Foreword

According to the requirements of Document JIANBIAO [2004] No. 67 issued by the Ministry of Construction – "Notice on Printing and Distributing 'the Development and Revision Plan of National Engineer Construction Standards in 2004'", this standard was revised by Nanjing Hydraulic Research Institute based on GBJ 145–90 *Standard for Classification of Soils*.

This standard includes five chapters. Its main technical contents include: general provisions; terms, symbols and designations; basic requirements; soil classification; simplified soil identification, classification and description. An appendix is also provided.

The main revisions made in this standard are as follows: the contexts relevant to special soils are removed. Terms, symbols and designations are added. Appendix 1 for basic designations is removed; one subgroup fractions are increased for gravel, two subgroup fractions are increased for sand; the plasticity chart with the liquid limits corresponding to 10 mm depth of fall-cone penetration is removed, along with its related contexts; and Appendix A: System block diagram for engineering classification of soils is added.

The Ministry of Construction is in charge of the administration of this standard. General Institute of Water Resources and Hydropower Planning and Design of Ministry of Water Resources is responsible for the routine management of this standard. Explanation of the technical content is undertaken by Nanjing Hydraulic Research Institute. All the relevant organizations are encouraged to obtain experience in using this standard, and also kindly requested to submit comments and advices, whenever necessary, to the Nanjing Hydraulic Research Institute (Address: 223 Guangzhou Road, Nanjing, 210029, China) for future revision.

Chief Development Organizations, Co-Development Organizations and Chief Drafters of this Stardand:

Chief Development Organizations:

Nanjing Hydraulic Research Institute

Co-Development Organizations:

China Academy of Building Research
Comprehensive Institute of Geotechnical Investigation and Surveying
Beijing Geotechnical Institute
Academy of Railway Sciences
Research Institute of Highway of Ministry of Communications
General Building Research Institute of China Metallurgy Group
Mechanical Industry Survey and Design Institute
China Institute of Water Resources and Hydropower Research
Yangtze River Scientific Research Institute
Xi'an University of Technology
Jilin University

Chief Drafters:

FAN Mingqiao TENG Yanjing WU Wei LIU Yanhua LUO Meiyun
WANG Yuan XIN Hongbo ZHANG Wei WEN Yanfeng GONG Biwei
HU Zaiqiang WANG Qing TIAN Xichun and WANG Fang

Contents

1 General provisions

1.0.1 This standard is formulated to unify the engineering classfication of soils to facilitate the qualitative evaluation of soil characteristics.

1.0.2 This standard is applicable to basic classification of soils. A specialized standard for soil classification may be formulated in compliance with this standard to meet the professional demands of relevant industries.

1.0.3 In addition to the requirements of this standard, the index testing for soil classification shall also comply with these specified in the relevant current national standards.

2 Terms, symbols and designations

2.1 Terms

2.1.1 grain size

The minimum diameter of sieve opening through which soil grain could pass, or the diameter of equivalent sphere which has the same velocity of soil grain settle in still water.

2.1.2 grain size distribution curve

A curve represents the mass percentage of soil grain finer than a specific grain size.

2.1.3 constrained grain size

The grain size corresponding to 60% finer on the cumulative grain-size distribution curve of soil.

2.1.4 effective grain size

The grain size corresponding to 10% finer on the cumulative grain-size distribution curve of soil.

2.1.5 fraction

A group of soil particles with a certain range of grain size distribution.

2.1.6 coefficient of uniformity

The coefficient indicating the degree of uniformity of grain sizes.

2.1.7 coefficient of curvature

The coefficient indicating the shape of grain-size distribution curve.

2.1.8 gradation

The mass proportion of each special grain-size group to the whole.

2.1.9 liquid limit

The water content boundary between liquid and plastic states of fine-grained soil.

2.1.10 plastic limit

The water content boundary between plastic and semi-solid states of fine-grained soil.

2.1.11 plasticity index

Numerical difference between the liquid and plastic limits of fine-grained soil.

2.1.12 plasticity chart

A chart for classifying fine-grained soils, in which the plasticity index I_P (ordinate) is plotted against the liquid limit w_L (abscissa).

2.1.13 organic soil

Clays or silts with certain organic content O_m ($5\% \leqslant O_m < 10\%$), special odor (smells) and high compressibility.

2.1.14 organo-soil

Clays or silts with high organic content O_m ($O_m \geqslant 10\%$), special odor (smells) and high compressibility.

2.2 Symbols

C_c — coefficient of curvature;

C_u — coefficient of uniformity;

d — grain size;

d_{60} — constrained grain size;

d_{10} — effective grain size;

I_P — elasticity index;

w_L — liquid limit;

w_P — plastic limit;

O_m — organic content.

2.3 Designations

2.3.1 Basic designations:

B — Boulder;

C — Clay;

Cb — Cobble;

F — Fine soil;

G — Gravel;

H — High liquid limit;

L — Low liquid limit;

M — Silt;

O — Organic soil;

P — Poorly-graded;

S — Sand;

SI — Mixture of very coarse soils;

W — Well-graded.

2.3.2 Group designations:

BSI — Boulders with finer soils;

CbSI — Cobbles with finer soils;

CH — High liquid limit clay (Fat clay);

CHG — Gravelly clay with high liquid limit (Gravelly fat clay);

CHO — Organic clay with high liquid limit (Organic fat clay);

CHS — Sandy clay with high liquid limit (Sandy fat clay);

CL — Low liquid limit clay (Lean clay);

CLG — Gravelly clay with low liquid limit (Gravelly lean clay);

CLO — Organic clay with low liquid limit (Organic lean clay);

CLS — Sandy clay with low liquid limit (Sandy lean clay);

GC — Clayey gravel;

GF — Gravel with fines;

GM — Silty gravel;

GP — Poorly-graded gravel;

GW — Well-graded gravel;

MH — High liquid limit silt (Elastic silt);

MHG — Gravelly silt with high liquid limit (Gravelly elastic silt);

MHO — Organic silt with high liquid limit (Organic elastic silt);

MHS—Sandy silt with high liquid limit (Sandy elastic silt);
ML —Low liquid limit silt (Silt);
MLG—Gravelly silt with low liquid limit (Gravelly silt);
MLO—Organic silt with low liquid limit (Organic silt);
MLS —Sandy silt with low liquid limit (Sandy silt);
SC —Clayey sand;
SF —Sand with fines;
SIB —Mixture of boulders and finer soils;
SICb —Mixture of cobbles and finer soils;
SM —Silty sand;
SP —Poorly-graded sand;
SW —Well-graded sand.

3 Basic stipulations

3.0.1 Classification of a soil shall be based on the following indices:

1 The grain-size distribution and characteristics of the soil.

2 The consistencys indices of the soil: liquid limit (w_L), plastic limit (w_p), and plasticity index (I_p).

3 The organic content of the soil.

3.0.2 The fraction of a soil shall be divided according to its grain size range as specified in Table 3.0.2.

Table 3.0.2 Division of fraction

Fraction	Component		Grain-size range (represented by diameter d, mm)
Very coarse grain	Boulder (Block stone)		$d>200$
	Cobble (Broken stone)		$60<d\leqslant200$
Coarse grain	Gravel	Coarse	$20<d\leqslant60$
		Medium	$5<d\leqslant20$
		Fine	$2<d\leqslant5$
	Sand	Coarse	$0.5<d\leqslant2$
		Medium	$0.25<d\leqslant0.5$
		Fine	$0.075<d\leqslant0.25$
Fine grain	Silt		$0.005<d\leqslant0.075$
	Clay		$d\leqslant0.005$

3.0.3 The gradation characteristics of soil shall be determined according to the coefficient of uniformity C_u and the coefficient of curvature C_c as follows:

1 The coefficient of uniformity C_u shall be calculated by the following equation:

$$C_u=\frac{d_{60}}{d_{10}} \tag{3.0.3-1}$$

2 The coefficient of curvature C_c shall be calculated by the following equation:

$$C_c=\frac{(d_{30})^2}{d_{10}\times d_{60}} \tag{3.0.3-2}$$

where d_{30} is the grain size corresponding to 30% finer on the cumulative grain-size distribution curve of the soil.

3.0.4 Soils can be classified into very coarse-grained, coarse-grained, and fine-grained types based on the relative content of different fractions and shall comply with the stipulations as follows:

1 Very coarse-grained soils shall be classified based on fraction.

2 Coarse-grained soils shall be classified based on fraction, gradation, content of fine-grained soil.

3 Fine-grained soils shall be classified based on the plasticity chart, type of coarse-grained component and organic content contained.

3.0.5 Fine-grained soils shall be classified with the plasticity chart (Figure 3.0.5).

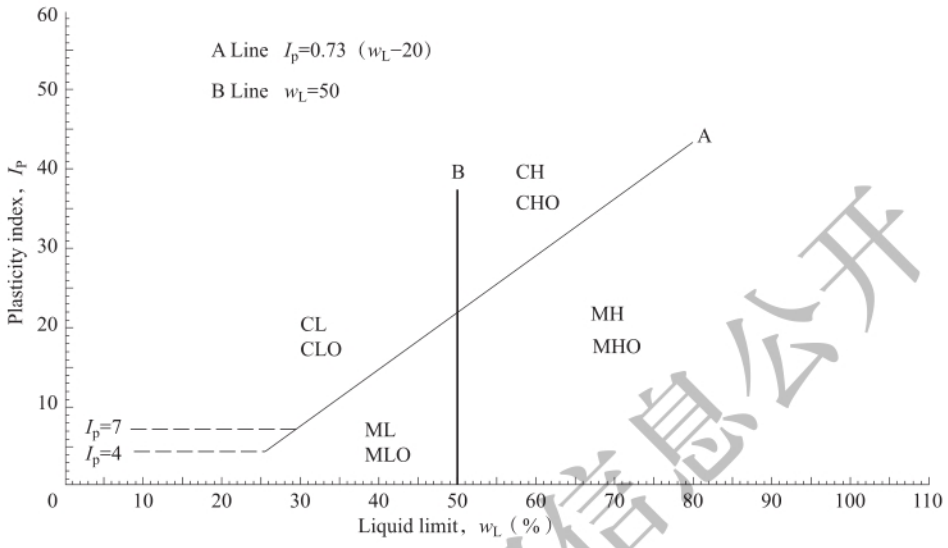


Figure 3.0.5 Plasticity chart

Note: 1 The abscissa of Figure 3.0.5 denotes the liquid limit (w_L) and the ordinate denotes the plasticity index (I_P) of the soil.

2 The liquid limit in Figure 3.0.5 is the water content measured with Casagrande percussion-cup apparatus, or the water content corresponding to a 17mm penetration of a falling cone with a mass of 76g and a tip angle of 30°.

3 The area between the dotted lines in Figure 3.0.5 is the transition zone from clay to silt.

4 Soil classification

4.0.1 Classification of very coarse-grained soils shall meet the stipulations specified in Table 4.0.1.

Table 4.0.1 Classification of very coarse-grained soils

Soil category	Fraction content		Group designation	Name
Very coarse-grained soils	Very coarse fraction content>75%	Boulder content> cobble content	B	Boulder (Block stone)
		Boulder content≤ cobble content	Cb	Cobble (Rubble)
Very coarse soils mixed with finer soils	50%<Very coarse fraction content≤75%	Boulder content> cobble content	BSI	Boulder (Block stone) with finer soils
		Boulder content≤ cobble content	CbSI	Cobble (Rubble)with finer soils
Finer soils mixed with very coarse soils	15%<Very coarse fraction content≤50%	Boulder content> cobble content	SIB	Mixture of finer soils and boulders (Block stones)
		Boulder content≤ cobble content	SICb	Mixture of finer soils and cobbles (Rubbles)

Note: Finer soils mixed with very coarse soils may be further subdivided based on the content of coarse grains or fines.

4.0.2 If the content of very coarse-grained fraction is 15% or less, the soil sample may be classified based on the corresponding stipulations for coarse grains or fines without consideration of very coarse-grained fraction. When very coarse-grained fraction has an influence on the overall properties of soil, it should be treated as gravel fraction.

4.0.3 Classify the soil as coarse-grained soils, if the coarse-grained fraction content is greater than 50%, and its classification shall meet the following stipulations:

1 Classify the soil as gravel, if gravel fraction content is greater than sand content;

2 Classify the soil as sand, if gravel fraction content is equal to or less than sand content.

4.0.4 The classification of gravels shall meet the stipulations specified in Table 4.0.4.

Table 4.0.4 Classification of gravel soils

Soil category	Fraction content		Group designation	Name
Gravel	Fines fraction<5%	$C_u \geqslant 5$ and $1 \leqslant C_c \leqslant 3$	GW	Well-graded gravel
		$C_u < 5$ or($C_c < 1$ or $C_c > 3$)	GP	Poorly-graded gravel
Gravel with fines	5%≤Fines fraction<15%		GF	Gravel with fines
Fines gravel	15%≤Fines fraction< 50%	Fines classified as clay*	GC	Clayey gravel
		Fines classified as silt**	GM	Silty gravel

Note: *The silt grained content of fine grained fraction is 50% or less;

**The silt grained content of fine grained fraction is greater than 50%.

4.0.5 Classification of sands shall meet the stipulations specified in Table 4.0.5.

Table 4.0.5 Classification of sand soils

Soil category	Fraction content		Group symbol	Name
Sand	Fines fraction<5%	$C_u \geqslant 5$ and $1 \leqslant C_c \leqslant 3$	SW	Well-graded sand
		$C_u < 5$ or ($C_c < 1$ or $C_c > 3$)	SP	Poorly-graded sand
Sand with fines	5%≤Fines fraction<15%		SF	Sand with fines
Fines sand	15%≤Fines fraction<50%	Fines classified as clay*	SC	Clayey sand
		Fines classified as silt**	SM	Silty sand

Note: *The silt grained content of fine grained fraction is 50% or less;

**The silt grained content of fine grained fraction is greater than 50%.

4.0.6 Classify the soil as fine-grained soils, if the fines fraction content is greater than 50%.

4.0.7 Fine-grained soil shall be classified according to the following stipulations.

1 Classify the soil as fines, if the coarse-grained fraction content is 25% or less.

2 Classify the soil as sandy or gravelly fines, if the coarse-grained fraction content is greater than 25% but 50% or less.

3 Classify the soil as organic soil, if the organic content is less than 10% but 5% or more.

4.0.8 The classification of fines shall meet the stipulations specified in Table 4.0.8.

Table 4.0.8 Classification of fines

Position of plastic indices of soil in plasticity chart Figure 3.0.5		Group designation	Name
$I_p \geqslant 0.73(w_L - 20)$ and Ip ≥ 7	$w_L \geqslant 50\%$	CH	High liquid limit clay (Fat clay)
	$w_L < 50\%$	CL	Low liquid limit clay (Lean clay)
$I_p < 0.73(w_L - 20)$ or $I_p \leqslant 4$	$w_L \geqslant 50\%$	MH	High liquid limit silt (Elastic silt)
	$w_L < 50\%$	ML	Low liquid limit silt (Slit)

Note: Soils in the transition zone from clay to silt (CL-ML) may be further subdivided in accordance with the types of adjacent soil layers.

4.0.9 Fines with coarse grains shall be classified according to the position of plastic indices of soil in plasticity chart and types of coarse grains, and their classification shall meet the following stipulations:

1 Classify the soil as gravelly fines and add symbol G at the end of the designation of fines, if the content of gravel in coarse grains is greater than that of sand.

2 Classify the soil as sandy fines and add symbol S at the end of the designation of fines, if the content of gravel in coarse grains is less than or equal to that of sand.

4.0.10 The classification of organic soils shall meet the stipulations specified in Table 4.0.8, and add symbol O at the end of the corresponding soil designation.

4.0.11 If the soil index equals the corresponding limit value as defined, the soil may be classified based on a safety principle for practical use.

4.0.12 Soils may be classified according to Appendix A.

5 Simplified identification, classification and description of soils

5.1 Simplified identification methods

5.1.1 Visual identification: spread a dispersed air-dried sample into a thin layer, and classify the soil according to the proportion of very coarse, coarse, and fine grains.

5.1.2 Dry strength test: pinch a small piece of soil into a pat. After drying in air, crumb, break off, and twist it with fingers. The following distinctions shall be made based on the finger pressure:

1 High dry strength: difficult to crumb or break off.

2 Medium dry strength: slight force to crumb or break off.

3 Low dry strength: easy to crumb or twist into powder.

Note: When the soil contains carbonates, iron oxides, and other components that may increase soil dry strength, wet samples should be used for hand-twist test to assess and check its dry strength.

5.1.3 Hand-twist test: pinch a small piece of slightly-wet or hard-plastic soil in hand, and pinch it into slices with thumb and index fingers. The following distinctions shall be made based on hand feeling and smoothness of soil slices:

1 High plasticity: creamy feeling, no sandy feeling, and smooth surface.

2 Medium plasticity: slightly creamy feeling, sandy feeling, and slightly smooth surface.

3 Low plasticity: slightly viscous feeling, strong sandy feeling, and rough surface.

5.1.4 Thread-rolling test: evenly knead a piece of soil with water content slightly higher than the plastic limit in hands, then roll it into a thread on palm. The following distinctions shall be made based on the minimum diameter that the soil thread could be formed without crumbling:

1 High plasticity: the diameter less than 1 mm.

2 Medium plasticity: the diameter between 1 mm and 3 mm.

3 Low plasticity: the diameter greater than 3 mm.

5.1.5 Toughness test: evenly knead a piece of soil with a water content slightly higher than the plastic limit in hands evenly, then roll it into a thread with a diameter of 3 mm on palm. The following distinctions shall be made based on whether the thread can be refolded and rerolled:

1 High toughness: being shaped into a pat, rolled into a thread, and refolded into a pat without crumbling pieces.

2 Medium toughness: being shaped into a pat and not easily crumbled.

3 Low toughness: being hardly or not to be shaped into a pat, and prone to crumbling by slight or no pinching.

5.1.6 Dilatancy test: mold the soil in soft or liquid plastic state into a ball, shake it repeatedly on the palm, and strike the side of the palm against by the other palm several times. Free water seeps out from the soil, and the ball surface shows luster. Pinch the soil ball with two fingers. After releasing, the water is reabsorbed and the luster disappears. The following distinctions shall be made based on the reaction speeds of water seepage and absorption:

1 Rapid reaction: quick water seepage and absorption.

2 Medium reaction: medium-speed water seepage and absorption.

3 Slow reaction: slow water seepage and absorption.

4 No reaction: no water seepage and absorption.

5.2 Identification and classification

5.2.1 Very coarse-grained and coarse-grained soils may be classified and named according to stipulations set out in 4.0.1 to 4.0.6 based on visual results.

5.2.2 Fine-grained soils may be classified and named based on results of dry strength, hand-twist, thread-rolling, toughness, and dilatancy tests according to stipulations set out in Table 5.2.2.

Table 5.2.2 Simplified classification of fine-grained soils

Dry strength	Hand-twist test	Thread-rolling test		Dilatancy test	Designation
		Minimum diameter of soil thread (mm)	Toughness		
Low-medium	Mainly silt, sandy feeling, slightly viscous, medium rough surface, and no luster	3 - 2	Low - medium	Quick - medium	ML
Medium-high	Containing sand grains, viscous, slightly creamy feeling; medium smooth surface, slightly lustrous	2 - 1	Medium	Slow - no	CL
Medium-high	Rich silt, viscous, slightly creamy feeling, medium smooth surface, slightly lustrous	2 - 1	Medium - high	Slow - no	MH
High- very high	No sandy feelings, highly viscous, strongly creamy feeling, smooth surface, lustrous	<1	High	No	CH

Note: For all types of soils listed in the table that are gray or dark in color and have a special smell, the symbol O shall be added at the end of corresponding soil designation, e. g., MLO, CLO, MHO, and CHO.

5.2.3 Organic matters in soils are incompletely decomposed animal or plant remains and amorphous substance. They may be identified by visual observation, hand touching or smelling. Generally, organic matters are grey or dark, with special odor, elasticity and sponge feeling.

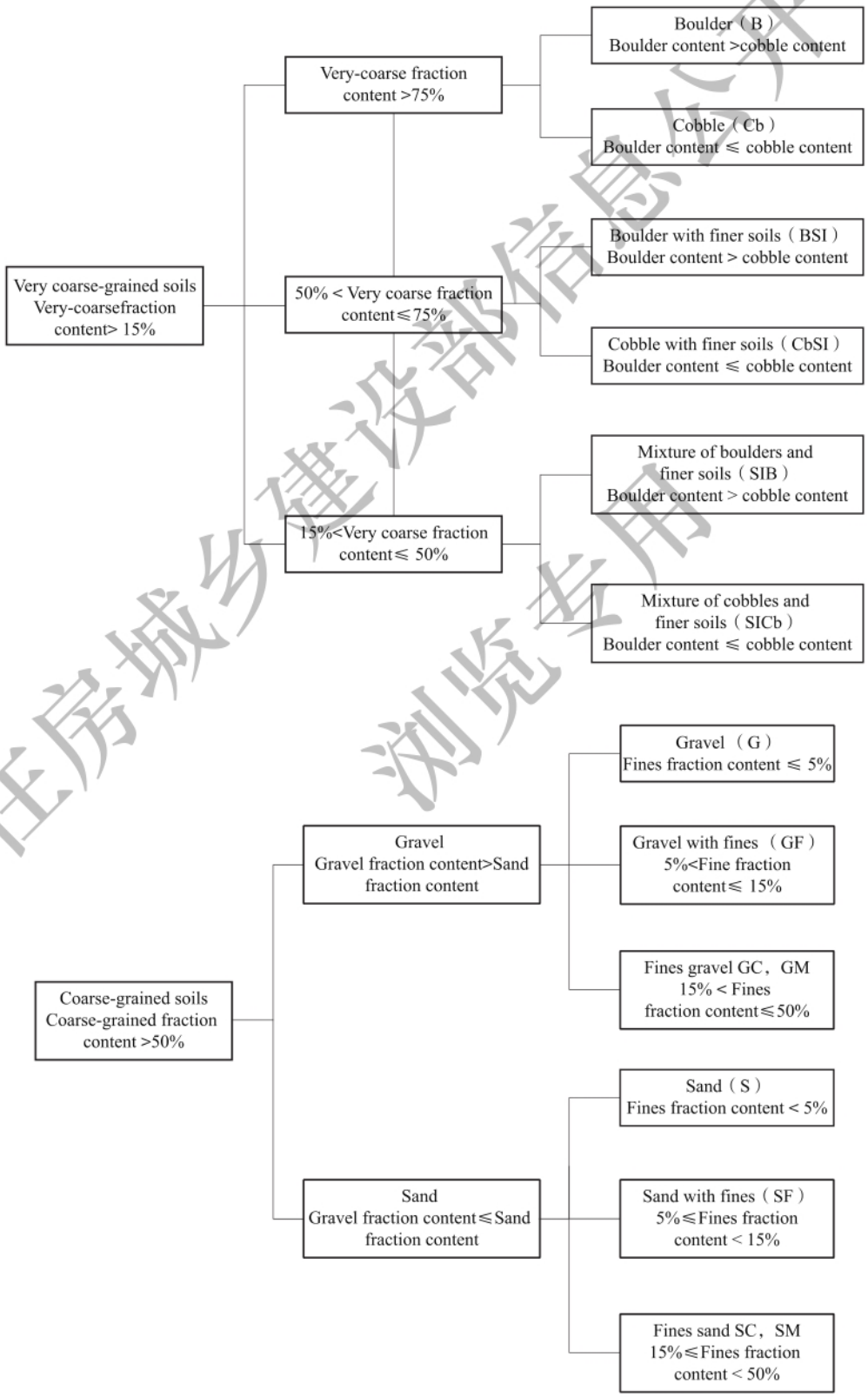
5.3 Soil description

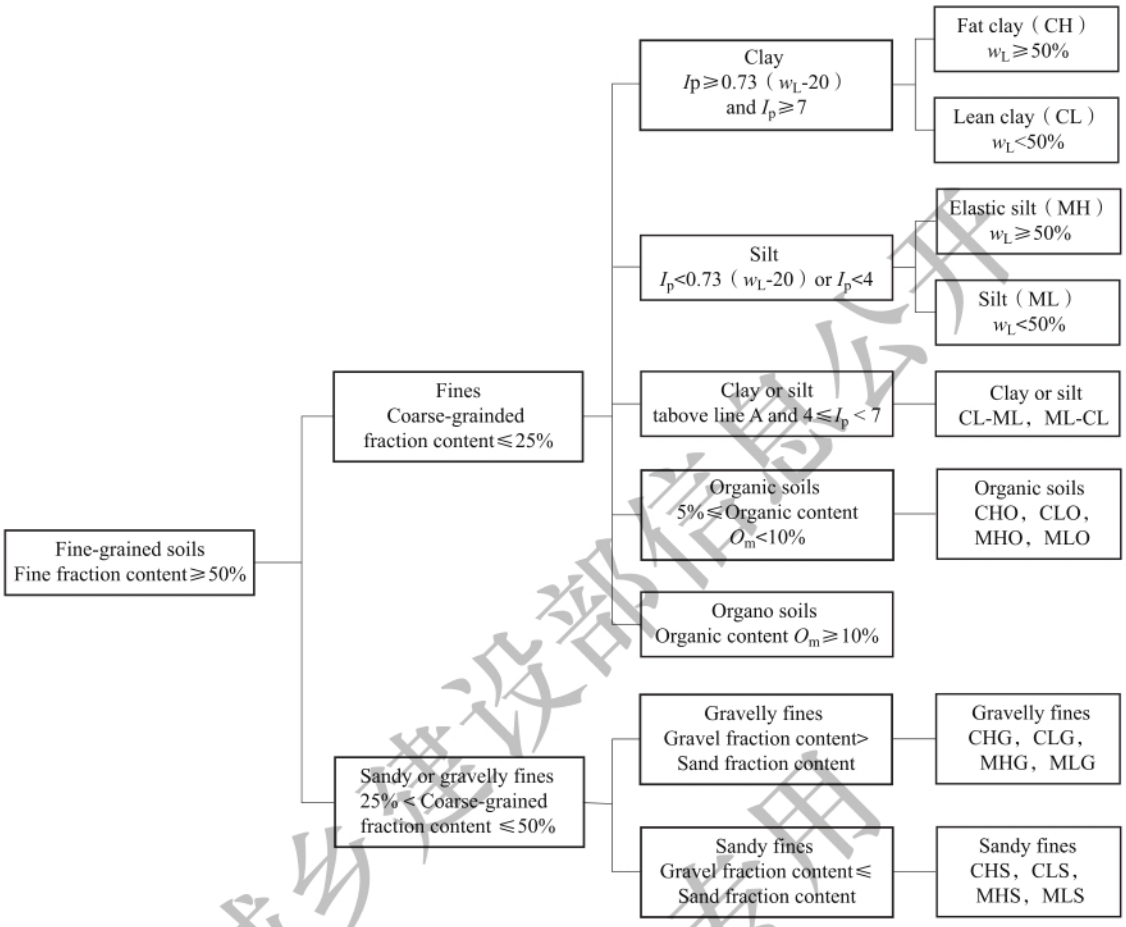
5.3.1 The description of soils should include the following items:

1 Very coarse-grained and coarse-grained soils: popular name and local name; maximum grain size; degree of weathering of particles; mass percentage of very coarse grains, gravel grains, and sand grains; shapes of very coarse or coarse grains (round, sub-round, angular or sub-angular); mineral composition of soil particles; color and organic matter; natural density; types of fines (clay or silt) contained; symbol and name of a soil or soil layer.

2 Fine-grained soils: popular name and local name; maximum grain size; mass percentage of very coarse grains, gravel grains, and sand grains; natural density; color and organic matter of the soil in wet state; humidity of the soil (dry, wet, very wet or saturated); consistency of the soil (liquid plastic, soft plastic, plastic, hard plastic, hard); plasticity of the soil (high, medium, or low); symbol and name of soils.

Appendix A　System block diagram for engineering classification of soils





Explanation of Wording in This Standard

1 Words used for different degrees of strictness are explained as follows in order to mark the differences in executing the requirements in this standard:

1) Words denoting a very strict or mandatory requirement:

"Must" is used for affirmation;"must not" for negation.

2) Words denoting a strict requirement under normal conditions:

"Shall" is used for affirmation;"shall not" for negation.

3) Words denoting a permission of a slight choice or an indication of the most suitable choice when conditions permit:

"Should" is used for affirmation;"should not" for negation.

"May"is used for express the option available,sometimes with the conditional permit.

2 "Shall comply with…" or "Shall meet the stipulation of…" is used in this standard to indicate that it is necessary to comply with the requirements stipulated in other related standards and codes.