to the face of the supports.

(5) The appearance and general utility of the structure may be impaired when the calculated sag of a beam, slab or cantilever subjected to quasi-permanent loads exceeds span/250 and shall consider that—

(a) the sag is assessed relative to the supports;

(b) pre-camber may be used to compensate for some or all of the deflection; and

(c) any upward deflection incorporated in the formwork should not generally exceed span/250.

(6) Deflections that could damage adjacent parts of the structure should be limited and for the deflection after construction, span/500 shall be an appropriate limit for quasi-permanent loads except that other limits may be considered, depending on the sensitivity of adjacent parts.

(7) The limiting deflections referred to in sub paragraphs (5) and (6) as derived from International Standards Organisation 4356 are intended to—

(a) result in satisfactory performance of buildings such as dwellings, offices, public buildings or factories;

(b) ensure that the limits are appropriate for the particular structure considered and that that there are no special requirements.

24. Structural floors

(1) Suspended structural floors in buildings shall generally be constructed in reinforced concrete decking composed of solid, ribbed (one way and two way spanning e.g. waffle slabs) or hollow core block slabs supported on masonry, plain or reinforced concrete walls, structural steel joists, or reinforced concrete beams.

(2) For the purposes of design, staircases shall be considered as floor slabs subjected to imposed loads applicable to the various occupancy classes as shown in Schedule 2.

25. Solid concrete slabs

(1) Solid slabs supported by beams or walls shall be designed to sustain the most unfavorable arrangements of design loads.

(2) The span-effective depth ratios for slabs shall not exceed the limits specified in Schedule 10.

(3) If slabs simply supported on two opposite edges carry one or more concentrated loads in line in the direction of spans, they shall be designed to resist maximum bending moments caused by the loading systems using the effective width of the slab calculated using the formula specified in Schedule 11.

(4) The bending moments in two-way slabs shall be calculated using the coefficients prescribed in Table 2 of Schedule 11, using the following equation—

$$M_{sx} = B_{sx} Wl_x^2$$

$$Msy = B_{sx} Wl_x^2$$

where,

B_{sx} = Coefficients given in Table 2 of Schedule 11;2

l_x = Lengths of shorter spans

(5) The bending moments referred to in subparagraph (4) shall be obtained in two directions for slabs whose longer spans do not exceed 1.5 times the shorter spans and taking into consideration the edge-conditions described in Table 2 of Schedule11.

(6) For the design of flat slabs with at least three spans in both directions and the longest span or shortest span ratio not exceeding 1.2, Table 3 of Schedule 11, shall be applied to obtain the bending moments and shear forces in the slabs and columns except that for flat slabs, which do not meet these conditions, the bending moments shall be calculated by frame analyses.

(7) Ribbed slabs with hollow blocks or voids shall be constructed as in-situ slabs, constructed as series of concrete ribs cast between blocks which shall remain part of the completed structure, with topping of the same concrete strength as in the ribs with topping cast on forms which shall be removed after concrete has set or with continuous top and bottom faces but containing voids or rectangular, oval or other shapes.

(8) Ribs shall be spaced a distance not more than 1.5 metres and their depth less than 4 x width of ribs or 50 mm, whichever is greater.

(9) Moments and forces due to the ultimate loads shall be calculated in similar manner as for solid slabs.

(10) All floor slabs shall have adequate depth and reinforcement cover to provide fire resistance according to Table 5 of Schedule 11.

26. Concrete beams

(1) Reinforced concrete beams shall have effective spans taken from the lesser of the distances between centres of supports and the clear distances between supports plus the effective depths, and for cantilevers the effective spans shall be the length of members to the faces of supports plus half the effective depths.

(2) For rectangular beams, actual beam widths are used.

(3) Flanged beams shall have effective width of flanges given by—

(a) web width + l_z/ 5 or actual flange width if less; for T beams

(b) web width + l_z /10 or actual flange width if less; for L-beams

where,

l_z = distance between zero moments (0.7 x effective span for continuous beams)

(4) For slenderness limits, the clear distance between restraints shall not exceed—

$60b_c$, or $250b_c^2/d$ if less; for simply supported and continuous beams $25b_c$, or $100\ b_c^2/d$ if less; for cantilevers.

where,

b_c = breadth of compression flange of beams

d = effective depth

(5) The span-effective depth ratios for reinforced concrete beams shall be in accordance with Part I Schedule 12.

(6) The limiting total deflections shall be span/360 or 20 mm whichever is lesser for spans up to 10 metres.

(7) Continuous beams, uniformly loaded with approximately equal spans shall have design ultimate moments and shears represented by Part II of Schedule 12 except that the characteristic imposed loads shall not exceed the characteristic dead loads.

(8) The design shear stress in beams at any cross section shall be calculated from the equation—

$v = V/bd$

where,

v = Design shear stress = $0.8\ (f_{cu})^{1/2}$ or 5 N/mm² if less

(9) The minimum tension reinforcement shall be provided as follows—

(c) $0.0024bh$; for f_y = 250 N/mm²: rectangular beams;

(d) $0.0020bh$; for f_y = 460 N/mm²: rectangular beams; and

(e) $0.0035b_wh$; for f_y = 460 N/mm²; b_w/b less than 0.4: flanged beams $0.0020b_wh$; for f_y = 460 N/mm²; b_w/b greater than 0.4: flanged beams and

(10) The minimum compression reinforcement shall be—

(a) $0.002bh$; for rectangular beam; and

(b) $0.002b_wh$; for flanged beam

(11) The loads in sub paragraph (5) shall be substantially uniformly distributed over the spans and the variations in span shall not exceed 15% of the longest spans.

(12) All reinforced concrete beams shall be sized to meet the fire resistance requirements given in Part III of Schedule 12.

(13) All reinforced concrete beams shall in addition to the requirements of sub-paragraph (10) fulfil the durability requirements given in Part V of Schedule 14.

27. Concrete columns

(1) Reinforced concrete columns shall be considered short when both the ratios l_{ex}/b, l_{ey}/h are less than 15 for braced columns and less than 10 for unbraced columns; otherwise they shall be taken as slender columns—

where,

l_{ex} = effective height about major axis
l_{ey} = effective height about minor axis
b = eidth of column
h = depth of column

(2) The clear distance between the end restraints of the columns shall not exceed 60 x least dimension of the column section.

(3) The axial forces in reinforced concrete columns shall be calculated on the assumption that beams and slabs transmitting forces are simply supported.

(4) Where moments are induced into the columns, the design moments shall not be less than those produced by considering the design ultimate axial loads as acting at minimum eccentricities equal to 0.05 x overall dimensions of columns in the planes of bending but considered less or equal to 20 mm.

(5) Short reinforced columns shall be designed as described in Schedule 13.

(6) Slender reinforced concrete columns shall be designed as short columns but account shall be taken of additional moments induced in the columns by deflection and that deflection for rectangular or circular columns under ultimate conditions shall be represented by an equation specified in Part I of Schedule 13.

(7) The additional moments shall be added to the initial moments to give the maximum moments for the ultimate limit state of the columns.

(8) Symmetrically reinforced rectangular sections subjected to biaxial bending shall be designed to withstand increased moments about the axes given by the equations in Part II of Schedule 13.

(9) Reinforcement shall be equal or greater than 0.4% but not more than 6% of gross concrete area. At laps total percentage shall not exceed 10%.

(10) For durability, reinforced concrete columns shall be subjected to similar requirements as for reinforced concrete walls, as provided in Part V of Schedule 14.

(11) All reinforced concrete columns shall meet the requirements given in Table 2 in Schedule 13 with respect to fire resistance.

28. Concrete walls

(1) The walls shall be designed to give economical combinations of the types of materials of which they are composed, the thickness and forms of the units, the thickness and types of the walls themselves and the detailing of connections to other parts of the structure.

(2) Concrete walls shall be designed so that they have inherent stability against overturning including—

(a) ensuring that the thickness is sufficient in relation to zigzag serpentine wall; and

(b) dividing walls into a series of buttressed panels or connecting the edges of wall panels to supports capable of transmitting lateral forces to suitable parts of the building structures.

(3) The relationship between the height to thickness of walls exposed to different wind pressures shall be specified in Part I of Schedule 14.

(4) The design strength of walls per unit length shall be obtained from the formula specified in Part II of Schedule 14.

(5) Plain concrete walls shall have slenderness ratios not more than 30, whether the walls are braced or unbraced.

(6) The effective heights of braced plain walls shall be 0.75 x the distance between lateral supports in cases where lateral supports resist both rotations and lateral movements, or equal to the distances between centres of supports in case where lateral supports resist only lateral movements.

(7) For unbraced walls under similar end-conditions as in sub paragraph (6), the corresponding effective heights shall be obtained by multiplying the distances between centres of supports with factors of 1.5 and 2.0 respectively.

(8) The design load per unit length shall be assessed on the basis of linear distribution of loads along the length of the wall, with no allowance for tensile strength.

(9) Reinforced concrete walls constructed monolithically with adjacent structural element shall have effective heights assessed as though the walls were columns subjected to bending at right angles to the planes of the walls.

(10) Where the members transmitting loads to reinforced concrete walls are taken as simply supported, the effective heights of the walls shall be assessed as for plain concrete walls and the slenderness ratios, shall not exceed those specified in Part III of the Schedule 14.

(11) Shear walls shall be designed as vertical cantilevers that are continuous throughout the height of the building and their shear

centres shall coincide approximately with the line of the resultant of the applied horizontal loads in two orthogonal directions.

(12) Where the condition referred to in sub regulation (11) is not fulfilled, shear walls shall be designed for resulting twisting moments.

(13) All reinforced concrete walls shall satisfy fire resistance requirements shown in Part IV of Schedule 14.

(14) All reinforced concrete walls shall also satisfy the durability requirements in any given environments shown in Part V of Schedule 14.

(15) Vertical reinforcement in walls shall be as designed except that the vertical reinforcement in walls shall not be less than 0.4% or more than 4% of the gross sections of concrete for any unit length.

(16) Limiting values for spacing of reinforcement in walls include—

(a) the distance between two adjacent vertical bars shall not exceed 3 times the wall thickness or 400 mm whichever is the lesser; and

(b) the spacing between two adjacent horizontal bars shall not be greater than 400 mm in accordance with—

(i) in case of ribbed bars, Uganda Standard US EAS 412-2: 2013, Steel for the reinforcement of concrete – Part 2: Ribbed bars; and

(ii) in case of plain bars, Uganda Standard US EAS 412-1: 2013, Steel for the reinforcement of concrete – Part 1: Plain round bars.

29. Retaining walls

(1) Retaining walls are structures designed and constructed to resist—

(a) lateral pressure from soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil;

(b) hydrostatic pressure from fluids; or
(c) a combination of (a) and (b).

(2) Retaining walls are of the following types—
(a) cantilevered wall;
(b) buttressed wall;
(c) counterfort wall;
(d) propped cantilevered wall; and
(e) integrated wall.

(3) The retaining walls in sub-paragraph (2) can take the form of gravity walls, masonry walls or reinforced concrete walls depending on the main materials used in their construction.

(4) Gravity walls depend on their mass to resist the lateral pressure behind them and are usually given a setback to improve stability by leaning back toward the retained soil.

(5) Temporary retaining walls may be required during construction of basements and other deep excavations and alternative retaining techniques to ensure soil stability include soil nailing, soil strengthening, gabion meshes, mechanical stabilisation.

(6) The design for retaining walls should take into consideration the following—
(a) function of the wall and the consequences of failure;
(b) stability of the wall (bearing resistance and resistance against rotation and sliding);
(c) economy (consider an economical cross section per unit length of wall);
(d) safety;
(e) mechanism of transmitting compressive and shearing loads to the foundation and the reaction of the foundation to such loads; and
(f) secondary effects of the foundation behaviour on the structure.

30. Structural steel

(1) Structural steelwork can be either a single member or an assembly of a number of steel sections connected together and capable of safely withstanding the design load subjected to it.

(2) Structural steel components shall be designed to facilitate fabrication, erection and future maintenance of the works.

(3) Structural steel components shall be in hot rolled sections or cold rolled sections of the following profiles—

(i) I-section,

(ii) H-section,

(iii) channel sections,

(iv) hollow sections

(v) Z-sections,

(vi) angles,

(vii) flat bars,

(viii) plates, or

(ix) other approved profiles.

(4) Structural steel for general structural use shall conform to Uganda Standard US ISO 630-2: 2011, Structural steels – Part 2.

(5) General steel grades 43, 50 and 55 shall be used for structural steelwork and shall have minimum corresponding design strength specified in Part I of Schedule 15.

(6) Structural steel may be used in the design and construction of stanchions, beams and joists, trusses, purlins, side rails, portal frames, staircases, floors, billboards, communication masts, pylons, towers and bridges.

31. Steel beams

(1) Beams constructed in structural steel shall be proportioned such that the deflections under serviceability loads shall not impair the strength or efficiencies of the structures or cause damage to finishes.

(2) The limiting values for deflection in beams shall be—

(a) length/180, for cantilever beams,

(b) span/360, for beams carrying brittle finishes; and

(c) span/200, for other beams.

(3) The shear forces shall be limited by the relationship specified in Part II of Schedule 15.

(4) Moment capacities for both low and high shear load shall be determined in Part II of Schedule 15.

32. Steel columns

(1) Structural steel columns shall be designed primarily to withstand axial loads subjected to them.

(2) In addition to axial loads, structural steel columns in simple construction shall be designed to sustain moments due to eccentricities of beams end-reactions and other loads.

(3) The eccentricities shall be arrived at as follows—

(a) for beams supported on cap plates, the loads shall be taken to act at the faces of columns or edges of packings; and

(b) in all other cases, the loads shall be taken to act at distances equal to 100 mm from the column faces, or at centres of lengths of stiff bearings, whichever might produce greater eccentricities.

(4) In complex construction, in addition to axial loads and eccentricity moments, the columns shall be designed to withstand other moment loads.

(5) Structural steel columns shall be made out of simple rolled sections, laced struts, battened-struts, batten-starred angle struts or cased sections and in all cases, the columns shall be designed as single integral members provided that the main components are effectively restrained against buckling.

(6) In multi-storey construction, columns shall be treated as continuous at their splices and the net moments applied at any level shall be shared between the upper and the lower columns in proportions to their stiffnesses.

(7) Column bases shall be of sufficient sizes and strengths to transmit axial loads, bending moments and shear forces in the columns to the foundations or other supports, without exceeding the load carrying capacities of those supports.

(8) For concrete foundations, the bearing strength shall be taken as $0.4f_{cu}$ and the minimum thickness of the base plates loaded concentrically by I, H, Channel, Box or RHS columns shall be given by the equation specified in Part III of Schedule 15.

(9) For encased steel columns, the encasing concrete shall extend the full length of members and connections and be reinforced with steel fabric.

(10) The compression resistance of enclosed column shall be given by—

$$P_c = (A_g + 0.45f_{cu}A_c/p_y)p_y$$

where,

P_c = Compression resistance of enclosed column

A_c = Gross area of concrete

A_g = Gross area of steel strut

p_y = Design strength of steel (not exceeding 355N/mm^2)

f_{cu} = Characteristic concrete strength (not exceeding 40N/mm^2)

$P_c \leq P_{cs}$

P_{cs} is the short strut capacity of the encased column given by-

$$P_{cs} = (A_g + 0.25f_{cu}A_c/p_y)p_y$$

(11) Encased columns subjected to both axial loads and moments shall have capacities represented by the conditions-

$$\frac{F_c}{P_{cs}} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} = 1 \text{ or less}$$

where,

F_c = Compressive forces due to loads

P_{cs} = Short strut capacity of the encased column

M_x = Applied moment about major axis

M_y = Applied moment about minor axis

M_{cx} = Capacity of steel sections about major axis

M_{cy} = Capacity of steel section about minor axis

33. Connections and joints

(1) All connections shall have a design resistance such that the structure remains effective and is capable of satisfying all the design requirements given in sub-paragraph (3).

(2) A connection shall be designed on the basis of a realistic assumption of the distribution of internal forces, provided that—

(a) the assumed internal forces and moments are in equilibrium with the applied forces and moments,

(b) each element in the connection is capable of resisting the internal forces or stresses,

(c) the internal forces follow the direct load path i.e., the path with the greatest rigidity through the elements of connections; and

(d) the deformations resulting from this load distribution are within the deformation capacity of the fasteners or welds and of the connected parts.

(3) The partial safety factor g_M shall be taken as follows—

(a) for resistance of bolted connections $g_{Mb} = 1.25$

(b) resistance of riveted connections $g_{Mr} = 1.25$

(c) resistance of pin connections $g_{Mp} = 1.25$

(d) resistance of welded connections $g_{Mw} = 1.25$

(e) resistance of net sections at bolted holes $g_{M2} = 1.25$

(4) Ease of fabrication and erection shall be considered in the design of joints and splices, and in particular—

(a) the clearance necessary for tightening of fasteners;

(b) the need for access of welding;

(c) subsequent inspection;

(d) the effects of angular and length tolerances on fit-up; and

(e) surface treatment and maintenance.

34. Bolted and riveted connections

(1) The size of holes for all fasteners shall not exceed the following dimensions—

(a) for a bolt shank diameter, d less than 14 mm, the clearance hole diameter shall be (d + 1) mm; and

(b) for a bolt shank diameter greater than 14 mm; the clearance hole diameter shall be (d + 2) mm.

(2) Edge distances and spacing of holes for fasteners shall be as follows—

(a) the minimum edge distance for a rolled, machine flame cut, sawn or planed edge shall be 1.25d;

(b) the minimum edge distance for a sheared or hand flame cut edge and any end shall be 1.40d;

(c) the minimum hole distance shall be 2.50d;

(d) the maximum edge distance shall be 12t or 150 mm, whichever is bigger; and

(e) the maximum hole distance shall be $12t$ or 200 mm, whichever is bigger.

where t is the thickness of the thinner outside ply and d is the diameter of the hole.

(3) In the design of connections in compression members, no deduction for fastener holes is normally required except for oversize or slotted holes.

(4) In the design of connections in other types of members, the following provisions shall apply—

(a) the net area of a cross section or element section shall be taken as its gross area less appropriate deductions for all holes and other openings.

(b) when calculating net section properties, the deduction for a single hole shall be the gross cross sectional area of the hole in the plane of its axis. For countersunk holes, appropriate allowance shall be made for the countersunk portion.

(c) provided that the fastener holes are not staggered, the total area to be deducted for fastener holes shall be the maximum sum of the sectional areas of the holes in any cross section perpendicular to the member axis.

(d) when the fastener holes are staggered, the total area to be deducted for fastener holes shall be the greater of:

(i) the deduction for non-staggered holes.

(ii) the sum of the sectional area of all holes in any diagonal or zig-zag line extending progressively across the member or part of the member, less $s^2t/(4p)$ for each gauge space in the chain of holes.

where;

s is the pitch, the spacing of the centres of two consecutive holes in the chain measured parallel to the member axis;

p is the spacing between the centres of two holes measured perpendicular to the member axis.
t is the thickness.

(5) The design value of the effective resistance $V_{eff,Rd}$ for rupture along a block shear failure path shall be determined from:

$$V_{eff,Rd} = \frac{0.60 f_y A_{v,eff}}{\gamma_{Mo}}$$

where,

γ_{Mo} =1.10

where,

g_{Mo} = 1.10
f_y = Yield strength
$A_{v,eff}$ = Effective shear area

(6) The effective shear area $A_{v,eff}$ for block shear failure shall be defined as follows -

$A_{v,eff} = t\ [L_v + L_1 + L_2 - nd_o]$

where,

L_v is the length of the shear face;
$L_1 = 2.5\ d_o$;
$L_2 = 5.0\ d_o$;
n is the number of fastener holes on the block shear failure path;
t is the *thickness* of the web or bracket; and
d_o is the diameter of the bolt;

(7) The effective capacity of a bolt in bearing on any ply shall be taken as the lesser of the bearing capacity of the bolt and the bearing capacity of the connected ply.

(8) The bearing capacity of the bolt $F_{bb,Rd}$ shall be taken as:

$$F_{bb,Rd} = d\,t\,f_{bb,Rd} \text{ but } \leq 1/2e_1\,tf_{bp,d}$$

where,

d is the nominal diameter of the bolt;

t is the thickness of the connected ply, or, if the bolts are countersunk, the thickness of the ply minus half of the depth of countersinking;

e1 is the edge distance;

$f_{bb,Rd}$ is the design bearing strength of the bolt; and

$f_{bp,d}$ is the design bearing strength of the connected parts

(9) The bearing capacity of the connected ply, $F_{bp,Rd}$ shall be taken as

$$F_{bp,Rd} = d\,t\,f_{bp,d} \text{ but} \leq 1/2e_1\,tf_{bp,d}$$

where,

d is the nominal diameter of the bolt

t is the thickness of the ply, as defined above

$f_{bp,d}$ is the design bearing strength of the connected parts

e_1 is the edge distance

35. Pin connections

(1) Pin connections are connections that are not subjected to moments.

(2) Where the connected elements are clamped together by external nuts, the limits on thickness do not apply to internal plies.

(3) The thickness of an unstiffened element containing a pinhole shall be greater than or equal to 0.25 times the distance from the edge of the element, measured at right angles to the axis of the member.

(4) The net area beyond a pinhole parallel to, or within 45^o of the axis of the member shall be greater than or equal to the net area required for the member. The sum of the areas at the pin hole

perpendicular to the axis of the member shall be at least 1.33A, where A is the cross sectional area of the pin.

(5) Pin plates provided to increase the net area of a member or to increase the bearing capacity of a pin should be arranged to avoid eccentricity and should be of sufficient size to distribute the load from the pin to the member.

(6) The capacity of a pin connection shall be determined from the shear capacity of the pin at the shear plane, the bearing capacity on each connected ply with regard to the distribution of load between the plies and the bending moment of the pin.

(7) The shear capacity $F_{v,Rd}$ of a pin shall be taken as—

$$F_{v,Rd} = 0.6Af_{up}/\gamma_{Mp}$$

where,
f_{up} is the specified minimum ultimate strength of the pin
A is the cross sectional area of the pin
γ_{Mp} is the partial factor of the pin material

(8) The bearing capacity $F_{b,Rd}$ of a pin shall be taken as

$$F_{b,Rd} = 1.5dtf_y/\gamma_{Mp}$$

where,
d is the diameter of the pin
t is the thickness of the connected part
f_y is the lower of the nominal yield strength of the pin and the connected part.

(9) The bending moments on a pin shall be calculated on the assumption that the forces transmitted between the pin and the connected parts are uniformly distributed along the length in contact in each case.

(10) The moment capacity of the pin, M_{Rd} shall be taken as—

$$M_{Rd} = 0.8Wf_{yp} / g_{Mp}$$

where,
W is the section modulus of the pin
f_{yp} is the nominal yield strength of the pin

(11) In case of combined shear and bending of the pin the resistance shall be calculated as:

$$\left[\frac{M_{Sd}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Sd}}{F_{v,Rd}}\right]^2 \leq 1.0$$

where,
M_{Sd} is the design moment
$F_{v,Sd}$ is the design shear force
M_{Rd} is the moment capacity
$F_{v,Rd}$ is the shear capacity

36. Splices

(1) Splices may be used for connecting members to achieve the desired length.

(2) Splices shall be designed to hold the connected members in place and wherever practicable the members shall be arranged so that the centroidal axis of the splice coincides with the centroidal axis of the members joined.

(3) Where eccentricity is present the resulting forces shall be taken into account.

(4) Where the members are not prepared for full contact in bearing, the splice shall be designed to transmit all the moments and forces to which the member at the joint is subjected.

(5) Where the members are prepared for full contact in bearing, the splice shall provide continuity of stiffness about both axes and resist in tension where bending is present.

(6) The splice should be as near as possible to the ends of the member or points of inflection.

(7) Where the conditions in sub-paragraph (6) are not achieved, account shall be taken of the moment induced by strut action.

(8) The splice shall be designed to transmit all the moments and forces to which the member at that point is subjected and have adequate stiffness against deflection.

37. Welded connections

(1) The provisions of welded connections apply to—

(a) weldable structural steels;

(b) welding by an arc welding process and specifically by —

  (i) shielded metal arc welding;

  (ii) gas metal arc welding;

  (iii) flux cored arc welding;

  (iv) metal cored arc welding;

  (v) submerged arc welding;

(c) materials thicknesses of not less than 4mm; for welds in thinner material reference should be made to specialist literature; and

(d) joints in which the weld metal is compatible with the parent metal in terms of mechanical properties.

(2) Welded connections shall be designed to have adequate deformation capacity.

(3) In joints where plastic hinges may form, the welds shall be designed to provide at least the same design resistance as the weakest of the connected parts.

(4) In other joints where deformation capacity for joint rotation is required due to the possibility of excessive straining, the welds require sufficient strength not to rupture before general yielding in the adjacent parent material.

(5) The condition in sub-paragraph (4) shall be satisfied if the design resistance of the weld is not less than 80% of the design resistance of the weakest of the connected parts.

38. Type of welds

Welds in construction can be of the following types—

a) fillet welds;

b) butt welds; or

c) spot welds

39. Fillet welds

(1) Fillet welds may be used for connecting parts where the fusion faces form an angle of between 60^o and 120^o.

(2) Smaller angles shall be permitted except that the weld shall be considered to be a partial penetration butt weld.

(3) For angles over 120^o, fillet welds shall not be relied upon to transmit forces.

(4) Fillet welds terminating at the ends or sides of parts shall be returned continuously around the corners for a distance of not less than twice the leg length*s* of the weld unless access or the configuration renders it impracticable.

(5) In lap joints the minimum lap shall not be less than 4*t* where *t* is the thickness of the thinner part joined.

(6) Single fillet welds shall only be used where the parts are restrained to prevent opening of the joint.

(7) Fillet welds may be continuous or intermittent.

(8) Intermittent fillet welds shall not be used in fatigue situations or where capillary action could lead to the formation of rust pockets.

(9) In an intermittent fillet weld, the clear unconnected gaps between the ends of each length of weld shall not exceed the smallest of—

(a) 200 mm;

(b) 12 times the thickness of the thinner part when the part connected is in compression;

(c) 16 times the thickness of the thinner part when the part connected is in tension; and

(d) one-quarter of the distance between stiffeners, when used to connect stiffeners to a plate or other part subjected to compression or shear.

(10) In an intermittent fillet weld, the clear unconnected gap shall be measured between the ends of welds on opposite sides or on the same side, whichever is shorter.

(11) In any run of intermittent fillet welds there shall be a length of weld at each end of the part connected.

(12) In a fabricated member in which plates are connected by means of intermittent fillet welds, a continuous fillet weld shall be provided on each side of the plate for a length at each end equal to at least three-quarters of the width of the narrower plate concerned.

(13) A single fillet weld shall not be subject to a bending moment about the longitudinal axis of the weld.

(14) When a single fillet weld is used to transmit a force perpendicular to its longitudinal axis, the eccentricity of the weld, relative to the line of action of the force to be resisted, shall be taken into account.

40. Design of a fillet weld

(1) The effective length of a fillet weld shall be taken as the overall length less one leg width for each end which does not continue at least twice the leg width*s* round a corner.

(2) The effective length shall not be less than 40mm or 6 times the throat thickness.

(3) Where the weld is a full size in sub-paragraph (1), no reduction in effective length need be made for either the start or the termination of the weld.

41. Throat thickness

(1) The effective throat size a of a fillet weld shall be taken as the perpendicular distance from the root of the weld to a straight line joining the fusion faces which lies within the cross section of the weld except that it shall not be taken greater than 0.707 times the effective leg widths.

(2) The throat thickness of a fillet weld shall not be less than 3mm.

42. Long joints

(1) In lap joints the design resistance of a fillet weld shall be reduced by multiplying it by a reduction factor β_{Lw} to allow for the effects of non-uniform distribution of stress along its length.

(2) Sub-paragraph (1) does not apply where the stress distribution along the weld corresponds to the stress distribution in the adjacent base metal.

(3) Generally in lap joints longer than 150a the reduction factor b_{Lw} should be taken as $b_{Lw,1}$ given by—

$$\beta_{Lw,1} = 1.2 - 0.2L_j/(150a) \quad \text{but} \quad \beta_{Lw,1} \leq 1.0$$

where L_j is the overall length of the lap in the direction of the force transfer.

a is the effective throat thickness of a fillet weld.

(4) For fillet welds longer than 1.7 metres connecting transverse stiffeners in plated members, the reduction factor b_{Lw} may be taken as $b_{Lw,2}$ given by:

$$\beta_{Lw,2} = 1.1 - L_w/17, \text{ but } \quad 0.6 \leq \beta_{Lw,2} \leq 1.0$$

where L_w is the length of the weld in metres.

43. Design strength of fillet weld

The design strength $F_{w,Rd}$ of a fillet weld per unit length shall be obtained from the equation below—

$$F_{w,Rd} = f_{vw,d}\, a$$

where $f_{vw,d}$ is the design shear strength of the weld determined by following formula:

$$f_{vw,d} = \frac{0.63 f_{ye}}{!_{!"}} \quad \text{but} \quad \leq \frac{0.65 f_u}{\gamma_{Mw}}$$

where;

f_{ye} is the minimum tensile strength of the electrodes

f_u is the specified minimum ultimate tensile strength of the weaker part joined

Y_{Mw} is material factor

44. Butt welds

(1) Butt welds may be used as fully penetrated or partially penetrated.

(2) A single-sided partial penetration butt weld shall not be used —

(a) to transmit a bending moment about the longitudinal axis of the weld if it produces tension at the root of the weld; or

(b) to transmit a significant tensile force perpendicular to the longitudinal axis of the weld in situations which would effectively produce a bending moment referred to in sub-paragraph (2)(a).

(3) A single sided partial penetration butt weld may be used as a part of a weld group around the perimeter of a hollow section.

(4) Intermittent butt welds shall not be used.

45. Design of a butt weld

(1) The design strength of a full penetration butt weld shall be taken as equal to that of the weaker of the parts joined, where the weld is made with a suitable electrode or other welding consumable which will produce all-weld tensile specimens having both a minimum yield strength and a minimum tensile strength not less than those specified for the parent metal.

(2) The design strength of a partial penetration butt weld shall be determined as for deep penetration fillet weld.

(3) The throat thickness of a partial penetration butt weld shall be taken as the depth of penetration that can consistently be achieved.

(4) The throat thickness that can consistently be achieved may be determined by preliminary trials.

(5) Where the weld preparation is of U, V, J or bevel type the throat thickness should be taken as the nominal depth of preparation minus 2mm, unless a larger value is shown to be justified by preliminary trials.

46. Tee-butt joints

(1) The resistance of a tee-butt joint, consisting of a pair of partial penetration butt welds reinforced by superimposed fillet welds, may be determined as for a full penetration butt weld if the total nominal throat thickness, exclusive of the unwelded gap, is not less than the thickness t of the part forming the stem of the tee joint where the unwelded gap is not more than t/5 or 3mm, whichever is less.

(2) The resistance of a tee-butt joint which does not meet the requirements given in sub-paragraph (1) above shall be determined as for a deep penetration fillet weld.

(3) The throat thickness shall be determined in conformity with the provisions for both fillet welds and partial penetration butt welds.

(4) The throat thickness should be taken as the nominal throat thickness minus 2mm unless a larger value is shown to be justified by preliminary trials.

47. Plug and slot welds

(1) Plug and slot welds may be used to—

(a) transmit shear;

(b) prevent buckling or separation of lapped parts; and

(c) inter-connect the components of built-up members

(2) Plug and slot welds shall not be used to resist externally applied tension.

(3) The diameter of a circular hole, or width of an elongated hole, for a slot weld shall be at least 8mm more than the thickness of the part containing it, but not more than 2.25 times this thickness.

(4) The ends of a slot shall be semi-circular or shall have corners which are rounded to a radius of not less than the thickness of the part containing the slot, except for those ends which extend to the edge of the part concerned.

(5) The thickness of a plug or slot weld in material up to 16mm shall be equal to the thickness of the material and the thickness of a plug or slot weld in material over 16mm thick shall be at least half the thickness of the material and not less than 16mm.

(6) The centre to centre spacing of the plug or slot welds shall not exceed the value necessary to prevent local buckling.

48. Design of plug and slot welds

(1) The design resistance $F_{w,Rd}$ of a plug or slot weld shall be taken as—

$$F_{w,Rd} = f_{vw,d} A_w$$

where,
$f_{vw,d}$ is the design shear strength of a weld; and
A_w is the effective area of a plug or slot, which is the area of the hole or slot.

(2) Fillet welds in holes or slots shall not be considered as plug or slot welds.

49. Flare groove welds

(1) In rectangular structural hollow sections the effective throat thickness of flare-V and the flare-bevel-groove welds shall be determined by means of trial welds for each set of procedural conditions.

(2) The trial welds shall be sectioned and measured to establish welding techniques that will ensure that the design throat thickness is achieved in production.

(3) For solid bars, the same procedure in sub-paragraph (1) shall be used to determine the effective throat thickness of flare-groove welds, when fitted flush to the surface of the solid section of the bars.

50. Joints to unstiffened flanges

(1) In a tee-joint of a plate to an unstiffened flange of an I, H or a box section, a reduced effective breadth shall be taken into account both for the parent metal and for the welds.

(2) For an I or H section the effective breadth, b_{eff} shall be obtained from—

$$b_{eff} = t_w + 2r + 7t \text{ but } b_{eff} \leq t_w + 2r + 7(t_f^2 / t_p)(f_y/f_{yp})$$

where,
f_y is the nominal yield strength of the member
f_{yp} is the nominal yield strength of the plate

(3) For a box section the effective breadth b_{eff} shall be obtained from—

$$b_{eff} = 2t_w + 5t_f \text{ but } b_{eff} \leq 2t_w + 5(t_f^2 / t_p)(f_y / f_{yp})$$

(4) If b_{eff} is less than 0.7 times the full breadth, the joint should be stiffened.

(5) The welds connecting the plate to the flange shall have a design resistance per unit length not less than the design resistance per unit width of the plate.

51. Angles connected by one leg

(1) In angles connected by one leg, the eccentricity of welded lap joint connections may be allowed for by adopting an effective cross-sectional area and then treating the member as concentrically loaded.

(2) For an equal-leg angle, or an unequal-leg angle connected by its long leg, the effective area may be taken as equal to the gross area of the section.

(3) For an unequal-leg angle connected by its short leg, the effective area shall be taken as equal to the cross-sectional area of an equivalent equal-leg angle of leg size equal to that of the short leg, when determining the design resistance of the cross section except that when determining the design buckling resistance of a compression member, the actual cross-sectional area should be used.

(4) Similar considerations in sub-paragraphs (2) and (3) should be given to other types of sections connected through outstands such as T-sections and channels.

52. Beam-to-column connections

(1) Beam-to-column connections may be classified by rotational stiffness or moment resistance.

(2) Beam-to-column connections shall be designed by the generally known and acceptable application rules and practices by engineers, which lead to a sufficient safety level.

53. Rotational stiffness

(1) Beam-to-column connections classified by rotational stiffness may be—

(a) nominally pinned;

(b) rigid; or

(c) semi-rigid.

(2) Classification of beam-to-column connections as rigid or nominally pinned may be based on particular or general experimental evidence, or significant experience of previous satisfactory performance in similar cases, or by calculations based on test evidence.

(3) Empirically, a nominally pinned connection will have its rotational stiffness S_j, which is based on moment rotation characteristics, satisfying the following condition—

$$S_j \leq 0.5\, EI_b/L_b$$

where,

S_j is the secant rotational stiffness of the connection

E is Young's modulus of elasticity

I_b is the second moment of area of the connected beam

L_b is the length of the connected beam

(4) A beam-to-column connection in a braced frame, or in an unbraced frame may be considered to be rigid if satisfies the following condition—

$$K_b/K_c \leq 0.1$$

where,

K_b is the mean value of I_b/L_b for all the beams at the top of that storey;

K_c is the mean value I_c/L_c for all the columns in that storey;

I_b is the second moment of area of a beam;

I_c is the second moment of area of a column;

L_b is the span of a beam (centre-to-centre of columns); and

L_c is the storey height for a column

(6) If the rising portion of its moment-rotation characteristic lies below the appropriate line in a beam-to-column connection, the connection shall be classified as semi-rigid, unless it also satisfies the requirements for a nominally pinned connection.

(7) Connections which are classified as rigid or nominally pinned may optionally be treated as semi-rigid.

54. Moment resistance

(1) With respect to the design moment resistance, beam-to-column connections may be classified as—

(a) nominally pinned;

(b) full-strength; or

(c) partial-strength.

(2) A beam-to-column connection may be classified as nominally pinned if its design moment resistance M_{Rd} is not greater than 0.25 times the design plastic moment resistance of the connected beam $M_{pl,Rd}$, provided that it also has sufficient rotation capacity.

(3) A beam-to-column connection may be classified as full-strength if its design moment resistance, M_{Rd} is at least equal to the design plastic moment resistance of the connected beam $M_{pl,Rd}$, provided that it also has sufficient rotation capacity.

(4) If the design moment resistance M_{Rd} of a beam-to-column connection is at least 1.2 times the design plastic moment resistance of the member $M_{pl,Rd}$ the rotation capacity of the connection need not be checked, provided that the applied rotational moment does not exceed 25% of the design plastic moment.

(5) A beam-to-column connection shall be classified as partial-strength if its design moment resistance M_{Rd} is less than $M_{pl,Rd}$.

55. Column bases

(1) Column bases shall be of sufficient size, stiffness and strength to transmit the axial load, bending moments and shear forces in columns to their foundations or other support, without exceeding the load carrying capacity of such supports.

(2) The nominal bearing pressure between the baseplate and the support may be determined on the basis of a linear distribution of pressure.

(3) For concrete foundations, the bearing strength may be taken as, $0.4f_{cu}$ where f_{cu} is the characteristic concrete strength at 28 days.

56. Empirical design of base plates

(1) In designing a baseplate, its size shall be determined either by effective area method, or other rational means

(2) Where the size of the baseplate is more than the minimum required, any portion of its area in excess may be taken as ineffective, provided that the bearing pressure calculated on the remaining effective area shall not exceed the bearing strength.

(3) If a rectangular plate is loaded concentrically by I, H, channel or box, its minimum thickness t shall be given by -

$$t = \sqrt{\frac{2.5}{f_{yp,d}} w(a^2 - 0.3\, b^2)} > tf$$

where,

a is the greater projection of the plate beyond the column

b is the lesser projection of the plate beyond the column

w is the pressure on the underside of the plate assuming uniform distribution

$f_{yp,d}$ is the design strength of the plate ($\leq$270 MPa)

t_f is the flange thickness of the column

(3) If gussets are used for transmitting forces to the baseplate, the projecting distances, a and b, are measured from the extremities of the gussets, provided that the gussets are designed for the resulting forces.

(4) For round or square solid columns, where loading on the cap or under the base is uniformly distributed over the whole area including the column shaft, the minimum thickness t,in mm, of a square or circular cap or base plate shall be—

$$t = \sqrt{\frac{w}{2.4 f_{yp,d}} D_p (D_p - 0.9D)}$$

where;

D_p is the length of the side or diameter of the cup or baseplate, but not less than 1.5(D + 75) mm

D is the diameter of the column

(5) If the bearing pressure beneath a baseplate is not uniform, or if the baseplate is rectangular, calculations shall be carried out to determine the bending moments in the baseplate.

(6) The maximum moment, M_{bp} for condition in sub-paragraph (5) shall not exceed -

$$M_{bp} \leq 1.05 f_{p,d} Z_p$$

where

$f_{p,d}$ is the design strength of the plate (≤ 270 MPa)

Z_p is the elastic section modulus of the baseplate

57. Gussets

(1) In a stiffened base, the moment in a gusset M_{bg} due to the bearing pressure on the effective area used in the design of the baseplate shall not exceed—

$$M_{bg} \leq f_{g,d} Z_g$$

where;

$f_{g,d}$ is the design strength of the gusset (≤ 270 MPa)

Z_g is the elastic section modulus of the gusset

(2) Where the effective area is less than its gross area, the connection of the gussets shall be checked for the effects of a nominal distribution of bearing pressure on the gross area as well as for the effects of the distribution used in the design of the baseplate.

58. Connection of base plates

(1) Provided that the contact areas on the base plate and the end of the column ,including, in stiffened bases, the contact surfaces on the stiffeners, are in tight bearing contact, compression may be transmitted to the base plate in direct bearing.

(2) Welds or fasteners shall be provided to transmit any shear or tension developed at the connection due to all realistic combinations of design loads.

(3) Where the contact surfaces are not suitable to transmit compression in direct bearing, welds or fasteners shall be provided to transmit all forces and moments.

59. Anchor bolts

(1) Anchor bolts shall be designed to resist the effect of the design loads and shall provide resistance to tension due to uplift forces, and bending moments and shear, where appropriate.

(2) When calculating the tension forces due to bending moments, the lever arm shall not be taken as more than the distance between the centroid of the bearing area of the compression side and the bolt group on the tension side, taking the tolerances on the positions of the anchor bolts into account.

(3) Anchor bolts shall either be anchored into the foundation by a hook or by a washer plate or by some other appropriate load distribution member embedded in the concrete.

(4) The plate or member in sub-paragraph (3) shall be designed to span any grout tubes or adjustment tubes provided for the anchor bolts.

(5) The embedment length of the anchor bolts and the arrangement of the load distribution assembly shall be such that in transmitting the loads from the anchorage to the footing, the load capacity of the footing as well as the foundation are not exceeded.

(6) The tension capacity of the bolt shall be determined in accordance with established procedure.

(7) If no special elements for resisting the shear force are provided, such as block or bar shear connectors, it shall be demonstrated that sufficient resistance to transfer the shear force between the column and the footing is provided by one of the following—

(a) the frictional resistance of the joint between the base plate and the footing,

(b) the shear resistance of the anchor bolts, and

(c) the shear resistance of the surrounding part of the footing.

60. Steel roof structures

(1) Steel roof structures shall be constituted by any or combination of among others; trusses, girders, rafters, etc.

(2) The roof structures shall be designed to sustain the dead loads, imposed loads and wind loads.

(3) The roofs shall be clad with such materials as to enable them provide shelter from the weather elements and afford protection against the spread of fire into the buildings or to adjoining properties.

(4) The roof covering materials deemed to satisfy the requirements in subparagraph (3) may be cement or clay tiles, galvanized corrugated steel sheets, pressed metal tiles and reinforced concrete slabs.

(5) Roofs shall be flat or pitched.

(6) Roof slopes shall vary according to the cladding materials to be used and in accordance with the recommendations of manufacturers of the coverings, provided that care shall be taken to make roofs weatherproof and leak-proof.

(7) The recommended minimum roof slopes for the various structures and cladding materials are specified in Part V of Schedule 15.

61. Design of structural steel trusses

(1) Truss members shall be designed to sustain axial, compression or tension forces or combinations arising out of the dead and imposed roof loads and shall be disposed symmetrically about the resultant line of the forces and the connections so arranged that the centroid lies on the resultant line of the forces they resist.

(2) Structural steel trusses shall normally be spaced at distances not exceeding 6.0m with double or mono pitches in accordance with Part II Schedule 15.

62. Design of structural steel purlins

(1) The structural steel purlins shall be designed for imposed loads not less than $0.50 kN/m^2$ and shall normally have spans L not exceeding 6.0 metres centre to centre of the main supports.

(2) The dimension D, perpendicular to the planes of the cladding, and the dimension B, parallel to planes of the cladding shall be as specified in Part IV of Schedule 15 for different sections of purlins.

(3) The empirical values of purlins are specified in Part IV of Schedule 15.

63. Composite beams

(1) The properties of concrete shall be similar to those described in Paragraphs 13 to 15.

(2) The properties of reinforcing steel and structural steel shall be similar to those described in Paragraphs 21 to 23.

(3) For the design of buildings, it is accurate enough to take account of creep by replacing concrete areas A_c by effective equivalent steel areas equal to

$$A_c/n,$$

where,
n is the nominal modular ratio, defined by

$$n = E_s / E_c$$

where,
E_s = is the elastic modulus of structural steel
E_c = is the "effective" elastic modulus of concrete

(4) The resistance of a shear connector is the maximum load in the direction considered that can be carried by the connector before failure.

(5) The resistance of a connector may be different when there is reversal of the direction of thrust. Due account shall be taken of this by considering the load case that gives the maximum loading effect.

(6) The design resistance P_{Rk} shall be the characteristic resistance divided by the appropriate partial safety factor.

(7) Considering critical cross-sections, composite beams shall be checked for resistance for lateral-torsional buckling, shear buckling and longitudinal shear.

(8) Allowance shall be given for the flexibility of concrete flange in-plane shear, shear lag, either by means of rigorous analysis, or by using an effective width of flange determined as follows—

(a) a constant effective width may be assumed over the whole of each span. This value may be taken as the value at mid-span, for a span supported at both ends, or the value at the support, for a cantilever;

(b) the total effective width b_{eff} of the concrete flange associated with each steel web should be taken as the sum of effective widths b_e of the portion of the flange on each side of the centreline of the steel web. The effective width of each portion should be taken as one tenth of the effective span but not greater than the actual width b; and

(c) the actual width b of each portion should be taken as half the distance from the web to the adjacent web, measured at mid-depth of the concrete flange, except that at a free edge the actual width is the distance from the web to the free edge.

(9) The elastic section properties of a composite cross-section should be expressed as those of an equivalent steel cross-section by dividing the contribution of the concrete component by a modular ratio n, as given in sub-section (3).

(10) The uncracked and cracked flexural stiffnesses of a composite cross section are defined as $E_a I_1$ and $E_a I_2$, respectively,

where,

- E_a is the modulus of elasticity for structural steel,
- I_1 is the second moment of area of the effective equivalent steel section calculated assuming that concrete in tension is uncracked; and
- I_2 is the second moment of area of the effective equivalent steel section calculated neglecting concrete in tension but including reinforcement.

64. Composite columns

(1) A composite column of any cross section, loaded by normal forces and bending moments, shall be checked for the compression resistance of the member, local buckling and shear between the steel and the concrete.

(2) The design for structural stability shall take account of second-order effects including imperfections and shall ensure that, for the most unfavourable combinations of actions at the ultimate limit state, instability does not occur; and that the resistance of individual cross sections subjected to bending and longitudinal force is not exceeded.

(3) Plane sections shall be assumed to remain plane in the design of composite columns.

(4) The full composite action up to failure shall be assumed between the steel and concrete components of the member, provided the shear action between the two components is maintained.

(5) The influence of local buckling of steel members on the resistance of the column shall be considered in design.

(6) The effects of local buckling of steel members in composite columns may be neglected for steel sections fully encased and for other types of composite columns.

(7) For fully-encased steel sections, at least a minimum reinforced concrete cover shall be provided to ensure—

(a) the safe transmission of bond forces;

(b) the protection of the steel against corrosion;

(c) that spalling will not occur; and

(d) an adequate fire resistance

(8) Where the fully encased steel section in sub-paragraph (7) is required to transmit bending moments, the longitudinal steel reinforcement in the encasing concrete shall be anchored to the steel section by welded studs of a specified size and spacing.

(9) For composite columns subjected to both axial and bending moments, a check is necessary for each of the axes using the relevant slenderness.

Part VII—General Provisions

65. Timber

(1) Timber for use in the construction of structures shall be organic—

(2) Commercial timbers may be hardwoods or softwoods according to their botanical classification rather than their physical strength.

(3) Hardwoods shall be obtained from broad leaved trees which are deciduous in temperate climates while softwoods shall be obtained from conifers, which are typically evergreen with needle shaped leaves.

(4) Structural timber is specified by four timber strength class namely SG4, SG8, SG12 and SG16, based on strength requirements only with corresponding allowable bending stress as prescribed in schedule 16

(5) Strength classes SG8 and SG12 are recommended for building construction where stiffness is a controlling factor and where strength requirements are not so critical.

(6) The basic stresses in timber differ depending on whether considered parallel or perpendicular to the grains.

(7) Structural timber may be used in—

(a) roof construction, as trusses, joists, purlins and battens;

(b) floors;

(c) columns;

(d) walls;

(e) staircases; and

(f) bridges

(8) All structural timber members, assemblies or framework in buildings shall be capable of sustaining, with due stability and stiffness, and without exceeding the limit of stresses specified, the whole dead, imposed and any other loading.

(9) The permissible stresses in timber are governed by—

(a) the general characteristics of particular species;

(b) the presence of visible gross features such as knots, shakes, splits, sloping grains, discolouring, twists, bows, springs, cups and wanes;

(c) the type of loading; and

(d) other conditions to which timber is subjected in service.

(10) The timber shall be seasoned to moisture content appropriate to the position and orientation in which it is to be used.

(11) The timber shall be chemically treated to preserve it against borers, termites and other pests. The preservation of timber shall be done in accordance with Uganda Standard US 324: 2006, Preservation of timber - Specifications.

(12) An indication of acceptable moisture content as percentage of dry weight for the various positions in buildings is prescribed in Part I of Schedule 16 .

(13) Structural timber shall be graded to establish and maintain the specified uniformity between products from different sources.

(14) Sawn timber sizes shall be in accordance with Uganda Standard US 323: 2002, Timber - Dimensions for coniferous sawn timber (Cypress and Pine), Sizes of sawn and planed timber.

(15) The allowable basic stresses for different loading conditions are specified in Part II of Schedule 16.

(16) The basic stresses in timber applicable for the various grades of timber shall be factored to take into account the application of loads in relation to the grains, either parallel or perpendicular to the grains.

(17) Where the direction of the load is inclined to the direction of the member the basic stresses shall be modified using the formula-

$$C_{bi} = C_{bt} C_b/(C_b \sin^2 è + C_{bt} \cos^2 è)$$

where,

C_b = Basic compressive stress parallel to the grain

C_{bi} = Basic compressive stress for inclined load

C_{bt} = Basic compressive stress perpendicular to the grain

$è$ = Angle between direction of load and direction of the grain

66. Timber trusses

(1) Timber trusses shall have spans not greater than 10.0m with single or double pitches in accordance with Part V of Schedule 15.

(2) For spans exceeding 10.0m, the designer must carry out a detailed structural analysis to determine the appropriate timber sections and means of enhancing rigidity of the assembly, or adopt more rigid materials such as structural steel.

(3) The joints of the trusses shall be firmly secured with either nails, screws, bolts and/or timber connectors.

(4) The maximum spacing of trusses, centre to centre, shall not exceed the following—

(a) 1.80 metres: for roofs with metal sheets;

(b) 1.80 metres: for roofs with concrete/clay tiles, incorporating common rafters spaced at 0.60 metres, centre to centre; and

(c) 2.10 metres: for roofs with metal tiles, incorporating common rafters spaced at 0.70 metres, centre to centre.

(5) Purlins to be used in sub-paragraph (4) shall have a minimum dimension of 75 x 50 mm and shall be spaced at distances not exceeding 1.20 metres centre to centre.

(6) Trusses may be placed at larger spacings than specified in sub-paragraph (4) where the designer can demonstrate structural sufficiency of the trusses through analysis or other means.

67. Determination of strength properties of timber

(1) The strength properties of timber that can be investigated are—

(a) allowable modulus of rupture (MOR);

(b) mean modulus of elasticity (MOE);

(c) compressive stress;

(d) tensile strength;

(e) shear strength; and

(f) cleavage strength.

(2) All specimens have to be air-dried to 12±3% moisture content prior to testing. Strength tests are then carried out using a Universal Testing Machine (UTM) at a relative humidity of 65±3% and temperatures of 20±3ºC. Results from specimens with failure due to internally hidden defects should be rejected.

(3) MOE and MOR can be determined in a static bending test on SCS of 300 mm × 20 mm × 20 mm using a Testometric UTM at a loading rate of 6.6 mm per minute. The load at elastic limit (P_e) and the deflections (δ) are recorded and used for computation of MOE (E) in N/mm^2 using the following equation—

$$E = \alpha K$$

where,
α is a specimen geometric parameter given by $L^3 / 4bd^3 = 34.3$ for L = 280 mm,
b = breadth (20mm), d = depth (20 mm).
K= the slope of the elastic portion of the Load -deflection graph.

(4) The load (P_e) can also be used for computation of MOR (σ_b) in N/mm^2 using the following equation -

$$\sigma_b = \beta P_e$$

where, β is a specimen geometric parameter given by $\beta = 3L/2bd^2 = 0.0525$.

(5) Tensile stresses (σ_T) can be derived from the MOR (σ_b) values using the following equation -

$$\sigma_T = 0.6\sigma_b$$

(6) Compression parallel to grain tests on SCS of 60 mm x 20 mm x 20 mm can be determined using a UTM at a rate of 0.6 mm per minute. The maximum load (P_{max}) is recorded and the compressive stress parallel to the grain, (σ_c) in N/mm^2 is calculated using the equation below:

$$\sigma_c = P_{max}/bd$$

(7) Ultimate shear strength parallel to grain involves measuring the maximum shear load (F_{max}) at a loading rate of 1.26 mm per minute and the shear stress, τ, is calculated using the following equation -

$$\tau = F_{max}/tl$$

where,

t is the thickness = 50mm, and

l is the length of the shearing plane = 40mm

68. Determination of physical properties of timber

(1) Basic density of timber can be obtained using green volume and oven-dry weight of 20 mm × 20 mm × 15mm specimens. Specimens are soaked in distilled water till they sink and attain green

volume (V_g). The specimens are then oven-dried at a temperature of 103±2°C to constant weight (W_d), and the basic density (ρ) is kg/m^3 is calculated using the equation below:

$$\rho = (W_d/V_g) \times 1000$$

(2) Moisture content can be determined in accordance with international standard ISO 3133 (1975a); specimens are weighed immediately after testing to obtain their weight (W_t) and oven-dried at a temperature of 103±2°C to constant weight to obtain the oven-dry weight (W_d). The moisture content is then calculated using the equation below:

$$MC = [(W_t - W_d)/W_d] \times 100\ \%$$

(3) All stresses are then adjusted to $P_{12\%}$, their 12% MC equivalents, using the equation below:

$$P_{12\%} = P(1 + Z)^n$$

where,
Z is the correction factor for moisture content
n = MC of specimen at the time of test -12, and
P is the stress at time of test.

(4) The minimum stresses are computed as the 5th-percentile minimum values from the following equation—

$$SCS_{0.05} = x - t_\alpha S$$

where,
t is the t-value at 95% confidence level dependent on sample size,
x is the mean stress,
$SCS_{0.05}$ is the 5th-percentile strength and
S is standard deviation.

(5) Allowable stresses (SCS_{basic}) can be derived using the following equation—

$$SCS_{basic} = SCS_{0.05}/F$$

where,

SCS_{basic} is the allowable bending stress, and

F is reduction factor =2.65 for tropical timbers; to allow for specimen size, rate of loading and safety considerations

69. Timber defects

(1) Timber defects refer to imperfections that occur in timber boards. They include splits, checks, warping, shakes, bowing, knots, twists and winds.

(2) Most drying defects or problems that develop in wood products during drying can be classified as fracture or distortion, warp, or discoloration.

(3) Wood shrinkage is mainly responsible for wood ruptures and distortion of shape. Cell structure and chemical extractives in wood contribute to defects associated with uneven moisture content, undesirable color, and undesirable surface texture.

(4) Surface checks occur early in drying when knots, decay, splits, insect holes, surface roughness, number of surface repairs, and other defects are considered.

(5) Natural defects such as pitch pockets may occur as a result of biological or climatic elements influencing the living tree.

(6) Manufacturing defects include all defects or blemishes that are produced in manufacturing, such as chipped grain, loosened grain, raised grain, torn grain, skips in dressing, hit and miss (series of surfaced areas with skips between them), variation in sawing, miscut lumber, machine burn, machine gouge, mismatching, and insufficient tongue or groove.

70. Seasoning of timber

(1) Timber is sensitive to weather and can degrade when subjected to varying temperature conditions.

(2) Differential swelling of timber occurs during wetting, when the timber is exposed to moisture, and shrinkage occurs during drying which is associated with a decrease in size as the timber loses moisture. This causes distortion of the timber.

(3) If, however, the timber is carefully stick-stacked and dried, the distortion is reduced to a minimum and any unavailable distortion can be cut or planed out of the timber before it is used.

(4) If it is left lying in the sun it will dry out on its top surface and this surface will shrink while the lower surface remains damp and does not shrink. This causes cupping and other distortions which will not disappear entirely even when the lower side dries to the same moisture content as the upper.

(5) In the areas like the lake shore region where much of the building work takes place, timber reaches an equilibrium moisture content in open sided sheds of 17-20% below which the moisture content will not drop regardless of the period the timber is stored.

(6) Timber to be used for furniture and joinery should be air dried to 12-15% moisture content, and stored in a sheltered building until it is used. Kiln drying is by far the quickest and most efficient way of seasoning timber to bring it to the right moisture content. It should be free of defects outlined in paragraph (68).

(7) For timber for formwork and falsework at construction sites, the moisture content of up to 20% is acceptable.

71. Masonry structures

(1) All masonry units, whether new or reused shall be selected for durability and strength, so as to be appropriate to the expected exposure and use.

(2) The layout of structure on plan, returns at the ends of walls, interaction between intersecting walls and the interaction between masonry walls and the other parts of the structure should be considered in order to ensure a robust and stable design.

(3) Masonry may be unreinforced, reinforced or pre-stressed. Reinforced masonry is masonry in which steel bars are introduced to resist the tensile stresses while prestressed masonry is masonry in which forces are introduced to eliminate the tensile stresses.

(4) Mortar shall consist of a mixture of cementitious material and sand (fine aggregate) that is free from material deleterious to the mortar and to embedded items; and to which sufficient water and any specified additives or chemical admixtures have been added. The ingredients shall be proportioned to produce a mortar that will have the following characteristics—

(a) adequate workability to permit the masonry units to be properly placed;

(b) appropriate durability in the specific local environment conditions; and

(c) the ability to impart to the masonry built with it the compressive strength and flexural tensile strength that are required to the structure.

(5) Mortar is the medium which binds together the individual structural units to create a continuous structural form e.g. blockwork, brickwork or stonework.

(6) Mortar serves a number of functions in masonry construction, namely—

(a) binds together the individual units;

(b) distributes the pressures evenly throughout the individual units;

(c) infill the joints between the units and hence increase the resistance to moisture;

(d) penetration;

(e) maintains the sound characteristics of a wall; and

(f) maintains the thermal characteristics of a wall.

(7) Cement for mortar shall be common cement in accordance with Uganda Standard US 366-1: 2004, Masonry cement – Part 1: Specification..

(8) Lime for mortar shall be hydrated lime that conforms to Uganda Standard, US 156-1: 2017, Building limes – Part 1: Specification..

(9) Lime is used in mortar for the following reasons—

(a) to create a consistency which enables the mortar to *'cling and spread'*;

(b) to help retain the moisture and prevent the mortar from setting too quickly; and

(c) to improve the ability of the mortar to accommodate local movement.

(10) Quick lime shall be slaked and all impurities and solid material shall be filtered out.

(11) Quick lime shall be stored and protected for not less than 10 days, after slaking and screening, before use.

(12) When slaked at the construction site, quick lime shall—

(a) be stored in boxes or lined pits, ensuring that no contact is made with earth or other objectionable materials; and

(b) shall be added to sufficient water to make the mix workable.

(13) Lime from different sources or different stacking times shall not be used in any one mix.

(14) Aggregate for mortar shall be naturally occurring river or pit sand or crushed aggregate.

(15) Water used in the preparation of mortar shall be free from harmful materials that are deleterious to the masonry, the reinforcement or any embedded items.

(16) The mortar bonding the masonry units shall satisfy the requirements shown in Part III of Schedule 16.

72. Clay bricks

(1) Clay bricks for load-bearing construction shall conform to Uganda Standard US 102:1995, Standard specification for burnt clay bricks.

(2) The properties of the bricks shall be as shown in Part 1V of Schedule 16.

(3) Bricks may be used in non-load bearing construction as facing or in-fill walling.

(4) The classes of bricks are—

(a) engineering bricks (EB);

(b) industrial bricks (IB);

(c) facing bricks (FB); and

(d) common bricks (CB)

(5) The characteristic compressive strength shall be determined by tests on brick specimens.

(6) For normally bonded masonry defined in terms of the shape and compressive strength of the structural unit and the designation of mortar the values shown in Part V of Schedule 16 shall be taken to be the characteristic compressive strength of walls constructed in bricks.

73. Concrete blocks

(1) Concrete blocks shall be used in the construction of load-bearing structural members and may also be used as infill walling in framed structures.

(2) Concrete blocks for load-bearing structural members shall be solid blocks with characteristic compressive strength shown in Part VI of Schedule 16.

(3) Where masonry has been used for the construction of units subjected to flexural stresses, the characteristic flexural strengths specified in Part VII of Schedule 16 shall apply.

74. Stabilized Soil blocks

Stabilized soil blocks (using cement and or lime) used for general construction shall conform to Uganda Standard, US 849:2011, Specification for stabilized soil blocks.

75. Natural stones

(1) Natural stone shall be classified as unreinforced masonry for the purpose of its structural use as a material in the building construction.

(2) Natural stone masonry may also be designed on the basis of solid concrete blocks masonry of equivalent compressive strength.

(3) The characteristic strength of random rubble masonry may be taken as 75% of the corresponding strength for natural stone masonry built with similar materials, subject to validation tests taken on samples of the rubble masonry.

(4) Natural stone may also be used for architectural and aesthetic reasons as facing or in-fill walling.

Part VIII—Geotechnical Investigations

76. Planning of ground investigations

(1) Geotechnical investigations shall be planned in such a way as to ensure that relevant geotechnical information and data are available

at the various stages of the project. Geotechnical information shall be adequate to manage identified and anticipated project risks. For intermediate and final building stages, information and data shall be provided to cover risks of accidents, delays and damage. Schedule 18 provides guidelines for planning for geotechnical investigations.

(2) The aims of geotechnical investigations are to establish the soil, rock and groundwater conditions, to determine the properties of the soil and rock, and to gather additional relevant knowledge about the site and to gather data to be used in the design of foundations.

(3) Careful collection, recording and interpretation of geotechnical information shall be made. This information shall include ground conditions, geology, geomorphology, seismicity and hydrology as relevant. Indications of the variability of the ground shall be taken into account.

(4) Ground conditions which may influence the choice of category of geotechnical investigations should be determined as early as possible in the investigation.

(5) Geotechnical investigations shall consist of ground investigations, and other investigations for the site, such as—

(a) the appraisal of existing buildings, bridges, tunnels, embankments and slopes;

(b) the history of developments on and around the site; and

(c) performance of earlier and or existing engineering subsurface structures.

(6) Before designing the investigation programme, the available information and documents shall be evaluated in a desk study.

(7) Information and documents to be used may include—

(a) topographical maps;

(b) old city/town maps describing the previous use of the site;

(c) geological maps and descriptions;

(d) engineering geological maps;

(e) hydrogeological maps and descriptions;

(f) geotechnical maps;

(g) aerial photos and previous photo interpretations;

(h) aero-geophysical investigations;

(i) previous investigations at the site and in the surroundings;

(j) previous experiences from the area; and

(k) local climatic conditions, etc.

(8) Ground investigations shall consist of field investigations, laboratory testing, additional desk studies and, controlling and monitoring, where appropriate.

(9) Before drawing up the investigation programme the site shall be visually examined and the findings recorded and crosschecked against the information gathered by desk studies.

(10) The ground investigation programme shall be reviewed as the results become available so that the initial assumptions can be checked, in particular—

a) the number of investigation points and depths shall be adjusted if it is deemed necessary to obtain an accurate insight into the complexity and the variability of the ground at the site;

b) the parameters obtained shall be checked to see that they fit into a consistent behavioural pattern for soil or rock. If necessary, additional testing should be specified; and

c) in case of any limitations in the geo-technical data brought about by the presence of hazardous materials or any other subsurface conditions revealed during the investigation, other appropriate methods shall be considered.

(11) Special attention shall be paid to sites that have been previously used, where disturbance of the natural ground conditions may have taken place and where there is presence of radio-active materials.

(12) An appropriate quality assurance system shall be put in place in the laboratory, field, engineering office, and quality control shall be exercised competently in all phases of the investigations and their evaluation.

77. Ground investigations

(1) Ground investigations shall provide a description of ground conditions relevant to the proposed building works and establish a basis for the assessment of the geotechnical parameters relevant for all construction stages.

(2) The information obtained shall enable assessment of the following—

(a) the suitability of the site with respect to the proposed construction and the level of acceptable risks;

(b) the deformation of the ground caused by the structure or resulting from construction works, its spatial distribution and behaviour over time;

(c) the safety with respect to limit states (e.g. subsidence, ground heave, uplift, slippage of soil and rock masses, buckling of piles, etc.);

(d) the loads transmitted to the structure from the ground (e.g. lateral pressures on piles) and the extent to which they depend on its design and construction;

(e) the foundation methods (e.g. ground improvement, whether it is possible to excavate, driveability of piles, drainage);

(f) the sequence of foundation works;

(g) the effects of the structure and its use on the surroundings;

(h) any additional structural measures required (e.g. support of excavation, anchorage, sleeving of bored piles, removal of obstructions);

(i) the effects of construction work on the surroundings;

(j) the type and extent of ground contamination on, and in the vicinity of the site; and

(k) the effectiveness of measures taken to contain or remedy contamination.

78. Construction materials

(1) Geotechnical investigations of soil and rock for use as construction materials shall provide a description of the materials to be used and shall establish their relevant parameters.

(2) The information obtained shall enable an assessment of the following aspects—

(a) the suitability for the intended use;

(b) the extent of deposits;

(c) whether it is possible to extract and process the materials, and whether and how unsuitable material can be separated and disposed of;

(d) the prospective methods to improve soil and rock;

(e) the workability of soil and rock during construction and possible changes in their properties during transportation, placement and further treatment;

(f) the effects of construction traffic and heavy loads on the ground; and

(g) the prospective methods of dewatering and or excavation, effects of precipitation, resistance to weathering, and susceptibility to shrinkage, swelling and disintegration.

79. Groundwater

(1) Groundwater investigations shall provide all relevant information on groundwater needed for geotechnical design and construction.

(2) Groundwater investigations shall provide, where appropriate, information on—

(a) the depth, thickness, extent and permeability of water-bearing strata in the ground and joint systems in the rock;

(b) the elevation of the groundwater surface or piezometric surface of aquifers and their variation over time and actual groundwater levels including possible extreme levels and their periods of recurrence;

(c) the pore water pressure distribution;

(d) the chemical composition and temperature of groundwater.

(3) The information obtained shall be sufficient to assess the following—

(a) the scope and nature of groundwater-lowering work;

(b) possible harmful effects of the groundwater on excavations or on slopes (e.g. risk of hydraulic failure, excessive seepage pressure or erosion);

(c) any measures necessary to protect the structure (e.g. waterproofing, drainage and measures against aggressive water);

(d) the effects of groundwater lowering, desiccation, impounding etc. on the surroundings;

(e) the capacity of the ground to absorb water injected during construction work; and

(f) whether it is possible to use local groundwater, given its chemical constitution, for construction purposes.

80. Sequence of ground investigations

(1) The composition and the extent of the ground investigations shall be based on the anticipated type and design of the construction, e.g. type of foundation, improvement method or retaining structure, location and depth of the construction.

(2) The results of the desk studies and site inspection shall be considered when selecting the investigation methods and locating the various investigation points. Investigations shall be targeted at points representing the variation in ground conditions for soil, rock and groundwater.

(3) Ground investigations may be performed in phases depending on the issues raised during planning, design and construction stages of the actual project and as prescribed in Schedule 26.

81. Preliminary investigations

(1) Preliminary investigations shall be planned in such a way that adequate data is obtained, so as to—

(a) assess the overall stability and general suitability of the site;

(b) assess the suitability of the site in comparison with alternative sites;

(c) assess the suitable positioning of the structure;

(d) evaluate the possible effects of the proposed works on surroundings, such as neighbouring buildings, structures and sites;

(e) identify borrow areas;

(f) consider the possible foundation methods and any ground improvements; and

(g) plan the design and control investigations, including identification of the extent of ground which may have significant influence on the behaviour of the structure.

(2) A preliminary ground investigation shall supply estimates of soil data concerning—

(a) the type of soil or rock and their stratification;

(b) the groundwater table or pore pressure profile;

(c) the preliminary strength and deformation properties for soil and rock; and

(d) the potential occurrence of contaminated ground or groundwater that might be hazardous to the durability of construction materials.

82. Detailed investigations

(1) In cases where the preliminary investigations do not provide the necessary information to assess the aspects mentioned in Paragraph 79, complementary field investigations shall be performed.

(2) The detailed field investigations may comprise—

(a) drilling and or excavations (test pits including shafts and headings) for sampling;

(b) active and passive seismic and resistivity tomography; geophysical investigations (e.g. ground penetrating radar, and down hole logging); and

(c) field testing (e.g. CPT, SPT, dynamic probings, WST, pressuremeter tests, dilatometer tests, plate load tests, field vane tests and permeability tests), which may involve -

(i) soil and rock sampling for description of the soil or rock and laboratory tests;

(ii) groundwater measurements to determine the groundwater table or the pore pressure profile and their fluctuations; and

(iii) large scale tests, for example to determine the bearing capacity or the behaviour directly on prototype elements, such as anchors.

(3) Where ground contamination including gaseous matter is expected, information shall be gathered from the relevant sources. This information shall be taken into account when planning the ground investigation.

(4) In cases where all investigations are performed at the same time, preliminary investigations and detailed investigations should be considered simultaneously.

(5) Schedule 19 shows some of the field tests listed together with the respective test results and shall be presented in the Ground Investigation Report.

83. Field investigation programme

The field investigation programme shall contain—

(a) a plan with the locations of the investigation points including the types of investigation;

(b) the depth of the investigations;

(c) the types of sample (category, etc.) to be taken including specifications for the number and depth at which they are to be taken;

(d) specifications on the groundwater measurement;

(e) the types of equipment to be used; and

(f) the standards to be applied.

84. Locations and depths of the investigation points

1) The locations of investigation points and the depths of the investigations shall be selected on the basis of the preliminary investigations as a function of the geological conditions, the dimensions of the structure and the engineering problems involved.

(2) When selecting the locations of investigation points, the following should be observed–

(a) the investigation points should be arranged in such a pattern that the stratification can be assessed across the site;

(b) the investigation points for a building or structure should be placed at critical points relative to the shape, structural behaviour and expected load distribution (e.g. at the corners of the foundation area);

(c) for linear structures, investigation points should be arranged at adequate offsets to the centre line, depending on the overall width of the structure, such as an embankment footprint or a cutting;

(d) for structures on or near slopes and steps in the terrain (including excavations), investigation points should also be arranged outside the project area, these being located so that the stability of the slope or cut can be assessed.

(e) where anchorages are installed, due consideration should be given to the likely stresses in their load transfer zone;

(f) the investigation points should be arranged so that they do not present a hazard to the structure, the construction work, or the surroundings (e.g. as a result of the changes they may cause to the ground and groundwater conditions);

(g) the area considered in the design investigations should extend into the neighbouring area to a distance where no harmful influence on the neighbouring area is expected;

(h) for groundwater measuring points, the possibility of using the equipment installed during the ground investigation for continued monitoring during and after the construction period should be considered.

(3) Where ground conditions are relatively uniform or the ground is known to have sufficient strength and stiffness properties, wider spacing or fewer investigation points may be applied. In either case, this choice should be justified by local experience.

(4) In cases where more than one type of investigation is planned at a certain location (e.g. CPT and piston sampling), the investigation points shall be separated by an appropriate distance.

(5) In the case of a combination of, for example, CPTs and boreholes, the CPTs should be carried out prior to the boreholes. The minimum spacing should then be such that the borehole does not, or is considered unlikely to, encounter the CPT hole. If the drilling is conducted first, the CPT should be carried out at a horizontal separation of at least 2 m.

(6) The depth of investigations shall be extended to all strata that will affect the project or are affected by the construction. For dams, weirs and excavations below groundwater level, and where dewatering work is involved, the depth of investigation shall also be selected as a function of the hydrogeological conditions. Slopes and steps in the terrain shall be explored to depths below any potential slip surface.

85. Sampling

(1) The sampling categories and the number of samples to be taken shall be based on—

(a) the aim of the ground investigation;

(b) the geology of the site; and

(c) the complexity of the geotechnical structure.

(2) For identification and classification of the ground, at least one borehole or trial pit with sampling shall be available. Samples shall be obtained from every separate ground layer influencing the behaviour of the structure.

(3) Sampling may be replaced by field tests if there is enough local experience to correlate the field tests with the ground conditions to ensure unambiguous interpretation of the results. This shall be recommended and done by a competent and qualified person.

86. Soil and rock sampling, and groundwater measurements

Sampling of soils and rocks by drilling and excavations and groundwater measurements shall be conducted comprehensively in order to obtain the necessary geotechnical design data.

87. Sampling by drilling

(1) The drilling equipment shall be selected according to—

(a) the sampling categories required;

(b) the depth to be reached and the required diameter of the sample; and

(c) the functions required from the drilling rig, e.g. recording of the drilling parameters, automatic or manual adjustment.

(2) All drilling operations and data obtained shall be site-specific.

88. Sampling by excavation

If samples are recovered from trial pits, headings or shafts, the requirements of International Standard, ISO 22475-1 shall be followed.

89. Categories of sampling methods and laboratory quality classes of samples

(1) Samples shall contain all the mineral constituents of the strata from which they have been taken and shall not be contaminated by any material from other strata or from additives used during the sampling procedure.

(2) Sampling method categories shall be considered in accordance with International Standard, ISO 22475-1, depending on the desired sample quality as follows—

(a) category A sampling methods: samples of quality class 1 to 5 can be obtained;

(b) category B sampling methods: samples of quality class 3 to 5 can be obtained;

(c) category C sampling methods: only samples of quality class 5 can be obtained.

(3) Samples of quality classes 1 or 2, in which no or only slight disturbance of the soil structure occurs during the sampling procedure or in the handling of the samples, should be obtained by using

category A sampling methods. ,Certain unforeseen circumstances such as variations in geological strata may lead to lower sample quality classes being obtained.

(4) For category B sampling methods, the samples obtained are expected to contain all the constituents of the in situ soil in their original proportions and the soil retains its natural water content. obtain. If the structure of the soil has been disturbed, certain unforeseen circumstances such as variation in geological strata may lead to lower sample quality classes being obtained.

(5) By using category C sampling methods, samples of quality classes better than those described in sub-paragraph (4) cannot be obtained. This is because the soil structure in the sample has been totally changed and the general arrangement of the different soil layers or components has been modified so that the in situ layers cannot be identified accurately. The water content of the sample need not represent the natural water content of the soil layer sampled.

(6) Soil samples for laboratory tests are divided in five quality classes with respect to the soil properties that are assumed to remain unchanged during sampling and handling, transport and storage. The classes are described in Schedule 4 together with the sampling category to be used.

90. Soil identification

Soil identification based on the examination of the samples recovered shall be adopted.

91. Planning of soil sampling

(1) The quality class and number of samples to be recovered shall be based on the aims of the soil investigations, the geology of the site, and the complexity of the structure and the construction method to be used.

(2) The following strategies may be followed for sampling by drilling—

(a) drilling aimed at recovering the complete soil column, with samples obtained by the drilling tools down the borehole and by special samplers at selected depths at the borehole bottom; and

(b) drilling to recover samples only at specific predetermined elevations, e.g. by separately conducted penetration tests.

(3) The sampling categories shall be selected considering the desired laboratory quality classes and the expected soil types and groundwater conditions.

(4) The requirements of International Standard ISO 22475-1 shall be followed, for the selection of the drilling or excavation methods and sampling equipment adequate to the soil sampling category prescribed.

(5) For a given project, specific sampling equipment and methods may be required.

(6) The dimensions of the samples to be recovered shall be in accordance with the type of soil and the type and number of tests to be performed.

(7) Samples shall be taken at any change of stratum and at a specified spacing, usually not larger than 3m. In non-homogeneous soil, or if a detailed definition of the ground conditions is required, continuous sampling by drilling should be carried out or samples recovered at very short intervals of 1m, 1.5m, and 2m.

92. Handling, transporting and storage of samples

(1) All soils samples other than rock samples shall be sealed in air-tight polythene bags, clearly and unambiguously labelled and transported to a materials laboratory immediately after extraction.

(2) Soil samples shall be protected at all times against damage, deterioration and excessive changes in temperature. Special care shall

be taken with undisturbed samples to prevent distortion and loss of water during the preparation of test specimens. The material used for sampling containers shall not react with the contained soil.

(3) Soil shall not be allowed to dry before testing if the test results can be affected by a loss of moisture.

(4) Undisturbed samples shall be prepared under conditions of controlled humidity. If preparation is interrupted, the specimen shall be protected from changes in water content.

(5) If disaggregating processes are applied, the breaking down of individual particles shall be avoided. If special treatment of bonded and cemented soil is required, this shall be specified.

(6) Subdivision methods shall ensure that representative portions are obtained, avoiding segregation of large particles.

93. Laboratory tests

(1) Prior to setting up a test programme, the expected stratigraphy at the site shall be established and the strata relevant for design selected to enable the specification of the type and number of tests in each stratum.

(2) Stratum identification shall be a function of the geotechnical problem, its complexity, the local geology and the required parameters for design.

94. Visual inspection and preliminary ground profile

(1) Samples and trial pits shall be inspected visually and compared with field logs of the drillings/excavations so that the preliminary ground profile can be established.

(2) For soil samples, the visual inspection shall be supported by simple manual tests to identify the soil and to give a first impression of its consistency and mechanical behaviour.

(3) If distinct and significant differences in the properties between different portions of one stratum are found, the preliminary soil profile shall be further subdivided.

(4) Where practicable, the quality of the sample shall be assessed before laboratory tests are performed.

95. Test programme

(1) The type of construction, the type of ground and stratigraphy and the geotechnical parameters needed for design calculations shall be taken into account when setting up the laboratory test programme.

(2) The laboratory test programme depends in part on whether comparable experience exists. The extent and quality of comparable experience for the specific soil or rock shall be established. The results of field observations on neighbouring structures, when available, shall also be used.

(3) The tests shall be run on specimens representative of the relevant strata. Classification tests shall be used to check whether the samples and test specimens are representative.

(4) The need for more advanced testing or additional site investigation as a function of the geotechnical aspects of the project, soil type, soil variability and computation model should be considered.

96. Number of tests

(1) The necessary number of specimens to be tested shall be established depending on the homogeneity of the ground, the quality and amount of comparable experience with the ground and the geotechnical category of the problem.

(2) To allow for difficult soil such as black cotton soil, damaged specimens and other factors, additional test specimens shall be made available, whenever possible.

(3) Depending on the test type, a minimum number of specimens shall be investigated.

(4) The minimum number of tests may be reduced if the geotechnical design does not need to be optimized and uses conservative values of the soil parameters, or if comparable experience or combination with field information applies.

97. Classification tests

(1) Soil and rock classification tests shall be performed to determine the composition and index properties of each stratum.

(2) The samples for the classification tests shall be selected in such a way that the test samples are a representative of the in-situ soils.

(3) The results from the classification tests shall give the range of index properties of the relevant layers.

(4) The results of the classification tests shall be used to check if the extent of the investigations was sufficient or if a second investigation stage is needed.

98. Tests on samples

(1) Soil samples and specimens for laboratory tests shall be as representative as possible of in-situ soils.

(2) Samples for testing shall be selected so as to cover the range of index properties of each relevant stratum.

(3) For purposes of preparation, five types of soil specimens shall be categorized as: disturbed, undisturbed, re-compacted, remoulded or reconstituted specimens.

(4) Reconstituted specimens shall have approximately the same composition, density and water content as in-situ material.

(5) The soil specimen used for testing shall be sufficiently large to take account of—

(a) the largest size of particles present in significant quantity; and

(b) the natural features such as structure and fabric (e.g. discontinuities).

(6) Laboratory tests for rock samples giving the necessary basis for the description of the rock material include—

(a) the geological classification;

(b) the density or bulk mass density (ρ) determination;

(c) the water content (w) determination;

(d) the porosity (n) determination;

(e) the uniaxial compression strength (σ_c) determination;

(f) the Young's modulus of elasticity (E) and Poisson's ratio (ν) determination or;

(g) the point load strength index test (I_{s50}).

(7) The classification of rock core samples shall comprise:

(a) a geological description;

(b) the core recovery;

(c) the Rock Quality Designation (RQD);

(d) the degrees of induration (hardness);

(e) fracture log;

(f) weathering and fissuring.

(8) In addition to sub-paragraph (5), other tests may comprise—

(a) density of grains determination;

(b) wave velocity determination;

(c) Brazilian tests;

(d) shear strength of rock and joints determination;

(e) slake durability tests;

(f) swelling tests and;

(g) abrasion tests.

(9) The properties of the rock mass including the layering and fissuring or discontinuities may be investigated indirectly by compression and shear strength tests along joints.

(10) In weak rocks, complementary tests in the field or large-scale laboratory tests on block samples may be made.

99. General requirements for laboratory tests

(1) The laboratory test program shall be consistent with the ground investigation program.

(2) Whenever possible, the information obtained from field tests including the ground sounding method, shall be used for selecting the test samples.

(3) Details of the tests required to determine the parameters needed for design shall be specified.

(4) The requirements given in this code shall be considered a minimum.

(5) The list of laboratory tests and the test results required is in Schedule 19.

(6) The laboratory tests and analysis of results shall conform to the requirements in Schedule 26.

100. Groundwater measurements in soils and rocks

(1) Groundwater measurements shall conform to paragraph 78.

(2) The determination of the groundwater table or pore water pressures in soils and rocks shall be made by installing open or closed groundwater measuring systems into the ground.

(3) The type of equipment to be used for groundwater measurements shall be selected according to the type and permeability of ground, the purpose of the measurements, the required observation time, the expected groundwater fluctuations and the response time of the equipment and ground.

(4) There are two main methods for measuring the groundwater pressure: open systems and closed systems.

(5) In open systems, the piezometric groundwater head is measured by an observation well, usually provided with an open pipe while in closed systems, the groundwater pressure at the selected point is directly measured by a pressure transducer.

(6) Open systems are best suited for soils and rock with a relatively high permeability (aquifers and aquitards), e.g. sand, gravel or highly fissured rock.

(7) With soils and rocks of low permeability they may lead to erroneous interpretations, due to the time lag for filling and emptying the pressure pipe. The use of filter tips connected to a small diameter hose in open systems, decreases the time lag.

(8) Closed systems can be used in all types of soil or rock. They should be used in very low permeability soils and rocks (aquicludes), e.g. clay or low fissured rock. Closed systems are also recommended when dealing with high artesian water pressure.

(9) When very short- term variations or fast pore water fluctuations are to be monitored, continuous recording shall be used by means of transducers and data loggers, with any types of soils and rocks.

(10) In cases where open water is situated within or close to the investigation area, the water level shall be considered in the interpretation of the groundwater measurements. The water level in wells, the occurrence of springs and artesian water shall also be noted.

(11) The number, location and depth of the measuring stations shall be chosen considering the purpose of the measurements, the topography, the stratigraphy and the soil conditions, especially the permeability of the ground or identified aquifers.

(12) For monitoring projects e.g. groundwater lowering, excavations, fillings and tunnels, the location shall be chosen with respect to the expected changes to be monitored.

(13) The number and frequency of readings and the length of the measuring period for a given project shall be planned considering the purpose of the measurements and the stabilisation period.

(14) During the drilling process, the observation of the water level at the end of the day and the start of the following day (before the drilling is resumed) is a good indication of the groundwater conditions and should be recorded. Any sudden inflow or loss of water during drilling should also be recorded, since it can provide additional useful information.

101. Evaluation of results of groundwater measurements

(1) The evaluation of groundwater measurements shall take into account the following—

(a) geological and geotechnical conditions of the site,

(b) the accuracy of individual measurements,

(c) the fluctuations of pore water pressures with time,

(d) the duration of the observation period,

(e) the season of measurements; and

(f) the climatic conditions during and prior to that period.

(2) The evaluated results of groundwater measurements shall comprise the observed maximum and minimum elevations of the water table, or pore pressures and the corresponding measuring period.

(3) If applicable, upper and lower bounds for both extreme and normal circumstances shall be derived from the measured values, by adding or subtracting the expected fluctuations or a reduced part of them, to the respective extreme or normal circumstances. The frequent lack of reliable data for extended periods of time of this type of measurements will necessitate the derived values being a cautious estimate based on the limited available information.

(4) The need for making further measurements or installing additional measuring stations should be assessed during the field investigations and in the ground investigation report.

102. Seismicity

(1) Earthquake activity/actions shall be considered for areas that are seismically active taking into account the different earthquake zones.

(2) In addition to being considered under geotechnical investigation/studies, earthquake actions shall be considered in general structural design.

(3) Design for earthquake actions shall conform to Uganda Standard, US 319:2003, Seismic code of practice for structural designs

SCHEDULE 1

Paragraph 11

Part I - Design Values of Actions

1) The design value F_d of an action F is expressed in general terms as—

$$F_d = \gamma_f F_{rep}$$

where,

γ_f is the partial safety factor for the action considered taking account of —

(a) the possibility of unfavourable deviation of the actions;
(b) the possibility of inaccurate modelling of the actions;
(c) uncertainties in the assessment of effects of the actions.

2) F_{rep} is the representative value of the action, obtained by—

$$F_{rep} = \psi F_k$$

where,

F_k is the characteristic value of the action.
ψ is either 1.00 or ψ_0, ψ_1 *or* $\psi_2 \psi_0, \psi_1$ *or* ψ_2
(Refer to Table 1 below).

Table 1 - Recommended values of ψ factors for buildings

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings			
Category A : domestic, residential areas	0.7	0.5	0.3
Category B : office areas	0.7	0.5	0.3
Category C : congregation areas	0.7	0.7	0.6
Category D : shopping areas	0.7	0.7	0.6
Category E : storage areas	1.0	0.9	0.8
Category F : traffic area, vehicle weight ≤ 30kN	0.7	0.7	0.6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0.7	0.5	0.3
Category H : roofs	0	0	0
Wind loads on buildings	0.6	0.2	0
Temperature (non-fire) in buildings	0.6	0.5	0

3) The expression for F_d is a general expression for determining an ultimate load.

4) Depending on the type of verification and combination procedures, design values for particular actions are expressed as follows—

$G_d = \gamma_g G_k$ or G_k
$Q_d = \gamma_q Q_k$ or Q_k

where,

G_k = the characteristic dead load
Q_k = the characteristic live load

5) A distinction has to be made between favourable and unfavourable effects of actions, two different partial factors of safety shall be used.

6) The partial factors of safety for favourable and unfavourable effects are to be obtained from the *National standards or Clause 6.5.3 and Tables A1.2(A), A1.2(B), A1.2(C), A1.3, A1.4 of Eurocode 0*.

Part II—Design Values of Material Properties

The design value X_d of a material or product property is generally defined as:

$$X_d = \eta \frac{X_k}{\gamma_m}$$

where,

gM is the partial safety factor for material or product property which covers:

(a) unfavourable deviation from the characteristic;
(b) inaccuracies in the convention factors; and
(c) uncertainties in the geometric properties and the resistance model.

h is the conversion factor taking into account the effect of the duration of the load, volume and scale effects of moisture and temperature and any other relevant parametres.

Part III - Load Combinations

The load combinations shall be investigated for the ultimate limit state and serviceability limit states *as per National Standards or Eurocode 0* and a load combination that gives maximum load effect shall be considered for design.

SCHEDULE 2

Paragraphs 12, 23

1) Areas in residential, social, commercial and administration buildings shall be divided into categories according to their specific uses shown in Schedule 2 Table 1 below.

2) Independent of this classification of areas, dynamic effects shall be considered where it is anticipated that the occupancy will cause significant dynamic effects.

Table 1 - Categories of use

Category	Specific Use	Example
A	Areas for domestic and residential activities	(1) Rooms in residential buildings and houses; (2) Bedrooms and wards in hospitals; (3) Bedrooms in hotels and hostels kitchens and toilets
B	Office areas	

C	Areas where people may congregate (with the exception of areas defined under category A, B, and D)	**C1**: Areas with tables, etc. e.g. areas in schools, cafés, restaurants, dining halls, reading rooms, receptions. **C2**: Areas with fixed seats, e.g. areas in churches, theatres or cinemas, conference rooms, lecture halls, assembly halls, waiting rooms, railway waiting rooms. **C3:** Areas without obstacles for moving people, e.g. areas in museums, exhibition rooms, etc. and access areas in public and administration buildings, hotels, hospitals, railway station forecourts. **C4**: Areas with possible physical activities, e.g. dance halls, gymnastic rooms, stages. **C5**: Areas susceptible to large crowds, e.g. in buildings for public events like concert halls, sports halls including stands, terraces and access areas and railway platforms

Table 1 - Categories of use (contd).

Category	Specific Use	Example
D	Shopping areas	**D1:** Areas in general retail shops **D2**: Areas in department stores

Values of actions

1) The categories of loaded areas, as specified in Schedule 2, Table 1 above, shall be designed by using characteristic values q_k (uniformly distributed load) and Q_k (concentrated load).

2) Where necessary q_k and Q_k should be increased in the design (e.g. for stairs and balconies depending on the occupancy and on dimensions).

3) For local verifications a concentrated load Q_k acting alone should be taken into account.

4) For concentrated loads from storage racks or from lifting equipment, Q_k should be determined for the individual case.

5) The concentrated load shall be considered to act at any point on the floor, balcony or stairs over an area with a shape which is appropriate to the use and form of the floor.

6) Where floors are subjected to multiple use, they shall be designed for the most unfavourable category of loading which produces the highest effects of actions (e.g. forces or deflection) in the member under consideration.

7) Provided that a floor allows a lateral distribution of loads, the self-weight of movable partitions may be taken into account by a uniformly distributed load q_k which should be added to the imposed loads of floors obtained from Schedule 2, Table 2. This defined uniformly distributed load is dependent on the self-weight of the partitions as follows:
   - for movable partitions with a self-weight $\leq$ 1.0 kN/m wall length: q_k =0.5 kN/m^2;
   - for movable partitions with a self-weight > 1$\leq$ 2.0 kN/m wall length: q_k =0.8 kN/m^2;
   - for movable partitions with a self-weight > 2$\leq$ 3.0 kN/m wall length: q_k =1.2 kN/m^2

8) Heavier partitions should be considered in the design taking account of:
– the locations and directions of the partitions;
– the structural form of the floors.

9) A reduction factor α_A may be applied to the q_k values for imposed loads for floors and for accessible roofs. The recommended value for the reduction factor α_A for categories A to D is determined as follows:

$$\alpha_A = 5/7\ \Psi_0 + A_0/A \leq 1.0$$

with the restriction for categories C and D: $\alpha_A \geq 0.6$
where:
Ψ_0 is the factor according to Schedule 1, Table 1
$A_0 = 10.0 m^2$
A is the loaded area

10) For columns and walls the total imposed loads from several storeys may be multiplied by the reduction factor α_n .

$$\alpha_n = (2 + (n - 2)\ \Psi_0)/n$$

where:
n is the number of storeys (>2) above the loaded structural elements from the same category;
Ψ_0 is the factor according to Schedule 1, Table 1 above

11) Values for q_k and Q_k are given in Schedule 2, Table 2 below. The recommended values, intended for separate application, are underlined. q_k is intended for determination of general effects and Q_k for local effects.

Table 2 – Imposed loads on floors, balconies and stairs in buildings

Categories of loaded areas (floor area usage)	Intensity of distributed load, q_k (kN/m^2)	Concentrated load, Q_k (kN)
Category A		
(a) Floors	1.5 to 2.0	2.0 to 3.0
(b) Stairs	2.0 to 4.0	2.0 to 4.0
(c) Balconies	2.5 to 4.0	2.0 to 3.0
Category B	2.0 to 3.0	1.5 to 4.5
Category C		
(a) C1	2.0 to 3.0	3.0 to 4.0
(b) C2	3.0 to 4.0	2.5 to 7.0 (4.0)
(c) C3	3.0 to 5.0	4.0 to 7.0
(d) C4	4.5 to 5.0	3.5 to 7.0
(e) C5	5.0 to 7.5	3.5 to 4.5
Category D		
(a) D1	4.0 to 5.0	3.5 to 7.0 (4.0)
(b) D2	4.0 to 5.0	3.5 to 7.0

SCHEDULE 3

Paragraph 13

Formula for converting wind speed to the free stream velocity

(1) The free stream wind velocity, q_b can be obtained using the formula—

$$q_b = \frac{1}{2}\rho V_b^2 q_b = \frac{1}{2}\rho V_b^2$$

where:
$\rho\rho$ = the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms.
V_b = the basic wind velocity.

(2) Real time wind data and weather information can be obtained from the Uganda National Meteorological Authority website link below:

http://196.0.33.173:8080/livedata/collection.jsf

(3) Wind maps can be generated using the real time wind data mentioned in (2) above.

SCHEDULE 4

Paragraph 13

(1) The design pressure on the surface of a roof, shall be determined as follows—

(a) for the design of roofs as a whole and for the design of roof claddings and their fixings in areas other than those given in (2) below, the design pressure on the external surface of the roof shall be determined by use of the equation—

$$P_z = (C_{pe} - C_{pi})\, q_z$$

where

C_{pe} = the external pressure coefficient

C_{pi} = the internal pressure coefficient

(b) for the design of roof claddings and their fixings in areas within a distance from any edge of the roof of *h* of 0.15*w* (whichever is less) the design pressure on the external surface of the roof shall be determined by the equation—

$p_z = +1.5\, q_z$
or
$p_z = -2.0\, q_z$

(2) For mono-pitched roofs and the first span of pitched roofs and saw-tooth roof of multi-span buildings, the coefficients in Part I below shall apply.

(3) For the intermediate spans of pitched roofs and saw-tooth roofs of multi-span buildings the pressure coefficient shall be—

(b) -0.5 for wind normal to ridge;
(c) –0.85 for wind parallel to ridge.

(4) For irregular shapes, an "equivalent regular shape" in area way be used as specified in Part II below.

Part I - External Pressure Coefficient C_{pe} for Pitched Roofs of Rectangular Clad Buildings

Roof angle (degrees)	Average C_{pe} for surface		
	Wind normal to ridge		Wind parallel to ridge
	Windward	Leeward	
0	-0.8	-0.5	-1.0
5	-0.9	-0.5	-0.9
10	-1.2	-0.5	-0.8
15	-0.8	-0.5	-0.8
20	-0.5	-0.5	-0.8
30	0.0	-0.5	-0.8
40	+0.3	-0.5	-0.8
50	+0.5	-0.5	-0.8
60	+0.7	-0.5	-0.8

Part II - Average Internal Pressure Coefficients C_{pi} for Rectangular Buildings of Open Interior Plan

Condition	Internal pressure coefficient C_{pi}
Two opposite walls equally permeable, Other walls impermeable: (a) Wind normal to permeable wall (b) Wind normal to impermeable wall	 +0.2 -0.3
Four walls equally permeable	-0.3 or 0.0, whichever is the more severe for combined loadings

Dominant opening on one wall, other walls of equal permeability: (a) Dominant opening on windward wall, having a ratio of permeability of windward wall total permeability of other walls and roofs subject to external suction, equal to 1 or less 1.5 2 3 6 or more (b) Dominant opening on leeward wall (c) Dominant opening on a face parallel to the wind (i) Any dominant opening not in an area of high local C_{pe} (ii) Any dominant opening in an area of high local C_{pi} (d) Dominant opening in a roof segment	 +0.1 +0.3 +0.6 +0.8 -0.3 -0.4 -0.8 Value of C_{pe}
A building effectively sealed and having non-opening windows	-0.2 or 0.0, whichever is the more sever fro combine loads

SCHEDULE 5

Paragraph 16, 17

Part I

Safe Bearing Resistances[1] under Vertical Static Loading

Supporting Ground Type	Description	Compactness[1] or Compactness[2]	Safe Bearing Resistance (kPa)	Remarks
Rocks	Massively crystalline igneous and metamorphic rock (granite, basalt, gneiss)	Hard and sound	5600	These values are based on the assumption that the foundations are carried down to unweathered rock
	Foliated metamorphic rock (slate, schist)	Medium hard and sound	2800	
	Sedimentary rock (hard shale, siltstone, sandstone, limestone)	Medium hard and sound Soft	2800 1400	
	Weathered or broken-rock (soft limestone)	Soft	850	
	Soft shale			
	Decomposed rock to be assessed as soil			

1 The given design bearing values do not include the effect of the depth of embedment of the foundation.

Supporting Ground Type	Description	Compactness[1] or Compactness[2]	Safe Bearing Resistance (kPa)	Remarks
Non-cohesive soils	Gravel, sand and gravel	Dense	560	Width of foundation (*B*) not less than 1.0 m
		Medium dense	420	
		Loose	280	Ground water level assumed to be depth not less than (*B*) below the base of the foundation
	Sand	Dense	420	
		Medium dense	280	
		Loose	140	

Supporting Ground Type	Description	Compactness[3] or Compactness[4]	Safe Bearing Resistance (kPa)	Remarks
Cohesive soils	Silt	Hard	280	
		Stiff	200	
		Medium stiff	140	
	Turf	Soft	70	
	Red coffee	Compact	200	
	Clay	Firm	150	
		Hard	420	
		Stiff	280	
		Medium stiff	140	
		Soft	70	
	Alluvium	Loose	50	
		Very soft	Not applicable	
		Firm	50	

Note: The data in Schedule 5 is just a guide to the designer and does not preclude comprehensive soil investigations to be undertaken.

Part II

Procedure for checking the design shears at faces of columns

(1) Calculate the plan area of the footing using the safe soil bearing capacity and critical loading arrangement at serviceability limit state.

(2) Column face shear is checked using the equation—

$$V_{Ed} \leq 0.5 b_w d v f_{cd} V_{Ed} \leq 0.5 b_w d v f_{cd}$$

where,

V_{Ed} = Design shear force

b_w = Perimeter of loaded area

d = Effective depth

v = strength reduction factor for concrete cracked in shear

(3) Check for shear without shear reinforcement is carried out using the equation—

$$v_{Ed} \leq v_{Rd,c} v_{Ed} \leq v_{Rd,c}$$

(4) Applied shear stress is designed using the equation -

$$v_{Ed} = \beta \frac{V_{Ed}}{u_i d}$$

(5) Shear stress without shear reinforcement is designed using the equation—

$$v_{Rd,c} = C_{Rd,c} k (100 \rho_1 f_{ck})^{1/3} + k \sigma_{cp} \geq (V_{min} + k_1 \sigma_{cp})$$

SCHEDULE 6

Paragraph 16

Structural performance factor K

Item	Structural type	Structural performance factor K
1(a)	Ductile moment-resisting frame	1.0
1(b)	Frame as in 1(a) with reinforced concrete shear walls	1.0
2(a)	Frame as in 1(a) with either steel bracing members detailed for ductility or reinforced concrete infill panels	1.5
2(b)	Frame as in 1 a with masonry infills	2.0
3	Diagonally braced steel frame with ductile bracing acting in tension only	2.0
4	Cable-stayed chimney	*3.0*
5	Structures of minimal ductility including reinforced concrete frames not covered by 1 or 2 above and mason bearing wall structures	4.0

SCHEDULE 7

Paragraph 21.

Part I

Standard Mixes for Ordinary Structural Concrete per 50 kg Bag of Cement

Concrete Grade	Nominal max. size of Aggregate (mm)	40		20		14		10	
	Workability	**Medium**	**High**	**Medium**	**High**	**Medium**	**High**	**Medium**	**High**
	Limits of slump that may be expected (mm)	**30 to 60**	**60 to 120**	**20 to 50**	**50 to 100**	**10 to 30**	**30 to 60**	**10 to 25**	**25 to 50**
C12/15	Total aggregate (kg) Fine aggregate (%) Vol. of finished concrete (m^3)	370 30 – 45 0.200	330 30 – 45 0.183	320 35 – 50 0.178	280 35 – 50 0.160	–	–	–	–
C16/20	Total aggregate (kg) Fine aggregate (%) Vol. of finished concrete (m^3)	305 30 – 35 0.165	270 30 – 40 0.155	280 30 – 40 0.156	250 35 – 45 0.143	255 35 – 45 0.146	220 40 – 50 0.130	240 40 – 50 0.137	200 45 – 55 0.121
C20/25	Total aggregate (kg) Fine aggregate (%) Vol. of finished concrete (m^3)	265 30 – 35 0.147	240 30 – 40 0.137	240 30 – 40 0.137	215 35 – 45 0.127	220 35 – 45 0.130	195 40 – 50 0.118	210 40 – 50 0.124	175 45 – 55 0.110
C25/ 30	Total aggregate (kg) Fine aggregate (%) Vol. of finished concrete (m^3)	235 30 – 35 0.134	215 30 – 40 0.127	210 30 – 40 0.124	190 35 – 45 0.115	195 35 – 45 0.115	170 40 – 50 0.106	180 40 – 50 0.109	150 45 – 55 0.097

Concrete mixes shall be designed to satisfy the specified characteristic strengths. The mean strength of the designed mix shall exceed the specified values by twice the expected standard deviation so as to take into account the inevitable variation.

Part II

Partial Safety Factors

Material	**Partial safety factor**
Reinforcement Steel	1.15
Concrete: flexure or axial load	1.50
Concrete: shear strength	1.25
Concrete: bond strength	1.40
Concrete: other strengths e.g. bearing	1.50

SCHEDULE 8

Paragraph 21

Table of Concrete Design Properties and Strength Classes for Concrete)

Symbol	Description	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60	C55/67	C60/75	C70/85	C80/95	C90/105
f_{ck} (MPa)	Characteristic cylinder compressive strength	12	16	20	25	30	35	40	45	50	55	60	70	80	90
f_{cm} (MPa)	Mean compressive strength	20	24	28	33	38	43	48	53	58	63	68	78	88	98
f_{ctm} (MPa)	Mean tensile strength	1.57	1.90	2.21	2.56	2.90	3.21	3.51	3.80	4.07	4.21	4.35	4.61	4.84	5.04
E_{cm} (MPa)	Elastic modulus	27085	28608	29962	31476	32837	34077	35220	36283	37278	38214	39100	40743	42244	43631
f_{cd} (MPa) (for $\alpha cc=1.00$)	Design compressive strength	8.00	10.67	13.33	16.67	20.00	23.33	26.67	30.00	33.33	36.67	40.00	46.67	53.33	60.00
f_{cd} (MPa) (for $\alpha cc=0.85$)	Design compressive strength	6.80	9.07	11.33	14.17	17.00	19.83	22.67	25.50	28.33	31.17	34.00	39.67	45.33	51.00
f_{ctd} (MPa) (for $\alpha ct=1.00$)	Design tensile strength	0.73	0.89	1.03	1.20	1.35	1.50	1.64	1.77	1.90	1.97	2.03	2.15	2.26	2.35
ρ_{min} (%)	Minimum longitudinal tension reinforcement ratio	0.13	0.13	0.13	0.133	0.151	0.167	0.182	0.197	0.212	0.219	0.226	0.24	0.252	0.262
$\rho_{w,min}$ (%)	Minimum shear reinforcement ratio	0.055	0.064	0.072	0.08	0.088	0.095	0.101	0.107	0.113	0.119	0.124	0.134	0.143	0.152

SCHEDULE 9

Paragraph 22

<u>*Values of* b_a</u>

Member	**Simply supported**	**End spans**	**Interior spans**	**Cantilevers**
Beams	20	24	28	10
Slabs				
(a) Span ratio = 2:1	25	30	35	12
(b) Span ratio = 1:1	35	40	45	10
Flat slabs (based on longer span)	24			-

Note: For slabs with intermediate span ratios interpolate linearly

SCHEDULE 10

Paragraph 24

Span/Effective Depth Ratios for Solid Slabs

Types of slabs	Span/depth ratios
Cantilever	7
Simply supported	20
Continuous	26

Span/Effective Depth Ratios for Ribbed and Coffered Slab

Types of slabs	Span/depth ratios
Cantilever	5.6
Simply supported	16
Continuous	20.8

SCHEDULE 11

Paragraph 24

Formulae for Slabs

(1) The effective width of the slabs is equal to—

$$b_e = l_w + 2.4(l - x/l)x$$

where,

l_w = Load width;

x = Distance to the nearer support from center of load;

l = Span of slab; and

b_e = Effective width of slab

(2) The moments and shear forces in continuous one-way spanning slabs shall be calculated in accordance with Table 1 below.

Table 1: Bending Moments and Shear Forces for One-Way Slabs

Conditions	**End Support**	**End Span**	**Penultimate Support**	**Interior K-Spans**	**Interior Supports**
Bending	0	0.086Fl	-0.086Fl	-0.063 Fl	-0.063Fl
Shear forces	0.4F	-	0.6F	-	0.5F

where,
F = total design ultimate load; and
l = span length

(3) The condition of restrained slabs with unequal conditions at adjacent panels needs to be considered for one-way slabs.

Table 2: Bending Moment Coefficients for Two-Way Spanning Rectangular Slabs

Types of panel and moments considered	Short-span coefficient B_{sx} values of I_y / l_x			Long-span coefficient B_{sy} for all values
	1.0	1.25	1.5	
1. Interior panels				
Negative moments at continuous edge	0.031	0.044	0.053	0.032
Positive moment at midspan	0.024	0.034	0.040	0.024
2. One short edge discontinuous				
Negative moment at continuous edge	0.039	0.050	0.058	0.037
Positive moment at midspan	0.029	0.038	0.043	0.028
3. One long edge discontinuous				
Negative moment at continuous edge	0.039	0.059	0.073	0.037
Positive moment at midspan	0.030	0.045	0.055	0.028
4. Two adjacent edges discontinuous				
Negative moment at continuous edge	0.047	0.066	0.078	0.045
Positive moment at midspan	0.036	0.049	0.959	0.034

Table 3: Bending Moment and Shear Force Coefficients for Flat Slabs of Three or more than Equal Spans

Continuous	Outer supports		Middle of end spans	First interior supports	Middle interior supports	Interior supports
	Columns	Walls				
Bending moments	-0.040*FI*	-0.20*FI*	0.080*FI*	-0.063*FI*	0.071*FI*	-0.05*FI*
Shear forces	0.45*F*	0.40*F*	-	0.60*F*	-	0.59*F*
Total columns moments	0.040*FI*	-	-	0.022*FI*	-	0.02*F*

The moments obtained from the frame analyses or Table 3, shall be shared between the column and middle strips in the proportions given in Table 4.

Table 4: Moments Sharing in Strips of Flats Slabs

Conditions	**Column strips**	**Middle strips**
Negative moments	75%	25%
Positive moments	55%	45%

The design shear stresses shall be given by the relationship:

$v = V/b_v d$

where;

V = Design shear forces due to design ultimate load;

b_v = Breath of slab; and

d = Effective depth of slab

Minimum reinforcement shall be not less than 0.0015*d* per metre width, where *d* = depth of slabs.

The design shear stresses shall be given by the formula:

$v = V/b_v d$

where,

V = Design shear force due ultimate load

b_v = Average width of rib

d = Effective depth

The span or effective depth ratios shall be checked as for flanged beams.

Table 5: Fire Resistance Requirements for Floor Slabs

Fire ratings (hours)	Plain soffit solid slab (including hollow pots, joists + blocks) Minimum overall depths (mm)		Ribbed soffit (including *T*, channel sections); *t* = total depth; *b* = widths of ribs. Minimum thickness/width mm	
	Simply Supported	**Continuous**	**Simply - supported (*t/b*)**	**Continuous (*t/b*)**
1.0	92	95	90/90	90/90
1.5	110	110	105/110	105/90
2.0	125	125	115/125	115/110
3.0	150	150	135/150	135/125
4.0	170	170	150/175	150/150
	Covers to main reinforcement (mm)			
1.0	20	20	20	20
1.5	25	20	35	25
2.0	35	25	45	35
3.0	45	35	55	45
4.0	55	45	65	55

SCHEDULE 12

Paragraph 25

Part I - Basic Span - Effective Depth Ratios for Reinforced Concrete Beams

Support Conditions	Beams
Cantilevers	7
Simply supported	20
Continuous	26

Part II - Design Ultimate Bending Moments and Shear Forces

Continuous	Outer supports	Middle of end spans	First interior supports	Middle interior supports	Interior Support
Moments	*0*	*0.09Fl*	*-0.11Fl*	*0.07 Fl*	*0.08Fl*
Shear	*0.45F*	-	*0.60F*	-	*0.55F*

where *F* = total design ultimate load.

Part III - Fire Resistance and Cover Requirements for Beams

Fire Ratings (hours)	Minimum width mm		Cover to main steel mm	
	Simply Supported	Continuous	Simply supported	Continuous
1.0	120	120	30	20
1.5	150	120	40	35
2.0	200	150	50	50
3.0	240	200	70	60
4.0	280	240	80	70

SCHEDULE 13

Paragraph 26

Part I: Deflection Equation

Equation for deflection for rectangular or circular columns under ultimate conditions

$a_u = B_a Kh$

where,

a_u = Deflection at ultimate limit state

B_a = (1/2000) $(1_e/b)^2$

b = Small dimensions of columns

K = Reduction factors correcting deflections 1.0 (approximately)

h = *Depth of column*

and shall induce additional moment given by

$M_{add} = Na_u$

where,
N = Design ultimate axial load

Part II: Equations for Moments

$M'_x = M_x + (Bh'/b')M_y$ for M_X/M_y greater than h'/b'

$M'_y = M_y + (Bh'/b')$ for M_x/M_y less than h'/b'

where,

h' = Effective depth of columns about major axes

b' = Effective depth of columns about minor axes

B = Coefficient shown in Table 1

Table 1: Values of Coefficient B

N/bhf_{cu}	0.0	0.1	0.2	0.3	0.4	0.5	0.6
B	1.00	0.88	0.77	0.65	0.53	0.42	0.30

Table 2: Fire Resistance Requirements for Reinforced Concrete Columns

Fire rating	**Minimum dimensions mm**			**Cover to main reinforcement**
(hours)	**Fully exposed**	**50% exposed**	**One side expose**	**(mm)**
1.0	200	200	200	25
1.5	250	200	200	30
2.0	300	200	200	35
3.0	400	300	200	35
4.0	450	350	240	35

SCHEDULE 14

Paragraph 25

Part I: Height to Thickness Ratios for Walls

Wind pressures (kN/m^2)	**Height/ thickness Ratio**
0.285	10 or more
0.575	7
0.860	5
1.150	4

Part II: Design strength of walls per unit length

The design strength of walls per unit length, F_w

$$F_w = \quad Bt\, f_k/\gamma_m$$

where,

F_w = Design vertical load resistance of walls

B = Capacity *reduction* factor allowing for effects of slenderness and eccentricity (see Part III below)

f_k = Characteristic strength

γ_m = Partial safety factor for materials (=3.5)

t = Thickness of wall

Part III: Capacity Reduction Factors of Walls

Slenderness Ratio	Eccentricity at top of walls, e_x			
(h_{ef}/t_{ef})*	**0.50*t***	**0. 1*t***	**0.2*t***	**0.3*t***
0	1.00	0.88	0.66	0.44
6	1.00	0.88	0.66	0.44
8	1.97	0.88	0.66	0.44
12	0.93	0.87	0.66	0.44
12	0.89	0.83	0.66	0.44
14	0.83	0.77	0.64	0.44
18	0.77	0.70	0.57	0.44
20	0.70	0.64	0.51	0.37
22	0.62	0.56	0.43	0.30
24	0.53	0.47	0.34	-
26	0.45	0.38	-	-
27	0.40	0.33	-	-

*h_e = Effective height of wall

*t_{ef} = Effective thickness of wall

Part IV: Maximum Slenderness Ratios for Reinforced Concrete Walls

Conditions of walls	Reinforcement	Maximum slenderness ratios (I_e/h)
Braced	Less than 1%	40
Braced	Greater than 1%	45
Unbraced	Both limits	30

Part V: Fire Resistance Requirements for Reinforced Concrete Walls

Fire rating (hours)	Minimum thickness (mm)	Reinforcement	Minimum cover to vertical Reinforcement (mm)
1.0	150	Less than 0.4%	25
1.5	150	0.4 -1.0%	25
1.5	175	Less than 0.4%	25
2.0	160	0.4-1.0%	25
3.0	150	Greater than 1.0%	25
3.0	200	0.4-1.0%	25
4.0	180	Greater than 1.0%	25
4.0	240	0.4-1.0%	25

Part VI: Durability Requirements for Reinforced Concrete Walls above Ground

Conditions of exposure	Cover to all reinforcement (mm)		
Mild: Concrete protected against weather or aggressive conditions.	25	20	20
Moderate: Concrete sheltered from severe rain or freezing; concrete continuously under water; concrete in contact with non aggressive soils; concrete subject to condensation	-	35	30

Severe: Concrete exposed to severe rain, alternative wetting and drying or occasional freezing or severe condensation.	-	-	40
Very severe: Concrete exposed to seawater spray de-icing salts, corrosive fumes, severe freezing conditions.	-	-	50
Water/ cement ratio Cement content (kg/m^3)	0.65 275	0.60 300	0.55 325
Characteristic concrete strength	C25/30	C30/37	40

SCHEDULE 15

Paragraph 29

Part I: Design Strength for Structural Steel

Grade	Thickness of material (mm)	Sections, plates, hollow sections (N/mm^2)	Other properties
43	16 40 63 100	275 265 255 245	Modulus of elasticity = 205 x 10^3 N/mm^2
50	16 40 63 100	355 345 340 325	Poisson's ratio = 0.30
55	16 40 63 100	450 439 415 400	Coefficient of linear expansion = 12 x 10^{-6} per ^{o}C

Part II: Equation for computing shear force

F_v = P_v or less

where,

F_v = Shear force in kN

P_v = Shear capacity = $0.6 p_y A_v$ in kN

A_v = Shear area in mm^2

p_y = Design strength of steel in kN/mm^2

The moment capacities shall be determined by the following equations:

$M_c = p_y S = 1.2p_y Z$ or less; for low shear loads

(i.e. $F_v = 0.6P_v$) or less

$M_c = p_y (S - S_v ql) = 1.2p_y Z$ or less; for high shear loads

(i.e. $F_v = 0.6P_v$) or more

where,

p_y = Design strength in kN/mm^2

S = Plastic modulus of section in mm^3

Z = Elastic modulus of section in mm^3

ql = $(2.5F_v - 1.5)/P_v$

Part III: Minimum thickness of the base plates loaded concentrically

Minimum thickness of the base plates loaded concentrically by I, H, Channel, Box or RHS columns is given by—

$$t = [2.5w(a^2-0.3b^2) / P_{yp}]^{½}$$

where,

a = Greater projection of plate beyond column

b = Lesser projection of plate beyond column

w = Pressure on underside or plate

P_{yp} = Design strength of plate (not exceeding 270 N/mm^2)

For solid or hollow circular columns, thickness of the base plates shall be given by the formula:

$$t = [wD_p (D_p-0.9d)2.4P_{yp}]^{1/2}$$

where,

D_P = length of sides or diameters of cap or base plates (not exceeding 1.5 (D +75)

d = Diameter of column

Part IV: Empirical Values for Purlins

Sections	**Minimum *Z*** **(cm)³**	***D*** **(mm)**	***B*** **(mm)**
Angles	$W_p L/1800$	$L/45$	$L/60$
CHS	$W_p L/2000$	$L/65$	$L/65$
RHS	$W_p L/1800$	$L/70$	$L/150$

where—

Z = elastic modulus of purlins about axes parallel to the planes of the cladding; and

W_p = unfactored loads on purlin in kilo Newtons.

For purlins with C-, Z- and S-cross-sections with or without additional stiffeners in web or flange, the design shall be done in accordance with Annex E of BS EN 1993-1-3:2006 or other approved standard.

Part V: Minimum Roof Slopes

Cladding materials	**Roof structures**	**Roof slopes**
Bitumen-based or other approved roofing product	Concrete slabs	3°
Cement/clay/metal tiles	Concrete slabs	10°
Cement/clay/metal tiles	Trusses	20°
Corrugated metal or other approved sheets	Trusses	15°
Long-span metal sheets	Trusses	5°

SCHEDULE 16

Paragraphs 64, 70, 71, 72

Part I: Timber Strength Classes and Properties

Strength Class	Allowable MOR (N/mm^2)	5^{th} Percentile MOR (N/mm^2)	Mean MOE (N/mm^2)
SG4	4	10.60	5710
SG8	8	21.20	8148
SG12	12	31.80	9710
SG16	16	42.40	11898

SG4 includes: Funtumia elastica *(Nkago)*, Pinus caribaea *(Pine)*, Maesopsis eminii *(Musizi)*, Albizia gummifera *(Red Nongo)*, Lovoa brownii *(Nkoba)* and Albizia coriaria *(Mugavu)*;

SG8 includes: Entandrophragma angolense *(Mukusu)*, Eucalyptus grandis *(Kalitunsi)*, Khaya anthotheca *(Ugandan Mahogany)*, Blighia unijugata *(Nkuzanyana)* and Aningeria altisima *(Enkalati)*;

SG12 includes: Markhamia lutea *(Nsambya)*, Piptadeniastrum africanum *(Mpewere)*, Albizia zygia *(White Nongo)* and Uapaca guineensis *(Namagulu)*; and

SG16 includes: Celtis mildbraedii *(Lufugo)* and Morus lacteal *(Mukooge)*.

Part II: Moisture Content of Timber for Various Positions in Buildings

Position	Moisture content of timber in its permanent position (%)	Moisture content of timber at time of erection (%)
Trusses (Rafters, struts, ties), battens, purlins	15	22
Floor joists and beams	15	22

T and G flooring	12 - 14	15 - 22
Columns	12 - 14	15 - 22
Walls	12 - 14	15 - 22

Part III: Basic Stresses for Structural Timber

Group	Flexure and compression parallel to grain (N/mm^2)	Compression perpendicular to grain (N/mm^2)	Tension (N/mm^2)	Shear parallel to grain (N/mm^2)	Mean modulus of elasticity (N/mm^2)
1	7.0	2.5	10.8	0.7	11,500
2	5.8	1.8	8.6	0.7	8,640

Part IV: Requirements for Mortars in Masonry Construction

Mortar Designation	Type of mortar in volumetric proportions			Mean compressive strength at 28 days	
	Cement/ lime/sand	Cement/ sand	Cement/ sand with plasticizer	Preliminary lab tests (N/mm^2)	Tests from site samples (N/mm^2)
1	1:1/4:3	-	-	16.0	11.0
2	1:1/2:4	1:3	$1:3^1/_2$	6.5	4.5
3	$1:1:5^1/_2$	$1:4^1/_2$	$1:5^1/_2$	3.6	2.5
4	$1:2:8^1/_2$	1:6	$1:7^1/_2$	1.5	1.0

Part V: Physical Properties of Bricks

Class of brick	Compressive strength (N/mm^2) Min	Water Absorption, % by mass, max
Engineering	20	6.3
Industrial	10	6.3
Facing	10	7.0
Common and others	3	No limits

Adopted from Uganda Standard, US 102: 1995, Standard specification for burnt clay bricks

Part VI: Characteristic Compressive Strength of Brickwork Masonry

Mortar designation (See Part IV)	Compressive strength of unit (N/mm²)							
	10	**15**	**20**	**27.5**	**35**	**50**	**70**	**100**
1	4.4	6.0	7.4	9.2	11.4	15.0	19.2	24.0
2	4.2	5.3	6.4	7.9	9.4	12.2	15.1	18.2
3	4.1	5.0	5.8	7.1	8.5	10.6	13.1	15.5
4	3.5	4.4	5.2	6.2	7.3	9.0	10.8	12.7

Part VII: Characteristic Compressive Strength of Concrete Blockwork Masonry

Mortar designation (See Part IV)	Compressive strength of unit (N/mm²)							
	2.8	**3.5**	**5.0**	**7.0**	**10.5**	**15**	**20**	**35**
1	2.1	2.6	3.8	5.1	6.6	9.0	11.1	17.1
2	2.1	2.6	3.8	4.8	6.3	8.9	9.6	14.1
3	2.1	2.6	3.8	4.8	6.2	7.5	8.7	12.8
4	2.1	2.6	3.3	4.2	5.3	6.6	7.8	11.0

Part VIII: Characteristic Flexural Strength of Masonry

Plane of Failure	Flexural strength of unit (N/mm²)					
	Parallel to bed joints			**Perpendicular to bed joints**		
Mortar Designation	1	2 and 3	4	1	2 and 3	4
Clay Bricks	0.4 – 0.7	0.3 – 0.5	0.25 – 0.4	1.1 – 2.0	0.9-1.5	0.8 – 1.2
Concrete Blocks	0.25	0.25	0.20	0.4 – 0.9	0.4 – 0.9	0.4 - 07

SCHEDULE 17

Paragraph 64

Part I: Tables for Design of Concrete Structures

Table 1: Cross sectional Area of Bars (mm^2)

Bar size (mm)	Number of bars									
	1	2	3	4	5	6	7	8	9	10
6	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600

Bar size (mm)	**Weight (kg/m)**	**Perimeter (mm)**
6	0.222	18.85
8	0.395	25.1
10	0.617	31.4
12	0.888	37.7
14	1.208	44.0
16	1.578	50.3
18	1.998	56.5
20	2.466	62.8
22	2.984	69.1
24	3.551	75.4
28	4.834	88.0
30	5.548	94.2
32	6.313	100.5
40	9,865	125.6

Table 2: Slab Reinforcement per meter (mm^2)

Spacing (mm)	Bars Per meter	Diameter (mm)								Spacing (mm)
		6	8	10	12	14	16	18	20	
50	**20.00**	**565**	**1005**	**1571**	**2262**	**3079**	**4021**	**5089**	**6283**	**50**
60	16.67	471	838	1309	1885	2566	3351	4241	5236	60
70	124.29	404	718	1122	1616	2199	2872	3635	4488	70
75	**13.33**	**377**	**670**	**1047**	**1508**	**2053**	**2681**	**3393**	**4189**	**75**
80	12.50	353	628	982	1414	1924	2513	3181	3927	80
85	11.76	333	591	924	1331	1811	2365	2994	3696	85
90	11.11	314	559	873	1257	1710	2234	2827	3491	90
95	10.53	298	529	827	1190	1620	2116	2679	3307	95
100	**10.00**	**283**	**503**	**785**	**1131**	**1539**	**2011**	**2545**	**3142**	**100**
105	9.52	269	479	748	1077	1466	1915	2424	2992	105
110	9.09	257	457	714	1028	1399	1828	2313	2856	110
115	8.70	246	437	683	983	1339	1748	2213	2732	115
120	8.33	236	419	654	942	1283	1676	2121	2618	120
125	**8.00**	**226**	**402**	**628**	**905**	**1232**	**1608**	**2036**	**2513**	**125**
130	7.69	217	387	604	870	1184	1547	1957	2417	130
135	7.41	209	372	581	837	1140	1489	1884	2326	135
140	7.14	202	359	561	808	1100	1436	1818	2244	140
145	6.90	195	347	542	780	1062	1387	1755	2167	145
150	**6.67**	**188**	**335**	**524**	**754**	**1026**	**1340**	**1696**	**2094**	**150**
155	6.45	182	324	507	730	993	1297	1642	2027	155
160	6.25	177	314	491	707	962	1257	1590	1963	160
165	6.06	171	305	476	685	933	1219	1542	1904	165
170	5.88	166	296	462	665	906	1183	1497	1848	170
175	5.71	**162**	**287**	**449**	**646**	**880**	**1149**	**1454**	**1795**	**175**
180	5.56	157	279	436	628	855	1117	1414	1745	180
185	5.41	153	272	425	611	832	1087	1376	1698	185
190	5.26	149	265	413	595	810	1058	1339	1653	190
195	5.13	145	258	403	580	789	1031	1305	1611	195
200	5.00	**141**	**251**	**393**	**565**	**770**	**1005**	**1272**	**1571**	**200**
250	4.00	113	201	314	452	616	804	1018	1257	250
300	3.33	94	168	262	377	513	670	848	1047	300

Table 3: Large Radius Bends: Internal Radius of Bend (mm) for fcu = 25 N/mm²

a_b	Design stress in bar at ultimate load	Bar size mm						
mm	N/mm²	10	12	16	20	24	32	40
25	100	30	35					
	150	45	55					
	200	55	75					
	250	70	90					
	300	85	110					
	350	100	130					
	400	115	150					
50	100	20	30	40	55	80		
	150	35	40	60	85	120		
	200	45	55	80	115	155		
	250	55	70	105	140	195		
	300	65	85	125	170	235		
	350	75	100	145	200	275		
	400	90	110	165	225	315		
75	100	20	25	35	50	65	95	
	150	30	35	55	70	100	140	
	200	40	50	70	95	130	185	
	250	50	60	90	120	165	235	
	300	60	75	110	145	195	280	
	350	70	85	125	170	230	325	
	400	80	100	145	195	260	375	
100	100	20	25	35	45	60	80	115
	150	30	35	50	65	90	125	170
	200	40	45	65	85	120	165	225
	250	45	60	85	110	145	205	285
	300	55	70	100	130	175	245	340
	350	65	80	115	155	205	290	395
	400	75	95	135	175	235	330	450
150 and over	100	20	25	30	40	50	70	95
	150	25	35	45	60	80	110	145
	200	35	45	60	80	105	145	195
	250	45	55	75	100	130	180	240
	300	55	65	90	120	155	215	290
	350	60	75	105	140	185	250	335
	400	70	85	120	160	210	285	385

Table 4: Large - Radius Bends: Internal Radius of Bend (mm) f_{cu} = 30 N/mm²

a_b mm	Design stress in bar at ultimate load N/mm²	Bar size (mm)						
		10	12	16	20	24	32	40
25	100	25	30					
	150	35	45					
	200	45	60					
	250	60	75					
	300	70	90					
	350	80	110					
	400	95	125					
50	100	20	25	35	45	65		
	150	25	35	50	70	100		
	200	35	45	70	95	130		
	250	45	60	85	120	165		
	300	55	70	105	140	195		
	350	65	80	120	165	230		
	400	75	95	135	190	260		
75	100	20	25	30	40	55	80	
	150	25	30	45	60	80	115	
	200	35	40	60	80	110	155	
	250	40	50	75	100	135	195	
	300	50	60	90	120	165	235	
	350	60	75	105	140	190	270	
	400	65	85	120	160	220	310	
100	100	20	20	30	40	50	70	95
	150	25	30	40	55	75	105	140
	200	30	40	55	75	100	135	190
	250	40	50	70	90	125	170	235
	300	45	60	85	110	145	205	285
	350	55	70	95	130	170	240	330
	400	65	80	110	145	195	275	375
150 and over	100	20	20	30	40	50	65	80
	150	20	25	40	50	65	90	120
	200	30	35	50	65	85	120	160
	250	35	45	65	85	110	150	200
	300	45	55	75	100	130	180	240
	350	50	65	90	115	155	210	280
	400	60	75	100	135	175	240	320

Table 5: Large - Radius Bends: Internal Radius of Bend (mm) f_{cu} = 40 N/mm²

a_b Mm	Design stress in bar at ultimate load N/mm²	Bar size (mm) 10	12	16	20	24	32	40
25	100	20	25					
	150	30	40					
	200	40	55					
	250	50	65					
	300	60	80					
	350	70	90					
	400	80	105					
50	100	20	25	35	45	65		
	150	25	30	50	70	100		
	200	30	40	70	95	130		
	250	40	50	85	120	165		
	300	45	60	105	140	195		
	350	55	70	120	165	230		
	400	65	80	135	190	260		
75	100	20	25	30	40	55	80	
	150	20	25	45	60	80	115	
	200	30	35	60	80	110	155	
	250	35	45	75	100	135	195	
	300	45	55	90	120	165	235	
	350	50	60	105	140	190	270	
	400	55	70	120	160	220	310	
100	100	20	25	30	40	50	70	95
	150	20	25	40	55	75	105	140
	200	25	35	55	75	100	135	190
	250	35	40	70	90	125	170	235
	300	40	50	85	110	145	205	285
	350	45	60	95	130	170	240	330
	400	55	65	110	145	195	275	375
150 and over	100	20	25	30	40	50	65	80
	150	20	25	35	50	65	90	120
	200	25	30	45	65	85	120	160
	250	30	40	70	85	110	150	200
	300	40	45	90	100	130	180	240
	350	45	55	100	115	155	210	280
	400	50	60	120	135	175	240	320

Table 6: Column ties data

Nominal size of vertical bars (mm)	Minimum size of ties (mm)	Maximum pitch of ties (mm)
12	6 (8 preferred)	125
16	6 (8 preferred)	175
20	6 (8 preferred)	225
25	8	300
32	8	375
40	10	475
50	16	600

Table 7: Areas of Reinforcement for Various Tie Combinations

Nominal Bar size	No. of Ties Legs	Areas, mm²									
		Pitch of ties (maximum 0.75d), mm									
		75	100	125	150	175	200	225	250	300	400
6	2	754	566	452	378	324	284	255	226	189	142
	4	1508	1132	904	756	648	568	510	452	378	284
	6	2262	1698	1356	1134	972	852	765	678	567	426
	8	3016	2264	1808	1512	1296	1136	1020	904	756	568
	10	3770	2830	2260	1890	1620	1420	1275	1130	943	710
8	2	1342	1006	804	670	574	504	453	402	336	252
	4	2684	2012	1608	1340	1148	1008	906	804	672	504
	6	4026	3018	2412	2010	1722	1512	1359	1206	1008	756
	8	5368	4024	3216	2680	2296	2016	1812	1608	1344	1008
	10	6710	5030	4020	3350	2870	2520	2265	2010	1680	1260
10	2	2100	1570	1256	1046	898	786	707	628	524	393
	4	4200	3140	2512	2092	1796	1572	1414	1256	1048	786
	6	6300	4710	3768	3138	2694	2358	2121	1884	1572	1179
	8	8400	6280	5024	4184	3592	3144	2828	2512	2906	1572
	10	10500	7850	6280	5230	4490	3930	3535	3140	2620	1965

12	2	3020	2260	1810	1508	1292	1132	1018	904	754	566
	4	6040	4520	3620	3016	2584	2264	2036	1808	1508	1132
	6	9060	6780	5430	4524	3876	3396	3054	2712	2262	1698
	8	12080	9040	7240	6032	5168	4528	4072	3616	3016	2264
	10	15100	11300	9050	7540	6460	5660	5090	4520	3770	2830
16	2	5360	4020	3220	2680	2300	2020	1804	1608	1340	1010
	4	-	8040	6440	5360	4600	4040	3608	3216	2680	2020
	6	-	12060	9660	8040	6900	6060	5412	4824	4020	3030
	8	-	16080	12880	10720	9200	8080	7216	6432	5360	4040
	10	-	20100	16100	13400	11500	10100	9020	8040	6700	5050

Check that clear distance between groups of multiple ties is 60 mm minimum.
Maximum pitch of tie legs at 90^{o} to span = 1.0 effective depth, *d*.

Table 8: Minimum Areas of Reinforcement, mm^2

For flanged beams: web in tension due to flexure

$f_y = 430$ N/mm²		Breadth of web, mm													
		250		**300**		**350**		**400**		**450**		**500**		**600**	
Web/flange		<0.4	0.4	<0.4	0.4	<0.4	0.4	<0.4	0.4	<0.4	0.4	<0.4	0.4	<0.4	0.4
Minimum %		0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13	0.18	0.13
Breadth of beam b (mm)	250	113	82	135	98	158	114	180	130	203	147	225	163	270	195
	275	124	90	149	108	174	126	198	143	223	161	248	179	297	215
	300	135	98	162	117	189	137	216	156	243	176	270	195	324	234
	325	147	106	176	127	205	148	234	169	264	191	293	212	351	254
	350	158	114	189	137	221	160	252	182	284	205	315	228	378	273
	375	169	122	203	147	237	171	270	195	304	220	338	244	405	293
	400	180	130	216	156	252	182	288	208	324	234	360	260	432	312
	425	192	139	230	166	268	194	306	221	345	249	383	277	459	332
	450	203	147	243	176	284	205	324	234	365	264	405	293	486	351
	475	214	155	257	186	300	217	342	247	385	278	428	309	513	371
	500	225	163	270	195	315	228	360	260	405	293	450	325	540	390
	525	237	171	284	205	331	239	378	273	426	308	473	342	567	410
	550	248	179	297	215	347	251	396	286	446	322	495	358	594	429
	575	259	187	311	225	363	262	414	299	466	337	518	374	621	449
	600	270	195	324	234	378	273	432	312	486	351	540	390	648	468
	750	338	244	405	293	473	342	540	390	608	439	675	488	810	585

Table 9: Minimum Areas of Reinforcement, mm^2

Flanged beams: flange in tension due to flexure over a continuous support

f_y = 430 N/mm²		Breadth of web, mm													
		250		300		350		400		450		500		600	
Flange type		T	L	T	L	T	L	T	L	T	L	T	L	T	L
Minimum %		0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20	0.26	0.20
Breadth of beam *b* (mm)	250	163	125	195	150	228	175	260	200	293	225	325	250	390	300
	275	179	138	215	165	251	193	286	220	322	248	358	275	429	330
	300	195	150	234	180	273	210	312	240	351	270	390	300	468	360
	325	212	168	254	195	296	228	338	260	381	293	423	325	507	390
	350	228	175	273	210	319	245	364	280	410	315	455	350	546	420
	375	244	188	293	225	342	263	390	300	439	338	483	375	585	450
	400	260	200	312	240	364	280	416	320	468	360	520	400	624	480
	425	277	213	332	255	387	298	442	340	498	383	553	425	663	510
	450	293	225	351	270	410	315	568	360	527	405	585	450	702	540
	475	309	238	371	285	433	494	380	556	428	613	475	741	570	371
	500	325	250	390	300	455	350	520	400	585	450	650	500	780	600
	525	342	263	410	315	478	368	546	420	615	473	683	525	819	630
	550	358	275	429	330	501	385	572	440	644	495	717	550	858	660
	575	374	288	449	345	524	403	598	460	673	518	748	575	897	690
	600	390	300	468	360	546	420	624	480	702	540	780	600	963	720
	750	488	375	585	450	683	525	780	600	878	675	975	750	1170	900

Part II: Tables for Design of Steel Structures

Table 1: Bending Strength, p_b, (in N/mm^2) for Rolled sections

p_y / λ_{LT}	245	265	275	325	340	355	415	430	450
30	245	265	275	325	340	355	408	421	438
35	245	265	273	316	328	341	390	402	418
40	238	254	262	302	313	325	371	382	397
45	327	242	250	287	298	309	350	361	374
50	217	231	238	272	282	292	392	338	350
55	206	219	226	257	266	274	307	315	325
60	195	207	213	241	249	257	285	292	300
65	185	196	201	225	232	239	263	269	276
70	174	184	188	210	216	222	242	247	253
75	164	172	176	195	200	205	223	226	231
80	154	161	165	181	186	190	204	208	212
85	144	151	154	168	172	175	188	190	194
90	135	141	144	156	159	162	173	175	178
95	126	131	134	144	147	150	159	161	163
100	118	123	125	134	137	139	147	148	150
105	111	115	117	125	127	129	136	137	139
110	104	107	109	116	118	120	126	127	128
115	97	101	102	108	110	111	117	118	119
120	91	94	96	101	103	104	108	109	111
125	86	89	90	90	96	97	101	102	103
130	81	83	84	89	90	91	94	95	96
135	76	78	79	83	84	85	88	89	90
140	72	74	75	78	79	80	83	84	84
145	68	70	71	74	75	75	78	79	79
150	64	66	67	70	70	71	73	75	75
155	61	62	63	66	66	67	69	70	70
160	58	59	60	62	63	63	65	66	66
165	55	56	57	60	60	60	62	62	63
170	52	53	54	56	56	57	59	59	59
175	50	51	51	54	54	54	56	56	56
180	47	48	49	51	51	51	53	53	53
185	45	46	46	48	48	49	50	50	51
190	43	44	44	46	46	47	48	48	48
195	41	42	42	44	44	44	46	46	46
200	39	40	40	42	42	42	43	44	44
210	36	37	37	38	39	39	40	40	40
220	33	34	34	35	35	36	36	37	37
230	31	31	31	32	33	33	33	34	34
240	29	29	29	30	30	30	31	31	31
250	27	27	27	28	28	28	29	29	29

Table 2: Bending Strength, p_b, (in N/mm^2) for Welded section

p_y / LT	245	265	275	325	340	355	415	430	450
30	245	265	275	325	340	355	401	412	427
35	245	265	272	307	317	328	368	378	391
40	231	244	250	282	292	301	337	346	358
45	212	224	230	259	268	276	308	316	327
50	196	207	212	238	246	253	282	288	297
55	180	190	195	219	225	232	257	263	275
60	167	176	180	201	207	212	245	253	264
65	154	162	166	188	196	204	235	242	251
70	142	150	155	182	189	196	224	230	238
75	135	145	151	175	182	188	212	218	225
80	131	141	146	168	174	179	201	205	211
85	127	136	140	160	165	171	188	190	194
90	123	131	135	152	157	162	173	175	178
95	118	125	129	144	147	150	159	161	163
100	113	120	123	134	137	139	147	148	150
105	109	115	117	125	127	129	136	137	139
110	104	107	109	116	118	120	126	127	128
115	97	101	102	108	110	111	117	118	119
120	91	94	96	101	103	104	108	109	111
125	86	89	90	90	96	97	101	102	103
130	81	83	84	89	90	91	94	95	96
135	76	78	79	83	84	85	88	89	90
140	72	74	75	78	80	80	83	84	84
145	68	70	71	74	75	75	78	79	79
150	64	66	67	70	71	71	73	74	75
155	61	62	63	66	66	67	69	70	70
160	58	59	60	62	63	63	65	66	66
165	55	56	57	60	60	60	62	62	63
170	52	53	54	56	56	57	59	59	59
175	50	51	51	54	54	54	56	56	56
180	47	48	49	51	51	51	53	53	53
185	45	46	46	48	48	49	50	50	51
190	43	44	44	46	46	47	48	48	48
195	41	42	42	44	44	44	46	46	46
200	39	40	40	42	42	42	43	44	44
210	36	37	37	38	39	39	40	40	40
220	33	34	34	35	35	36	36	37	37
230	31	31	31	32	33	33	33	34	34
240	29	29	29	30	30	30	31	31	31
250	27	27	27	28	28	28	29	29	29

Table 3: Bending Strength, p_b (in N/mm^2) for Rolled sections with Equal Flanges

(a) p_y = 265 N/mm^2

x	5	10	15	20	25	30	35	40	45	50
30	265	265	265	265	265	265	265	265	265	265
35	265	265	265	265	265	265	265	265	265	265
40	265	265	265	265	265	264	264	264	263	263
45	265	265	261	258	256	255	254	254	254	254
50	265	261	253	249	247	246	245	244	244	244
55	265	255	246	241	238	236	235	235	234	234
60	265	250	239	233	229	227	226	225	224	224
65	265	245	232	225	221	218	216	215	214	214
70	265	240	225	217	212	209	207	205	204	204
75	263	235	219	210	204	200	198	196	194	194
80	260	230	213	202	196	191	189	187	185	Z184
85	257	226	207	195	188	183	180	178	176	175
90	254	222	201	188	180	175	171	169	167	166
95	252	217	196	182	171	167	163	160	158	157
100	249	213	190	176	166	160	156	153	150	149
105	247	209	185	170	160	153	148	145	143	142
110	244	206	180	164	154	147	142	138	136	134
115	242	202	176	159	148	140	135	132	129	127
120	240	198	171	154	142	135	129	125	123	121
125	237	195	167	149	137	129	124	120	117	115
130	235	191	163	144	132	124	119	114	111	109
135	233	188	159	140	128	119	114	109	106	104
140	231	185	155	136	124	115	109	105	102	99
145	229	182	152	132	120	111	105	101	97	95
150	227	179	148	129	116	107	101	97	93	91
155	225	176	145	125	112	103	97	93	89	87
160	223	173	142	122	109	100	94	89	86	83
165	231	170	139	119	106	97	91	86	83	80
170	229	167	136	116	103	94	88	83	80	77
175	227	165	133	113	100	91	85	80	77	74
180	215	162	130	110	97	88	82	77	74	71
185	213	160	128	108	95	86	79	75	71	69
190	211	157	125	105	92	83	77	73	9	66
195	209	155	123	103	90	81	75	70	67	64
200	207	153	120	101	88	79	73	68	65	62
210	204	148	116	96	84	75	69	64	61	58
220	200	144	112	93	80	71	65	61	58	55
230	197	140	108	89	77	68	62	58	54	52
240	194	136	104	86	74	65	59	55	52	49
250	190	132	101	83	71	63	57	52	49	47

Table 3: Bending Strength, p_b (in N/mm2) for Rolled sections with Equal Flanges

(b) p_y = 275 N/mm^2										
x	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
30	275	275	275	275	275	275	275	275	275	275
35	275	275	275	275	275	275	275	275	275	275
40	275	275	275	275	274	273	272	272	272	272
45	275	275	269	266	264	263	263	262	262	262
50	274	269	261	257	255	253	253	252	252	251
55	275	263	254	248	246	244	243	242	241	241
60	275	258	246	240	236	234	233	232	231	230
65	275	252	239	232	227	224	223	221	221	220
70	274	247	232	223	218	215	213	211	210	209
75	271	242	225	'	209	206	203	201	200	199
80	268	237	219	208	201	196	193	191	190	189
85	265	233	185	200	193	188	184	182	180	179
90	262	228	180	193	185	179	175	173	171	169
95	260	224	175	186	177	171	167	164	162	160
100	257	219	171	180	170	164	159	156	153	152
105	254	215	190	174	163	156	151	148	146	144
115	252	211	185	168	157	150	144	141	138	136
115	250	207	180	162	151	143	138	134	131	129
120	247	204	175	157	145	137	132	128	125	123
125	245	200	171	152	140	132	126	122	119	116
130	242	196	167	147	135	126	120	116	113	11
135	240	193	162	143	130	121	115	111	108	106
140	238	190	159	139	126	117	111	106	103	101
145	236	186	155	135	122	113	106	102	99	96
150	233	183	151	131	118	109	102	98	95	92
155	231	180	148	127	114	105	99	94	91	88
160	229	177	144	124	111	101	95	90	87	84
165	227	174	141	121	107	98	92	87	84	81
170	225	171	138	118	104	95	89	84	81	78
175	223	169	135	115	101	92	86	81	78	75
180	221	166	133	112	99	89	83	78	75	72
185	219	163	130	109	96	87	80	76	72	70
190	217	161	127	107	93	84	78	73	70	67
195	215	158	125	104	91	82	76	71	68	65
200	213	156	122	102	89	80	74	69	65	63
210	209	151	118	98	85	76	70	65	62	59
220	206	147	114	94	81	72	66	62	58	55
230	202	143	110	90	78	69	63	58	55	52
240	199	139	106	87	74	66	60	56	52	50
250	195	135	103	84	72	63	57	53	50	47

__Table 3: Bending Strength, p_b (in N/mm2) for Rolled sections with Equal Flanges__

(c) p_y = 340 N/mm^2

x	5	10	15	20	25	30	35	40	45	50
30	340	340	340	340	340	340	340	340	340	340
35	340	340	340	340	340	340	339	339	339	339
40	340	333	333	320	328	327	327	326	326	326
45	340	333	323	318	316	315	314	314	313	313
50	340.	322	312	307	302	302	301	301	300	300
55	340	315	303	296	292	290	288	287	286	286
60	337	308	293	285	280	277	275	274	273	272
65	333	301	283	273	268	264	262	260	159	258
70	329	294	274	263	256	251	248	246	245	244
75	325	287	265	252	244	239	235	233	231	230
80	321	281	257	242	232	227	223	220	218	216
85	318	275	248	232	222	215	211	207	205	203
90	214	269	240	223	211	204	199	196	193	191
95	311	263	232	213	201	194	188	185	182	180
100	307	257	225	205	192	184	178	174	171	169
105	304	252	218	197	184	175	169	165	161	159
115	301	246	211	189	176	166	160	156	152	150
115	297	241	205	182	168	159	152	147	144	142
120	194	236	199	176	161	151	145	140	136	134
125	291	231	193	170	155	145	138	133	129	127
130	288	227	188	164	148	138	131	126	123	120
135	285	222	183	1.58	143	133	125	120	117	114
140	282	218	178	153	138	127	120	115	111	108
145	279	213	173	148	133	122	116	110	106	103
150	276	209	168	144	128	118	110	105	101	99
155	273	205	164	139	124	113	106	101	97	94
160	270	207	160	135	120	109	102	97	93	90
165	267	197	156	132	116	106	98	93	89	86
170	265	194	153	128	112	102	95	90	86	83
175	262	190	149	125	109	99	92	86	82	79
180	259	187	146	121	106	96	88	83	79	76
185	257	184	142	118	103	93	86	80	77	74
190	254	180	139	115	100	90	83	78	74	71
195	251	177	136	113	98	87	80	75	71	68
200	249	174	134	110	95	85	78	73	69	66
210	244	168	128	105	90	81	74	69	65	62
220	239	163	123	101	86	77	70	65	61	58
230	234	158	119	96	82	73	66	61	58	55
240	230	153	115	93	79	70	63	58	55	52
250	225	149	111	89	76	67	60	56	52	49

Table 3: Bending Strength, p_b (in N/mm2) for Rolled sections with Equal Flanges

(d) p_y= 355 N/mm^2										
x	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
30	355	355	73-	355	355	355	355	355	355	355
35	355	355	355	354	353	353	352	352	352	352
40	355	352	346	342	341	340	339	339	339	339
45	355	344	335	320	328	327	326	325	325	325
50	355	335	324	318	315	313	312	311	311	311
55	354	327	314	306	302	300	298	297	297	296
60	350	319	303	294	289	286	284	283	282	281
65	346	312	293	283	276	273	270	268	267	266
70	341	305	283	271	264	259	256	254	252	251
75	337	298	274	260	251	246	242	240	238	236
80	333	291	265	249	239	233	229	226	224	222
85	329	284	256	238	228	221	216	213	210	209
90	326	278	247	228	217	209	204	200	198	196
95	322	271	239	219	206	198	193	189	186	184
100	318	265	231	210	197	188	182	178	175	173
105	315	260	224	202	188	178	172	168	165	162
115	311	254	217	194	179	170	164	159	155	153
115	308	248	210	186	171	162	155	150	147	144
120	305	243	204	180	164	154	147	142	139	136
125	301	238	198	173	157	147	140	135	131	129
130	298	233	192	167	151	141	133	128	125	122
135	295	228	187	161	145	135	122	122	118	116
140	292	223	181	156	140	129	117	117	113	110
145	288	219	176	151	135	124	111	111	108	105
150	285	214	172	146	130	119	112	107	103	100
155	282	210	167	142	126	115	107	102	98	95
160	279	206	163	138	121	111	103	98	94	91
165	276	202	159	134	118	107	100	94	90	87
170	273	198	155	130	114	103	96	91	87	84
175	270	195	152	126	111	100	93	87	83	80
180	268	191	148	123	107	97	89	84	80	77
185	265	188	145	120	104	94	87	81	77	74
190	262	184	142	117	101	91	84	79	75	72
195	259	181	139	114	99	88	81	76	72	69
200	257	178	136	111	96	86	79	74	70	67
210	251	172	130	106	91	81	74	69	65	62
220	246	166	125	102	87	77	70	65	62	59
230	241	161	121	98	83	74	67	62	58	55
240	236	156	116	94	80	70	64	59	55	52
250	231	151	112	90	77	67	61	56	52	50

Table 4: Critical Shear Strength, q_{cr}, (in N/mm²)

(a) Grade 43 steel (p_y = 265 N/mm)

	Stiffener spacing ratio a/d													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**-**
55	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
60	159	159	159	159	159	159	159	159	159	159	159	159	159	159	159
65	159	1	159	159	159	159	159	159	159	159	159	159	159	159	157
70	159	1159	159	159	159	159	159	159	159	159	159	158	155	153	148
75	159	159	159	159	159	159	159	159	158	155	152	150	147	145	140
80	159	159	159	159	159	159	159	157	152	148	145	143	140	137	132
85	159	159	159	159	159	159	158	150	145	141	138	136	132	130	124
90	159	159	159	159	159	158	152	144	138	134	131	128	124	122	116
95	159	159	159	159	159	153	146	137	131	127	123	121	117	114	108
100	159	159	159	159	155	147	140	131	124	120	116	114	109	107	100
105	159	159	159	159	150	141	133	124	118	113	109	106	102	98	91
115	159	159	159	155	145	136	127	118	111	106	102	98	93	90	83
115	159	159	159	150	139	130	121	111	104	98	93	90	85	82	76
120	159	159	158	146	134	124	115	105	96	90	86	82	78	75	69
125	159	159	154	141	129	118	109	97	88	83	79	76	72	69	64
130	159	159	150	136	124	113	103	90	82	77	73	70	66	64	59
135	159	159	145	131	118	107	96	83	76	71	68	65	61	59	55

140	159	158	141	126	113	101	89	78	71	66	63	61	57	55	51
145	159	154	141	122	108	94	83	72	66	61	59	56	53	52	48
150	159	150	137	117	103	88	78	68	61	57	55	53	50	48	44
155	159	147	128	112	96	83	73	63	58	54	51	49	47	45	42
160	159	143	124	107	90	78	68	59	54	51	48	46	44	42	39
165	159	139	120	102	85	73	64	56	51	47	45	44	41	40	37
170	158	136	116	97	80	69	61	53	47	45	43	41	39	37	35
175	155	132	111	91	76	65	57	50	45	43	40	39	37	35	33
180	152	128	107	86	71	61	54	47	43	40	38	37	35	33	31
185	149	125	103	82	68	58	44	44	40	38	36	35	33	32	29
190	146	121	98	77	64	55	42	42	38	36	34	33	30	30	28
195	143	117	93	73	61	52	46	40	36	34	32	31	28	28	26
200	140	114	88	70	58	50	44	38	35	32	31	30	28	27	25
205	136	110	84	66	55	47	42	36	33	31	29	28	27	26	25
210	133	106	80	63	52	45	40	34	31	29	28	27	25	25	23
215	130	103	76	60	50	43	38	33	30	28	27	26	4	23	22
220	127	98	73	58	48	41	36	31	29	27	25	25	23	22	21
225	124	94	70	55	46	39	35	30	27	26	24	23	22	21	20
230	121	90	67	53	44	38	33	29	26	24	23	22	21	20	19
235	118	86	64	51	42	36	32	28	25	23	22	22	20	20	18
240	115	82	61	48	40	34	30	26	24	22	21	19	19	19	17
245	112	79	59	46	39	33	29	25	23	22	21	19	18	18	17
250	109	76	56	45	37	32	28	24	22	21	20	18	17	17	16

Table 4: Critical Shear Strength, q_{cr}, (in N/mm²)

(b) Grade 43 steel (p_y = 275 N/mm²)															
	Stiffener spacing ratio a/d														
d/t	**0.4**	**0.**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**-**
55	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
60	165	165	165	165	165	165	165	165	165	165	165	165	165	165	165
65	165	165	165	165	165	165	165	165	165	165	165	165	165	165	160
70	165	165	165	165	165	165	165	165	165	165	165	165	165	157	152
75	165	165	165	165	165	165	165	165	165	165	165	165	4-65	148	143
80	165	165	165	165	165	165	165	161	155	151	148	146	142	140	135
85	165	165	165	165	165	165	162	154	148	144	141	138	134	132	126
90	165	165	165	165	165	162	155	147	141	136	133	131	‘26	124	118
95	165	165	165	165	165	156	149	140	134	129	125	123	118	116	110
100	165	165	165	165	159	150	142	133	126	121	118	115	110	108	100
105	165	165	165	164	154	144	136	126	119	114	110	107	102	98	91
115	165	165	165	159	148	138	130	119	112	107	102	98	93	90	83
115	165	165	165	154	142	132	123	112	105	98	93	90	85	82	76
120	165	165	162	149	137	126	117	106	96	90	86	82	78	75	69
125	165	165	158	144	131	120	110	120	88	83	79	76	72	69	64
130	165	165	153	139	126	114	104	90	82	77	73	70	66	64	59
135	165	165	149	134	120	108	96	83	76	71	68	65	61	59	55
140	165	162	144	129	114	101	89	78	71	66	63	61	57	55	51

145	165	158	140	123	109	94	83	72	66	61	59	56	53	52	48
150	165	154	135	118	103	88	78	68	61	57	55	53	50	48	44
155	165	150	131	113	96	83	73	63	58	54	51	49	47	45	59
160	165	146	126	108	90	78	68	59	54	51	48	46	44	42	55
165	165	142	122	103	85	73	64	56	51	47	45	44	41	40	51
170	162	138	117	97	80	69	61	53	48	45	43	41	39	37	48
175	158	134	113	91	76	65	57	50	45	42	40	39	35	35	44
180	155	131	108	86	71	61	54	47	43	40	38	37	35	33	31
185	152	127	103	82	68	58	51	44	40	38	36	35	33	32	29
190	149	123	98	77	64	55	48	42	38	36	43	33	31	30	28
195	146	119	93	73	61	52	46	40	36	34	32	31	29	28	26
200	142	115	88	70	58	50	44	38	35	32	31	30	27	27	25
205	139	111	84	66	55	47	42	36	33	31	29	28	27	26	24
210	136	107	80	63	52	45	40	34	31	29	28	27	25	25	23
220	133	103	76	60	50	43	38	33	30	28	27	26	24	23	22
240	130	98	73	58	48	41	36	31	29	27	25	25	23	22	21
250	126	94	70	55	46	39	30	30	27	26	24	23	22	21	20
230	123	90	67	53	44	38	33	29	26	24	23	22	21	20	19
235	120	86	64	51	42	36	32	28	25	23	22	22	20	20	28
240	117	82	61	48	40	34	30	26	24	22	21	21	19	18	17
245	114	79	59	46	39	33	29	25	23	22	21	21	19	18	17
250	110	76	56	45	37	32	28	24	22	21	20	20	18	17	16

Table 4: Critical Shear Strength, q_{cr}, (in N/mm²)

(c) Grade 50 steel (p_y = 340N/mm²)

	Stiffener spacing ratio *a/d*													
d/t	**0.4**	**0.**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**-**
55	204	204	204	204	204	204	204	204	204	204	204	204	204	204	204
60	204	204	204	204	204	204	204	204	204	204	204	204	204	202	195
65	204	204	204	204	204	204	204	204	204	201	198	196	91	189	183
70	204	204	204	204	204	204	204	202	196	191	188	204	180	178	171
75	204	204	204	204	204	204	202	193	184	181	177	174	169	167	160
80	204	204	204	204	204	202	194	183	176	171	167	163	158	155	148
85	204	204	204	204	204	194	185	174	166	160	156	153	147	144	136
90	204	204	204	204	197	186	176	164	156	150	146	142	136	133	123
95	204	204	204	202	189	177	167	155	146	140	135	131	124	120	111
100	204	204	204	195	181	169	158	146	136	129	123	119	112	108	100
105	204	204	204	188	174	161	150	136	125	117	112	108	102	98	91
115	204	204	198	181	166	153	141	126	114	107	102	98	93	90	83
115	204	204	192	174	158	144	132	115	105	98	93	90	85	82	76
120	204	204	186	167	151	136	122	106	96	90	86	82	78	75	69
125	204	201	179	160	143	127	112	97	88	83	79	76	76	69	64
130	204	196	173	153	135	117	104	90	82	77	73	70	66	64	59
135	204	190	167	146	127	109	96	83	76	71	68	65	61	59	55

140	204	185	161	139	118	101	89	78	71	66	63	61	57	55	51
145	204	179	155	132	110	94	83	72	66	61	59	56	53	52	48
150	202	174	148	124	103	88	78	68	61	57	55	53	50	48	44
155	198	169	142	116	96	83	73	63	58	54	51	49	47	45	42
160	194	163	136	109	90	78	68	59	54	51	48	46	44	42	39
165	189	158	130	103	85	73	64	56	51	47	45	44	41	40	37
170	185	153	122	98	80	69	61	53	48	45	43	41	39	37	35
175	180	147	115	88	76	65	57	50	45	42	40	39	37	35	33
180	176	142	109	86	71	61	54	47	43	40	38	37	35	33	31
185	172	137	103	82	68	58	51	44	40	38	36	35	33	32	29
190	167	131	98	77	64	55	48	42	38	36	43	33	31	30	28
195	163	125	93	73	61	52	46	40	36	34	32	31	29	28	26
200	158	119	88	70	58	50	44	38	35	32	31	30	27	27	25
205	154	113	84	66	55	47	42	36	33	31	29	28	27	26	24
210	150	108	80	63	52	45	40	34	31	29	28	27	25	25	23
220	145	103	76	60	50	43	38	33	30	28	27	26	4	23	22
240	141	98	73	58	48	41	36	31	29	27	25	25	23	22	21
250	136	94	70	55	46	39	30	30	27	26	24	23	22	21	20
230	132	90	67	53	44	38	33	29	26	24	23	22	21	20	19
235	127	86	64	51	42	36	32	28	25	23	22	22	20	20	28
240	122	82	61	48	40	34	30	26	24	22	21	21	19	18	17
245	117	79	59	46	39	33	29	25	23	22	21	21	19	18	17
250	112	76	56	45	37	32	28	24	22	21	20	20	18	17	16

Table 4: Critical Shear Strength, q_{cr}, (in N/mm²)

(concluded)

(d) **Grade 50 steel (p_y = 355N/mm²)**														
	Stiffener spacing ratio a/d													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**	**-**
55	213	213	213	213	213	213	213	213	213	213	213	213	213	213	213
60	213	211	213	213	213	213	213	213	213	213	213	208	206	206	200
65	213	212	213	213	213	213	213	213	212	207	204	197	194	194	188
70	213	211	213	213	213	213	213	208	201	196	192	185	82	182	175
75	213	213	213	213	213	213	208	198	191	185	181	173	170	170	163
80	213	213	213	213	213	208	199	188	180	174	170	167	161	158	150
85	213	213	213	213	210	199	190	178	170	163	159	155	150	146	138
90	213	213	213	213	202	190	180	168	159	152	148	144	138	134	123
95	213	213	213	208	194	182	171	158	148	142	136	132	124	120	111
100	213	213	213	200	186	173	161	148	138	129	123	119	112	108	100
105	213	213	210	193	178	164	152	138	125	117	112	108	102	98	91
115	213	213	204	186	169	155	143	126	114	107	102	98	93	90	83
115	213	213	197	178	161	146	132	115	105	98	93	90	85	82	76
120	213	212	190	171	153	137	122	105	96	90	86	82	78	75	69
125	213	207	184	163	145	127	112	97	88	83	79	76	76	69	64
130	213	201	177	156	137	117	104	90	82	77	73	70	66	64	59
135	213	195	171	148	127	109	96	83	76	71	68	65	61	59	55

140	213	190	164	141	118	101	89	78	71	66	63	61	57	55	51
145	213	184	157	133	110	94	83	72	66	61	59	56	53	52	48
150	208	178	151	124	103	88	78	68	61	57	55	53	50	48	44
155	204	172	144	116	96	83	73	63	58	54	51	49	47	45	42
160	199	167	137	109	90	78	68	59	54	51	48	46	44	42	39
165	194	161	130	103	85	73	64	56	51	47	45	44	41	40	37
170	190	155	122	98	80	69	61	53	48	45	43	41	39	37	35
175	185	150	115	88	76	65	57	50	45	42	40	39	37	35	33
180	180	144	109	86	71	61	54	47	43	40	38	37	35	33	31
185	175	138	103	82	68	58	51	44	40	38	36	35	33	32	29
190	171	132	98	77	64	55	48	42	38	36	43	33	31	30	28
195	166	125	93	73	61	52	46	40	36	34	32	31	29	28	26
200	161	119	88	70	58	50	44	38	35	32	31	30	27	27	25
205	157	113	84	66	55	47	42	36	33	31	29	28	27	26	24
210	152	108	80	63	52	45	40	34	31	29	28	27	25	25	23
220	147	103	76	60	50	43	38	33	30	28	27	26	24	23	22
240	143	98	73	58	48	41	36	31	29	27	25	25	23	22	21
250	138	94	70	55	46	39	30	30	27	26	24	23	22	21	20
230	132	90	67	53	44	38	33	29	26	24	23	22	21	20	19
235	127	86	64	51	42	36	32	28	25	23	22	22	20	20	28
240	122	82	61	48	40	34	30	26	24	22	21	21	19	18	17
245	117	79	59	46	39	33	29	25	23	22	21	21	19	18	17
250	112	76	56	45	37	32	28	24	22	21	20	20	18	17	16

Table 5: Basic Shear Strength, q_b (in N/mm^2)

(a) Grade 43 steel (p_y = 265 N/mm^2)													
	Stiffener spacing ratio *a/d*												
D/t	**0.4**	**0.**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	159	159	159	159	159	159	159	159	159	159	159	159	159	159
60	159	159	159	159	159	159	159	159	159	159	159	159	59	159
65	159	159	159	159	159	159	159	159	159	159	159	159	159	159
70	159	159	159	159	159	159	159	159	159	159	159	159	139	159
75	159	159	159	159	159	159	159	159	159	159	159	159	150	158
80	159	159	159	159	159	159	159	159	159	151	149	148	145	143
85	159	159	159	159	159	159	159	159	149	147	145	143	140	137
90	159	159	159	159	159	159	159	149	145	142	140	138	134	131
95	159	159	159	159	159	159	150	145	141	138	135	133	128	125
100	159	159	159	159	159	150	147	142	137	133	130	127	122	119
105	159	159	159	159	159	148	144	138	133	129	125	122	116	111
115	159	159	159	159	150	145	141	134	128	124	120	116	109	104
115	159	159	159	159	147	142	137	130	124	118	113	109	102	97
120	159	159	159	159	145	140	134	126	118	112	107	103	96	91
125	159	159	159	148	143	137	131	121	113	107	102	98	91	86
130	159	159	159	146	140	133	127	116	108	102	97	93	86	81
135	159	159	150	144	137	130	123	112	104	97	93	89	82	77
140	159	159	149	142	135	127 I	118	108	100	94	89	85	78	73
145	159	159	147	140	132	123	114	104	96	90	85	81	75	70

150	159	159	145	138	129	119	111	100	93	87	82	78	71	67
155	159	151	144	135	126	116	108	97	90	84	79	75	69	64
160	159	150	142	133	122	113	105	94	87	81	76	73	66	61
165	159	149	140	130	119	110	102	92	84	79	74	70	64	59
170	159	147	138	127	116	107	99	89	82	76	72	68	61	57
175	159	146	136	125	114	105	97	87	80	74	70	66	59	55
180	159	145	134	122	111	102	95	85	78	72	68	64	58	53
185	159	143	132	119	109	100	93	83	76	71	66	63	56	52
190	151	142	130	117	107	98	91	82	74	69	65	61	54	50
195	150	140	128	115	105	96	89	80	73	67	63	59	53	49
200	149	139	125	113	103	94	88	78	71	66	62	58	52	47
205	148	137	123	111	101	93	86	77	70	65	60	57	50	46
210	147	136	121	109	99	91	85	76	69	63	59	56	49	45
220	146	134	119	107	98	90	83	74	68	62	58	55	48	44
240	145	132	117	106	96	89	82	73	66	61	57	54	47	43
250	144	130	116	104	95	87	81	72	65	60	56	53	46	42
230	143	129	114	103	94	86	80	71	64	59	55	52	45	41
235	142	127	113	101	92	85	79	70	64	58	54	51	45	40
240	141	125	111	100	91	84	78	69	63	58	53	50	44	39
245	140	124	110	99	90	83	77	68	62	57	53	49	43	39
250	139	122	109	98	89	82	76	68	61	56	52	49	42	38

Table 6: Basic Shear Strength, q_b (in N/mm^2)

(a) Grade 43 steel ($p_y = 265\ N/mm^2$)													
	Stiffener spacing ratio *a/d*												
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	159	159	159	159	159	159	159	159	159	159	159	159	159	159
60	159	159	159	159	159	159	159	159	159	159	159	159	59	159
65	159	J59	159	159	159	159	159	159	159	159	159	159	159	159
70	159	159	159	159	159	159	159	159	159	159	159	159	139	159
75	159	159	159	159	159	159	159	159	159	159	159	159	150	158
80	159	159	159	159	159	159	159	159	159	151	149	148	145	143
85	159	159	159	159	159	159	159	159	149	147	145	143	140	137
90	159	159	159	159	159	159	159	149	145	142	140	138	134	131
95	159	159	159	159	159	159	150	145	141	138	135	133	128	125
100	159	159	159	159	159	150	147	142	137	133	130	127	122	119
105	159	159	159	159	159	148	144	138	133	129	125	122	116	111
115	159	159	159	159	150	145	141	134	128	124	120	116	109	104
115	159	159	159	159	147	142	137	130	124	118	113	109	102	97
120	159	159	159	159	145	140	134	126	118	112	107	103	96	91
125	159	159	159	148	143	137	131	121	113	107	102	98	91	86
130	159	159	159	146	140	133	127	116	108	102	97	93	86	81
135	159	159	150	144	137	130	123	112	104	97	93	89	82	77
140	159	159	149	142	135	127 I	118	108	100	94	89	85	78	73

145	159	159	147	140	132	123	114	104	96	90	85	81	75	70
150	159	159	145	138	129	119	111	100	93	87	82	78	71	67
155	159	151	144	135	126	116	108	97	90	84	79	75	69	64
160	159	150	142	133	122	113	105	94	87	81	76	73	66	61
165	159	149	140	130	119	110	102	92	84	79	74	70	64	59
170	159	147	138	127	116	107	99	89	82	76	72	68	61	57
175	159	146	136	125	114	105	97	87	80	74	70	66	59	55
180	159	145	134	122	111	102	95	85	78	72	68	64	58	53
185	159	143	132	119	109	100	93	83	76	71	66	63	56	52
190	151	142	130	117	107	98	91	82	74	69	65	61	54	50
195	150	140	128	115	105	96	89	80	73	67	63	59	53	49
200	149	139	125	113	103	94	88	78	71	66	62	58	52	47
205	148	137	123	111	101	93	86	77	70	65	60	57	50	46
210	147	136	121	109	99	91	85	76	69	63	59	56	49	45
220	146	134	119	107	98	90	83	74	68	62	58	55	48	44
240	145	132	117	106	96	89	82	73	66	61	57	54	47	43
250	144	130	116	104	95	87	81	72	65	60	56	53	46	42
230	143	129	114	103	94	86	80	71	64	59	55	52	45	41
235	142	127	113	101	92	85	79	70	64	58	54	51	45	40
240	141	125	111	100	91	84	78	69	63	58	53	50	44	39
245	140	124	110	99	90	83	77	68	62	57	53	49	43	39
250	139	122	109	98	89	82	76	68	61	56	52	49	42	38

Table 6: Basic Shear Strength, qb (in N/mm²)

(b) Grade 43 steel (p_y = 275 N/mm²)														
	Stiffener spacing ratio a/d													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	165	165	165	165	165	165	165	165	165	165	165	165	165	165
60	165	165	165	165	165	165	165	165	165	165	165	165	165	165
65	165	165	165	165	165	165	165	165	165	165	165	165	165	165
70	165	165	165	165	165	165	165	165	165	165	165	165	165	165
75	165	165	165	165	165	165	165	165	165	165	165	165	154	152
80	65	165	165	165	165	165	165	165	165	155	153	152	149	147
85	165	165	165	165	165	165	165	156	153	151	149	147	143	140
90	165	165	165	165	165	165	165	153	149	146	144	141	137	134
95	165	165	165	165	165	165	154	149	145	142	138	136	131	127
100	165	165	165	165	165	155	151	146	141	137	133	130	124	120
105	165	165	165	165	157	152	148	142	136	131	127	124	117	112
115	165	165	165	165	154	150	145	137	131	126	121	117	110	105
115	165	165	165	165	152	147	141	133	126	120	114	110	103	98
120	165	165	165	155	149	143	137	1’29	120	114	109	104	97	92
125	165	165	165	153	147	140	134	123	115	108	103	99	92	87
130	165	165	165	151	144	137	130	118	110	103	98	94	87	82
135	165	165	155	148	141	134	125	114	105	99	94	90	83	78
140	165	165	153	146	138	130	121	110	101	95	90	86	79	74

145	165	165	152	144	135	125	117	106	98	92	87	83	76	71
150	165	165	150	141	132	122	113	102	94	88	83	79	72	68
155	165	156	148	139	128	118	110	99	91	85	80	77	70	65
160	165	155	146	136	125	115	107	96	89	83	78	74	67	62
165	165	153	144	133	122	112	104	94	86	80	75	72	65	60
170	165	152	142	130	119	109	102	91	84	78	73	69	62	58
175	165	150	140	127	116	107	99	89	82	76	71	67	60	56
180	165	149	138	125	114	105	97	87	80	74	69	65	59	54
185	165	148	136	122	111	102	95	85	78	72	67	64	57	52
190	156	146	133	120	109	100	93	83	76	70	66	62	55	51
195	155	144	131	118	107	99	91	82	74	69	64	61	54	49
200	154	143	128	116	105	97	90	80	73	67	63	59	53	48
205	153	141	126	114	103	95	88	79	72	66	62	58	51	47
210	152	140	124	112	102	94	87	77	70	65	60	57	50	46
220	151	138	122	110	100	92	85	76	69	64	59	56	49	45
240	150	136	120	108	99	91	84	75	68	63	58	55	48	44
250	149	134	119	107	97	90	83	74	67	62	57	54	47	43
230	148	132	117	105	96	88	82	73	66	61	56	53	46	42
235	147	130	116	104	95	87	81	72	65	60	56	52	45	41
240	145	129	114	103	94	86	80	71	64	59	55	51	45	40
245	144	127	113	102	93	85	79	70	64	58	54	50	44	40
250	143	125	112	101	92	84	78	69	63	57	53	50	43	39

Table 6: Basic Shear Strength, q_b (in N/mm²)

(c) Grade 50 steel (p_y = 340 N/mm²)														
	Stiffener spacing ration a/d													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	204	204	204	204	204	204	204	204	204	204	204	204	204	204
60	204	204	204	204	204	204	204	204	204	204	204	204	204	204
65	204	204	204	204	204	204	204	204	204	204	204	204	194	192
70	204	204	204	204	204	204	204	204	204	194	192	190	187	184
75	204	204	204	204	204	204	204	204	191	188	186	184	179	176
80	204	204	204	204	204	204	204	190	186	182	179	176	171	167
85	204	204	204	204	204	204	191	185	180	176	172	169	162	158
90	204	204	204	204	204	192	187	180	174	169	164	161	154	149
95	204	204	204	204	193	188	183	174	167	162	157	153	144	138
100	204	204	204	204	190	184	178	169	161	1S4	148	143	134	128
105	204	204	204	193	187	180	173	163	1S3	14S	139	134	12S	119
11S	204	204	204	190	183	176	168	1S6	14S	137	131	126	117	111
11S	204	204	204	187	179	171	163	149	138	130	124	119	110	104
120	204	204	193	184	176	166	1S6	142	132	124	118	113	104	98
12S	204	204	190	181	172	161	1S0	136	126	119	112	107	99	93
130	204	204	188	178	168	1S6	14S	131	121	114	107	103	94	88
13S	204	204	18S	17S	163	1S0	140	127	117	109	103	98	89	84

140	204	193	183	171	1S8	146	13S	122	112	10S	99	94	86	80
14S	204	191	180	168	1S3	141	131	118	109	101	9S	91	82	76
1S0	204	189	177	164	149	137	128	115	105	98	92	87	79	73
155	204	187	175	159	145	134	124	112	102	95	89	85	76	70
160	204	185	172	156	142	130	130	109	99	92	87	82	73	68
165	204	183	169	152	138	127	127	106	97	90	84	79	71	65
170	193	181	165	149	135	125	125	103	94	87	82	77	69	63
175	192	179	162	146	133	122	122	101	92	85	80	75	67	61
180	190	177	159	143	130	120	111	99	90	83	78	73	65	59
185	189	174	156	140	128	117	109	97	88	82	76	72	63	58
190	188	172	153	138	125	115	107	95	87	80	74	70	62	56
195	186	169	150	135	123	113	105	94	85	78	73	68	60	55
200	185	167	148	133	121	112	103	92	84	77	71	59	59	54
205	183	164	146	131	113	110	102	91	82	76	70	66	58	52
210	182	162	143	129	118	109	100	89	81	74	69	65	57	51
220	180	159	141	127	116	107	99	88	80	73	68	63	55	50
240	179	157	140	126	115	106	98	87	79	72	67	62	54	49
250	177	155	138	124	113	104	97	86	78	71	66	6	53	48
230	175	153	136	123	112	103	96	85	77	70	65	61	53	47
235	173	151	135	121	111	102	95	84	76	69	64	60	52	46
240	171	150	133	120	110	101	94	83	75	68	63	59	51	46
245	169	148	132	119	109	100	93	82	74	68	62	58	50	45
250	167	146	130	118	108	99	92	81	73	67	62	57	50	44

Table 6: Basic Shear Strength, q_b (in N/mm²)

(d) Grade 50 steel (p_y = 355 N/mm`)														
	Stiffener spacing ration a/d													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	213	213	213	213	213	213	213	213	213	213	213	213	213	213
60	213	213	213	213	213	213	213	213	213	213	213	213	213	213
65	213	213	213	213	213	213	213	213	213	213	213	213	200	198
70	213	213	213	213	213	213	213	213	213	213	201	198	193	190
75	213	213	213	213	213	213	213	213	202	198	194	192	184	181
80	213	213	213	213	213	213	213	197	192	188	184	181	175	171
85	213	213	213	213	213	213	198	191	186	181	177	1731	166	162
90	213	213	213	213	213	199	193	186	179	173	169	164	157	151
95	213	213	213	213	201	195	189	180	172	166	160	155	145	139
100	213	213	213	213	197	190	183	173	165	157	150	145	135	129
105	213	213	213	200	193	186	178	167	156	148	141	136	126	120
115	213	213	213	197	189	181	173	159	148	140	133	128	118	112
115	213	213	202	194	185	176	166	152	141	133	126	121	112	105
120	213	213	200	191	181	171	160	145	135	126	120	115	106	99
125	213	213	197	188	177	165	154	139	129	121	114	109	100	94
130	213	213	195	184	173	159	148	134	124	116	110	104	95	89
135	213	202	192	180	167	154	143	129	119	111	105	100	91	85
140	213	200	189	177	162	149	139	125	115	107	101	96	87	81

145	213	198	18.6	173	157	145	135	121	111	104	97	93	84	77
150	213	196	183	168	153	141	131	118	108	100	94	89	80	74
155	213	194	180	164	149	137	127	114	105	97	91	86	77	72
160	213	192	177	160	146	134	124	111	102	94	89	84	75	69
165	202	189	173	156	142	131	121	109	99	92	86	81	72	67
170	201	187	170	153	139	128	119	106	97	90	84	79	70	64
175	199	185	166	150	136	125	116	104	95	87	82	77	68	62
180	198	183	163	147	134	123	114	102	93	85	80	75	66	61
185	196	180	160	144	131	121	112	100	92	84	78	73	65	59
190	195	177	157	142	129	119	110	98	89	82	76	72	63	57
195	193	174	155	139	127	117	108	96	87	80	75	70	62	56
200	191	172	152	137	125	115	107	95	86	79	73	69	60	55
205	190	169	150	135	123	113	105	93	85	78	72	68	59	53
210	188	167	148	133	133	112	104	92	83	76	71	66	58	52
220	186	167	146	131	131	110	102	91	82	75	70	65	57	51
240	185	162	144	130	130	109	101	90	81	74	69	64	56	50
250	183	160	142	128	128	108	100	89	80	73	68	63	55	49
230	181	158	140	127	116	106	99	88	79	72	67	62	54	48
235	179	156	139	125	114	105	98	87	78	71	66	62	53	48
240	177	154	137	124	113	104	97	86	77	77	65	61	52	47
245	175	153	136	123	112	103	96	85	76	70	64	60	52	46
250	173	151	135	122	111	102	95	84	76	69	64	59E	51	45

Table 7: Flange Dependent Shear Strength Factor, q_b (in N/mm²)

(a) Grade 43 steel (p_y = 265 N/mm²)

d/t	Stiffener spacing ratio *a/d*													
	0.4	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	0	9
75	0	0	0	0	0	0	0	0	0	0	27	52	67	68
80	0	0	0	0	0	0	0	0	44	79	92	96	96	89
85	0	0	0	0	0	0	0	67	106	119	122	122	114	104
90	0	0	0	0	0	0	51	120	140	145	144	141	128	115
95	0	0	0	0	0	29	116	154	165	165	162	156	139	124
100	0	0	0	0	0	110	155	180	185	182	176	168	148	131
105	0	0	0	0	81	151	184	201	202	196	188	179	156	138
115	0	0	0	0	133	182	208	219	217	209	199	189	165	144
115	0	0	0	79	168	207	228	235	230	221	210	198	171	149
120	0	0	0	132	197	229	247	250	243	232	219	205	176	152
125	0	0	0	168	221	248	264	264	255	241	226	211	180	155
130	0	0	91	197	242	266	278	277	264	248	231	216	183	158
135	0	0	138	221	261	281	293	288	272	254	236	220	186	160

140	0	0	172	243	278	296	307	297	278	259	240	223	188	162
145	0	0	200	262	293	312	318	304	284	263	244	226	190	163
150	0	86	224	279	308	325	328	310	288	267	246	228	192	164
155	0	133	245	296	324	336	336	316	292	270	249	231	193	165
160	0	166	264	311	338	346	343	321	296	272	251	232	194	166
165	0	194	282	325	350	354	349	325	299	275	253	234	195	167
170	0	218	298	340	360	361	355	329	302	277	255	235	196	168
175	0	239	313	354	369	368	359	332	304	279	256	237	197	168
180	65	258	327	366	377	373	364	335	306	280	258	238	198	169
185	116	275	341	377	384	378	347	337	308	282	259	239	199	170
190	151	292	356	386	390	383	349	340	310	283	260	240	199	170
195	178	307	370	394	396	387	350	342	312	285	261	241	200	170
200	202	321	382	402	401	391	351	344	313	286	262	241	200	171
205	223	335	392	408	405	394	379	346	314	287	263	242	201	171
210	242	348	402	414	409	397	382	347	316	288	264	243	201	171
220	260	360	411	420	413	400	384	349	317	289	264	243	202	172
240	276	374	418	425	417	402	386	350	318	289	265	244-	202	172
250	291	387	425	429	420	405	388	351	319	290	265	244	202	172
230	305	399	432	433	423	407	389	352	319	291	266	245	203	172
235	319	409	438	437	425	409	391	354	320	291	266	245	203	173
240	332	419	443	441	428	411	392	355	321	292	267	245	203	173
245	344	427	448	444	430	412	394	355	322	292	267	246	203	173
250	356	435	452	447	432	414	395	356	322	293	268	246	204	173

Table 7: Flange Dependent Shear Strength Factor, q_b (in N/mm²) **(continued)**

(b) Grade 43 steel (p_y = 275 N/mm)														
	Stiffener spacing ratio *a/d*													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	‘0	0	0	0	0	0	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0	0	0	0	0	0	17	40
75	0	0	0	0	0	0	0	0	0	3	57	71	80	78
80	0	0	0	0	0	0	0	0	72	97	109	106	106	146
85	0	0	0	0	0	0	0	92	122	133	133	123	123	152
90	0	0	0	0	0	0	83	138	154	158	152	137	137	156
95	0	0	0	0	0	73	136	170	179	178	166	148	148	160
100	0	0	0	0	0	132	173	195	199	195	179	157	157	163
105	0	0	0	0	108	170	210	216	216	209	200	190	166	146
110	0	0	0	0	154	200	225	235	231	222	211	200	174	152
115	0	0	0	109	188	225	245	251	244	235	222	209	180	156
120	0	0	0	155	216	247	264	258	258	245	230	216	184	160
125	0	0	52	189	240	266	280	281	269	254	237	222	188	163
130	0	0	121	217	261	284	296	293	278	260	243	226	191	165
135	0	0	162	241	280	300	312	303	286	266	247	230	194	167
140	0	0	194	262	297	316	325	312	292	271	251	233	196	169

145	0	54	221	282	313	331	336	319	297	275	254	236	198	170
150	0	119	245	300	329	344	345	325	302	278	257	238	200	171
155	0	159	266	316	345	355	253	331	306	282	260	240	201	172
160	0	190	285	331	358	364	360	335	309	284	262	242	202	173
165	0	217	303	347	370	272	366	340	312	287	264	244	203	174
170	0	240	319	363	380	279	371	343	315	289	265	245	204	175
175	32	261	335	376	388	386	376	346	317	290	267	246	205	175
180	106	280	349	388	396	391	380	349	319	292	268	247	206	176
185	146	298	364	398	403	296	384	352	321	294	270	248	207	176
190	177	314	380	407	409	400	387	354	323	295	371	249	207	177
195	203	330	393	415	414	404	390	356	324	296	272	250	208	177
200	226	344	404	422	419	408	393	358	326	297	272	251	208	178
205	247	358	415	429	224	411	396	360	327	298	273	252	209	178
210	266	371	424	434	428	414	398	362	328	299	274	252	209	178
220	283	385	433	440	432	417	400	363	329	300	275	253	210	178
240	299	399	440	445	435	420	402	364	330	301	275	253	210	179
250	314	412	447	449	438	422	422	366	301	302	275	434	210	179
230	329	423	453	453	441	424	405	367	332	302	276	254	211	179
235	343	433	459	457	444	426	407	368	333	303	277	255	211	179
240	356	443	464	460	446	428	408	369	334	303	277	255	211	180
245	368	451	469	463	448	430	410	370	334	304	278	255	211	180
250	380	459	474	466	450	431	411	371	335	304	278	256	212	180

Table 7: Flange Dependent Shear Strength Factor, q_b (in N/mm^2) **(continued)**

(c) Grade 50 steel (p_y = 340 N/mm)														
	Stiffener spacing ratio *a/d*													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	I 0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	0	33	71	76
70	0	0	0	0	0	0	0	0	31	92	110	118	119	112
75	0	0	0	0	0	0	0	85	135	152	157	156	146	133
80	0	0	0	0	0	0	81	160	184	190	188	183	166	149
85	0	0	0	0	0	79	164	207	218	218	212	202	182	161
90	0	0	0	0	0	164	214	242	246	241	232	221	195	171
95	0	0	0	0	143	216	252	270	269	261	249	236	207	181
100	0	0	0	62	202	256	284	295	289	278	265	251	217	189
105	0	0	0	157	245	288	312	316	309	295	279	262	224	195
110	0	0	0	212	281	317	336	337	326	308	289	270	230	199
115	0	0	121	254	312	342	357	356	340	318	297	277	235	203
120	0	0	186	289	339	365	380	371	350	327	304	283	239	206
125	0	0	233	319	363	363	387	384	359	334	310	288	242	208
130	0	53	271	346	385	408	414	394	367	340	314	291	245	210
135	0	148	303	371	407	426	427	402	373	344	318	295	247	212
140	0	202	332	393	429	440	438	410	378	2149	321	297	249	213

145	0	244	358	414	447	453	447	416	383	352	324	300	251	214
150	0	279	382	436	464	462	455	421	387	355	327	302	252	215
155	0	309	404	456	475	473	462	426	391	358	329	304	253	216
160	103	337	424	473	486	481	468	430	394	360	331	305	254	217
165	167	362	444	488	496	488	473	434	396	363	333	307	255	218
170	212	385	466	501	504	494	478	437	399	364	334	308	256	218
175	249	406	484	512	512	500	482	440	401	366	336	309	257	219
180	280	426	500	522	519	505	486	443	403	368	337	310	258	219
185	309	445	515	531	525	509	489	445	405	369	338	311	268	220
190	334	463	527	539	530	513	493	447	406	370	339	312	259	220
195	357	483	538	546	535	517	495	449	408	371	340	313	259	221
200	379	501	548	552	540	520	498	451	409	372	341	313	260	221
205	399	518	557	558	544	523	500	453	410	373	342	260	260	221
210	419	532	565	563	548	526	503	454	411	374	342	261	261	222
220	437	545	573	568	551	529	505	456	412	375	343	261	261	222
240	454	557	580	573	554	531	506	457	413	376	343	261	261	222
250	470	567	586	577	557	533	508	458	414	376	343	262	262	222
230	486	577	591	581	560	535	510	459	415	377	345	317	262	223
235	504	586	597	584	562	537	511	460	416	378	345	317	262	223
240	521	594	602	587	565	539	512	461	417	378	345	317	262	223
245	536	601	606	590	567	540	514	462	417	379	346	318	263	223
250	550	608	610	593	569	542	515	463	418	379	346	318	263	223

Table 7: Flange Dependent Shear Strength Factor, q_b (in N/mm²) (continued)

(d) Grade 50 steel (p_y = 355 N/mm)

	Stiffener spacing ratio *a/d*													
d/t	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**	**2.5**	**3.0**
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0	0	0	0	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0	0	45	74	93	93
70	0	0	0	0	0	0	0	0	84	120	133	1	134	124
75	0	0	0	0	0	0	0	121	160	173	176	173	173	145
80	0	0	0	0	0	0	122	186	206	209	206	200	179	160
85	0	0	0	0	0	124	192	230	240	237	230	220	195	172
90	0	0	0	0	91	195	240	265	267	260	249	237	208	183
95	0	0	0	0	177	244	278	293	290	280	266	253	221	193
100	0	0	0	119	232	282	310	318	311	299	283	267	230	200
105	0	0	0	193	274	315	337	340	331	315	296	278	237	206
110	0	0	67	243	309	344	361	362	248	327	306	286	243	210
115	0	0	164	284	340	369	385	380	361	337	314	293	248	213
120	0	0	222	319	367	367	407	395	371	345	321	298	251	216
125	0	0	266	349	392	397	425	401	380	252	326	303	254	218
130	0	122	303	376	414	437	440	417	387	357	330	306	257	220
135	0	190	335	401	439	454	452	425	393	362	334	309	259	222
140	0	239	364	424	459	468	463	432	398	366	338	312	261	223

145	0	278	390	447	477	480	472	438	403	370	340	315	263	224
150	0	312	414	491	470	490	480	443	407	373	343	317	264	225
155	74	343	436	489	504	499	486	448	410	375	345	318	265	226
160	158	370	457	505	515	507	492	452	413	378	347	320	266	227
165	210	395	480	519	524	514	498	563	416	380	349	321	267	228
170	251	418	501	532	532	520	502	472	418	382	350	323	268	228
175	285	440	519	543	543	526	507	480	420	383	351	324	269	229
180	316	460	534	552	547	531	510	464	422	385	353	325	270	230
185	344	480	548	561	553	535	514	467	424	386	354	326	270	230
190	369	5U1	560	569	558	539	517	469	426	388	355	326	271	230
195	392	521	571	576	563	543	520	471	427	389	356	327	271	231
200	414	538	581	582	546	546	522	473	428	390	356	328	272	231
205	435	554	490	588	571	549	524	474	429	391	357	328	272	231
210	454	568	598	593	575	552	527	476	431	392	358	329	272	232
220	473	581	605	598	578	554	529	477	432	392	359	330	273	232
240	490	592	611	602	582	557	530	478	433	393	359	338	273	232
250	507	602	617	606	584	559	532	480	433	394	360	330	273	232
230	526	612	623	610	587	561	534	481	434	394	360	331	274	233
235	544	620	628	613	590	563	535	482	435	395	361	331	274	233
240	561	628	633	616	592	564	536	483	436	395	361	332	274	233
245	575	635	637	619	594	565	538	483	436	396	362	332	274	233
250	589	642	641	622	596	567	539	484	437	396	362	332	275	233

Table 8(a): Compressive Strength, p_c. (in N/mm^2) for struts

p_y / e	225	245	255	265	275	305	320	325	331	340	355	395	410	411	430	450
15	225	245	255	265	275	305	320	325	335	340	355	394	409	414	429	448
20	225	244	254	264	273	303	317	322	332	337	351	390	405	410	424	444
25	222	241	251	261	270	299	314	318	328	333	347	386	400	405	419	438
30	220	239	248	258	267	296	310	315	324	329	343	381	395	399	414	432
35	217	236	245	254	264	292	306	310	320	324	338	375	389	393	407	425
40	214	233	242	251	260	287	301	305	215	319	333	368	382	386	399	417
42	213	251	240	249	258	285	299	303	312	317	330	365	378	383	396	413
44	212	230	239	248	257	283	297	301	310	314	327	362	375	379	392	409
46	210	228	237	246	255	281	294	299	307	312	325	359	317	375	388	404
48	209	227	236	244	253	279	292	296	305	309	322	355	367	371	383	399
50	208	225	234	242	251	277	289	293	302	306	318	351	363	367	379	394
52	206	223	232	241	249	274	286	291	299	303	315	346	358	362	373	388
54	205	222	230	238	247	271	283	287	295	299	311	342	353	356	367	381
56	203	220	228	236	244	268	280	284	292	296	307	336	347	350	361	374
58	201	218	226	234	242	265	277	281	288	292	303	331	341	344	354	366

60	200	216	224	232	239	262	273	277	284	288	298	325	335	337	347	358
62	198	214	221	229	236	259	269	273	280	283	293	318	328	330	339	349
64	196	211	219	226	234	255	265	268	275	278	288	311	320	322	331	340
66	192	209	216	223	230	251	261	264	270	273	282	304	312	314	322	330
68	192	206	213	220	227	247	256	259	265	268	276	296	304	306	313	320
70	189	204	210	217	224	242	251	254	259	262	270	288	295	297	303	310
72	187	201	207	214	220	237,	246	248	253	256	264	280	287	288	294	299
74	184	198	204	210	216	233	240	243	247	250	256	272	278	279	284	289
76	182	194	200	206	212	227	235	237	241	243	249	264	269	270	275	279
78	179	191	197	202	208	222	229	231	235	237	242	255	260	261	265	269
80	176	188	193	198	203	217 I	223	225	229	230	235	247	251	252	256	259
82	173	184	189	194	199	211	217	219	222	224	228	239	243	243	247	250
84	170	181	185	190	194	206	211	213	216	217	221	231	234	235	238	240
86	167	177	181	186	190	200	205	207	209	211	214	223	226	226	229	231
88	164	173	177	181	185	195	199	200	203	204	208	215	218	218	221	223
90	161	169	173	177	180	189	193	195	197	198	201	208	211	211	213	215
92	158	166	169	173	176	184	188	189	191	192	194	201	203	203	206	207
94	154	162	165	168	171	179	182	183	185	186	188	194	196	196	198	200
96	151	158	161	164	166	173	176	177	179	180	182	187	190	189	191	192
98	147	154	157	159	162	168	171	172	173	174	176	181	183	183	185	186

Table 8 (a) (concluded)

p_y / e	225	245	255	265	275	305	320	325	335	340	355	395	410	415	430	450
100	144	150	153	155	157	163	166	167	168	169	171	175	176	177	178	179
102	141	146	149	151	153	158	161	161	163	163	165	169	170	171	172	173
104	137	142	145	147	149	154	156	156	158	158	160	163	165	165	166	167
106	134	139	4141	143	145	149	151	152	153	153	155	158	159	159	160	161
108	131	135	137	139	141	145	146	147	148	149	150	153	154	154	155	156
110	127	132	133	135	137	140	142	143	144	144	145	148	149	149	150	151
112	124	128	130	131	133	136	138	138	139	140	141	143	144	144	145	146
114	121	125	126	128	129	132	134	134	131	131	132	135	135	135	136	137
116	118	121	123	124	125	129	130	130	131	131	132	135	135	135	136	137
118	115	118	120	121	122	125	126	127	127	128	139	130	131	131	132	133
120	112	115	116	118	119	121	122	123	123	124	125	127	127	127	128	129
122	109	112	113	114	115	118	119	119	120	120	121	123	123	123	124	125
124	107	109	110	111	112	115	116	116	116	117	117	119	120	120	120	121
126	104	106	107	108	109	111	112	113	113	113	114	116	116	116	117	117
128	101	104	105	105	106	108	109	109	110	110	111	112	113	113	113	114
130	99	101	102	103	103	105	106	106	107	107	108	109	110	110	110	111
135	93	95	96	96	97	98	99	99	100	100	101	102	102	102	103	103
140	87	89	90	90	91	92	93	93	93	94	94	95	95	96	96	96
145	82	84	84	85	85	86	87	87	87	88	88	89	89	89	90	90
150	78	79	79	80	80-	81	82	82	82	82	83	83	84	84	84	89
155	73	74	75	75	75	76	77	77	77	77	78	78	79	79	79	79

160	69	70	71	71	71	72	72	72	73	73	73	74	74	74	74	74
165	65	66	67	67	67	68	68	68	69	69	69	70	70	70	70	70
170	62	63	63	63	64	64	65	65	65	65	65	66	66	66	66	66
175	59	59	60	60	61	61	61	61	61	62	62	62	62	62	62	63
180	56	56	57	57	58	58	58	58	58	59	59	59	59	59	59	59
185	53	54	54	54	54	55	55	55	55	55	55	56	56	56	56	56
190	51	51	51	51	52	52	52	52	52	53	53	53	53	53	53	53
195	48	49	49	49	49	49	49	50	50	50	50	50	50	51	51	51
200	46	46	47	47	47	47	47	48	48	48	48	48	48	48	48	48
210	42	42	42	42	43	43	43	43	43	44	44	44	44	44	44	44
220	38	39	39	39	39	39	39	39	40	40	40	40	40	40	40	40
230	35	35	36	36	36	36	36	36	36	36	36	37	37	37	37	37
240	33	33	33	33	33	33	33	33	33	33	34	34	34	34	34	34
250	30	30	30	30	30	31	31	31	31	31	31	31	31	31	31	31
260	28	28	28	28	28	28	29	29	29	29	29	29	29	29	29	29
270	26	26	26	26	26	26	27	27	27	27	27	27	27	27	27	27
280	24	24	24	24	25	25	25	25	25	25	25	25	25	25	25	25
290	23	23	23	23	23	23	23	23	23	23	23	2,3	23	23	23	23
300	21	21	21	21	21	21	22	22	22	22	22	22	22	22	22	22
310	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
320	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
330	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
340	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
350	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Table 8 (b) Compressive Strength, p_c (in N/mm^2) for Struts

p_y / e	225	245	255	265	275	305	320	325	335	340	355	395	410	415	430	450
15	225	245	255	265	275	305	320	325	335	340	355	394	409	413	428	447
20	224	243	253	263	272	301	315	320	330	334	349	387	401	406	420	439
25	220	239	248	258	267	295	309	314	323	328	342	379	393	397	411	430
30	216	234	243	253	262	289	303	307	316	321	335	371	384	389	402	420
35	211	229	238	247	256	283	296	300	309	313	327	361	374	379	392	409
40	207	244	233	241	250	276	288	293	301	305	318	351	364	368	380	396
42	205	222	231	239	248	273	285	289	298	302	314	347	35Q	363	375	391
44	203	220	228	237	245	270	282	286	294	298	310	342	354	358	369	385
46	201	218	226	234	242	267	279	283	291	294	306	337	349	352	364	379
48	199	215	223	231	239	263	275	279	287	291	302	332	343	347	358	372
50	197	213	221	229	237	260	271	275	283	286	298	327	337	341	351	365
52	195	210	218	226	234	256	267	271	278	282	293	321	331	334	349	358
54	192	208	215	223	230	253	263	267	274	278	288	315	325	328	337	350
56	190	205	213	220	227	249	259	263	260	273	283	309	318	321	330	342
58	188	202	210	217	224	245	255	258	265	268	278	302	311	314	322	333
60	185	200	207	214	221	241	250	254	260	263	272	295	304	306	314	325
62	183	197	204	210	217	236	246	249	255	258	266	288	296	299	306	316
64	180	194	200	207	213	232	241	244	249	252	261	281	289	291	298	307
66	178	191	197	203	210	227	236	239	244	247	255	274	281	283	289	298

68	175	188	194	200	206	223	231	233	239	241	249	267	273	275	281	288
70	172	185	190	196	202	218	226	228	233	235	242	259	265	267	272	279
72	169	181	187	193	198	213	220	223	227	230	236	252	257	259	264	270
74	167	178	183	189	194	208	215	217	222	224	230	249	249	251	255	261
76	164	175	180	185	190	204	210	212	216	218	223	237	241	243	247	252
78	161	171	176	181	186	199	205	206	210	212	217	230	234	235	239	244
80	158	168	172	177	181	194	199	201	204	206	211	222	226	227	231	235
82	155	164	169	173	177	189	194	196	199	200	205	215	219	220	223	227
84	152	161	165	169	173	184	189	190	193	195	199	209	212	213	216	219
86	149	157	161	165	169	179	183	185	188	189	193	202	295	206	208	212
88	146	154..	158	161	165	174	178	180	182	183	187	195	198	199	201	204
90	143	150	154	157	161	169	173	175	177	178	181	189	192	192	195	197
92	139	147	150	153	156	165	168	170	172	173	176	183	185	186	188	191
94	136	143	147	150	152	160	164	165	167	168	171	177	179	180	182	184
96	133	140	143	146	148	156	159	160	162	163	165	171	173	174	176	178
98	130	137	139	142	145	151	154	155	157	158	160	166	168	168	170	172
100	127	133	136	138	141	147	150	151	152	153	155	161	162	163	164	166
102	124	130	132	135	137	143	146	146	148	149	151	156	157	158	159	161
104	122	127	129	131	133	139	141	142	144	146	151	152	153	153	154	156
106	119	124	126	128	130	135	137	138	139	140	142	146	148	148	149	151
108	116	121	123	125	126	131	133	134	135	136	138	142	143	143	144	146

Table 8 (b) Compressive Strength, p_c, (in N/mm²) for Struts (concluded)

p_y / e	225	245	255	265	275	305	320	325	335	340	355	395	410	415	430	450
110	113	118	120	121	123	128	130	130	131	132	134	137	139	139	140	141
112	111	115	117	118	120	124	126	127	128	128	130	133	134	135	136	137
114	108	112	114	115	117	121	123	123	124	125	126	129	130	131	132	133
116	105	109	111	112	114	117	119	120	121	121	122	125	1226	127	128	129
118	103	1061	108	109	111	114	116	116	117	118	119	122	123	123	124	125
		..														
120	100	104	105	107	108	111	113	113	114	114	116	118	449	119	120	121
122	98	401	103	104	105	108	110	110	111	111	112	115	116	116	117	118
124	96	99-	100	101	102	105	107	107	108	108	109	112	112	113	113	114
126	94	96	97	99	100	103	104	104	105	105	106	109	109	110	110	111
128	91	94	95	96	97	100	101	101	102	102	103	106	106	106	107	108
130	89	92	93	94	95	97	98	99	99	100	101	103	103	104	104	105
135	84	86	87	88	89	91	92	93	93	93	94	96	96	97	97	98
140	79	81	82	83	84	86	87	87	87	88	88	90	90	91	91	92
145	75	77	78	78	79	81	81	82	82	82	83	84	85	85	85	86
150	71	72	73	74	74	76	77	77	77	77	78	79	80	80	80	81
155	67	69	69	70	70	72	72	72	73	73	73	75	75	75	75	76
160	64	65	66	66	66	68	68	69	69	69	70	71	71	71	71	71
165	60	61	62	63	63	64	65	65	65	66	66	67	67	67	67	67

170	57	58	59	59	60	61	61	61	61	62	62	63	63	63	63	64
175	55	56	57	58	58	58	58	58	58	68	59	59	60	60	60	60
180	52	53	53	53	54	54	55	55	55	55	55	56	57	57	57	57
185	49	50	51	51	51	52	52	52	52	53	53	53	54	54	54	54
190	47	48	48	48	49	49	50	50	50	50	51	50	51	51	51	52
195	45	46	46	46	47	47	47	48	48	48	48	48	49	49	49	49
200	43	44	44	44	44	45	45	45	46	46	46	46	46	46	47	47
210	39	40	40	40	41	41	41	41	42	42	42	42	42	42	42	43
220	36	37	37	37	37	38	38	38	38	38	38	39	39	39	39	39
230	33	34	34	34	34	35	35	35	35	35	35	35	35	35	36	36
240	31	31	31	31	32	32	32	32	32	32	32	33	33	33	33	33
250	29	29	29	29	29	29	30	30	30	30	30	30	30	30	30	30
260	27	27	27	27	27	27	28	28	28	28	28	28	28	28	28	28
270	25	25	25	25	25	26	26	26	26	26	26	26	26	26	26	26
280	23	23	23	24	24	24	24	24	24	24	24	24	24	24	24	24
290	22	22	22	22	22	22	22	22	22	22	23	23	23	23	23	23
300	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
310	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
320	18	18	18	18	18	18	18	18	18	18	19	19	19	19	19	19
330	17	17	17	17	17	17	17	17	18	18	18	18	18	18	18	18
340	16	16	16	16	16	16	16	16	17	17	17	17	17	17	17	17
350	15	15	15	15	15	15	15	15	16	16	16	16	16	16	16	16

Table 8 (c) Compressive Strength, p_c (in N/mm²) for Struts

p_y / e	225	245	255	265	275	305	320	325	335	340	355	395	410	415	430	450
15	225	245	255	265	275	305	320	325	335	340	355	393	408	413	427	446
20	224	242	252	261	271	299	312	317	326	331	345	382	396	401	414	433
25	217	235	245	254	263	290	303	308	317	321	335	370	384	388	402	419
30	211	22	237	246	2SS	281	294	298	307	311	324	3S8	371	37S	388	40S
3S	204	2N	230	238	247	272	284	288	296	300	313	34S	357 7	361	374	389
40	198	1.14	222	230	238	262	274	278	28S	289	301	332	343	347	3S8	373
42	19S	211	219	227	23S	258	269	273	281	28S	296	326	337	340	3S1	366
44	193	208	216	224	231	2S4	26S	269	276	280	291	320	330	334	344	3S8
46	190	20S	213	220	228	2S0	261	264	271	27S	286	314	324	327	337	3S1
48	187	202	209	217	224	246	256	260	267	270	280	307	317	321	330	343
S0	184	199	206	213	220	241	2S2	255	262	26S	27S	301	310	314	323	33S
S2	181	196	203	210	217	237	247	2S0	2S7	260	270	294	303	306	31S	327
54	179	193	199	206	213	232	242	24S	2S2	2SS	264	288	296	299	308	319
S6	176	189	196	202	209	228	237	240	246	249	258	281	289	292	300	310
58	173	186	192	199	205	223	232	235	241	244	252	274	282	284	292	302
60	170	183	189	195	201	219	227	230	236	238	247	267	274	277	284	293
62	167	179	185	191	197	214	222	225	230	233	241	260	267	269	276	285
64	164	176	182	188	193	210	217	220	225	227	235	253	260	262	268	276

66	161	173	178	184	189	205	212	215	220	222	229	246	252	254	260	268
68	158	169	175	180	185	200	207	210	214	216	223	239	245	247	252	259
70	155	166	171	176	181	195	202	204	209	211	217	232	238	239	244	251
72	152	163	168	172	177	191	197	199	203	205	211	226	231	232	237	243
74	149	159	164	169	173	186	192	194	198	200	205	219	223	225	229	236
76	146	156	160	165	169	181	187	189	193	194	200	212	217	218	222	227
78	143	152	157	161	165	177	182	184	187	189	194	206	210	211	215	220
80	140	149	153	157	161	172	177	179	182	184	188	200	203	205	208	213
82	137	146	150	154	157	168	173	174	177	179	183	193	197	198	201	205
84	134	142	146	150	154	163	168	169	172	174	178	187	191	192	195	199
86	132	139..	143	146	150	159	163	165	168	169	173	182	185	186	189	192
88	129	136	139	143	146	155	159	160	163	164	168	176	179	180	183	186
90	126	133	136	139	142	151	155	156	158	159	163	171	173	174	177	180
92	123	130	133	136	139	147	150	152	154	155	158	165	168	169	171	174
94	120	127	130	133	135	143	146	147	149	150	153	160	163	163	166	168
96	118	124	127	129	132	129	142	143	145	146	149	155	158	158	160	163
98	115	121	123	126	129	135	138	139	141	142	145	151	43	154	155	158
100	112	118	120	123	125	132	134	135	137	138	140	146	148	149	151	152
102	110	115	118	120	122	128	131	132	133	134	136	142	144	144	146	148
104	107	112	115	117	119	125	127	128	130	130	133	138	130	140	142	143
106	105	110	112	114	116	121	124	125	126	127	129	134	135	136	137	139
108	102	107	109	111	113	118	120	121	123	123	125	130	131	132	133	135

Table 8 (c) Compressive Strength, p_c, (in N/mm²) for Struts (concluded)

p_y / e	225	245	255	265	275	305	320	325	335	340	355	395	410	415	430	450
110	100	104	106	108	110	115	117	118	119	120	122	126	127	128	129	131
114	96	99	101	103	105	109	111	112	113	113	115	119	120	121	122	123
116	93	97	99	101	102	106	108	109	110	110	112	116	117	117	118	120
118	91	95	96	98	100	104	105	106	107	107	109	112	114	114	115	116
120	89	96	94	96	97	101	103	10	104	105	106	109	110	111	112	113
122	87	91	92	93	95	98	100	100	101	102	103	106	107	108	109	110
124	85	88	90	91	92	96	97	98	99	99	100	103	104	105	106	107
126	83	86	88	89	90	94	95	95	96	97	98	101	102	102	103	104
128	82	84	86	87	88	91	93	93	94	94	95	98	99	99	100	101
130	80	82	84	85	86	89	90	91	91	92	93	95	96	97	97	98
135	75	78	79	80	81	84	85	85	86	86	87	89	90	90	91	92
140	71	74	75	76	76	79	80	80	81	81	82	84	85	85	85	86
145	68	70	70	71	72	75	75	76	76	76	77	79	80	80	80	81
150	64	66	67	68	68	70	71	71	72	72	73	74	75	75	76	76
155	61	63	63	64	65	66	67	67	68	68	69	70	71	71	71	72
160	58	59	60	61	61	63	64	64	64	64	65	66	67	67	67	68
165	55	56	57	58	58	60	60	60	61	61	61	63	63	63	64	64

170	52	54	54	55	55	57	57	57	58	58	58	59	60	60	60	61
175	50	51	52	52	53	54	54	54	55	55	55	56	57	57	57	58
180	48	49	49	50	50	51	52	52	52	52	53	54	54	54	54	55
185	46	46	47	47	48	49	49	49	50	50	50	51	51	51	52	52
190	43	44	45	45	46	46	47	47	47	47	48	48	49	49	49	49
195	42	42	43	43	43	44	45	45	45	45	46	46	46	47	47	47
200	40	41	41	41	42	42	43	43	43	43	43	44	44	44	45	45
210	36	37	38	38	38	39	39	39	39	39	40	40	41	41	41	41
220	34	34	35	35	35	36	36	36	36	36	36	37	37	37	37	38
230	31	32	32	32	32	33	33	33	33	33	34	34	34	34	34	35
240	29	29	29	30	30	30	31	31	31	31	31	31	32	32	32	32
250	27	27 >	27	28	28	28	28	28	29	29	29	29	29	29	29	29
260	25	25	26	26	26	26	26	26	27	27	27	27	27	27	27	27
270	23	24	24	24	24	24	24	25	25	25	25	25	25	25	25	25
280	22	22	22	22	23	23	23	23	23	23	23	23	24	24	24	24
290	21	21	21	21	21	21	21	21	22	22	22	22	22	22	22	22
300	19	20	20	20	20	20	20	20	20	20	20	21	21	21	21	21
310	18	18	18	18	19	19	19	19	19	19	19	19	19	19	19	20
320	17	7	17	17	18	18	18	18	18	18	18	18	18	18	18	18
330	16	16	16	17	17	17	17	17	17	17	17	17	17	17	17	17
340	15	15	15	16	16	16	16	16	16	16	16	16	16	16	16	16
350	14	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

Table 8(d) Compressive Strength, p_c, (in N/mm^2) for Struts

p_y / e	225	245	255	265	275	305	320	325	335	340	355	395	410	415	430	450
15	225	245	255	265	275	305	320	325	335	340	355	393	407	411	425	444
20	223	241	250	259	269	296	309	314	323	327	341	376	390	394	408	426
25	214	215	240	249	257	283	296	301	309	313	326	360	373	377	390	407
30	205	222	230	238	247	271	283	287	296	300	312	344	li6	360	372	388
35	196	212	220	228	236	259	271	274	282	286	297	327	339	342	353	368
40	188	203	210	218	225	247	258	261	268	272	283	310	321	324	334	348
42	184	199	206	214	221	242	252	256	263	266	277	304	314	317	327	340
44	181	195	202	209	216	237	247	251	257	261	271	297	306	309	319	331
46	178	192	199	89	90	94	95	95	96	97	98	101	102	102	103	104
48	174	188	195	201	208	227	237	240	246	249	259	283	291	294	303	314
50	171	184	191	197	204	222	232	235	241	244	253	276	284	287	295	306
52	168	181	187	193	199	217	226	229	235	238	246	269	277	279	287	298
54	165	177	183	189	195	213	221	224	229	232	240	262	269	272	279	289
56	161	173	179	185	191	208	216	219	224	227	234	255	262	264	271	281
58	158	170	175	181	187	203	211	213	218	221	229	248	255	257	264	272
60	155	166	172	177	183	198	206	208	213	215	223	241	247	250	256	264
62	152,	163	168	173	178	193	201	203	208	210	217	234	240	242	248	256
64	149	159	164	169	174	189	196	198	202	204	211	227	233	235	241	248

66	145	156	160	165	170	184	191	193	197	199	205	221	226	228	234	240
68	142	152	157	162	166	179	186	188	192	194	200	214	220	221	226	233
70	139	149	153	158	162	175	181	183	187	189	194	208	213	215	219	225
72	136	145	150	154	158	170	176	178	182	183	189	202	207	208	213	218
74	133	142	146	150	155	166	171	173	177	178	183	196	200	202	206	211
76	130	139	143	147	151	162	167	169	172	173	178	190	194	195	199	204
78	127	136	139	143	147	157	162	164	167	169	173	184	188	189	193	198
80	125	132	136	140	143	153	158	160	163	164	168	179	182	184	187	191
82	122	129	133	136	140	149	154	155	158	159	163	173	177	178	181	185
84	119	126-	130	133	136	145	150	151	154	155	159	168	171	172	176	179
86	117	123	127	130	133	142	146	147	149	151	154	163	166	167	170	174
88	114	120	123	127	130	138	142	143	145	146	150	158	161	162	165	168
90	111	118	121	123	126 ~	134	138	139	141	142	146	154	156	157	160	163
92	109	115	118	120	123	131	134	135	137	138	142	149	152	152	155	158
94	106	112	115	117	120	127	131	132	134	135	138	145	147	148	150	153
96	104	109	112	115	117	124	127	128	130	131	134	140	+43	143	146	148
98	101	107	109	112	114	121	124	125	126	127	130	136	138	139	141	144
100	99	104	107	109	11	117	120	121	123	124	126	132	134	135	137	139
102	97	102	104	106	108	114	117	118	120	121	123	129	131	131	133	135
104	95	99	102	104	106	111	114	115	116	117	120	125	127	127	129	131
106	93	97	99	101	103	109	111	112	113	114	116	121	123	124	125	127
108	90	95	97	99	101	106	108	109	110	111	113	118	120	120	122	124

Table 8(d) Compressive Strength, p_c, (in N/mm²) for Struts (continued)

p_y / e	225	245	255	265	275	305	320	325	331	340	315	395	410	415	430	450
110	88	93	95	96	98	103	105	106	108	108	110	115	116	117	118	120
112	86	90	92	94	96	I 101	103	103	105	105	107	112	113	114	115	117
114	84	88	90	92	94	98	100	101	102	103	104	109	110	110	112	113
116	83	88	88	90	91	96	98	98	99	100	102	106	107	107	109	110
118	81	84	86	88	89	93	95	96	97	97	99	10	105	105	106	107
120	79	83	84	86	87	91	93	94	94	95	96	100	102	102	103	104
122	77	81	82	84	85	89	91	91	92	92	94	99	99	99	100	102
‘24	76	79	81	82	83	87	88	89	90	90	92	96	96	96	97	99
126	74	77	79	80	84	84	86	87	88	88	89	94	94	94	95	96
128	72	75	77	78	79	83	84	85	85	86	87	92	92	92	93	94
130	71	74	75	76	77	81	82	83	83	84	85	88	89	89	90	91
135	67	70	71	72	73	76	77	79	79	79	80	83	84	84	85	86
140	64	66	67	68	69	72	73	74	74	74	75	78	79	79	80	81
145	60	63	64	65	66	68	69	70	70	70	71	73	74	74	75	76
150	58	59	61	61	62	62	65	66	66	66	67	69	70	70	71	71
155	55	57	58	58	59	61	62	62	63	63	64	65	66	66	67	67
160	52	54	54	55	56	58	59	59	59	60	60	62	63	64	63	64
165	50	51	51	53	53	55	56	46	56	57	57	59	59	59	60	60

170	47	49	49	50	51	52	53	53	53	54	54	46	56	56	57	57
175	45	47	47	48	48	50	50	51	51	52	52	54	54	54	54	54
180	43	45	45	46	46	47	48	48	49	49	50	50	51	51	51	52
185	42	42	43	43	44	45	46	46	46	47	48	48	48	48	49	46
190	40	41	41	42	42	43	44	44	44	45	46	46	46	46	47	47
195	38	39	40	40	40	41	42	42	42	43	44	44	44	44	44	45
200	36	37	38	38	39	40	40	40	41	41	42	42	42	42	42	43
210	34	34	35	35	35	36	37	37	37	37	38	39	39	39	39	39
220	31	32	32	32	32	33	34	34	34	34	35	35	35	35	35	35
230	29	29	30.	30	30	31	31	31	31	31	33	33	33	33	33	33
240	27	27	28	28	28	29	29	29	29	29	30	30	30	30	30	30
250	25	25	26	26	26	27	27	27	27	27	28	38	38	38	38	38
260	23	24	24	24	24	25	25	25	25	25	26	26	26	26	26	26
270	22	22	23	23	23	23	23	23	23	23	24	24	24	24	24	24
280	20	21	21	21	21	22	22	22	22	22	22	22	22	22	22	22
290	19	20	20	20	20	20	20	20	20	20	21	21	21	21	21	21
300	18	18	19	19	19	19	19	19	19	19	10	10	10	10	10	10
310	17	17	18	18	18	18	18	18	18	18	18	19	19	19	19	19
320	16	16	17	17	17	17	17	17	17	17	17	18	18	18	18	18
330	15	15	16	16	16	16	16	16	16	16	16	17	17	17	17	17
340	14	15	15	15	15	15	15	15	15	15	15	16	16	16	16	16
350	14	14	14	14	14	14	14	14	14	14	15	15	15	15	15	15

Table 9: Allowable Stress in Axial Tension

Form	Grade	Thickness or diameter mm	Tensile stress (N/mm^2)
Rolled I-beams channels	43	All	155
Universal beams and columns	43	Up to and including 40 Over 40	155 140
Plates;-bars and sections other than above	43 50 55	Up to and including 40 Over 40 Up to and including 65 Over 65 Up to and including 40 Over 40	155 140 215 $Y_S/1.63$* 265 245
Hot rolled hollow sections	43 50 55	All All All	155 215 265

*Y_S = yield stress less or equal to 350 N/mm^2

SCHEDULE 18

GEOTECHNICAL DESIGN INFORMATION AND GUIDELINES

(1) The geotechnical design information usually required to facilitate engineering design of building structures includes –

(a) soil formation,

(b) engineering properties; and

(c) water level

(2) The nature of soil varies in some areas depending on the geological formation process or some disturbing conditions.

(3) A Geotechnical Specialist should review geotechnical reports and supporting data for major or unusual geotechnical features, described in (5) and (6) below. Developers may also request for review by Geotechnical Specialists to determine the need for expert review or analysis.

(4) Supporting data for these reviews includes preliminary plans, specifications, and cost estimates (if available at the time of geotechnical report submittal). Emphasis is required at the preliminary stage in order to optimize cost savings through early identification of potential problems or more innovative designs.

(5) "Major" Geotechnical Features: A major geotechnical feature involves the following project complexity criteria:

i) For earthworks – soil or rock cuts or fills

(a) the maximum height of cut or fill exceeds 15 m, or

(b) the cuts or fills are located in topography and/or geological units with known stability problems.

ii) For soil and rock instability corrections – cut, fill, or natural slopes which are presently or potentially unstable.

iii) For retaining walls (geotechnical aspects) - maximum height at any point along the length exceeds 9m.

Geotechnical reports and supporting data for major geotechnical project features should be submitted to a Geotechnical Specialist for review.

(6) "Unusual" Geotechnical Features: An unusual geotechnical project feature is any geotechnical feature involving:

(a) difficult or unusual problems, e.g. construction of an embankment on a weak and compressible foundation material (difficult) or fills constructed using degradable shale (unusual);

(b) new or complex designs, e.g. geotextile soil reinforcement, permanent ground anchors, French drains, ground improvement technologies; and

(c) questionable design methods, e.g. experimental retaining wall systems, pile foundations where dense soils exists.

Geotechnical reports and supporting data for all projects containing unusual geotechnical features should be submitted to a Geotechnical Specialist for review.

(7) Subsurface Investigation:

(1) Site investigation involves assessing the physical characteristics of the site and includes documentary studies, site surveys and ground investigation. Ground investigation refers to the actual surface or subsurface/soil investigation, including site and laboratory tests. Practically site investigation includes study of the site history and environment, interpretation and analyses of all available data, and making recommendations on the favorable/unfavorable locations, economic and safe design, and prediction of potential risks. In any site investigation work, the questions which should be resolved in determining the investigation plan are what, why, where and how. Another question which one should always ask oneself is whether the investigation is sufficient or too much. With these questions answered, a geotechnical engineer can then have better guidelines to determine what to do. Knowing the site history and availability of the data would be a part of preliminary stage of geotechnical design.

(2) The main component of site investigation is subsurface investigation. Sufficient information of site geologic and geotechnical soil conditions is the most important aspects of a design. The need for adequate geologic input into civil engineering projects is common knowledge to all. However, quite surprisingly, in many construction projects, geologic input is either totally lacking or highly inadequate.

(3) Geological/geotechnical investigations should be conducted for new projects and reviewed for existing structures to determine the following:

a) The geologic conditions related to selection of the site;

b) The characteristics of the foundation soils and rocks;

c) Any other geologic conditions that may influence design, construction, and long term operation;

d) Seismicity of the area; and

e) The sources of construction materials.

(4) The methods of subsurface investigations used are dependent on the data required to fully understand the foundation or treatment for both constructed and proposed projects. These investigative methods actually depend on the types and size of the structures involved, and on the extent and quality of the information needed. The geotechnical engineer plays the main role to decide type of information to be collected. It is important at site during soil investigation, geotechnical engineers should supervise, recording the drilling process, soil and rock sampling, classification, progress control and making judgments. Once back to office, engineers must designate laboratory tests and integrate the field data and the laboratory test results.

(5) This work practice will make sure the quality of soil investigation is guaranteed and parameters needed for design can be fully obtained.

(6) The selection of types of field tests and sampling methods should be based on the information gathered from the desk study and site reconnaissance. Method of soil testing can be carried out as in-situ test and laboratory test. The in-situ test gives results immediately. It is mainly for determination of soil strength, test such as light dynamic penetrometer, standard penetration test (SPT), Plate Load Test (PLT), cone penetration test (CPT) and Vane Shear Test (VST) are commonly used. Standard Penetration Test (SPT) and Plate Load Test (PLT) are the most commonly used in-situ tests.

SCHEDULE 19: FIELD TEST RESULTS OF GEOTECHNICAL STANDARDS

Paragraph 81

Field Test	**Test Results**
CPT	− Cone penetration resistance (q_c) − Local unit side friction (f_s) − Friction ratio (R_f)
CPTU	− Corrected cone resistance (q_t) − Local unit side friction (f_s) − Measured pore pressure (*u)*
Dynamic probing	− Number of blows *N*10 for the following tests: DPL,DPM, DPH − Number of blows N_{10} or N_{20} for the DPSH test
SPT	− Number of blows (*N)* − Energy correction (E_r) − Soil description
PLT	− Ultimate contact pressure (P_u) − Settlement of foundation (S_f) − Settlement of loaded plate area (S_p) − Ultimate bearing pressure vs settlement curve − Soil description
Ménard pressuremeter test	− Pressuremeter modulus (E_M) − Creep pressure (p_f) − Limit pressure (p_{LM}) − Expansion curve

Flexible dilatometer test	− Dilatometer modulus (E_{FDT}) − Deformation curve
All other pressuremeter tests	− Expansion curve
Field vane test	− Undrained shear strength (uncorrected) (c_{fv}) − Remoulded undrained shear strength (c_{rv}) − Torque-rotation curve
Weight sounding test	− Continuous record of weight sounding resistance − Weight sounding resistance is: a) the penetration depth for a standard load; or b) the number of half-turns required for every 0.2 m penetration at the standard load of 1 kN
Flat dilatometer test	− Corrected lift-off pressure (p_0) − Corrected expansion pressure (p_1) at 1.1 mm − Dilatometer modulus (E_{DMT}), material index (I_{DMT}) and horizontal stress index (K_{DMT})

SCHEDULE 20

LOCATIONS AND DEPTHS OF INVESTIGATION POINTS

Paragraph 76

Type of Development	Method of Testing	Minimum number of Borings or Test-pits	Minimum Depth of Borings
Building structures	SPT	For each substructure unit under 30m in width For each substructure unit over 30m in width Additional borings are required in areas of erratic subsurface conditions	a) For spread footings: 2B where L< 2B, 4B where L > 2B and interpolate for L between 2B and 4B b) For deep foundations: 6m below tip elevation or two times maximum pile group dimension, whichever is greater c) If bedrock is encountered: for piles core 3m below tip elevation; for shafts core 3D or 2 times maximum shaft group dimension below tip elevation, whichever is greater.
	PLT	2 per substructure unit under 30m in width 4 per substructure unit over 30m in width Only applicable in areas of no water logging. Applicable to buildings designed not to exceed five storeys.	3m below ground elevation; for open excavations in cuts or fill, the test is performed on the formation level or foundation level.

	CPT	For each substructure unit under 30m in width For each substructure unit over 30m in width Additional borings are required in areas of erratic subsurface conditions	a) Spread footings: 2B where L< 2B, 4B where L > 2B and interpolate for L between 2B and 4B b) Deep foundations: 6m below tip elevation or two times maximum pile group dimension, whichever is greater c) If bedrock is encountered, the cone penetration test is terminated.
Retaining Walls	SPT	a) per substructure unit under 30m in width b) per substructure unit over 30m in width c) Additional borings in areas of erratic subsurface conditions	a) Spread footings: 2B where L< 2B, 4B where L > 2B and interpolate for L between 2B and 4B. b) If bedrock is encountered: for piles core 3m below tip elevation; for shafts core 3D or 2 times maximum shaft group dimension below tip elevation, whichever is greater.
	PLT	a) 2 per sub-structure unit under 30m in width b) 4 per substructure unit over 30m in width c) Only applicable in areas of no water logging. Applicable to buildings designed not to exceed five storeys.	3m below ground elevation; for open excavations in cuts or fill, the test is performed on the formation level or foundation level.

Monopoles and Trans-mission Towers	SPT	At each location	0.0m to 20.0m high, D = 4.5m 20.0m to 30.0m high, D = 6.0m 30.0m to 40.0m high, D = 7.5m 40.0m to 50.0m high, D = 9.0m 60.0m to 70.0m high, D = 10.5m 70.0m to 80.0m high, D = 15.0m

SCHEDULE 21

QUALITY CLASSES OF SOIL SAMPLES FOR LABORATORY TESTING AND SAMPLING CATEGORIES

Paragraph 88

<table>
<tr><th>Soil properties / quality class</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>Unchanged soil properties</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>(1) Particle size</td><td>*</td><td>*</td><td>*</td><td>*</td><td></td></tr>
<tr><td>(2) Water content</td><td>*</td><td>*</td><td>*</td><td></td><td></td></tr>
<tr><td>(3) Density, density index, permeability</td><td>*</td><td>*</td><td></td><td></td><td></td></tr>
<tr><td>(4) Compressibility, shear strength</td><td>*</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Properties that can be determined</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>a) Sequence of layers</td><td>*</td><td>*</td><td>*</td><td>*</td><td>*</td></tr>
<tr><td>b) Boundaries of strata – broad</td><td>*</td><td>*</td><td>*</td><td>*</td><td></td></tr>
<tr><td>c) Boundaries of strata – fine</td><td>*</td><td>*</td><td></td><td></td><td></td></tr>
<tr><td>d) Atterberg limits, particle density, organic content</td><td>*</td><td>*</td><td>*</td><td>*</td><td></td></tr>
<tr><td>e) Water content</td><td>*</td><td>*</td><td>*</td><td></td><td></td></tr>
<tr><td>f) Density, density index, porosity, permeability</td><td>*</td><td>*</td><td></td><td></td><td></td></tr>
<tr><td>g) Compressibility, shear strength</td><td>*</td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">Sampling category according to EN ISO 22475-1</td><td colspan="5">A</td></tr>
<tr><td></td><td colspan="4">B</td></tr>
<tr><td></td><td></td><td></td><td></td><td>C</td></tr>
</table>

SCHEDULE 22
LIST OF LABORATORY TEST RESULTS OF GEOTECHNICAL STANDARDS

Paragraph 91

Laboratory test	**Test results**
1) Water content (soil)	− Value of w
2) Bulk mass density (soil)	− Value of γ_d
3) Particle mass density (soil)	− Value of γ_m
4) Particle size distribution (soil)	− Grain size distribution curve
5) Consistency limits (soil)	− Plastic and liquid limit values PL, LL
6) Density index (soil)	− Values of e_{max}, e_{min} and I_d − Values of e_{max}, e_{min} and I_d
7) Organic content (soil)	− Value of organic content
8) Carbonate content (soil)	− Value of carbonate content Ca_2CO_3
9) Sulf ate content (soil)	− Value of sulfate content $CaSO_4$ or $CaSO_3$
10) Chloride content (soil)	− Value of chloride content $CaCl_2$
11) pH (soil)	− Value of pH
12) Compressibility oedometer (soil)	− Compressibility curve (different options) − Consolidation curves (different options) − Secondary compression curve (creep curve) − Values of [E_{oed} (stress interval) and σ’p] or [*C*s, *C*c, σ’p] − Value of *C*α
13) Laboratory vane (soil)	− Value of strength index *c*u
14) Fall cone (soil)	− Value of strength index *c*u
15) Unconfined compression (soil)	− Value of strength index $q_u = 2C_u$

16) Unconsolidated undrained compression (soil)	− Value of undrained shear strength C_u
17) Consolidated triaxial compression (soil)	− Stress-strain curve (s) and pore pressure curve − Stress paths − Mohr circles − *c*', ϕ' or *c*u − Variations of *c*u with σ'c − Deformation parameter(s) *E*' or *E*u
18) Consolidated direct shear box (soil)	− Stress-displacement curve − τ−σ diagram − *c*', ϕ' − Residual parameters
19) California bearing ratio (soil)	Value of the CBR index I_{CBR}
20) Permeability (soil)	− Value of permeability *k*: − from direct laboratory permeability test − from field permeability tests − from odometer test
21) Water content (rock)	− Value of *w*
22) Density and porosity (rock)	− Value of ρ and *n*
23) Swelling (rock)	− Swelling Strain Index − Swelling pressure − Free swell − Swell under constant load
24) Uniaxial compression and 25) deformability (rock)	− Value of (σc) − Value of deformation modulus (E) − Value of Poisson's ratio (ν)
26) Point-load test (rock)	− Strength index Is50

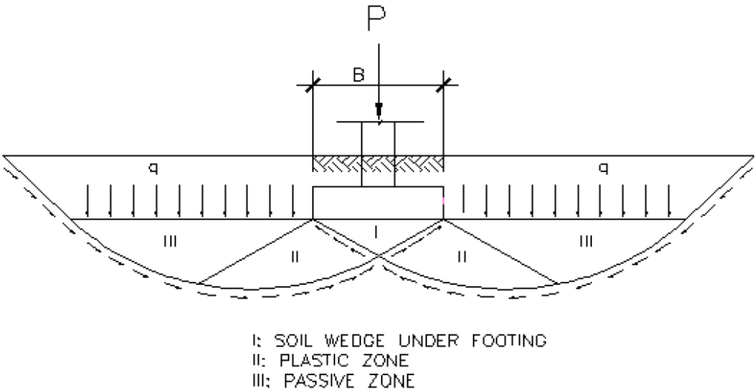
27) Direct shear test (rock)	− Stress-displacement curve − Mohr diagram − c’, ϕ’ − Residual parameters
28) Brazil test (rock)	− Tensile strength (σT)
29) Triaxial compression test (rock)	− Stress-strain curve (s) − Stress paths − Mohr circles − c’, ϕ’ − Values of deformation modulus E and Poisson’s Ratio (ν)

SCHEDULE 23

DESIGN VALUES

Paragraph 81

Bearing capacity of soils for shallow foundations



Shear stresses based on Terzaghi's soil bearing capacity theory, column load P is resisted by shear stresses at edges of three zones under the footing and the overburden pressure, q (=γD) above the footing. The first term in the equation is related to cohesion of the soil. The second term is related to the depth of the footing and overburden pressure. The third term is related to the width of the footing and the length of shear stress area. The bearing capacity factors, N_c, N_q, N_γ, are function of internal friction angle, Φ.

Terzaghi's bearing capacity equations[2]:

Strip footings: $Q_u = c\ N_c + \gamma\ D\ N_q + 0.5\ \gamma\ B\ N_\gamma$ ……………………………………

Square footings: $Q_u = 1.3\ c\ N_c + \gamma\ D\ N_q + 0.4\ \gamma\ B\ N_\gamma$ ………………………………………….....Circular footings: $Q_u = 1.3\ c\ N_c + \gamma\ D\ N_q + 0.3\ \gamma\ B\ N_\gamma$ ……………………………………………..

2 SMITH G. N. and SMITH I. G. N (2003); Elements of Soil Mechanics, pp. 275, Seventh Edition, Blackwell Science

Where:

c is the cohesion of soil,

γ is the unit weight of soil,

D is the depth of footing,

B is the width of footing,

N_c, N_q, N_γ are Terzaghi's bearing capacity factors depending on the soil friction angle, Φ, as follows:

N_c=cot Φ (Nq –1) ………………………………………………

N_q = $e^2(3\pi/4 - \Phi/2)\tan\Phi / [2\cos^2(45+\Phi/2)]$ ……………………

$N\gamma = (1/2)\tan\Phi(K_{pr}/\cos^2\Phi - 1)$……………………………………..

Where, K_{pr} is the passive pressure coefficient.

Bearing Capacity factors based on Terzhagi's Model[3]

(Φ) Degrees	N_c	N_q	N_γ
0	5.14	1.00	0.00
5	6.50	1.60	0.10
10	8.35	2.47	1.22
15	11.00	3.90	2.65
20	14.80	6.40	3.00
25	20.70	10.70	6.80
30	30.10	18.40	15.10
35	46.10	33.30	33.90
40	75.30	64.20	79.50
45	133.90	134.90	200.80
50	266.90	319.10	568.50

3 SMITH G. N. and SMITH I. G. N (2003); Elements of Soil Mechanics, pp. 292, Seventh Edition, Blackwell Science

Bearing capacity based on SPT N values[4]

One of most commonly used method for determining allowable soil bearing capacity is from Standard Penetration Test (SPT) numbers. It is simply because SPT numbers are readily available from soil boring.

The equations that are commonly used were proposed by Meryerhof based on 25mm of foundation settlement. Bowles revised Meyerhof's equations because he believed that Meryerhof's equation might be conservative.

Meryerhof's equations[5]**:**

For footing width, 1.2m or less:

$Q_{all} = (N/4) / K$ ……………………………………………………[

For footing width, greater than 1.2:

$Q_{all} = (N/6)[(B+1)/B]^2 / K$ ……………………………………..

Bowles' equations:

For footing width, 1.2 or less:

$Q_{all} = (N/2.5) / K$ ……………………………………………….

For footing width, greater than 1.2:

$Q_{all} = (N/4)[(B+1)/B]^2 / K$ ……………………………………….

Where,

Q_{all} is the allowable soil bearing capacity, in kPa or kN/m^2.
N is the SPT N value below the footing.
B is the width of the footing, in m
K is a factor obtained as $K = 1 + 0.33(D/B) \leq 1.33$
D is the depth from ground level to the bottom of footing, in m.

The bearing capacity based on SPT N values is widely used in construction projects than other known methods. The formulae proposed by Meyerhof and Bowles can also be directly read off from the correlation graph of allowable bearing capacity and SPT N values for non-cohesive soils.

4 BOWLES, JOSEPH E (1997); Foundation Analysis and Design, Fifth International Edition, McGraw Hill Companies, Inc

5 BOWLES, JOSEPH E (1997); Foundation Analysis and Design, Fifth International Edition, McGraw Hill Companies, Inc

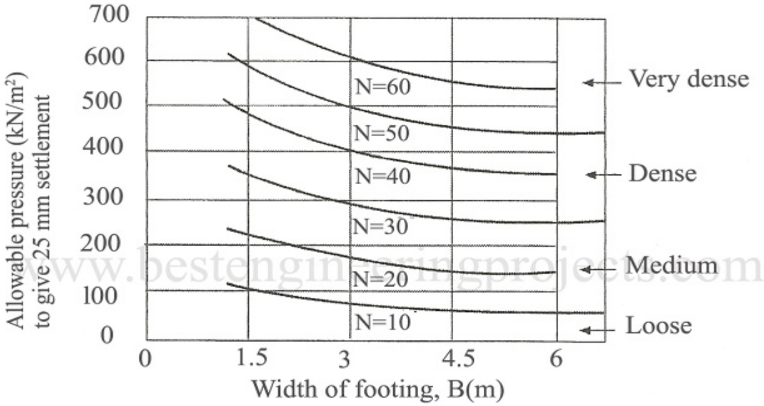
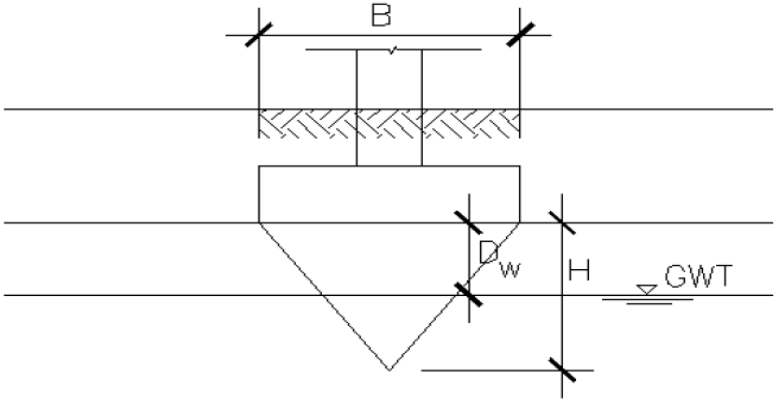


Fig 1 Correlation of Allowable Bearing Pressure to Give 25 mm Settlement to SPT 'N' Value after Terzaghi and Peak (1948)

This curve applies to unsaturated soils i.e. when the water table is at a depth of at least 1.0 B below the foundation. The general practice is now to apply 50 percent reduction in the bearing capacity if the water level is at or above the foundation level, and to apply the reduction if the ground water level occurs at a depth of at least B below the foundation level.

For cohesive soils, the relationship $q_u = 13.1$ x design N value is used for the evaluation of unconfined compressive strength q_u, the cohesion $C_u = q_u/2$ and $q_{ult} = 5.14 \times c_u$ and q_{all} is evaluated using a factor of safety of 3.

Effect of water table on soil bearing capacity



When the water table is above the wedge zone, the soil parameters used in the bearing capacity equation should be adjusted. Bowles proposed an equation to adjust unit weight of soil as follows:

$$\gamma_e = (2H-D_w)(D_w/H^2)\gamma_m + (\gamma'/H^2)(H-D_w)^2 \ldots\ldots\ldots\ldots\ldots\ldots$$

Where:

γ_e = Equivalent unit weight to be used in bearing capacity equation,

H = 0.5B tan (45+Φ/2), is the depth of influence zone,

D_w = Depth from bottom of footing to ground water table,

γ_m = Moist unit weight of soil above ground water table,

γ' = Effective unit weight of soil below ground water table.

Conservatively, one may use the effective unit water underground water table for calculation. Equation 1.16 can also be used to adjust cohesion and friction angle if they are substantially different.

Bearing Capacity based on Plate Load Test

The allowable pressures the soils are capable of resisting can be estimated from the plate bearing test. The total value of load on the plate at each stage is divided by the area of the steel plate to give the value of the ultimate bearing capacity of soil**.**

Terzaghi and Peck (1948) proposed the following equation based on settlement consideration for an intensity of load (q_o) and produced the following relationship[6]:

$$S_f = S_P \left(\frac{B}{B+0.3}\right)^2$$

for clayey soils, dense sand or gravel. ……………………...

Where:

S_f = settlement of foundation in mm;

S_p = settlement of loaded plate area 0.305 m square or 0.300m diameter plate; and

B = width of foundation in metres.

It is generally accepted that maximum allowable settlement is 25mm for all loading conditions unless otherwise. If S_f is put equal to 25mm and the numerical value of B is inserted in the formula, then S_p is accordingly obtained.

6 SMITH G. N. and SMITH I. G. N (2003); Elements of Soil Mechanics, pp. 323, Seventh Edition, Blackwell Science

SCHEDULE 24

DETERMINATION OF COEFFICIENT OF PERMEABILITY

Paragraphs 78. 81

The coefficient of permeability[7] may be determined by the following methods:

a) Falling Head Permeability

The formula for determination of coefficient of permeability using the falling head permeameter[8] is:

$$k = 2.3\frac{al}{At}\log_{10}\frac{h_1}{h_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

where:

A = cross-sectional area of sample in mm^2
a = cross-sectional area of stand pipe in mm^2
l = length of sample in mm
t = elapsed time of test in seconds
h1 = head at the beginning in mm
h2 = head at the end in mm
k = coefficient of permeability in mm/s

b) Constant Head Permeability

The formula for determination of coefficient of permeability using the constant head permeameter is:

$$k = \frac{qL}{Ah} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

where:

A = cross-sectional area of sample in mm^2
L = length of sample in mm
q = discharge in mm^3/s
h = constant head causing flow in mm
k = coefficient of permeability in mm/s

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7 SMITH G. N. and SMITH I. G. N (2003); Elements of Soil Mechanics, pp. 38&39, Seventh Edition, Blackwell Science

8 KNAPPETT J. A and CRAIG R.F (2012); Craig's Soil Mechanics, Eighth Edition, Spon Press, 2 Park Square, Milton Park, Abington, Oxon OX14 4RN, USA.

SCHEDULE 25

DETERMINATION OF COEFFICIENT OF VOLUME COMPRESSIBILITY, m_v

Paragraph 88

The value, which is sometimes called the coefficient of volume decrease, represents the compression of a soil per unit of original thickness due to unit increase in pressure[9]. This can be stated as:

m_v = volumetric change/unit of pressure

If H_1 = original thickness and H_2 = final thickness:

$$Volumetric\,\square = \frac{V_1 - V_2}{V_1} = \frac{H_1 - H_2}{H_1} = \frac{e_1 - e_2}{1+e_1}$$

$$a = \frac{e_1 - e_2}{dp}$$

$$Volumetric\,\square = \frac{adp}{1+e_1}$$

$$m_v = \frac{adp}{1+e_1}\,\frac{1}{dp} = \frac{a}{1+e_1}$$

m^2/MN……………………………………

where:

γ

a = slope of the e-p curve

e_1 = initial void ratio

Once the coefficient of volume decrease has been obtained, we know the compression/unit thickness/unit pressure increase. It becomes easy to predict the total consolidation settlement of clay layer of thickness H.

9 SMITH G. N. and SMITH I. G. N (2003); Elements of Soil Mechanics, pp. 326, Seventh Edition, Blackwell Science

Total settlement, $p_c = m_v dpH$

Typical values of m_v

Soil	m_v (m^2/MN)
Peat	10.0 – 2.0
Plastic clay (normally consolidated alluvial clays)	2.0 – 0.25
Stiff clay	0.25 – 0.125
Hard clay	0.125 – 0.0625

Coefficient of consolidation, c_v

The coefficient of consolidation is based on Terzaghi's theory that the coefficient of permeability and the coefficient of volume compressibility remain constant; Darcy's Law is valid at all hydraulic gradients; the soil is homogeneous and fully saturated, the soil particles and water are incompressible; compression and flow are one-dimensional (vertical); strains are small; and there is a unique relationship, independent of time, between void ratio and effective stress.

$$c_v = \frac{k}{m_v \gamma_w} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

where:

k = coefficient of permeability in mm/s

c_v = coefficient of consolidation, with a suitable unit being m^2/year

m_v = coefficient of volume compressibility in m^2/MN

γ_w = unit weight of water ($9.81 kN/m^3$)

Since k and m_v are assumed constants, c_v is constant during consolidation[10].

Rearranging equation 1.21, the coefficient of permeability becomes:

$$k = c_v m_v \gamma_w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

Equation 1.21 gives the constrained modulus (also called one-dimensional elastic modulus), E'_{oed} which is the reciprocal of m_v (i.e. having units of stiffness, MN/m^2 = MPa)

$$E'_{oed} = \frac{1}{m_v} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

10 KNAPPETT J. A and CRAIG R.F (2012); Craig's Soil Mechanics, Eighth Edition, Spon Press, 2 Park Square, Milton Park, Abington, Oxon OX14 4RN, USA.

Measurement of concrete/rock core sample strength

1) For cores free of reinforcement; estimated in-situ cube strength = [D/(1.5 + Z)] x measured compressive strength of cube;

Where:

D is 2.5 for cores drilled horizontally; or 2.3 for cores drilled vertically

$Z = 1/\lambda$

2) For cores with reinforcement perpendicular to the cores axes; estimated in-situ cube strength is calculated by multiplying the measured compressive strength of cube by the following factors:

a) for cores containing a single bar;

$$1.0 + 1.5\frac{\phi_r d}{\phi_c l}$$

b) for specimens containing two bars no further apart than the diameter of the larger bar, only the bar corresponding to the higher value of $\phi_r d$ need to be considered. If the bars are further apart, their combined effect should be assessed by using the factor:

$$1.0 + 1.5\frac{\square\phi_r d}{\phi_c l}$$

Where:

ϕ_r = diameter of the reinforcement

ϕ_c = diameter of the concrete or rock specimen

d = distance of the axis of axis of bar from nearer end of specimen

l = the length of the specimen after end preparation by grinding and capping

NOTE: The in-situ strengths estimated from the above formulae cannot be equated to the standard cube strengths.

SCHEDULE 26: REQUIRED GEOTECHNICAL ENGINEERING ANALYSIS

Paragraph 68

Soil Classification			**Embankment and Cut Slopes**		**Structure Foundations (Bridges and Retaining Structures)**		**Retaining Structures (Conventional, Crib and MSE)**	
Unified	**AASHTO**[5]	**Soil type**	**Slope stability analysis**[6]	**Settlement analysis**	**Bearing capacity analysis**	**Settlement analysis**	**Lateral earth pressure**	**Stability analysis**
GW	A-1-a	GRAVEL Well-graded GRAVEL	Generally not required if cut or fill slope is 1.5H to 1V or flatter, and underdrains are used to draw down the water table in a cut slope.	Generally not required except possibly for SC soils.	Required for spread footings, pile or drilled shaft foundations.	Generally not needed except for SC soils or for large, heavy structures.	GW, SP, SW & SP soils generally suitable for backfill behind or in retaining or reinforced soil walls.	All walls should be designed to provide minimum F.S. = 2 against overturning & F.S. = 1.5 against sliding along base.
GP	A-1-a	Poorly-graded GRAVEL						
GM	A-1-b	Silty	Erosion of slopes may be a problem for SW or SM soils.		Spread footings generally adequate except possibly for SC soils	Empirical correlations with SPT values usually used to estimate settlement	GM, GC, SM & SC soils generally suitable if have less than 15% fines. Lateral earth pressure analysis required using soil angle of internal friction.	External slope stability considerations same as previously given for cut slopes & embankments.
GC	A-2-6 A-2-7	GRAVEL Clayey						
SW	A-1-b	SAND Well-graded						
SP	A-3	SAND Poorly-graded						
SM	A-2-4 A-2-5	SAND Silty						
SC	A-2-6 A-2-7	SAND Clayey						

SCHEDULE 26

REQUIRED GEOTECHNICAL ENGINEERING ANALYSIS (Continued)

Soil Classification			Embankment and Cut Slopes		Structure Foundations (Bridges and Retaining Structures)		Retaining Structures (Conventional, Crib and MSE)	
Unified	**AASHTO**	**Soil type**	**Slope stability analysis**	**Settlement analysis**	**Bearing capacity analysis**	**Settlement analysis**	**Lateral earth pressure**	**Stability analysis**
ML	A-4	SILT Inorganic silt Sandy	Required unless non-plastic. Erosion of slopes may be a problem.	Required unless non-plastic.	Required. Spread footing generally adequate.	Required. Can use SPT values if non-plastic.	These soils are not recommended for use directly behind or in retaining or reinforced soil walls.	
CL	A-6	CLAY Inorganic Lean Clay	Required	Required				
OL	A-4	SILT Organic	Required	Required				
MH	A-5	SILT Inorganic	Required. Erosion of slopes may be a problem	Required.	Required.	Required.	These soils are not recommended for use directly behind or in retaining walls	All walls should be designed to provide minimum F.S. = 2 against overturning & F.S. = 1.5 against sliding along base. External slope stability considerations

					Deep foundation generally required unless soil has been preloaded.	Consolidation test data needed to estimate settlement amount and time.		
CH	A-7	CLAY Inorganic Fat Clay	Required.	Required.			.	
OH	A-7	CLAY Organic	Required.	Required.				
PT		PEAT Muck	Required.	Required. Long term settlement can be significant	Deep foundation required unless Peat excavated and replaced.	Highly compressible and not suitable for foundation support		
Rock			Fills – not required for slopes 1.5H to 1V or flatter. Cuts – required but depends on spacing, orientation and strength of discontinuities and durability of rock		Required for spread footings or drilled shafts. Empirically related to RQD[7]	Required where rock is badly weathered or closely fractured (low RQD). May require in situ test such as pressuremeter.	Required. Use rock backfill angle of internal friction	same as previously given for cut slopes & embankments

REMARKS:

1) Soils – temporary ground water control may be needed for foundation excavations in GW through SM soils.

2) Backfill specifications for reinforced soil walls using metal reinforcements should meet the following requirements in insure use of non-corrosive backfill: pH range = 5 to 10; Resistivity > 3000 ohm-cm; Chlorides < 100 ppm; Sulfates < 200 ppm; Organic content 1% maximum

3) Rock – Durability of shales (siltstone, claystone, mudstone, etc.) to be used in fills should be checked. Non-durable shales should be embanked as soils, i.e., placed in maximum 0.3m loose lifts and compacted with heavy sheepsfoot or grid rollers.