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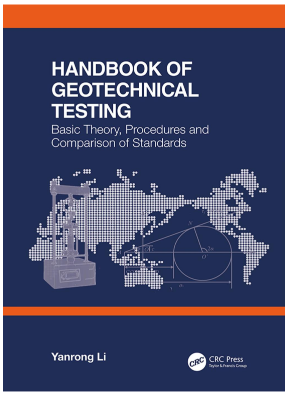

Handbook of Geotechnical Testing
Basic Theory, Procedures and Comparison of Standards

Yanrong Li

International standard systems

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Chapter 4

International standard systems

4.1 Introduction

In the 1940s, the soil test methods began to be standardized. In 1942, the American Association of State Highway and Transportation Officials (AASHO) established standards for test methods, apparatuses and physical properties of soil. In 1948, the United Kingdom issued the first test method (BS1377: 1948) of soil for civil engineering. In 1956, the Ministry of Water Resources of the People's Republic of China issued China's first *Specification of Soil Test*. In 1974, the International Society for Rock Mechanics published the suggested method for rock tests.

The widely applicable standards are those of China, the United Kingdom, the United States, South Africa, Japan, Singapore, Australia, and the International Society for Rock Mechanics. China's standards include national standards (represented by GB/T 50123-1999, GB/T 50266-2013), industry standards (e.g. JTJ 051-93 for transportation industry), and local standards (e.g. the Tianjin standard, DB 29-20-2002). Most of other countries have only one set of national standards, such as the ASTM (American Society for Testing and Materials) in the USA, BS (the British Standards) in the UK, SS (the Singapore Standards), and SANS (the South African National Standards), JIS (Japanese Industrial Standards), AS (Australia Standards), and ISRM Suggested Methods of the International Society for Rock Mechanics.

The purpose of these standards is to regulate soil test to ensure correct assessment of the engineering properties of soils and rocks, and to provide reliable parameters for engineering design and construction. The national standardization systems have been widely investigated. Bian[1] studied the current status of soil standards in China, briefly described the basic regulations of the standard system, and introduced the content of current standards in categories. He pointed out that the naming and classification of standards are somehow confusing in China. Gao[2] put forward that the terminology in some local standards of China are incompatible with those of national and industry standards. Xu[3] reviewed Japan's standardization system and made a brief comparison with China's standardization system. He indicated that both China and Japan's standardization are of government-led. However, the formulating and revising standards is more accessible to the public in Japan than China. An[4] made a summary of South Africa's standardization: clear legislation, timely updating, smooth procedures for revising, and few standards being mandatory. Xia[5] introduced the process of standardization in Singapore and briefed the Singapore standardization system. Ding[6] made a comparison of soil test standards of the United Kingdom, the United States and China, including liquid limit of soils, particle analysis, direct shear test, etc. He pointed out that the test procedures and some specific requirements are quite different.

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Understanding the scope of each standard is important for engineers. We have collected the most widely used standards throughout the world, including those of China, the United Kingdom, the United States, Singapore, South Africa, Australia, Hong Kong, and the International Society for Rock Mechanics. In addition, we have collated the classifying strategy and development history of each standard system. We also reviewed the development and revision process of each standard and clarified the correlation among various standards. Finally, the systems of test standards of different countries were compared in terms of classification, formulation, development, and usage of the standards.

4.2 International standards

4.2.1 China's standards

China's soil test standards are divided into national standards, industrial standards, and local standards.[1] The national standard is the first-class standard, and standards at other levels should be compatible with national standard;[1] the industry standard is at the second-level; the local standard is at the third-level for specific geological conditions in a certain region. The latter two are the refinement and concretization of national standards.

As shown in Table 4.1, China's geotechnical test standards are approved and developed by government agencies. With the approval of the Ministry of Construction, the national standards are submitted to the relevant departments for editorial review, and issued by the competent department of national standards, or jointly issued with the Ministry of Construction.[6] The proposal of industrial standards is launched by the national industry authorities and transferred to the nominated academic institutions or practicing companies for drafting. The standard is issued by the competent national authorities, after being reviewed by the editorial board to make sure that the contents meet the requirements of national standards. The local standards are initialized by local competent authority and formulated by relevant professional committees or research institutes. They are issued by regional competent authority. The contents of local standards should be consistent with the relevant industrial and national standards.

The national standard is numbered as 'code + serial number + approval year' (Table 4.1). For example, *Standard for Soil Test Method* has such number as GB/T (code) 50123 (serial number) -1999 (approval year). The letter 'T' in the code section indicates a mandatory standard. Industrial standard is named in the same way as national standard. Naming of local standard is nonuniform, although they all have a code DB indicating they are locally valid.

Revision of the standard is regularly conducted by the government. The standards at other two levels would be updated once the related national standards are renewed. The local standards hold the highest priority, and then industrial and national standards.

4.2.2 ASTM standards

Unlike the classification of Chinese standards, ASTM (American Society for Testing and Materials) standards are published in form of ASTM Standard Annual Book. ASTM standards are divided into 15 categories, covering metals, coatings, plastics, textiles, petroleum, construction, energy, environmental, consumer products, medical services, equipment and electronics, and advanced materials. The ASTM standard is quite complete, rich in content, and has been cited by many countries in the world. The marketing data show that 50% of ASTM standards are sold abroad each year.[7]

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Table 4.1 China's standards for geotechnical testing

Title	*Code*	*Class*	*Valid date*	*Organization*	*Editorial board*	*Scope*	*Remarks*
Standard test methods of geotechnics	GBJ123-88	National	1989.3.1	Ministry of Construction	Ministry of Water Resources and Power	Basic engineering properties test of foundation soil and landfill materials for industrial and civil construction, transportation, water conservancy and other projects	
	GB/T 50123-1999		1999.10.1		Ministry of Water Resources		In force
Standard test method of rock mass	GB/T 50266-99	National	1999.5.1	Ministry of Construction	Ministry of Power Industry	Rock tests for water conservancy, hydropower, mining, railway, transportation, petroleum, national defense, industrial and civil construction projects	
	GB/T 50266-2013		2013.9.1		Power Enterprise Association	Engineering rock mass test of foundation, surrounding rock, slope and filling materials	In force

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Table 4.1 (Continued)

Title	*Code*	*Class*	*Valid date*	*Organization*	*Editorial board*	*Scope*	*Remarks*
Geotechnical test procedure	SDS01-79	Industrial (Water Conservancy and Power Engineering)	1980	Ministry of Water Resources Power Industry	Nanjing Hydraulic Research Institute	Identification, naming and description of engineering soil	
	SD128-84 SD128-86, SD128-87,		1989	Ministry of Water Resources Department of Energy	Nanjing Hydraulic Research Institute		
	SL 237-1999		1999.4.15	Ministry of Water Resources	Nanjing Hydraulic Research Institute		In force
Test methods for rocks in water resources and hydropower engineering	DLJ204-81, SL2-81	Industrial (Water Conservancy and Power Engineering)	1982	Ministry of Water Resources	Ministry of Power Industry	Rock test of rock foundation, rock slope and underground cavern of first- and second-class buildings in water conservancy and hydropower projects	
	SL 264-2001		2001.4.1		Yangtze River Academy of Sciences	Rock test of water conservancy and hydropower projects	In force

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Standard soil test methods for water resources and hydropower engineering	DL/T 5355-2006	Industrial (Power)	2007.5.1	Development and Reform Commission	Chengdu Survey and Design Institute of China Hydropower Consulting Group	Hydropower and water conservancy projects to test the basic engineering properties of foundations, slopes, underground caverns, filling materials, and the control and inspection of construction quality	In force
Test methods for geotechnical engineering	YBJ 42-92 YSJ 225-92	Industrial (Metallurgical and Non-ferrous Metallurgical)	1993.7.1	Former Metallurgical Ministry of Nonferrous Metals	Changsha Institute of Nonferrous Metallurgy Exploration Technology Exploration Institute	Geotechnical test in construction of nonferrous metallurgical industry	
	YS/T 5225-2016		2016.9.1	Ministry of Industry and Information Technology	Changsha Institute of Nonferrous Metallurgy Exploration Technology Exploration Institute		In force

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Table 4.1 (Continued)

Title	*Code*	*Class*	*Valid date*	*Organization*	*Editorial board*	*Scope*	*Remarks*
Geotechnical test methods for railway industry	TB 10102-2004	Industrial (Railway)	2004.4.1	Ministry of Railways	First Survey and Design Institute of Ministry of Railways	Basic properties test of various foundation soils and fillers in railway engineering	
	TB 10102-2010		2010.11.21		China Railway First Survey and Design Institute Group Co., Ltd.	Physical and mechanical properties test of various foundation soils and fillers in railway engineering	In force
Rock test methods for railway industry	TB 10115-98	Industrial (Railway)	1998.7.1	Ministry of Railways	First Survey and Design Institute of Ministry of Railways	Test on Railway engineering foundations, slopes, tunnels and rock used as building materials	
	TB 10115-2014		2015.2.1		China Railway First Survey and Design Institute Group Co., Ltd.	Rock test during railway survey, design and construction	In force

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Geotechnical test methods for transport industry	JTJ 051-93	Industrial (Transport)	1993.12.1	Ministry of Transport	Science Research Institute of railway	Basic engineering properties test of foundation soil, roadbed soil and other road soils for highway engineering	
	JTG E40-2007		2007.10.1		Science Research Institute of railway		In force
Rock test methods for transport industry	JTJ 054-94	Industrial (Transport)	1994.12.1	Ministry of Transport	Second Highway Survey and Design Institute	Rock test of roadbed, pavement, bridge and culvert and tunnel engineering in highway engineering	
	JTJ E41-2005		2005.8.1		Second Highway Survey and Design Institute		In force
Geotechnical test regulations	-	Local (Shandong Province)	1993.9.1	Urban and Rural Construction Committee of Shandong Province	Shandong Exploration and Design Association		In force
Specification of geotechnical engineering	DB 29-20-2002	Local (Tianjin City)	2001.4.1	Urban and Rural Construction Committee of Tianjin	Construction and Design Institute of Tianjin University	Geotechnical investigation, design and construction in construction, municipal and harbor projects in Tianjin	In force

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The soil test standards belong to Category D as listed in Table 4.2. The numbering format of ASTM standard follows 'code + type + serial number + approval year', for instance ASTM (code) D (type) 7263 (serial number) - 09 (year). A letter 'M' following the serial number indicates that the standard is in metric unit system, such as D2435M-11. If there is no letter 'M' in the title, the British unit system is employed, for example D7263-09. In some cases, the reapproval year was given in parentheses, e.g. D5312/D5312M-12 (reapproved in 2013). The superscript (ε1, ε2, etc.) after the approval year indicates that the standard has been experienced minor editorial modification without substantial content change, e.g. D4318-10$^{\varepsilon 1}$.

Table 4.2 Geotechnical test standards in ASTM

Test	*Standard*	*Code*
Particle-size distribution of soils,(d<75 μm)	Standard test method for particle-size distribution (gradation) of fine-grained soils using the sedimentation (hydrometer) analysis	D7928-16$^{\varepsilon 1}$
Particle-size distribution of soils (d>75 μm)	Standard test methods for particle-size distribution (gradation) of soils using sieve analysis	D6913-04 (Reapproved 2009)$^{\varepsilon 1}$
Density (unit weight) of soil specimens	Standard test methods for laboratory determination of density (unit weight) of soil specimens	D7263-09
Maximum index density and unit weight of soils	Standard test methods for maximum index density and unit weight of soils using a vibratory table	D4253-16
Minimum index density and unit weight of soils	Standard test methods for minimum index density and unit weight of soils and calculation of relative density	D4254-16
Specific gravity of soil solids	Standard test methods for specific gravity of soil solids by water pycnometer	D854-14
Water content of soil and rock (oven-drying method)	Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass	D2216-10
Water content of soil (direct heating)	Standard test method for determination of water content of soil by direct heating	D4959-16
Limit moisture of soils	Standard test methods for liquid limit, plastic limit, and plasticity index of soils	D4318-10$^{\varepsilon 1}$
Consolidation properties of soils	Standard test methods for one-dimensional consolidation properties of soils using incremental loading	D2435 / D2435M-11

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Test	*Standard*	*Code*
Unconsolidated-undrained triaxial compression	Standard test method for unconsolidated-undrained triaxial compression test on cohesive soils	D2850-15
Consolidated-undrained triaxial compression	Standard test method for consolidated-undrained triaxial compression test for cohesive soils	D4767-11
Consolidated-drained triaxial compression	Standard test method for consolidated-drained triaxial compression test for soils	D7181-11
One-dimensional swell or collapse of soils	Standard test methods for one-dimensional swell or collapse of soils	D4546-14
Expansion index of soils	Standard test method for expansion index of soils	D4829-11
Direct shear test of soils	Standard test method for direct shear test of soils under consolidated-drained conditions	D3080 /D3080M-11
Compaction characteristics of soil (standard effort)	Standard test methods for laboratory compaction characteristics of soil using standard effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))	D698-12$^{\varepsilon 2}$
Compaction characteristics of soil (modified effort)	Standard test methods for laboratory compaction characteristics of soil using modified effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))	D1557-12$^{\varepsilon 1}$
Maximum dry unit weight and water content range (vibrating hammer)	Standard test methods for determination of maximum dry unit weight and water content range for effective compaction of granular soils using a vibrating hammer	D7382-08
California bearing ratio (CBR) of soils	Standard test method for California bearing ratio (CBR) of laboratory-compacted soils	D1883-16
Unconfined compressive strength of cohesive soil	Standard test method for unconfined compressive strength of cohesive soil	D2166/D2166M-16
Unconfined compressive strength of compacted soil-lime mixtures	Standard test methods for unconfined compressive strength of compacted soil-lime mixtures	D5102-09
Direct shear test of soils under consolidated-drained conditions	Standard test method for direct shear test of soils under consolidated-drained conditions	D3080 /D3080M-11
Organic matter of soils	Standard test methods for moisture, ash, and organic matter of peat and other organic soils	D2974-14

(Continued)

Table 4.2 (Continued)

Test	*Standard*	*Code*
pH of soils	Standard test method for pH of soils	D4972-13
Water content of soil and rock by mass	Standard test methods for laboratory determination of water (moisture) content of soil and rock by mass	D2216-10
Splitting tensile strength of rock core	Standard test method for splitting tensile strength of intact rock core specimens	D3967-16
Compressive strength and elastic moduli of intact rock core	Standard test methods for compressive strength and elastic moduli of intact rock core specimens under varying states of stress and temperatures	D7012-14
Point load strength index of rock	Standard test method for determination of the point load strength index of rock and application to rock strength classifications	D5731-16
Direct shear strength tests of rock specimens under constant normal force	Standard test method for performing laboratory direct shear strength tests of rock specimens under constant normal force	D5607-16
Durability of rock under freezing and thawing conditions	Standard test method for evaluation of durability of rock for erosion control under freezing and thawing conditions	D5312/D5312M-12 (reapproved 2013)
Slake durability of rocks	Standard test method for slake durability of shales and other similar weak rocks	D4644-16
Absorption of rock	Standard test method for specific gravity and absorption of rock for erosion control	D6473-15
Rock hardness by rebound hammer method	Standard test method for determination of rock hardness by rebound hammer method	D5873-14

Founded in 1898 by the chemist Dr. Charles B. Dudley in Pennsylvania Railroad, the ASTM International, originally known as the American Society for Testing and Materials, is one of the world's largest non-profit standard development organizations. This organization was renamed ASTM International in 2001.

The process to set up any ASTM standard is shown in Figure 4.1. Anyone (normally a US citizen) may submit a proposal for new standards. The technical committee of ASTM International is responsible for approval of the proposal. Once the proposal is approved, the draft standard would be reviewed by a board with members from academia, industry, and government. All standards issued by ASTM International follow the *ASTM Technical Committee Regulations* and *ASTM Standard Forms and Styles*. ASTM International reviews

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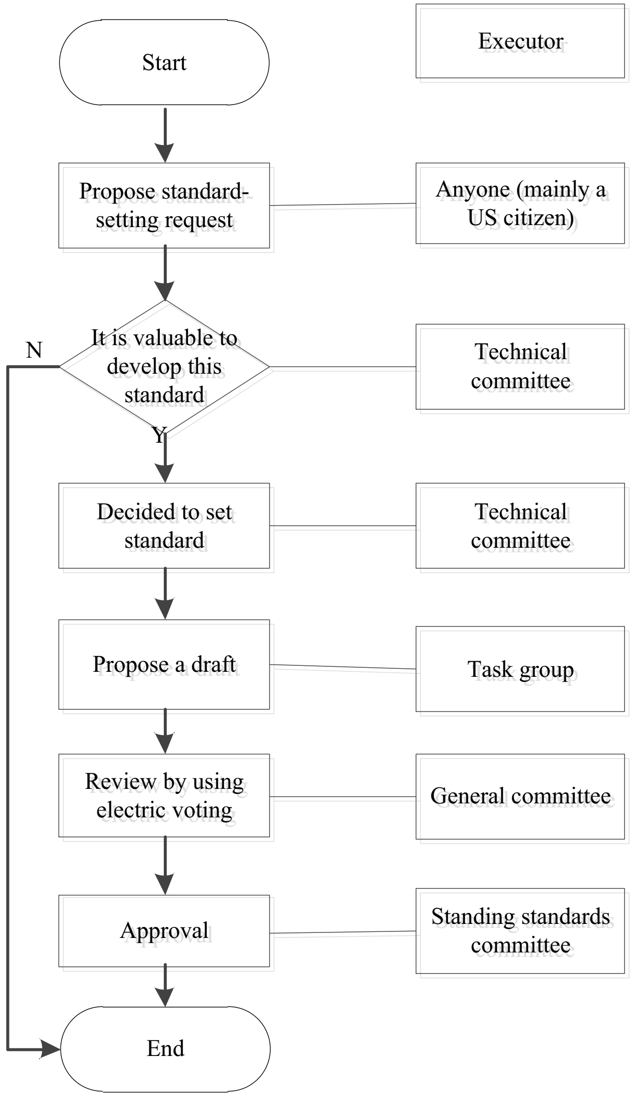

Figure 4.1 Flowchart for setting up the ASTM Standard

standards in force every five years. The technical committee carry out the revision via unscheduled and scheduled (twice a year) meetings.

4.2.3 BSI standards

The UK's soil test standards include not only the BS 1377 series developed in the UK but also the standards from European Codes and ISO. BS 1377 classifies soil tests into nine categories. The indoor test methods are listed in Table 4.3. The coding of standard is formulated as 'BS + serial number + issue year'. The BSI standards is widely applied and cited by other countries in the world.

Table 4.3 Geotechnical test standards in BSI

Code	*Status*
BS1377:1948	Abolished
BS1377:1961	Abolished
BS1377:1967	Abolished
BS1377:1975	Abolished
BS1377-1:1990	Abolished
BS1377-2:1990	Current
BS1377-3:1990	Current
BS1377-4:1990	Current
BS1377-5:1990	Current
BS1377-6:1990	Current
BS1377-7:1990	Current
BS1377-8:1990	Current
BS1377-1:2016	Current
BS EN ISO 17892-1:2014	Current
BS EN ISO 17892-2:2014	Current
BS EN ISO 17892-3:2015	Current
BS EN ISO 17892-4:2016	Current
BS EN ISO 17892-5:2017	Current

The British Standards Institute (BSI) has developed the BS1377 series. Founded in 1901, BSI is the first national standardization organization in the world and is an unofficial, profitable organization with a high international reputation.

A great number of standards issued by BSI are cited from ISO, the International Electro-technical Commission (IEC), the European Committee for Standardization (CEN), or the European Committee for Electro-technical Standardization (CENELEC). Founded in 1906, IEC is a global leader in development and publication of international standards for electrical, electronic and related technologies. CEN is an association that brings together national standardization bodies from 34 European countries to develop the European Codes. It serves aerospace, chemical, construction, consumer products, defense and safety, energy, environment, food and feed, health and security, healthcare, ICT (information and communication technology), mechanical materials, stress equipment, services, smart life, and standardization activities in areas such as transportation and packaging. CENELEC was found in 1973 by merging the two former European organizations, CENELCOM and CENEL, and was designated as the official European Organization for Standardization.

The BSI Technical Committee has developed the remaining BS standards. Figure 4.2 shows the development flowchart. Anyone (normally a British citizen) may propose a new standard. The BSI Technical Committee evaluates the draft standard, finalizes and publishes the standard.

BS1377:1948 is the earliest version of BS1377 (Table 4.3). Prior to 1990, the BS1377 was revised in series. After 1990, the standards were revised in category (Table 4.4).

The Technical Committee regularly reviews standards in force through online meetings, conference calls, letters or meetings at least every five years. Publishing errata will correct

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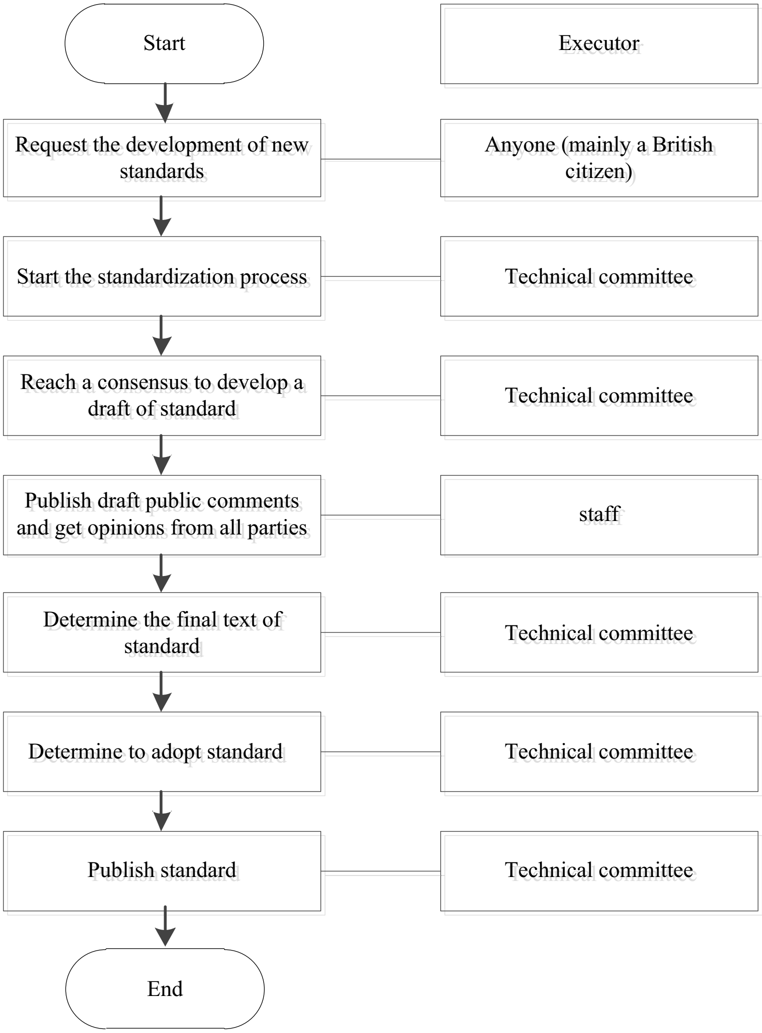

Figure 4.2 Flowchart for development of BS

unintentional errors. The calibration record is marked on the standard and the standard revision history is shown on the standard front page. If the standard fails review, the standard will be revoked.

4.2.4 ISRM suggested methods

The International Society of Rock Mechanics (ISRM) is a non-profit rock mechanics research society that has published a number of methods for rock tests mainly in form of journals. The methods suggested by ISRM are widely cited worldwide. The main indoor rock test methods suggested by ISRM are listed in Table 4.5.

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Table 4.4 Classification of geotechnical tests in BS

Test	*Standard*	*Code*	*Valid date*	*Revision*
General requirements and sample preparation	Methods of test for soils for civil engineering purposes–Part 1: General requirements and sample preparation	BS1377-1:2016	2016.7.31	
Classification and basic physical properties test of soils (moisture, limit moisture, Shrinkage, density, particle density& particle analysis)	Methods of test for Soils for civil engineering purposes–Part 2: Classification tests	BS1377-2:1990	1990.8.31	1996.5
Chemistry and electrochemistry (organic matter content, burning mass loss, sulfate content, carbonate content, chloride content, soluble content, pH, resistivity and redox potential)	Methods of test for Soils for civil engineering purposes–Part 3: Chemical and electrochemical tests	BS1377-3:1990	1990.8.31	1996.5
Compaction (compaction, relative density, water state value, chalk crushing value and bearing ratio)	Methods of test for Soils for civil engineering purposes–Part 4: Compaction-related tests	BS1377-4:1990	1990.8.31	1995.1
Compressibility, permeability and durability (one-dimensional consolidation, swelling and collapsibility, Permeability of Soils: Falling-head Method disintegration and frost heaving)	Methods of test for Soils for civil engineering purposes–Part 5: Compressibility, permeability and durability tests	BS1377-5:1990	1990.8.31	1994.11
Consolidation and permeability tests in hydraulic cells and with pore pressure measurement	Methods of test for Soils for civil engineering purposes–Part 6: Consolidation and permeability tests in hydraulic cells and with pore pressure measurement	BS1377-6:1990	1990.11.30	1994.11

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Shear strength tests (total stress) (indoor vane shear, direct shear, ring shear, single-stage and multi-stage loading test UU)	Methods of test for Soils for civil engineering purposes–Part 7: Shear strength tests (total stress)	BS1377-7:1990	1990.6.29	1994.11
Shear strength tests (effective stress) (CU, CD)	Methods of test for Soils for civil engineering purposes–Part 8: Shear strength tests (effective stress)	BS1377-8:1990	1990.10.31	1995.1
Water content	Geotechnical investigation and testing–Laboratory testing of soil Part 1: Determination of water content	BS EN ISO 17892-1:2014	2014.12.31	
Bulk density	Geotechnical investigation and testing–Laboratory testing of soil Part 2: Determination of bulk density	BS EN ISO 17892-2:2014	2014.12.31	
Particle density	Geotechnical investigation and testing–Laboratory testing of soil Part 3: Determination of particle density	BS EN ISO 17892-3:2015	2016.1.31	
Particle size distribution	Geotechnical investigation and testing–Laboratory testing of soil Part 4: Determination of particle size distribution	BS EN ISO 17892-4:2016	2016.12.31	
Oedometer test	Geotechnical investigation and testing–Laboratory testing of soil Part 5: Incremental loading oedometer test	BS EN ISO 17892-5:2017	2017.4.30	

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Test methods issued by the ISRM are included in *the Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006*, (commonly known as the Blue Book) and *the ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 2007-2014*, (commonly known as the Yellow Book). The Blue Book contains suggested methods from 1974 to 2006, and the Yellow Book contains suggested methods from 2007 to 2014. Recent papers related to rock tests were published in *Rock Mechanics and Rock Engineering*.

It can be seen in Table 4.5 that ISRM suggested methods for indoor rock tests are originally published in two journals: *International Journal of Rock Mechanics and Mining Science* (formerly *International Journal of Rock Mechanics and Mining Science and Geomechanics Abstracts*) and *Rock Mechanics and Rock Engineering*.

The method published by ISRM was reviewed and approved by the Commission on Testing Methods of the Rock Mechanics Society. The review procedure for the proposed method is shown in Figure 4.3. Applicants who are interested in developing a method submit method proposal to the committee. If the committee accepts the proposal, the draft by the applicants would be submitted to the chair of the committee for review after being first evaluated by more than three experts in the field. Upon subsequent revisions, if any, the draft is designated as suggested method and published in ISRM journals.

4.2.5 Hong Kong's standards

The soil test standard in Hong Kong is called *Geospec 3: Model Specification for Soil Testing* (2017 ver.), which was issued by Geotechnical Engineering Office (GEO) of Civil Engineering and Development Department (CEDD) of the Hong Kong Special Administrative Region (HKSAR) of China. *Geospec 3* consists of three parts: the first part covers the general technical procedures for planning and supervising laboratory tests, the second and third parts detail the technical procedures for individual tests. *Geospec 3* is mainly applicable in HKSAR.

Geospec 3 was developed by CEDD in accordance with the British Standard *BS1377* series. CEDD was formed by merging the former Civil Engineering Department (CED) and the Territory Development Department (TDD) in July 2004. The GEO carried out technical update in soil test standards and implemented relevant technical guides through publications of CEDD.

4.2.6 Australia's standards

Soil test methods in Australia Standards (AS) have been recognized and widely cited by Australian industry. The standards are divided into different categories according to test type (Table 4.6). The standard is numbered in format of 'AS + serial number + issue year'. Some standard numbers have suffix 'R + year', which means when the standard was reviewed and reconfirmed, such as 4133.4.1-2007 (R2016). The others are followed by ''Admt' number + year' where the number stands for times of amendments, and the year represents the time of amendment. For example, AS 1289.3.8.3: 2014 / Amdt 1:2015.

AS was developed by Standards Australian Association, an independent non-governmental and non-profit standard organization. In 1922, the Australian Commonwealth Engineering Standards Association was established. In 1929, it was renamed as the Standards Association of Australia (SAA). In 1988, SAA became the Australian Bureau of Standards. In 1999, it became an Australian Public Company Limited.

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Table 4.5 ISRM suggested methods for rock tests

Test	*Method*	*Source*	*Publication*
Density, gravity density, water, content, water absorption, swelling, and disintegration resistance	Suggested methods for determining water content, porosity, density, absorption and related properties and swelling and slake-durability index properties	International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts Vol. 16 No. 2, pp. 141–156	1979.4
Indirect tensile strength of rocks (Brazilian test)	Suggested method for determining mode I fracture toughness using cracked chevron notched Brazilian disc (CCNBD) specimens	International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts Vol. 32, No. 1 pp. 57–64	1995
Uniaxial compressive strength and deformability of rock	Suggested methods for determining the uniaxial compressive strength and deformability of rock materials	International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts Vol. 16 No. 2, pp. 135–140	1979.4
Sound velocity	Suggested method for determining sound velocity	Rock Mechanics and Mining Science & Geomechanics Abstracts Vol. 15 No. 2, pp. 53–58	1978.4
Triaxial compression	Suggested methods for determination the strength of rock materials in triaxial compression: revised version	International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts Vol. 15 No. 2, pp. 47–51	1978.4
Point load strength	Suggested method for determining point load strength	International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts Vol 22, No. 2, pp. 51–60	1985.4
Shear strength of rock joints	Suggested method for laboratory determination of the shear strength of rock joints: revised version	Rock Mechanics and Rock Engineering Vol. 47 No. 1 pp. 291	2014.1
Sound velocity	Upgraded ISRM suggested method for determining sound velocity by ultrasonic pulse transmission technique	Rock Mechanics and Rock Engineering Vol. 47, No. 1, pp. 255–259	2014.1
Swelling	Suggested methods for laboratory testing of swelling rocks	International Journal of Rock Mechanics and Mining Sciences Vol. 36, No. 3, pp. 291–306	1999.4
Schmidt hammer rebound hardness	Suggested method for determination of the Schmidt hammer rebound hardness: revised version	International Journal of Rock Mechanics and Mining Sciences Vol. 46, No. 3, pp. 627–634	2009.4

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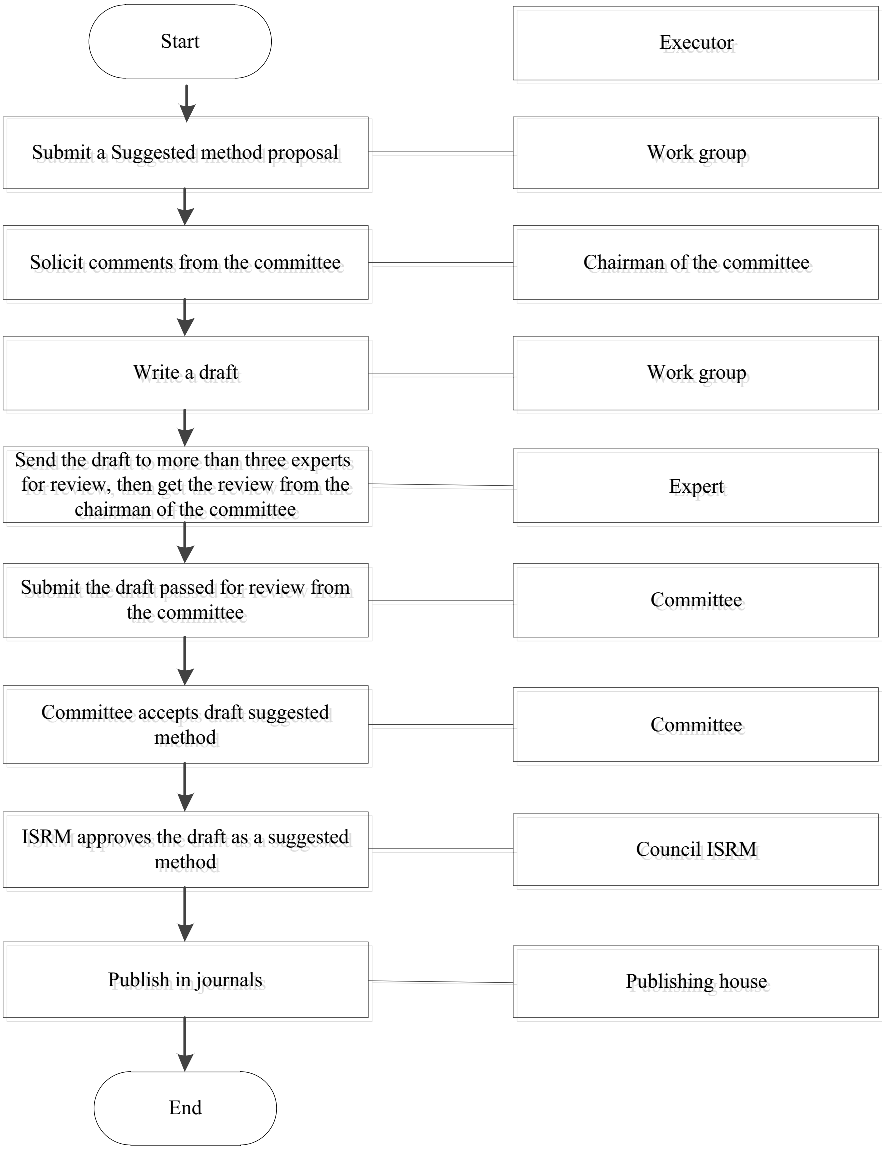

Figure 4.3 Flowchart of setting up an ISRM suggested method

The procedure for issuing and updating a standard in AS is similar to that in ASTM. Anyone (normally an Australian citizen) may make a proposal for developing or revising a standard. If approved, the committee would organize the development or revision. The standards in force are reviewed every five years by the committee in order to reconfirm, modify or even withdraw the existing standards according to the state-of-art technology.

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Table 4.6 Geotechnical test methods in AS

Test	*Standard*	*Code*
Deformability of rock materials in uniaxial compression (rock strength less than 50 MPa)	Methods of testing rocks for engineering purposes rock strength tests–determination of the deformability of rock materials in uniaxial compression–rock strength less than 50 MPa	AS 4133.4.3.2-2013
Uniaxial compressive strength of rock (strength less than 50 MPa)	Methods of testing rocks for engineering purposes rock strength tests–determination of uniaxial compressive strength–rock strength less than 50 MPa	AS 4133.4.2.2-2013
Uniaxial compressive strength of rock (strength greater than 50 MPa)	Methods of testing rocks for engineering purposes rock strength tests–determination of uniaxial compressive strength of 50 MPa and greater	AS 4133.4.2.1-2007
Point load strength index of rock	Methods of testing rocks for engineering purposes rock strength tests–determination of point load strength index	AS 4133.4.1-2007 (R2016)
Rock porosity and dry density (saturation and caliper techniques)	Methods of testing rocks for engineering purposes rock porosity and density tests–determination of rock porosity and dry density–saturation and caliper techniques	AS 4133.2.1.1-2005 (R2016)
Rock porosity and dry density (saturation and buoyancy techniques)	Methods of testing rocks for engineering purposes rock porosity and density tests–determination of rock porosity and dry density–saturation and buoyancy techniques	AS 4133.2.1.2-2005 (R2016)
Moisture content of rock (oven drying method)	Methods of testing rocks for engineering purposes rock moisture content tests–determination of the moisture content of rock–oven drying method (standard method)	AS 4133.1.1.1-2005 (R2016)
Swelling strain developed in an unconfined rock specimen	Methods of testing rocks for engineering purposes rock swelling and slake durability tests–determination of the swelling strain developed in an unconfined rock specimen	AS 4133.3.1-2005 (R2016)
California bearing ratio of a soil	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of the California bearing ratio of a soil–standard laboratory method for an undisturbed specimen	AS 1289.6.1.2-1998 (R2013)
Preparation of disturbed soil samples	Methods of testing soils for engineering purposes sampling and preparation of soils–disturbed samples–standard method	AS 1289.1.2.1-1998 (R2013)
Pinhole dispersion classification of a soil	Methods of testing soils for engineering purposes soil classification tests–dispersion–determination of pinhole dispersion classification of a soil	AS 1289.3.8.3:2014/ Amdt 1:2015
Definitions and general requirements of soil	Methods of testing soils for engineering purposes definitions and general requirements	AS 1289.0:2014
Dry density of a soil (water replacement method)	Methods of testing soils for engineering purposes soil compaction and density tests–determination of the field dry density of a soil–water replacement method	AS 1289.5.3.5-1997 (R2013)

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Table 4.6 (Continued)

Test	*Standard*	*Code*
Compaction control test (Hilf density ratio and Hilf moisture variation)	Methods of testing soils for engineering purposes soil compaction and density tests–compaction control test – Hilf density ratio and Hilf moisture variation (rapid method)	AS 1289.5.7.1-2006
Compaction control test (density index method)	Methods of testing soils for engineering purposes soil compaction and density tests–compaction control test–density index method for a cohesionless material	AS 1289.5.6.1-1998 (R2016)
Dry density/moisture content relation of a soil (standard compactive effort)	Methods of testing soils for engineering purposes soil compaction and density tests–determination of the dry density/moisture content relation of a soil using standard compactive effort	AS 1289.5.1.1:2017
Dry density/moisture content relation of a soil (modified compactive effort)	Methods of testing soils for engineering purposes soil compaction and density tests–determination of the dry density/moisture content relation of a soil using modified compactive effort	AS 1289.5.2.1:2017
Liquid limit of a soil (four-point Casagrande method)	Methods of testing soils for engineering purposes soil classification tests–determination of the liquid limit of a soil – four-point Casagrande method	AS 1289.3.1.1-2009 (R2017)
Liquid limit of a soil (one-point Casagrande method)	Methods of testing soils for engineering purposes soil classification tests–determination of the liquid limit of a soil–one-point Casagrande method (subsidiary method)	AS 1289.3.1.2-2009 (R2017)
Cone liquid limit of a soil	Methods of testing soils for engineering purposes soil classification tests–determination of the cone liquid limit of a soil	AS 1289.3.9.1:2015
Compressive strength of a specimen tested in undrained triaxial compression (with measurement of pore water pressure)	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of compressive strength of a soil–compressive strength of a saturated specimen tested in undrained triaxial compression with measurement of pore water pressure	AS 1289.6.4.2:2016
Compressive strength of a specimen tested in undrained triaxial compression (without measurement of pore water pressure)	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of compressive strength of a soil–compressive strength of a specimen tested in undrained triaxial compression without measurement of pore water pressure	AS 1289.6.4.1:2016
California bearing ratio of a soil	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of the California bearing ratio of a soil–standard laboratory method for a remoulded specimen	AS 1289.6.1.1:2014/ Amdt 1:2017

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Test	*Standard*	*Code*
Particle density of a soil	Methods of testing soils for engineering purposes soil classification tests–determination of the soil particle density of a soil–standard method	AS 1289.3.5.1-2006
Dry density of a soil (water replacement method)	Methods of testing soils for engineering purposes soil compaction and density tests–determination of the field dry density of a soil–water replacement method	AS 1289.5.3.5-1997 (R2013)
Assignment of maximum dry density and optimum moisture content values	Methods of testing soils for engineering purposes soil compaction and density tests–compaction control test–assignment of maximum dry density and optimum moisture content values	AS 1289.5.4.2-2007 (R2016)
Dry density ratio, moisture variation and moisture ratio of soils	Methods of testing soils for engineering purposes soil compaction and density tests–compaction control test–dry density ratio, moisture variation and moisture ratio	AS 1289.5.4.1-2007 (R2016)
Minimum and maximum dry density of a cohesionless material	Methods of testing soils for engineering purposes soil compaction and density tests–determination of the minimum and maximum dry density of a cohesionless material–standard method	AS 1289.5.5.1-1998 (R2016)
Shrinkage index of a soil (shrink-swell index)	Methods of testing soils for engineering purposes soil reactivity tests–determination of the shrinkage index of a soil–shrink-swell index	AS 1289.7.1.1-2003
Shrinkage index of a soil (loaded shrinkage index)	Methods of testing soils for engineering purposes soil reactivity tests–determination of the shrinkage index of a soil–loaded shrinkage index	AS 1289.7.1.2-2003
Shear strength of a soil	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of shear strength of a soil–direct shear test using a shear box	AS 1289.6.2.2-1998
Penetration resistance of a soil (9 kg dynamic cone penetrometer)	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of the penetration resistance of a soil – 9 kg dynamic cone penetrometer test	AS 1289.6.3.2-1997 (R2013)
Penetration resistance of a soil (perth sand penetrometer)	Methods of testing soils for engineering purposes soil strength and consolidation tests–determination of the penetration resistance of a soil–Perth sand penetrometer test	AS 1289.6.3.3-1997 (R2013)
Moisture content of soil (oven drying method)	Methods of testing soils for engineering purposes soil moisture content tests–determination of the moisture content of a soil–oven drying method (standard method)	AS 1289.2.1.1-2005 (R2016)

(*Continued*)

Table 4.6 (Continued)

Test	*Standard*	*Code*
Moisture content of soil (sand bath method)	Methods of testing soils for engineering purposes soil moisture content tests–determination of the moisture content of a soil–sand bath method (subsidiary method)	AS 1289.2.1.2-2005 (R2016)
Moisture content of soil (microwave-oven drying method)	Methods of testing soils for engineering purposes soil moisture content tests–determination of the moisture content of a soil–microwave-oven drying method (subsidiary method)	AS 1289.2.1.4-2005 (R2016)
Moisture content of soil (infrared lights method)	Methods of testing soils for engineering purposes soil moisture content tests–determination of the moisture content of a soil–infrared lights method (subsidiary method)	AS 1289.2.1.5-2005 (R2016)
Moisture content of soil (hotplate drying method)	Methods of testing soils for engineering purposes soil moisture content tests–determination of the moisture content of a soil–hotplate drying method	AS 1289.2.1.6-2005 (R2016)
The total suction of a soil (standard method)	Methods of testing soils for engineering purposes soil moisture content tests–determination of the total suction of a soil–standard method	AS 1289.2.2.1-1998 (R2013)

4.2.7 Japan's standards

The standardization for soil experiments in Japan is similar to that in China and it is proceeded by government agencies. The national standard in Japan is called JIS (Japanese Industrial Standard). JIS covers civil engineering and construction, steel, non-ferrous metals, energy, welding, chemical products, chemical analysis, polymers, textiles, furnaces, daily necessities, mechanical parts, machine tools, precision machinery, general machinery, automotive, aerospace, railway, marine, packaging and transportation, electrical, electronics, household appliances, medical safety appliances, atomic energy and intelligence. Soil testing standards are included in the M (Mine) and A (Architecture) categories (Table 4.7). The standard code is formatted as 'JIS + M/A + series number + year'.[8]

JIS is formulated and revised by Japanese Industrial Standards Committee (JISC). JISC was found on December 6, 1945 as a specifically private institution for standardization work, and serves as the most authoritative agency in Japan for standardization.

Similar to the ASTM, development process of JIS is illustrated in Figure 4.4. Any groups or individual (normally Japanese citizens) may submit the draft standard for JIS to discuss. The approved draft is then transferred to the Ministry of Industry and JISC for reviewing. If JISC considers the draft reasonable, the Minister of Industry will publish it. The departments in charge will revise the draft according to the comments from the public. The draft will be confirmed to be officially involved in JIS and published in the official gazette once it satisfies the quality checking.

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Table 4.7 Japanese geotechnical test standards

Test	*Code*	*Standard*
Tensile strength of rock	JIS M 0303: 2000	Method of test for tensile strength of rock
Compressive strength of rock	JIS M 0302: 2000	Method of test for compressive strength of rock
Preparation of rock samples	JIS M 0301: 1975	Methods of sampling of rock and preparation of test piece for strength test
Soil density (sand replacement method)	JIS A 1214: 2013	Test method for soil density by the sand replacement method
Load test on soil for road	JIS A 1215: 2013	Method for plate load test on soil for road
Soil compaction (rammer)	JIS A 1210: 2009	Test method for soil compaction using a rammer
Density of soil particles	JIS A 1202: 2009	Test method for density of soil particles
One-dimensional consolidation properties of soils (constant rate of strain loading)	JIS A 1227: 2009	Test method for one-dimensional consolidation properties of soils using constant rate of strain loading
Preparation of disturbed soil samples	JIS A 1201: 2009	Practice for preparing disturbed soil samples for soil testing
Bulk density of soils	JIS A 1225: 2009	Test method for bulk density of soils
Minimum and maximum densities of sands	JIS A 1224: 2009	Test method for minimum and maximum densities of sands
Permeability of saturated soils	JIS A 1218: 2009	Test methods for permeability of saturated soils
One-dimensional consolidation properties of soils (incremental loading)	JIS A 1217: 2009	Test method for one-dimensional consolidation properties of soils using incremental loading
Unconfined compression test of soils	JIS A 1216: 2009	Method for unconfined compression test of soils
California bearing ratio (CBR) of soils	JIS A 1211: 2009	Test methods for the California bearing ratio (CBR) of soils in laboratory
Shrinkage parameters of soils	JIS A 1209: 2009	Test method for shrinkage parameters of soils
Liquid limit and plastic limit of soils	JIS A 1205: 2009	Test method for liquid limit and plastic limit of soils
Particle size distribution of soils	JIS A 1204: 2009	Test method for particle size distribution of soils
Water content of soils	JIS A 1203: 2009	Test method for water content of soils
One-dimensional consolidation properties of soils (constant rate of strain loading)	JIS A 1227: 2009	Test method for one-dimensional consolidation properties of soils using constant rate of strain loading

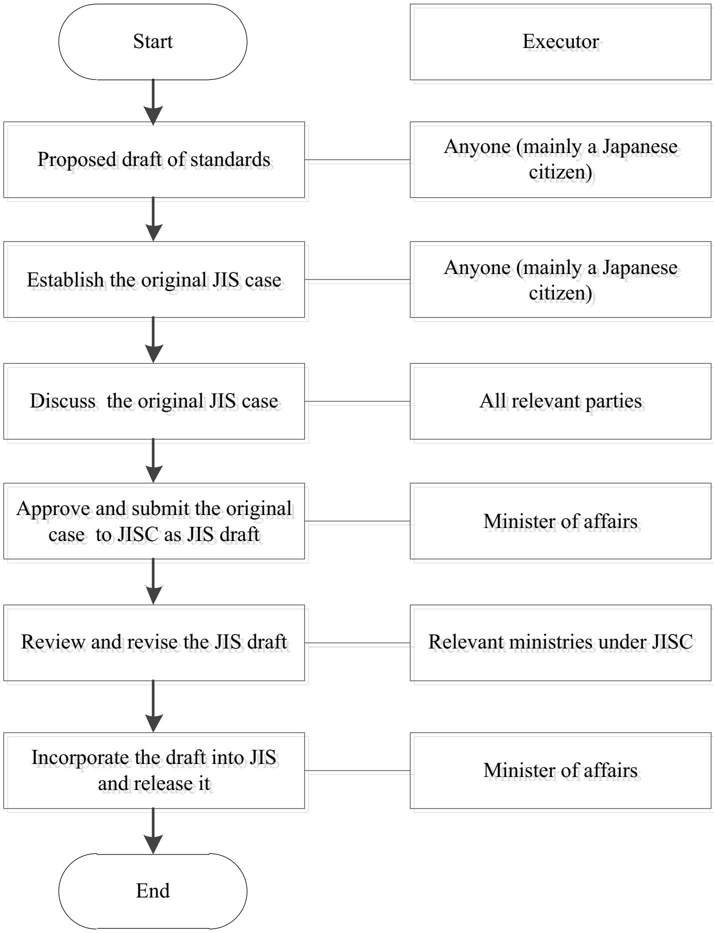

Figure 4.4 Flowchart of standardization in Japan

4.2.8 South Africa's standards

Table 4.8 shows that the locally developed South African National Standards (SANS) for geotechnical tests cover a relatively narrow scope. The ISO or IEC standards are cited whenever the local standards are incompetent.[4]

The SANS was developed by the South African Standard Technical Committee and its development process is shown in Figure 4.5. The South African Bureau of Standards (SABS) initiates the formulation of a standard. The technical committee under SABS is responsible for drafting the standards, soliciting public comments, and modifying the draft according to the comments. The draft will be submitted to the Standards Approval Board for approval and being published.

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Table 4.8 Geotechnical test standards in South Africa

Test	*Standard*	*Code*
Rock durability	Civil engineering test methods part AG15: determination of rock durability using 10% fact (fines aggregate crushing test) values after soaking in ethylene glycol	SANS 3001-AG15 Ed. 1 (2012)
Wet preparation and particle size analysis	Civil engineering test methods part GR1: wet preparation and particle size analysis	SANS 3001-GR1:2013 (Ed. 1.02)
Liquid limit, plastic limit plasticity index and linear shrinkage	Civil engineering test methods part GR10: determination of the one-point liquid limit, plastic limit, plasticity index and linear shrinkage	SANS 3001-GR10:2013 (Ed. 1.02)
Liquid limit (two-point method)	Civil engineering test methods part GR11: determination of the liquid limit with the two-point method	SANS 3001-GR11:2013 (Ed. 1.02)
Moisture content (oven-drying)	Civil engineering test methods part GR20: determination of the moisture content by oven-drying	SANS 3001-GR20:2010 (Ed. 1.01)
Maximum dry density and optimum moisture content	Civil engineering test methods part GR30: determination of the maximum dry density and optimum moisture content	SANS 3001-GR30:2015 (Ed. 1.02)
Dry density (sand replacement)	Civil engineering test methods part GR35: determination of in-place dry density (sand replacement)	SANS 3001-GR35:2015 (Ed. 1.00)
California bearing ratio	Civil engineering test methods part GR40: determination of the California bearing ratio	SANS 3001-GR40:2013 (Ed. 1.01)

4.2.9 Singapore's standards

Soil test standards used in Singapore consist of the Singapore Standards (SS) issued by the Standards Committee of Singapore and the *Eurocode 7*. SS is classified into recommended standards and mandatory technical standards. The standard number is formatted as 'code + series number'.

The Standards, Productivity and Innovation Commission (SPRING Singapore) has developed the Singapore standards. SPRING Singapore is the statutory committee of the Ministry of Industry and Trade of Singapore, which was formed by combining and

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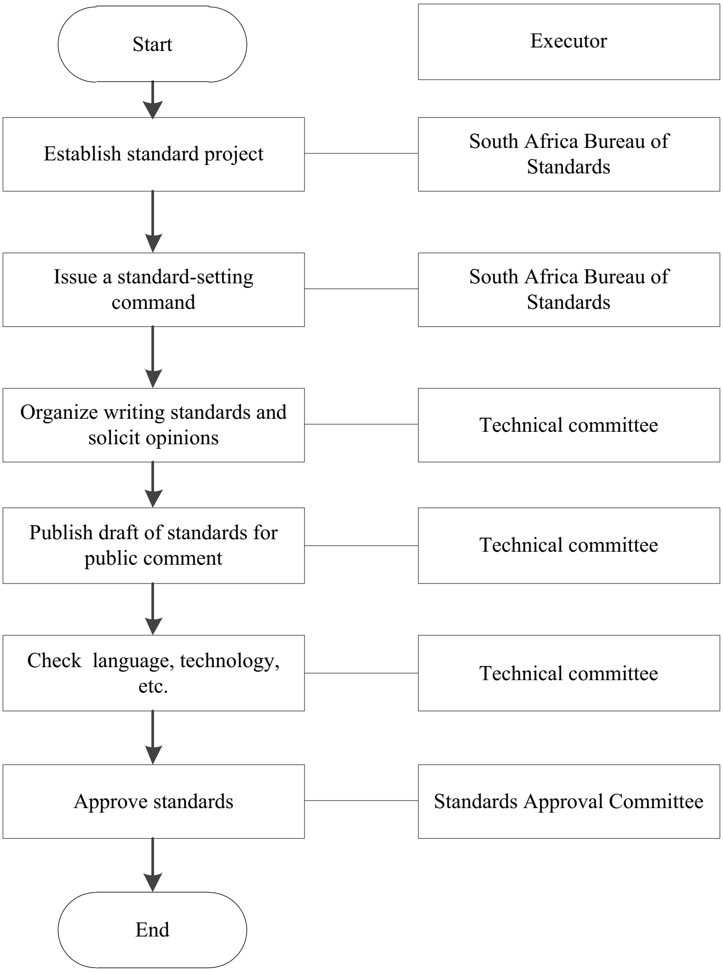

Figure 4.5 Flowchart for establishing test standards in South Africa

reorganizing the former Singapore Productivity and Standards Agency (PSB), the National Productivity Commission (NPB) and the Singapore Standards and Industries Association (SISIR) in 1996. SPRING Singapore was renamed SPRING in April 2002.

The Singapore standard system was established on the basis of international standards. Any proposed Singapore standards must be consulted with all relevant parties prior to publication.

The process of developing Singapore standards is shown in Figure 4.6. Any Singapore citizens may submit a request to Standards Committee for developing new standards. Once the request is accepted, the Standards committee starts to establish the proposed standard, which is then transferred to the Technical Committee for soliciting and reviewing before being published. All Singapore standards must be reviewed every five years to determine if they need revision.[5]

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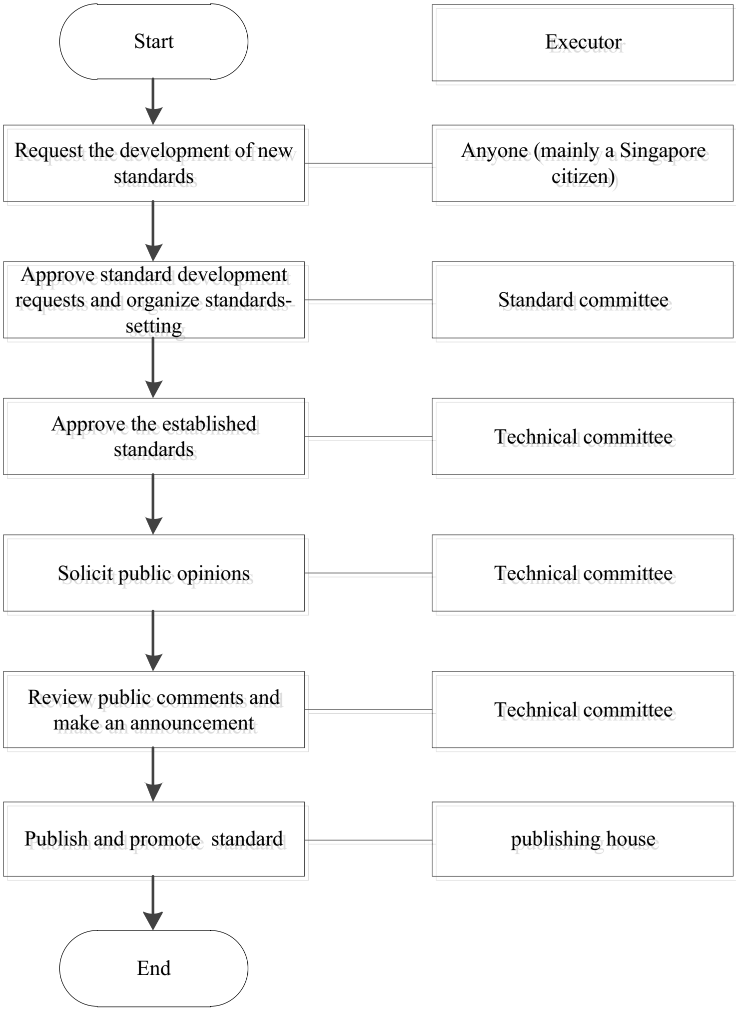

Figure 4.6 Flowchart for establishing a standard in Singapore

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