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MARINE PORT FACILITIES: DESIGN STANDARDS - PART 3: TECHNICAL REQUIREMENTS FOR THE MATERIALS

HANOI – 2015

Contents

Preface

TCVN xxx-3: 2015 Mairine Port Facilities - Design standards -Part 3: Technical requirements for materials are compiled based on the **"Technical Standards and Commentaries for Port and Harbour Facilities" in Japan**, version OCDI 2009.

TCVN xxx-3: 2015 Mairine Port Facilities - Design standards - Part 3: Technical requirements for materials compiled Institute of Trasportation for Science and Technology (ITST), the Ministry of Transportation (MOT) Proposal, the General Department of Standardization, Metrology and Quality Appraisal, Ministry of Science and Technology Ministry Announced.

Marine Port Facilities: Disegn Standards - Part 3: Technical Requirements for the materials

1. Scope of application

1.1 The materials specified in the design criteria are used in new construction projects of all kinds of seaport facilities (jetties, breakwaters, shore protection works, road traffic in the Port ...) or for other types of infrastructure projects have used similar conditions within the territory of Vietnam.

1.2 For the maintenance and repair of port facilities will damaged or downgraded port, in addition to the materials mentioned in this standard, we should have more references about the other criteria for the selection of appropriate materials, in order to ensure quality of construction.

2. Documents of references

The following reference documents are essential for the application of this standard. For the record documents have year of publication, apply the mentioned version. For reference documents not recorded, apply the lastest versions, including the latest amendments and supplements (if any).

- TCVN 5574-2012	Concrete and reinforced concrete structures - Design standard
- TCVN 4116-1985	Concrete and reinforced concrete structures of hydraulic engineering constructions - Design standard
- TCVN 9346-2012	Concrete and reinforced concrete structures - Requirementd of protection from corrosion in marine environment
- TCVN 7570-2006	Aggregates for concrete and mortar − Specifications
- TCVN 9205-2012.	Crushed sand for concrete and mortar
- TCVN 4033-1995	Portland pozzolan cement - Technical requirements
- TCVN 2682-2009	Portland cements - Specifications
- TCVN 4316-2007	Portland blast furnace slag cement
- TCVN 6067-2004	Sulphate resisting portland cement - Technical requirements
- TCVN 6260-1997	Portland blended cement – Specifications
- TCVN4506-2012	Water for concrete and mortar - Technical speccification
- TCVN 8826-2011	Chemical admixtures for concrete
- TCVN 8827-2011	Highly activity puzzolanic admixtures for concrete and mortar - Silicafume and rice husk ash

-	TCVN5575-2012.	Steel structures - Design standard
-	TCVN 9245-2012	Steel pipe piles
-	TCVN 9246-2012	Steel pipe sheet piles
-	TCVN 9685- 2013	Hot - rolled steel sheet piles. Specifications
-	TCVN 9686- 2013	Weldable hot rolled steel sheet piles. Specifications
-	TCVN 7571-2006	Hot-rolled steel section
-	TCVN 1651-1-2008	Steel for the reinforcement of concrete – Part 1: Plain bars
-	TCVN 1651-2-2008	Steel for the reinforcement of concrete – Part 2: Ribbed bars
-	TCVN 1651-3-2008	Steel for the reinforcement of concrete - Part 3: Welded fabric
-	TCVN 10264 : 2014	Athode Protection for steel structures of Ports and Marine Works – Design standard
-	TCVN 10263: 2013	Anodes sacrifice - Technical Requirements
-	TCVN 8789: 2011	Protective paint systems for steel and bridge structures – Specifications and Test Methods.
-	TCVN 4399:2008	Steel and steel products - General technical delivery requirements
-	TCVN 1845-1989	Hot - rolled steel bands. Dimensions
-	TCVN 6524:2006	Cold-reduced steel sheet of structural quality
-	TCVN 2057-77	Plates and wide flats of general structural hot – rolled. Technical requirements
-	TCVN 2058-77	Stell plates hot-rolled Measurements
-	TCVN 2735-78	Corrosion and heat resisiting wronght steel bars - Technical requirements
-	TCVN 7573:2006	Continuously hot-rolled steel sheet products – Dimensional and shape tolerances
-	TCVN 1765-1975	Steel carbon for structure ordinary. Technical requirements
-	TCVN 6522:1999	Hot-rolled steel sheet of structural quality
-	TCVN 6523:1999	Hot-rolled steel sheet of high yield stress structural quality
-	TCVN 6525:2006	Continouos hot-dip zinc-coated carbon steel sheet of structural quality
-	TCVN 6526:2006	Hot-rolled steel strip of structural quality
-	TCVN 6527:1999	Hot-rolled structural steel wide flats -Tolerance on dimensions and shape
-	TCVN 2364:1978	Hot - rolled steel coil . Sizes, parameters and dimensions
-	TCVN 2365:1978	Cold rolled steel coil. Sizes, parameters and dimensions

- TCVN 2055-1977 Seamless hot-rolled steel tubes. Sizes, parameters and dimensions

3. Symbol, terminology and definitions

3.1 Symbol

- TCVN: Vietnamess National Standadrs
- 22TCN: Standard of transport
- JIS: Japanese Industrial Standards. In this standard use symbols following:
- ASTM: Standards – American Society for Testing and Material standards.
- BS: British Standards
- M.L.W.L Mean low water level
- L.W.L Low water level
- H.W.L Hight water level

3.2 Terminology and definitions

See in "**Marine Port Facilities. Design Standards - Part 1: General Rules**"

4. General

Materials used in construction of ports include many types, which has two main materials are steel and concrete. This Standard sets out the main technical requirements of materials, as a basis for the verification performance of parts of structures.

5. Steel

5.1 General Requirement

5.1.1 Steel used in port facilities shall be selected from appropriate materials taking into account effects on actions, deterioration, working life time, shape, constructability, economy and environment, and other factors related.

5.1.2 Steel used in port facilities must have the necessary qualities to satisfy the required functionality of the port facilities and comply with the TCVNs. Where the steel used according to foreign standards, they must have similar or higher quality of the TCVNs.

Table 5.1 and **Table 5.2** lists the types of steel complying with the TCVN that are most often used in port facilities.

Also, depending on the specific requirements of each project, can refer to types of steel accordance with the foreign standards outlined in appendices (JIS - Appendix A, ASTM - Appendix B, BS - Appendix C).

5.1.3 In general, structural steel with a tensile strength of 490 N/mm2 or more is called high-strength steel. Highstrength steel has an important characteristic that the higher the strength it has the larger is its yield ratio, namely the ratio of the yield strength to the tensile strength.

5.1.4 Corrosion resistant steel has excellent resistance to particles of seawater salt above the sea level, and they may be use alloy steel.

Table 5.1 - Quality Standards for Steel Materials (TCVN)

Type of steel material	Standard		Symbols	Applications
Structural steel	TCVN 6522:1999	Hot-rolled steel sheet of structural quality	HR 275 HR 355	Thick plate steel 1.6 ÷ 6 mm, width ≥ 600 mm
	TCVN 6523: 2006 (ISO 4996: 1999)	Hot-rolled steel sheet of hight yield stress structural quality	HS355, HS 390 HS 420, HS 460, HS 490	Plate steel thick 1.6 ÷ 6 mm, width ≥ 600 mm
	TCVN 6525:2006 (ISO 4998:2005)	Continouos hot-dip zinc-coated carbon steel sheet of structural quality	Z320, Z350, Z380, Z450	Steel plates, sheets thick 0.25 ÷ 5 mm, width ≥ 600 mm
	TCVN 6526:2006 (ISO 6316:2000)	Hot-rolled steel strip of structural quality	HR 235 HR 275 HR 355	Steel plates, sheets thick 0.65 ÷ 12 mm, width ≥ 600 mm
	- TCVN 2057: 77 and - TCVN 1765: 75	- Plates and wide flats of general structural hot – rolled. Technical requirements, and - Carbon steel of general structural - Steel grade and technical requirements	- Group A: CT according to mechanical properties. - Group B: BCT according to the chemical composition - Group C: CCT according to the mechanical properties and chemical composition	- Steel bars, plates, strips widebands, shapings thick. - Steel ingots, billets roughing, slab, billet casting or rolling
		Steel for general	- CT38n,	

Structural steel		strucres	CT38nMn - CT42s, CT42n - CT51n, CT51 - CT52nMn	
		Steel for welded structures	- CT38, CT42 - BCT38n, BCT38, BCT38nMn. - CCT38, CCT38nMn, CCT42, CCT52	
	TCVN 2735: 1978	Corrosion and heat resisting wronght steel bars – Technical requirement (for wilded structrures)	08Cr17Ti, 15Cr25, 08Cr18Ni11, 12Cr18Ni9Ti 08Cr18Ni12Ti	Steel bars, steel plates
Steel pipe	TCVN 2055: 1997	Seamless hot-rolled steel tubes – Sizes, measuremnets		
Steel pile	TCVN 9245: 2012	Steel pipe piles	SPP 345, SPP400, SPP90	
Sheet pile	TCVN 9685- 2013	Hot- rolled steel sheet piles	SSP 295, SSP 390	U-shaped, Z-shaped, H-shaped, flat
	TCVN 9686- 2013	Weldable hot- rolled steel sheet piles	SSPW 240 SSPW 295, SSPW 390	
	TCVN 9246-2012	Steel pipe sheet piles	SPSP 345, SPSP400, SPSP490	
Cast or forged items	TCVN 385, 386:1970	Cast iron castings		Mooring post
	TCVN 3223:2000 (ISO 2560:1973)	Covered electrodes for manual arc welding of mild stell and low steel –	E430 ÷ E435, E510 ÷ E515	

Welding rods		symbol, dimension and general technical requiremnet		
Welding rods	TCVN 3734:1989	Electrodes for arc welding – symbols		- N50-6B (for manual arc welding of mild stell and low steel) - Đ05.Cr45.Mn 20-50 (welding rod up) - Hn.Cr85, Mo10, V04-450R (Heat resistant Welding rods) - Hb, Cr10, Ni8, Mn-600B (Heat resistance welding rods and against corrosion) - Hc60, Cr18, V, W, Me-B (welding rods alloy high strength) - GK3-B (ast iron welding rods) - Hm, Cu, Si24, Mn15-B (Nonferrous alloy Welding rods).
Steel materials use for joining	TCVN 1876: 1976 TCVN 1892: 1976	Hexagon nuts (rough precition) - Dimensions. Hexagon nuts (hight precition) – dimensions		
	TCVN 1896: 1976 TCVN 1905: 1976	Hexagon nuts (rough precition) – Dimnesions Hexagon nuts (hight precition) – Dimensions		
Wires	TCVN 6284- 1÷ 4: 1997	Steel for the restressing of concrete	- TCVN 6284-2: 1997 - processing	

		- Part 2: Cold-Drawn wire - Part 3: Quenched and tempered wire. - Part 4: Strand	methods (M/S) – surface (P/l /C/ R) – Diameter – Tensile strength - The level recovery. - TCVN 6284-4: 1997 - Type of strand - Diameter - Tensile strength - The level recovery - Twisted direction	
Steel bar	TCVN 1651-1: 2008	Steel for reinforcement of concrete – Part 1: Plain bars.	CB 240-T, CB 300-T	
	TCVN 1651-2: 2008	Steel for RC - Part 2: Ribbed bars.	CB300-V, CB400-V, CB500-Vb.	
	TCVN 6284-1, 5:1997	Steel for the restressing of concrete.	TCVN-5:1997- Bar- Diameter - Tensile strength - Round/Ribbed.	

Table 5.2 - Shape Specifications for Steel (TCVN)

Type of steel		Standard	Materials used
Structural steel	Steel bar	TCVN 6283-1÷4:1997 Hot-rolled bars – Dimensions and tolerance (ISO 1035-1÷4:1980)	
	Shaped steel	TCVN 7571-16: 2006	H200, H220, H250
	Steel Plate and Steel Strips	- TCVN 7573:2006 (ISO 16160:2005) Continuously hot-rolled steel sheet products - dimensional and shape tolerance. - TCVN 2364: 1978	- HR 275, HR 355 - HS355, HS 390, HS 420, HS 460, HS 490 - HR 235, HR 275,

		Hot - rolled steel coil . Sizes, parameters and dimensions	HR 355
	Flat steel	- TCVN 6527: 1999 (ISO 9034:1987) Thép dải khổ rộng kết cấu cán nóng. Dung sai kích thước và hình dạng Hot-rolled structural steel wide flats – Tolerances on dimentions and shaps - TCVN 2058: 1977. Thép tấm dày cán nóng. Cơ, thông số, kích thước. (steel plates hot-rolled. Measurements)	Group A: - CT38n, CT38, CT38nMn - CT42, CT42s, CT42n - CT51n, CT51, CT52nMn Group B and C: Add symbols B or C at the top
Shaped steel	TCVN 7571-16: 2006	Hot-rolled steel section – Part 16: Steel H - Dimension and sectional properties	H200, H220, H250
Steel pile	Steel pipe pile	TCVN 9245-2012	SPP345, SPP400, SPP490
Sheet pile	Hot rolled steel sheet pile	TCVN 9685- 2013	SSP 295, SSP 390
	Weldable hotrolled steel sheet piles	TCVN 9686: 2013	SSPW 240, SSPW 295, SSPW 390
	Steel pipe sheet pile	TCVN 9246-2012	SPSP 345 SPSP400, SPSP490
Steel materials used for joining	Hexagonal head bolts	TCVN 1876: 1976 (rough precition) TCVN 1892: 1976 (hight precition)	
	Hexagonal shape nuts	TCVN 1892: 1976 (rough precition) TCVN 1905: 1976 (hight precition)	

Steel bar	Steel bar for reinforced concrete	TCVN 1651-1,2-2008	CB 240-T, CB 300-T. CB 300-V, CB 400-V, CB 500-Vb.
Prestressd concrete	PC steel wire and strands	TCVN 6284-1÷4: 1997	- TCVN 6284-2: 1997 - processing methods (M/S) – Surface (P/I /C/ R) – Diameter – Tensile strength - The level recovery - TCVN 6284-4: 1997 - Type of strand - Diameter - Tensile strength - The level recovery -Twisted direction.
	PC steel bars	TCVN 6284-1,5: 1997	TCVN 6284-5: 1997 - Bar - Diameter - Tensile Strength – Surface (P/R)
Wire mesh	Welded wire mesh	TCVN 1651-3-2008	Welded wire mesh TCVN 1651-3 - Distance of the wire – Diameter - Length x width - Steel grade.

5.1.5 When using rolled steel for general structures, rolled steel for welded structures, or corrosion resistant hot rolled steel for welded structures, it is necessary to choose the thickness comply with TCVN standards corresponding to each type of steel, particularly steel for welded structures.

5.1.6 When using wire and prestressed steel bundles (PC) should be noted that meet the requirements of strength and chemical composition of the steel.

5.1.7 In facilities that have many welded portions, for example, facilities with joint construction, it is necessary to pay attention to the chemical composition and weldability of the steel.

5.2 Characteristic Values of Steel

5.2.1 Characteristic values for various constants of the steel and cast steel required for performance verification are appropriately specified by considering factors such as strength characteristics.

5.2.2 In general, characteristic values for the Young's modulus, the shear modulus, Poisson's ratio, and the linear expansion coefficient of steel and cast steel can use the values given by **Table 5.3.** Also, the constants for steel used in reinforced concrete and prestressed concrete can refer to the values given in the standards **TCVNs** for Concrete Structures.

Table 5.3 - Mechanical Characteristics for Steel

Young's modulus *E* 2.0 × 105 N / mm2	2.0 X 10^5 N / mm2
Shear modulus *G* 7.7 × 104 N / mm2	7.7 X 10^4 N/ mm2
Poisson's ratio *v* 0.30	0,30
Linear expansion coefficient *α* 12	12 X 10^{-6} l/°C

5.2.3 Characteristic Values of Yield Strength

Characteristic values of yield strength for steel and cast steel are appropriately specified based on test results.

5.2.3.1 Structural steel

1) Generally, the values listed in Table 5.4 can be used as characteristic values of yield strength for structural steel based on the grade of steel and the thickness.

2) The shear yield strength calculated by Von Mises formula (in **table 5.4** temporary taken 57.5% of tensile yield strength)

3) When the contact mechanism between two steel is a flat surface against a flat surface including cylindrical surfaces and curved surfaces that are nearly flat, the bearing yield strength may be taken as 50% more than the tensile yield stress.

Table 5.4 - Characteristic Values of Yield Strength for Structural Steel (TCVN 1765:1975)

Type of steel	**Thickness (mm)**	**Yield strenght (N/mm²)**				**Tensile strength (N/mm²)**
		Tensile	**compressive**	**Shear**	**Bearing yield strength between steel plate and steel plate**	
CT 38s	≤ 20	≥ 240	≥ 240	138	360	370 ÷ 470
	20 ÷ 40	≥ 230	≥ 230	132	345	
	40 ÷ 100	≥ 220	≥ 220	127	330	
	≥100	≥ 200	≥ 200	115	300	
CT 38n, CT 38	≤ 20	≥ 250	≥ 250	144	375	380 ÷ 490
	20 ÷ 40	≥ 240	≥ 240	138	360	
	40 ÷ 100	≥ 230	≥ 230	132	345	
	≥100	≥ 210	≥ 210	121	315	
CT 38nMn	≤ 20	≥ 250	≥ 250	144	375	380 ÷ 500
	20 ÷ 40	≥ 240	≥ 240	138	360	

	40 ÷ 100	≥ 230	≥ 230	132	345	
	≥100	≥ 210	≥ 210	121	315	
CT 42s	≤ 20	≥ 260	≥ 260	150	390	410 ÷ 520
	20 ÷ 40	≥ 250	≥ 250	144	375	
	40 ÷ 100	≥ 240	≥ 240	138	360	
	≥100	≥ 230	≥ 230	132	345	
CT 42n, CT 42	≤ 20	≥ 270	≥ 270	155	406	420 ÷ 540
	20 ÷ 40	≥ 260	≥ 260	150	390	
	40 ÷ 100	≥ 250	≥ 250	144	375	
	≥100	≥ 240	≥ 240	138	360	
CT 51n, CT 51	≤ 20	≥ 290	≥ 290	167	436	510 ÷ 640
	20 ÷ 40	≥ 280	≥ 280	161	421	
	40 ÷ 100	≥ 270	≥ 270	155	406	
	≥100	≥ 260	≥ 260	150	390	
CT 52nMn	≤ 20	≥ 290	≥ 290	167	436	460 ÷ 640
	20 ÷ 40	≥ 280	≥ 280	161	421	
	40 ÷ 100	≥ 270	≥ 270	155	406	
	≥100	≥ 260	≥ 260	150	390	

5.2.3.2 Characteristic values for steel pile and steel pipe sheet pile

1) As characteristic values of yield stress for steel pile and steel pipe sheet pile, generally the values of **Table 5.5** can be used, based on the types of steels and stresses.

Table 5.5 Characteristic Values of Yield Strength for Steel Pile and Steel Pipe Sheet Pile

(N/mm^2)

Steel grade / Type of stress	TCVN 9245: 2012	TCVN 9246: 2012
	SPP400, SPSP400	**SPP490, SPSP490**
Axial tensile stress (per net cross-sectional area)	235	315
Bending tensile stress (per net cross-sectional area)	235	315
Bending compression stress (per total cross-sectional area)	235	315
Shear stress (per total cross-sectional area)	136	182

2) When it is necessary to combine the axial stress and shear stress, yield strength may be determined by referencing to the appropriate foreign standards (JIS. ASTM…)

3) Buckling strength depends on the condition of the member and is specified appropriately during the verification of facility.

5.2.3.3 Steel sheet pile

As characteristic values of yield strength for steel sheet pile, generally the values of Table 5.6 can be used, based on the types of steels and stresses.

Table 5.6 - Characteristic Values of Yield Strength for Steel Sheet Pile (TCVN 9685-2013)

(N/mm^2)

Type of stress \ Steel	SSP 295	SSP 390
Bending tensile stress (per net cross-sectional area)	295	390
Bending compression stress (per total cross-sectional area)	295	390
Shearing stress (per total cross-sectional area)	170	225

5.2.3.4 Cast and forged items

As characteristic values of yield strength for cast and forged structures may be determined by referencing to the appropriate foreign standards (JIS, ASTM…)

5.2.3.5 Yield strength for welded portions and steel materials used for joining

1) As characteristic values of yield strength for welded portions, the values in **Table 5.7** can be referred, based on the types of steels and strength. When joining steel of different strengths generally the value for the steel with lower strength shall be used.

2) If welding technology on-site was implemented and quality control appropriately, the yield strength can take as welding at the factory. In locations where it is difficult to verify that the environmental conditions are good for the welding of materials such as steel pipe pile and steel pipe sheet pile, the yield strength for on-site welding can be taken to be 90% of the value for factory welding.

3) The characteristic yield strength for anchor bolts and pins may be determined by referencing to the appropriate standards.

4) It is assumed that the specified anchor bolts are used as embedded in concrete. Since construction using anchor bolts can often be insecure, and it is necessary to maintain a strength balance with the concrete that they support, the calculation of design values should sufficiently include an extra margin of safety

Table 5.7 Characteristic Values of Yield Strength for Welded Portions (TCVN)

(N/mm^2)

Type of welding		Steel / Type of strength	CT38 CT38nMn, BCT38, BCT38n CCT38, CCT38nMn	CT42, CCT42	CCT52
Shop welding	Full penetration groove welding	240	250	280	355
		240	250	280	355
		138	144	161	205
	Fillet welding, partial penetration groove welding	138	144	161	205
On-site welding		1) As a rule, use the same values as for factory welding. 2) For steel pipe pile and steel pipe sheet pile, use 90% of the factory value.			

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5) Since pins do not use bolt holes as in sheet or shaped steel, and usually do not use notches, there is no concern that they will concentrate stress. Also, although pins are often verified for shear and bearing, their limit values are not lowered for shear accompanied by sliding. With these considerations in mind, values for shear yield strength are specified larger than the values listed in Table 5.4 or appropriate standards has been reference.

6) **Table 5.8** lists the characteristic yield strength for finished bolts.

Table 5.8 Yield Strength for Finished Bolts (TCVN 1916-95)

(N/mm^2)

Strength categories / Type of stress	4,6	8,8	10,9
Tensile	240	640	900
Shearing	140	370	520
Bearing	360	960	1350

5.2.3.6 Foreign standards about steel materials for reference

1) Appendix A: Standards of Japan
2) Appendix B: Standards ASTM of American
3) Appendix C: British Standards

5.3 Corrosion Protection

5.3.1 Overview

1) Corrosion protection should be taken into consideration when using steel because of the harsh corrosive environmental conditions. Severe localized corrosion occurs particularly in sections immediately below the mean low water level and, therefore, appropriate measures should be taken.

2) The distribution of corrosion rate with respect to the depth of steel driven into the sea generally is shown in **Fig. 5.1** The corrosion is particularly heavy in the splash zone, where the structure is exposed to sea water splashes and there is an adequate supply of oxygen. In particular, the rate of corrosion is the highest in the section immediately above the high water level.

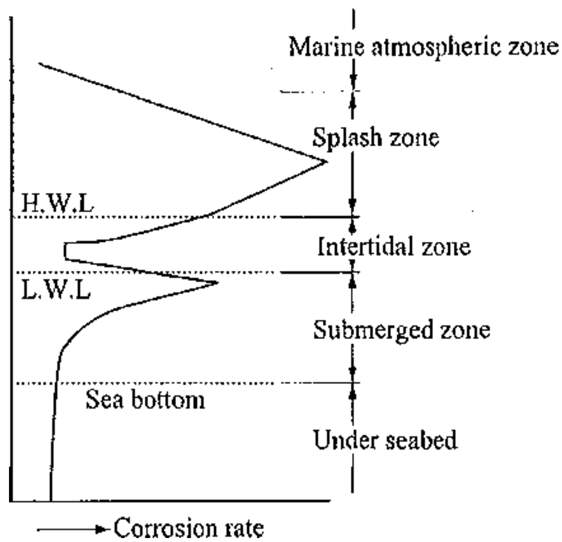

Fig. 5.1 Distribution of Corrosion Rates of Steel StructuresHình

Among the submerged sections in **Fig. 5.1**, the corrosion rate is the highest in the section immediately below the intertidal zone. However, the corrosion rate in this section differs greatly depending on the environmental conditions and the cross-sectional shape of the structure. In steel sheet piles and steel pipe pile structures submerged in clean sea water, the corrosion rate in the section immediately below the mean low water level, MLWL, is often not much different from that in submerged zone. Depending on the environmental conditions of the structure, however, the corrosion rate in the section immediately below MLWL may be much larger than that in the submerged zone, and in some cases may even exceed the value in the splash zone. This remarkable local corrosion is called the concentrated corrosion.

3) For all aspects of corrosion control, may be refer to the TCVNs as follows:

- TCVN 8789: 2011 Protective paint systems for steel and bridge structures – Specifications and Test Methods.

- TCVN 10264: 2014. Cathodic protection to the steel structure of the Ports facilities - Design Standards.

- TCVN 10263: 2013. Sacrifice Anodes - Technical Requirements and test methods

5.3.2 Corrosion Rates of Steel

1) The corrosion rate of steel shall be determined as appropriate in view of the environmental conditions of the site where structures are placed because the corrosion rate depends on the corrosive environmental conditions .

2) The corrosion rate of steel used in port and harbor structures is influenced by the environmental conditions including the weather conditions, the salinity and pollution level of the sea water, the existence of river water inflow, etc. Therefore, the corrosion rate should be determined by referring to past cases in the vicinity and survey results under similar conditions.

3) Currently in Vietnam, there is no sufficient data on the corrosion rate of steel in marine environment. So, can refer to the values about the corrosion rate of steel in **Appendix D**.

4) In oxygen-isolated spaces such as the inside of steel pipe piles, it may be assumed that corrosion cannot occur because there is no supply of oxygen.

5) Sand abrasion is a phenomenon in which the rust layer on the steel surface is removed by the movement of sand to expose the bare steel and to result in increasing the corrosion rate. There are examples where steel sheet pile was used as a sediment control groin and the mean corrosion rate due to sand corrosion directly above the sand surface was from 1.25 to 2.39 mm/year. When the vertical motion of the sand surface is small, the sections of abrasion are limited to areas immediately above the sand surface and so it is said that the corrosion rates become larger in these sections.

5.3.3 Corrosion protection methods

1) Corrosion protection methods for steel shall be undertaken as appropriate by employing the cathodic protection method, the covering/coating method, or other corrosion prevention method, depending on the environmental conditions in which the steel material exists. For the sections below the mean low water level, the cathodic protection shall be employed. For the sections above the depth of 1.0 m below M.L.W.L., the covering/coating method shall be employed.

2) In the intertidal zone and submerged zone, there is a risk of concentrated corrosion, depending on the corrosive environmental conditions. Therefore, in principle, corrosion protection by means of the thickness allowance should not be undertaken as a corrosion protection method for steel structures in Japan. However, in the case of temporary structures, it is acceptable to employ the allowance for corrosion mitigation.

3) The backfilling side of steel sheet pile has a slower corrosion rate than that of the seaward side, and thus no corrosion protection is required in particular. In cases where a strongly corrosive environment is conjectured due to the influence of waste material in the backfill, however, surveys should be conducted in advance and appropriate measures should be taken.

4) For the most effective actual corrosion protection, the covering/coating method is used for sections above 1 m below L.W.L., while cathodic protection is used for submerged sections below M.L.W.L and for sections in the sea bottom soil, and their reliability has been verified. When the covering/coating method is used underwater it is necessary to pay attention to durability when selecting the covering/coating material and to watch for damage, such as during construction or from collisions with driftwood. In cases where the covering/coating is used both in the air over the sea and in sections within the water, while the cathodic protection is used in the sea bottom soil, if a margin to estimate the degradation and damage of the covering/coating material is specified for the performance verification of the cathodic protection and then cathodic protection can compensate the degraded and damaged parts of the portions that use covering/coating protection

5.3.4 Cathodic Protection Method

5.3.4.1 Range of Application

1) The range of application of the cathodic protection shall in principle be at or below M.L.W.L.

2) Above the MLWL, corrosion control must be carried out by covering/coating. The zone between M.L.W.L and the L.W.L. is submerged for a shorter time than that below L.W.L., and thus the corrosion rate is slightly lower. Also, because the sections immediately below L.W.L. are susceptible to corrosion, the covering/coating should extend to a certain depth below L.W.L. and should be combined with the cathodic protection.

3) During port construction there may be a period with no corrosion protection after steel pipe pile and steel sheet pile have been driven in and before the superstructure has been constructed, and there may be periods of no corrosion protection when the anodes used for cathodic protection are replaced. During such periods of no corrosion protection the steel may have been exposed to concentrated corrosion, so sufficient care should be taken.

4) As listed in **Table 5.12**, the effect of the cathodic protection, the corrosion rate increases when the period of immersion of the steel subject to corrosion in sea water is longer and decreases when it is shorter. The seawater immersion ratio and the corrosion rate are expressed in **equation (5-1)** and **(5-2),** respectively.

$$\text{Sea water immersion ratio} = \frac{\text{Total immersion time of test piece}}{\text{Total test time}} \times 100\% \qquad (5\text{-}1)$$

$$\text{Corrosion Control Ratio} = \frac{\text{Mass reduction of unelectrified test piece} - \text{Mass reduction of electrified test piece}}{\text{Mass reduction of unelectrified test piece}} \times 100\% \qquad (5\text{-}2)$$

Table 5.12 Corrosion Control Ratio of the Cathodic Protection Method

Seawater immersion ratio(%)	Corrosion control rate
≤ 40 %	≤ 40 %
equal to or greater than 40 % but below 80 %	equal to or greater than 40 % but below 60 %
equal to or greater than 80 % but below 100 %	equal to or greater than 60 % but below 90 %
100%	≥ 90%

5) In general, 90% is used for the standard corrosion efficiency rate for the area below M.L.W.L.

6) The cathodic protection is divided into a galvanic anode method and a impressed current method.

Under the sacrifice anodes method: Aluminum (Al), magnesium (Mg), zinc (Zn) and other alloy are electrically connected to the steel structure and the electric current generated by the difference in potential between the two metals is used as a corrosion protection current. This method is applied almost universally in cathodic protection of port steel structures in Japan, mainly because of ease of maintenance. The characteristics of the galvanic anode materials are listed in **Table 5.13**. Aluminum alloy anodes offer the highest flux of current generated per unit of mass, are outstandingly economical, and are suited to both the seawater zone and seabed environments. Therefore, aluminum alloy anodes are most commonly used for port steel structures. Technical requirements and testing methods of sacrifice anodes according to **TCVN 10263: 2014**. Problems in the design, installation and inspection for system of cathodic protection by sacrifice anode according to **TCVN 10264: 2014**.

Under the impressed current method, an electrode is connected to the positive pole of an external DC power source and the steel structure is connected to the negative pole. Then a protective current is applied towards the steel structure from the current electrode. In sea water, a platinum or oxide coating electrode is often used as the working electrode. Since the output voltage can be arbitrary adjusted with the impressed current method, it can be applied to the environments featuring pronounced fluctuations such as strong currents or the inflow of river water, and the places where a fine potential control is required. Problems in the design, installation and inspection for system of cathodic protection by impressed current according to **TCVN 10264: 2014**

5.3.5 Covering/Coating

5.3.5.1 Range of Application

1) It is better to apply the covering/coating method to the sections in port steel structures, where the duration of seawater immersion is short because the cathodic protection cannot be applied to them.

As described in **5.3.4 Cathodic Protection Method**, the range of application of the cathodic protection method is designated as below M.L.W.L. However, concentrated corrosion is liable to occur in the vicinity of M.L.W.L., while the duration of immersion in seawater is shortened by the effects of waves and seasonal fluctuations in tide levels. Therefore, the covering/coating method should be applied in combination with the cathodic protection to the sections above the depth of 1 m below L.W.L.

2) Trong các kè cọc ván thép ở các vùng biển nông, phương pháp bọc/phủ đôi khi được áp dụng cho toàn bộ chiều dài theo chiều sâu kết cấu. Bằng cách kết hợp phương pháp bảo vệ ca-tốt và các phương pháp sơn phủ đối với các đoạn ngâm trong nước biển thì tuổi thọ các a-nốt kẽm có thể được kéo dài.

3) In steel sheet pile revetments in shallow sea areas, the covering/coating method is sometimes applied to the whole length of the structure depthwise. By combining the cathodic protection and covering/coating methods in sea water sections, the life of the sacrifice anode may be extended.

5.3.5 .2 Applicable Methods

1) The covering/coating method applied to port steel structures shall be one of the following four methods:

(a) Painting

(b) Organic covering/coating

(c) Petrolatum covering/coating

(d) Inorganic covering/coating

2) The covering/coating protection method basically controls corrosion by blocking the covered/coated material from corrosive environmental factors. The applicable range for the covering/coating protection method depends on the type, so that there are some methods that apply mainly to the intertidal zone, the splash zone, and the atmospheric zone, and there are other methods that apply in the seawater. In the seawater, the covering/coating method may be used together with the cathodic corrosion protection, or coating corrosion protection may be used alone. Moreover, some methods are only applicable to new facilities and other methods are applicable to not only new facilities but also existing facilities.

5.3.5.3 Selection of Methods

When selecting the covering/coating protection method and determining the specification it is necessary to investigate each of the following items:

a. Environmental conditions

b. Range of corrosion protection

c. Design working life

d. Maintenance plan

e. Construction conditions

f. Construction duration

g. Corrosion state and degradation of existing covering/coating material

h. Initial design conditions

i. Others

The above g) and h) are only applicable to existing structures.

6. Concrete and Reinforcement Concrete

6.1 General requirements

1) Materials used to produce concrete and reinforced concrete (RC) need to ensure technical requirements according to the existing TCVN.

2) Also, depending on the specific requirements of each port facilities, can refer to other foreign standards (JIS, ASTM, BS ...) as appropriate.

6.2 Materials made of Concrete and Reinforcement Concrete

6.2.1 Cement

1) Types of cement used to make concrete for PC for the port facilities must meet the technical requirements of the standard TCVN include the following:

- TCVN 4033-1995 Portland pozzolan cement - Technical requirements
- TCVN 2682-2009 Portland cements - Specifications
- TCVN 4316-2007 Portland blast furnace slag cement
- TCVN 6067-2004 Sulphate resisting portland cement - Technical requirements
- TCVN 6260-1997 Portland blended cement – Specifications

2) The selection of a appropriate cement to determine depending on the type of structure to use, environment of use. In which, types cement has good properties to prevent sea water is:

- Cement pooclan medium heat;
- Cement portland blast furnace slag spread;
- Portland cement fly ash land

The advantages of these types of cement are that they have excellent performance in durability against seawater, greatly promote long-term strength, and have low hydration heat. However, they also have the disadvantage as relatively low initial strength. Therefore, when using these types of cement, all due care needs to be given to initial curing.

3) The anti-corrosion properties of steel reinforcement in concrete produced with type B blast furnace slag cement is better than concrete made with ordinary Portland cement.

6.2.2 Water

1) Water used for mixing concrete and PC is clean water to satisfy the technical requirements of the standard **TVCN 4506:** 2012 **"Water for concrete and mortar - Technical specification"** is outlined in **Table 6.1** below.

Table 6.1 - Properties of mixing water

Properties	Requirement values
PH value	6,5÷12,5
Content of chloride ions in water, no more than	350mg/ lít
The total soluble salt content, no more than	2000mg/lít
The equivalent Na_2O content in the water, no more than	1000mg/lít.
SO_3 content, no more than	1000 mg/L

2) Seawater must not be used as mixing water for reinforced concrete. It may be used for non-reinforced concrete only when it is difficult to obtain clean freshwater. One must note that, when seawater is used, the setting time of the cement becomes short, so the concrete tends to lose its consistency at an early stage. In such cases a retarder may be used as necessary.

6.2.3 Aggregate

1) The types aggregate used for concrete and RC including fine aggregate (sand) and coarse aggregate (crushed stone or gravel) must satisfy the requirements **of TCVN 7570: 2006 "Aggregates for concrete and mortar - Specifications** "and **TCVN 9205: 2012 " Crushed sand for concrete and mortar** ".

2) The chlorine content in each types aggregate must be equal to or less than 0.01% by weight of each type for PC and ≤0,05% for ordinary RC.

6.2.4 Admixtures

1) Admixture used in concrete to and RC need to comply with **TCVN 8826-2011 "Chemical admixtures for concrete"** và **TCVN 8827-2011 "Highly activity puzzolanic admixtures for concrete and mortar – Silicafume and rice husk ash"**

2) Depending on specific conditions, may be use appropriate admixtures as follows:

- Use of plastic additives, superplasticizer to increase workability of the concrete mix, or reduce the rate of water / cement to increase the strength and impermeability;

- Use of highly active mineral additives (silica fume, rice husk ash ...) to improve water-resistant, decrease chloride ion penetration in concrete and enhance the protection of reinforcing steel;

- Use corrosion inhibitor reinforcement (Ca(NO2)2 or other form) to decrease the rate of reinforced corrosion in the marine atmosphere.

6.3 Requirements for concrete and mortar

6.3.1 Alkali Aggregate Reaction Prevention Measures

To prevent alkali aggregate reactions it is necessary to make appropriate choices among the following three preventative measures:

1) Controlling the total amount of alkali within the concrete by use a material such as Portland cement for which the total amount of alkali is known and verify that the total amount of alkali within the concrete is no more than 3.0 kg/m3.

2) Using materials such as mixed cement type B or type C blast furnace slag cement or type B or type C fly ash cement.

3) Methods that Use Aggregates Known to be Safe.

6.3.2 Initial Chloride Ion Content

To reduce the risk of corrosion of steel inside the concrete, the amount of chloride ion contained in fresh concrete should be no more than 0.30 kg/m^3 for PC and no more than 0.60 kg/m^3 for RC.

6.4 Concrete Quality and Performance Characteristics

6.4.1 Concrete should be of uniform quality with good workability and have the properties for meeting the strength requirements, durability, impermeability, crack resistance and protection of steel reinforcement, accordance with the standards following :

1) TCVN 4116-85 "Concrete and reinforced concrete structures of hydraulic engineering constructions - Design standard" ;

2) TCVN 9346-2012 "Concrete and reinforced concrete structures - Requirementd of protection from corrosion in marine environment".

6.4.2 Concrete should be resistant against deterioration caused by environmental actions, waves and mechanical actions such as impact and friction caused by drifting solids.

6.4.3 Characteristic Values for Concrete Strength

1) For the characteristic values of concrete strength of an ordinary concrete to be used in the performance verification of the main structural members of port facilities, was determined in accordance with **TCVN 4116-85 "Concrete and reinforced concrete structures of hydraulic engineering constructions - Design standard**".

For reinforced concrete, in cases when the maximum water-to-cement ratio is specified as

50% or lower in consideration of durability, 30 N/mm2 may be used as the characteristic value for the compression strength. For concrete lids of non-reinforced concrete, in cases where there is a risk of wave impact or submerging in the early stage after concrete placement, or when construction is done in a cold climate, a characteristic value of 24 N/mm2 may be used for the compression strength. For large, deformed blocks of non-reinforced concrete it is possible to specify the characteristic value based on the conditions, such as using 21 N/mm2 as the characteristic value for compression strength for types from 35t to 50t of their nominal weights.

2) Characteristic values for the bond strength of ordinary concrete in the performance verification can be calculated from **equation (6-1).**

$$f_{b0k} = 0,28 f_{ck}^{2/3} \tag{6.1}$$

Trong đó:

f_{bo_k}: Characteristic value of the bond strength of ordinary concrete (N/mm^2)

f_{c_k}: characteristic value of the compressive strength of ordinary concrete (N/mm^2)

Equation (6.1) applies to the use of deformed reinforcing bar conformed to JIS G 3112, Steel Bar for Reinforced Concrete. When ordinary round steel bars are used, values that are 40% of the values calculated from **equation (6.1)** may be used under the condition of providing semicircular hooks on the edges of the reinforcement.

6.4.4 Mixture conditions for concrete must be specified appropriately in consideration of durability. **Table 6.2**, which provides standard mixture conditions for each type of structural member, is based upon verification results of the existing concrete structures in ports and upon research results and technical knowledge on the durability of concrete that is affected by seawater, and may be used as a reference. For the structural members for which there have been loss in performance by chloride attack, such as the superstructures of piers, it is necessary to examine durability, changes in performance over time, and appropriately specify the mixture conditions in order to achieve the desired performance for the facility.

Table 6.2 Concrete Mixture Conditions based on the Type of Structural

Type	Examples of types of structural members	Mixture conditions	
		Maximum water-to-cement ratio (%)	Maximum size of the coarse aggregate
Non reinforced concrete	Superstructure of breakwater, concrete lid, main block, deformed block (for wave dissipation or shielding), foot protection block, packed concrete	60	40
	Superstructure of quaywall, parapet, mooring vertical foundation (gravity type)		
Reinforced concrete	Mooring post foundations (pile-type), chest walls, superstructure of quaywalls 1)	55	20,25,40
	Superstructure of open-type wharf	50	20,25,40
	Caisson, well, cellular block, L-shaped block	50	20, 25,40
	Wave-dissipating block	50	20, 25,40
	Anchor wall, superstructure of anchor piles	55	20, 25, 40
Concrete apron pavement		-	25 (20)2) , 40

Note : 1) Excludes superstructure of piers.

2) Use 25 mm for gravel and 20 mm for crushed stone.

6.4.5 Concrete must have the best consistency sufficient for its working conditions. As a rule, AE concrete shall be used when there are no special requirements, usually with an air content of 4.5%.

6.4.6 Self-compacting concrete

1) Self-compacting concrete is high quality concrete with characteristics: It is a high flow, high resistance for professional stratification and the ability to fill formwork without compaction, made from a mixture of aggregates, pooclan cement and the appropriate additives (finely ground mineral additives, additives reduce water level, and a number of other chemical additives).

2) The use of this high-performance concrete makes it possible to place concrete into sections such as in congested reinforced sections or in spaces enclosed by steel shells in which concrete placing have been difficult by using ordinary concrete.

3) To assessment of characteristics of self-compacting needs to be evaluated simultaneously in three experiments on flow ability, the ability to flow through the rebar and against stratified.

The limit is acceptable for the feasibility of the self-compacting concrete with 20 mm maximum aggregate are shown in **Table 6.3**.

Table 6.3- Workable requirements of self-compacting concrete

No.	Test methods for workability	Units	Limitations	
			Minimum	Maximum
1	Cone flow	mm	600	800
2	Time flow test through the funnel V (V test)	sec	6	20
3	Ability to flow through the rebar (L-box test)	mm	30	38

6.4.7 Construction Joints

In case of port facilities, damage often arises from joints in the concrete. Therefore, construction joints should be avoided as much as possible. When joints are inevitable in view of shrinkage of the concrete or the conditions of construction, necessary measures should be taken on the joints.

6.4.8 Surface Protection

For facilities that experience harsh conditions such as abrasion or impact, such as from flowing water that contains sand particles or from waves that contain pebbles, it is necessary to protect the surfaces with appropriate materials, or to increase the material's cross-section or the concrete cover to reinforcement. Surface protection materials include surface coatings that use timber, high quality stone, steel materials, or polymer materials, and also include polymer-impregnated concrete.

6.4.9 Structural Types

It is known that there is a close connection between the structural type of a facility and the occurrence of chlorideinduced deterioration. As far as the type of member is concerned, beams and slabs are more sensitive to chlorideinduced deterioration than are columns and walls. Chloride ions, oxygen, and water cause deterioration when they penetrate through the concrete surface, so it is preferable to make the area of the concrete surface of a member as small as possible. For example, it is easier to decrease the concrete surface area by using box-shaped beams and slabs than by using T-shaped beams and I-shaped beams, and this is desired from the viewpoint of durability. Assuming that there will be degradation, an additional consideration is to select structural types that permit easy repair, strengthening, or replacement

6.5 Underwater concrete

6.5.1 Performance verification of underwater concrete shall be verified its performance and be executed according to:

1) **TCVN 4116-85. Concrete and reinforced concrete structures of hydraulic engineering**

constructions - Design standard .

2) **TCVN 9346-2012 . Concrete and reinforced concrete structures - Requirementd of protection from corrosion in marine environment.**

3) **TCVN 9139:2012. Rrigation works - concrete, reinforced concrete coastal areas - technical requirements.**

6.5.2 In addition to the underwater concrete that has generally been usedin the past, today it is also possible to use antisegregation underwater concrete, which uses anti-segregation underwater admixtures whose main components are cellulose or acrylic water-soluble polymers.

6.5.3 It is preferable to avoid concrete construction joints, and when they are not avoidable appropriate processing must be performed.

6.5.4 The concrete cover used in underwater construction should be 10 cm or more. This value is determined by referring to sources such as standards for underwater concrete used for cast-in-place pile and continuous underground walls.

6.6 Concrete Pile Materials

6.6.1 The physical values of concrete pile materials used in port facilities shall be appropriately specified based on their characteristics

6.6.2 Precast Concrete Pile Molded by Centrifugal Force

1) Precast concrete pile molded by centrifugal force includes:

- RC pile, which is a reinforced concrete pile that is made in the factory;
- PC pile, to which a tensile force is applied on reinforcement or PC tendon, thereby increasing its tensile strength and bending strength (and this is divided into three types, A, B, and C, based on the amount of effective pre-stress);
- PHC pile, which uses high-strength concrete with a standard design strength of 80 N/mm^2 or more. Recently, the main trend has been to use PHC pile.

2) Beside these, there are PRC piles, which is a pile that adds reinforcement to PHC pile in order to increase its toughness, and SC pile, which has high-strength concrete formed on the inside of a steel pipe to provide large bending strength and shear strength.

3) For PC and PHC piles, in the performance verification, when specifying characteristic values for the concrete strength and yield strength of steel of precast concrete pile it is possible to refer to TCVN 7888:2008 “Pretensioned Spun Concrete Piles”.

6.6.3 Cast-In-Place Concrete Pile

1) Cast-in-place concrete pile is divided into types with and without an outer shell. The special feature of cast-inplace concrete pile is that the pile is constructed while it is situated in the ground.

2) Therefore, the cast-in-place concrete pile is different from the precast concrete pile in that it is not necessary to be concerned with influences such as impact when it is placed into the ground, but rather, different from the case when it is fabricated on land, there is the problem that during its construction it is influenced by pile constructed in the surrounding ground. For this reason, the cast-in-place concrete pile has some insecure characteristics during construction, and those without an outer shell have greater insecurity, so care must be taken.

7. Bituminous Materials

7.1 General

7.1.1 Bituminous materials used in port facilities shall satisfy the required quality and performance of facilities as required by **TCVN 7493: 2005. Bitumen - Specifications**, shall include elasticity, cohesion, impermeability, waterproofness, durability, and weatherproofness.

7.1.2 Bituminous materials are rarely used alone, which usually mixed with other aggregates to be used for different purposes as: as an asphalt mixture in asphalt concrete for pavement, asphalt mats, sand mastic asphalt, and asphalt stabilization. The type and mix proportioning of asphalt depend on its use. Therefore, it is important to select a material that will meet the required objective.

7.2 Asphalt Mats

7.2.1 General

1) Asphalt mats shall have an appropriate structure in consideration of the required strength, durability, and workability based on the purpose of their use, the location of their use, and the marine conditions of the site.

2) Asphalt mats are made by embedding reinforcement material and wire rope for suspension into a compound material mixed from asphalt, limestone filler, sand and crushed stone. They are then formed into a mat-shape (see **Fig. 7.1**).

3) Types of asphalt mats include friction enhancement mats that increase the sliding resistance of gravity type structure walls, scouring prevention mats that prevent the scouring of structural foundations, and sand washing out prevention mats that prevent the washing out of foundation sand mound and backfilling sand from revetments.

When asphalt mats are used sufficient care should be given to their quality, long-term durability, and constructability, based on the purpose of their use, the location of their use, and the marine conditions of the site. In particular, when there are special marine conditions such as cold regions, subtropical regions, or tidal zones, one must consider the harsh environmental conditions with regard to long-term durability, and careful studies should be made, including the determination of appropriateness.

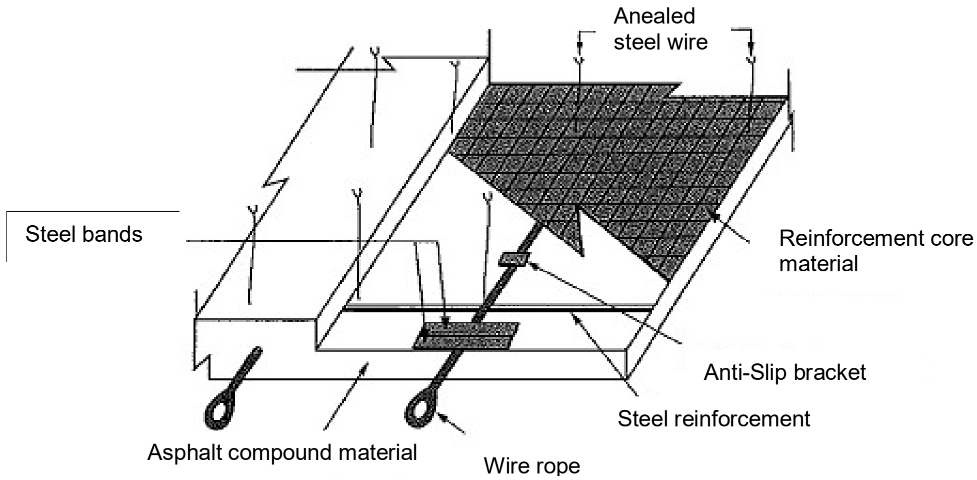

Fig. 7.1 Example of Structure of Friction Enhancement Asphalt Mat

7.2.2 Materials

1) Asphalt mat materials shall be selected as appropriate to yield the required strength and durability.

2) The following materials can be used in asphalt mats:

- Asphalt
- Sand
- Filler
- Crushed Stone

7.2.3 Mix Proportion

1) The mix proportion used for asphalt mixture is determined by mix proportion test to get the desired strength and flexibility. May refer to the percentage given in Table 7.1, except for special use conditions.

Table 7.1 Standard Proportion for Asphalt Mixture

Material	**Ratio by mass(%)**	
	Friction enhancement mat	**Scouring prevention mat**
Asphalt	10-14	10-14
Dust (with a grain size of 0.074 mm or less)	14-25	14-25
Fine aggregate (is crushed stone, sand, or filler with a grain size from 0.074 to 2.5 mm)	20-50	30-50
Coarse aggregate (is crushed stone with a grain size of 2.5 mm or larger)	30-50	25-40

7.3 Paving Materials

7.3.1 Paving materials shall in principle comply with **TCVN 8819: 2011. Specification for Construction of Hot Mix Asphalt Concrete Pavement and Acceptance**, except in the areas subject to special load conditions.

7.3.2 For the "areas subject to special load conditions", traffic on pavements particularly apron paving in port areas (unlike that on roads in city areas, almost invariably involves heavy vehicles) includes heavy machinery with large contact pressure. This type of load rarely travels at high speed and is almost always stationary or moving at low speeds. Parts of these paved areas are also used for cargo stacking. Thus, when considering the paving materials to be applied to such areas, care should be taken to the fact that bituminous materials are susceptible to static loading.

7.3.3 Guss asphalt paving has the properties of being non-permeable and of following deflection well, so it is often used for steel floor slab paving and bridge surface paving.

7.4 Sand Mastic Asphalt

7.4.1 General

1) Sand mastic asphalt is made of asphalt heat-mixed with an ore-based filler or additive and sand. The sand mastic asphalt is an asphalt mixture virtually free of voids and does not require rolling compaction after grouting.

2) Sand mastic asphalt at a certain high temperature is grouted into gaps between rubbles without segregation in water by pouring it onto the rubble mound. The grouted sand mastic asphalt wraps itself around the rubble to form a single unit, thus preventing the stone from breaking off or being washed away. It is sometimes used when it is not possible or uneconomical to obtain rubbles of the size required.

3) When conducting the performance verification of sand mastic asphalt, due attention should be paid to the plastic flow due to the material properties of asphalt so that stability problem will not arise.

7.4.2 Materals

1) Materials for sand mastic asphalt shall be selected as appropriate to meet the required strength and durability.

2) For example, the following can be used as sand mastic materials:

- Asphalt
- Sand
- Filler

3) Asphalt that is used as sand mastic in underwater construction 6), 7) should have sufficient fluidity so that, if it is flowed down, the rubble is completely filled in with no pores.

4) With regard to the effect of sand on mixtures, the larger the sand grains the greater is the fluidity of the mixture, and although a certain amount of fluidity can be obtained with a small amount of asphalt the mixture readily segregates.

The smaller the grain size the less fluidity there is, creating a dense sand mastic.

Therefore, it is preferable that the sand grain sizes be continuous, where the grain-size curve changes smoothly, so that the mixture does not segregate.

5) When filler is mixed into asphalt mixtures, it mixes with the asphalt to fill in the spaces among the aggregate while simultaneously working as a binding agent to decrease the fluidity of the mixture, thus increasing the viscosity and stability. Asphalt usually adheres well to filler that is slightly alkali, so it is possible to use filler made from slightly alkali lime powder.

Technical requirements for to filler refer **TCVN 8819: 2011**.

7.4.3 Mix Proportion

1) The mix proportioning shall be determined through mixing proportion tests to obtain the required fluidity and strength in view of the work and natural conditions.

2) General

The values listed in **Table 7.2** are commonly used as the mix proportion for sand mastic asphalt applied underwater.

Table 7.2 Standard Proportion for Sand Mastic Asphalt Mix

Material	**Proportion by mass(%)**
Asphalt	16-20
Dust	18-25
Fine aggregate	55-66

Ghi chú: *Bụi có nghĩa là cát hoặc chất độn lọt qua sàng 0,074 mm.*
Cốt liệu nhỏ là đá dăm, cát, hoặc chất độn còn lại trên sàng 0,074 mm.

3) Notes on the Performance Verification

Notes on the design of sand mastic asphalt is as follows:

- It should not be used in locations directly affected by powerful impulsive wave pressure or drifting objects.
- It should not be used in locations where rapid sedimentation is anticipated.
- The gradient of the rubble surface where sand mastic is executed is preferably gentle than 1:1.3.

- Suitable reinforcement should be used on the slope shoulder, slope toe, and the edges of the execution area.

- The relationship between the design working life of port facilities and the durability of the sand mastic asphalt should be fully taken into account.

8. Stone

8.1 General

8.1.1 Stone shall be selected in view of the required quality and performance to suit its purpose and its cost.

8.1.2 Generally, stone is used in large quantities for port facilities such as breakwaters and quaywalls. Selection of stone materials has a major impact on the stability of the structure as well as the period and cost of construction.

8.1.3 The types of stone mainly used in port construction and their physical properties are given in **Table 8.1.** It should be borne in mind that the physical properties of stone of the same classification may differ depending on the region and site of quarries.

Table 8.1 – Physical properties of stone

Rock classification	Subclassificatio	Apparent density (t/m^3)	Water absorption rate (%)	Compressive strength (N/mm^2)
Igneous rock	Granite	2.60-2.78	0.07 - 0.64	85- 190
	Andesite	2.57-2.76	0.27 -1.12	78- 269
	Basalt	2.68 (absolute)	1.85	85
	Gabbro	2.91 (absolute)	0.21	177
	Peridotite	3.18	0.16	187
	Diabase	2.78-2.85	0.008 - 0.03	123-182
Sedimentary rock	Tuff	2.64	0.16	377
	Slate	2,65-2,74	0.08 - 1.37	59 -185
	Sandstone	2,29-2,72	0.04-3.65	48 -196
	Limestone	2,36-2,71	0.18 - 2.59	17-76
	Chert	2,64	0.14	119
Metamorphic rock	Hornfels	2.68	0.22	191

8.2 Rubble for Foundation Mound

8.2.1 Rubble for foundation mounds shall be hard, dense and durable, and free from the possibility of breaking due to weathering. The shape of rubbles shall not be flat or oblong.

8.2.2 When determining which type of stone to use, tests should first be conducted and the material properties be fully ascertained. The ease of procurement, transportability, and price should also be taken into account.

8.2.3 The shear properties of rubble stones have been studied by Shoji 1) using various large-scale triaxial compression tests. This study is based on the state of rubble actually used in port and harbor construction works.

8.2.4 As a guideline proposed by Minakami and Kobayashi 2) for determining the strength constant without conducting large-scale triaxial compression tests, a shear strength of 0.02 N/mm^2 and a shearing resistance angle of 35º can be expected if the unconfined compressive strength is 30 N/mm^2 or more.

8.3 Backfilling Materials

8.3.1 Backfilling materials shall be selected in view of their properties such as angle of shear resistance and specific weight.

8.3.2 Rubble, unscreened gravel, cobblestone, and steel slag are generally used as backfilling materials. The material properties of mudstone, sandstone, and steel slag vary greatly, and therefore these should be examined carefully before use.

8.3.3 The values listed in **Table 8.2** are often used as characteristic values for backfilling materials.

Table 8.2 Characteristic Values for Backfilling Materials

		Angle of shear resistance(°)	Unit weight		Slope gradient
			Above residual water level (kN/m^3)	Below residual water level (kN/m^3)	
Rubble	Ordinary type	40	18	10	1:1.2
	Brittle type	35	16	9	1:1.2
Unscreened gravel		30	18	10	1:2—1:3
Cobblestone		35	18	10	1:2—1:3

8.3.4 Rubble” used in ports and harbors may be determined by referencing to the appropriate foreign standards

8.3.5 “Unscreened gravel” consists approximately half and half of sand and gravel.

8.3.6 The slope gradient is the standard value of the natural gradient of backfilling materials executed in the sea. Generally, a larger value is adopted when the effect of waves are small at the time of backfilling execution, and a smaller value when the effect of waves are large.

8.3.7 For steel slag, see **10.2 Slag**.

8.4 Base Course Materials of Pavement

8.4.1 Base course materials of pavement shall be selected so as to have the required bearing capacity and high durability and to allow easy compaction.

8.4.2 Normally, granular material, cement stabilized soil, or bituminous stabilized soil is used as a base course material. Granular materials include crushed stone, steel slag, unscreened gravel, pit gravel, unscreened crushed stone, crushed stone dust, and sand. These may be used on their own or mixed with other granular materials.

8.4.3 The base course serves to disperse the surcharge transmitted from above and to transfer it to the course bed. Normally, it is divided into a lower base course and an upper base course. Materials used for the lower base course are cheaper and have relatively small bearing capacity. The upper base course requires materials of good quality with large bearing capacity.

9. Timber

9.1 General

Timber has the following characteristics in contrast to other construction materials. It is necessary to consider these characteristics when using timber in port facilities.

9.1.1 Strength Performance

Timber's strength is high compared to its mass. Strength along fiber direction is greater than that perpendicular to the fiber. Tensile strength is greater than that of compression, and bending failure begins by buckling on the compressed side. The shear strength is small. The changes in strength, dimensions, and specific gravity due to water content cannot be ignored. There is large creep deformation under a continuous load.

9.1.2 Durability

Degradation, such as discoloration, surface contamination, morphology change, and reduction in strength may occur due to organisms such as bacteria, insects, and marine life and meteorological factors such as ultraviolet light, rain, and temperature. The main degradation factors vary greatly depending on the usage environment and the water content.

9.1.3 Environmental Character

Wood grows by using the sun's energy to fix carbon dioxide from the air, so it is a material that results in little carbon dioxide release as a result of its growth. The use of wood from routine thinning contributes to the conservation of artificial wood. One should be cautious about using natural timber for reasons such as that it leads to the destruction of forests.

9.1.4 Other

Timber is combustible. It is attractive if there is the proper amount of irregular grain patterns and color variation. The smell is pleasing to mind and body. It has sufficient resilience to be able to reduce injuries from falls. It is warm to the touch because it has low heat conductance. Its frictional coefficients are large, with almost no difference between the static friction coefficient and dynamic friction coefficient, so it is easy to walk on.

9.2 Strength Performance

The specification of characteristic values for timber strength and the verification of its strength as a material can be based on the Limit State Design Guide for Wood Structures. The following items are of particular concern when timber is used in port facilities.

9.2.1 Water Content

1) The water content of timber is expressed as (mass of water) / (total dry mass of the timber) x 100 (%). Water within timber is either bound water or free water. Bound water is bound to cellulose within the cell walls of the timber. Free water exists in cell cavities. If the water content is no more than about 28% then there is no free water. Bound water affects timber strength, but free water doesn't. As shown in the conceptual drawing of **Fig. 9.1**, the strength goes down as the bound water content increases from the totally dry condition to a water content of 28%, the fiber saturation point, and the strength stays roughly the same when the water content increases beyond the fiber saturation point and the free water increases. Under the meteorological conditions the water content reaches equilibrium around 15%. Therefore, the standard strength characteristic values are specified based on tests with a water content of 15%. May be defines constantly: Wet conditions to be usage environment I, intermittently wet conditions to be usage environment II, and other environments to be usage environment III, and in usage environment I the standard strength characteristic values are reduced by multiplication by a coefficient of 0.7, while for usage environment II they are reduced by a factor of 0.8. For port facilities all materials can be assumed to be in a wet condition, so it is necessary to reduce the standard strength characteristic values by the coefficient for usage environment I or II.

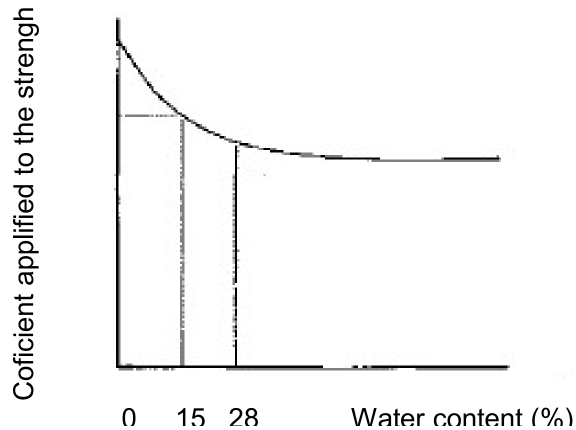

Fig. 9.1 Effect of Timber Water Content on Strength (Conceptual Drawing)

2) With regard to dimensional changes of timber, expansion, or contraction, it is true again that bound water has an effect but free water doesn't. The dimensions grow as the water content increases from the completely dry condition to a water content of 28%, fiber saturation point, and the dimensions stay roughly the same as the water content increases beyond the fiber saturation point and the free water increases. The dimensional change ratio varies with the direction, where "direction tangential to the rings" > "direction radial with respect to the rings" » "fiber direction", with a ratio of about 1 : 0.5 : 0.1. In applications where the water content below the tissue saturation point is expected to change it is necessary for the design to consider dimensional changes from the beginning.

3) The specific gravity of timber varies greatly with the species and water content. For undried logs immediately after felling and timber that is used underwater the water content may range from 80% to 150%, so the estimated specific gravity including the water would be as much as twice that when dry. In the design of port facilities it is assumed that the specific gravity of timber is 0.8, using a density of 7.8 kN/m3, but it is necessary to remember that the estimated specific gravity can vary greatly with species and water content, and not err on the dangerous.

9.2.2 Continuous Loading Time

The relationship between continuous loading time and its effect on the influence coefficients is given as in **Fig. 9.2**. When a load continues longer than 10 minutes, which is the standard timber test time, the standard strength characteristic value is multiplied by an influence coefficient for the effect of the continuous loading time. Similarly, for port facilities, it is necessary to specify continuous loading times for such factors as the temporary loading time during construction and the long-term continuous loading time after completion, and reduce the strength characteristic values by the influence coefficients for those effects.

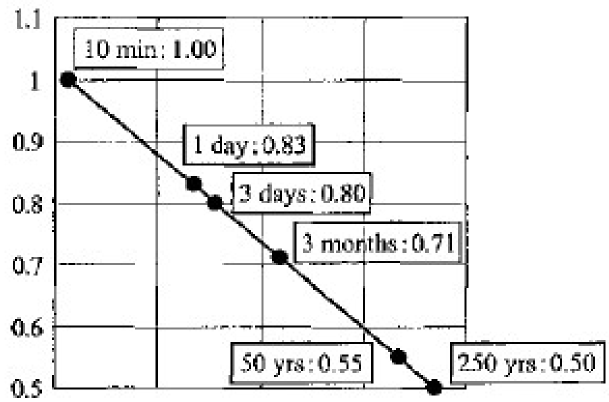

Fig. 9.2 Continuous Loading Time and Influence Coefficients

9.2.3 Standard Strength Characteristic Values for Logs

In logs, the fibers are not cut, so logs are mechanically better than manufactured wood, and they are applicable to port facilities both in terms of economics and environmental impact. The Guide (Draft) says that the standard strength characteristic values of logs may be taken from the standard strength characteristic values given for mechanical grade classifications of manufactured wood.

9.3 Durability

Examples of degradation phenomena that occur when timber is used include discoloration, surface contamination, morphology change, and reduction in strength. Whether these are considered as problems depends on the timber application. Discoloration, surface contamination, and morphology change are problems in applications where appearance is important, such as boardwalks and decks. While for construction materials that are out of sight, such as pile, reduction in strength would be a problem.

9.3.1 Causes of Degradation

Examples of factors that cause degradation phenomena include organisms such as bacteria, insects, and marine life, and meteorological factors such as ultraviolet light, rain, and temperature. The main degradation factors depend on the environment in which the timber is used and its water content, as shown in **Table 9.1**. The water content conditions in the table are: “dry”, meaning the condition where the water content is below the fiber saturation point, about 28% so that there is no free water, “wet”, meaning that the water content is at the fiber saturation point or higher but the cell cavities are not saturated with water, and “saturated”, meaning the condition where the cell cavities are saturated with water.

9.3.2 Preventative Measures for Degradation

Examples of preventative measures for degradation include the use of natural materials with high durability, protective processing, and maintenance.

Table 9.1 Usage Environments and Degradation

Usage environment		Examples of application	Water content	Main degradation factors
Indoor		Residence	Wet	Fungous bodies, termites
			Wet	Fungous bodies, termites
Outdoor	In the air	Outdoor construction	Dry	Meteorological factors, harmful insects of dry wood
			Wet	Fungous bodies, termites, meteorological factors
	In the ground	Pile	Wet	Fungous bodies, termites
			Saturated	None
	In fresh water	River facilities	Wet	Fungous bodies
			Saturated	None
	In the seawater	Port facilities	Wet	Fungous bodies, marine life
			Saturated	Marine life

10. Recyclable Materials

10.1 General

10.1.1 Recyclable materials shall be used as appropriate in accordance with the characteristics of the materials and the facilities.

10.1.2 Recyclable materials in port construction include slag, coal ash, crushed concrete, dredged soil, and asphalt concrete mass. Most of these can be used in landfill materials, sub-base course materials, soil improvement materials, and concrete aggregate.

10.1.3 Effective use of recyclable materials is extremely important. Port and harbor construction works use large quantities of materials and it is, therefore, very important that they contribute to environmental conservation and sustainable development by recycling and using fewer natural materials. We also need to undertake exhaustive studies before using recycled materials to ensure that no environmental issues arise.

10.1.4 The properties of recyclable materials are quite variable. Therefore, their physical and dynamic properties and the volume to be supplied should be fully examined in advance to ensure the purpose of use.

10.2 Slag

10.2.1 Slag includes ferro-slag, water granulated copper-slag, and ferronickel granulated slag

10.2.2 Ferro-slag is industrial waste generated in large quantities by the steel industry. It is broadly divided into blast furnace slag and steel- making slag.

10.2.3 Air-cooled blast furnace slag is a granular material mainly used as road construction material and has been effectively utilized. Water granulated blast furnace slag is a lightweight sand-like material. As well as being used as a raw material for blast furnace cement, it is also increasingly used as a backfilling material for ports facilities and sand compaction material, in view of its lightness.

10.2.4 Because steel- slag causes expansion and disintegration when free lime reacts with water, in order to avoid adverse effect, it is steam autoclaved and used as road and soil improvement materials**.**

Table 10.1 lists a comparison of chemical compositions of ferro-slag and ordinary earth materials. **Table 10.2** lists the physical and dynamic properties of steel- slag and air-cooled blast-furnace slag.

Water granulated copper-slag is a sandy material obtained through high-speed cooling with water in the copper refining process similar to the water granulated blast furnace slag. It has a higher particle density than sand. Although it is susceptible to particle crushing, its angle of shear resistance and hydraulic conductivity are about the same as those of beach sand. As well as being used for fine aggregate of concrete, sand mat and as a filling material, it has been experimentally used in the sand compaction pile method.

Ferronickel granulated blast furnace slag is obtained during the manufacturing of ferronickel that is a raw material for stainless steel. Its specific weigh is larger than that of sand, and has been used as a caisson filling material.

Table 10.1 Chemical Compositions of Slag and Other

(Unit:%)

Item / Component	Blast furnace slag	Converter slag	Electric furnace slag		Mountain soil	Andeszit	Ordinary Portland cement
			Oxidizing slag	Reducing slag			
SiO2	33.8	13.8	17.7	27.0	59.6	59.6	22.0
CaO	42.0	44.3	26.2	51.0	0.4	5.8	64.2
Al_2O_3	14.4	1.5	12.2	9.0	22.0	17.3	5.5
T-Fe	0.3*	17.5	21.2	1.5		3.1*	3.0**
MgO	6.7	6.4	5.3	7,0	0.8	2.8	1.5
S	0.84	0,07	0.09	0.50	0.01	-	2, 0**
MnO	0.3	5.3	7,9	1.0	0.1	0.2	-
Ti02	1.0	1.5	0.7	0.7	-	0.8	-

Table 10.2 Physical and Dynamic Properties of Steel-Slag and Air-Cooled Blast Furnace Slag

	Steel- slag	Air-cooled blast furnace slag	
		MS-25	CS-40
Bone dryness density (BD) (g/cm^3)	3.19-3.40	-	-
Water absorption rate (%)	1.77-3.02	-	_
Unit weight (kN/m^3)	19.7-22.9	17.2-17.8	16.7-17.2
Optimum moisture content (%)	5.69-8.24	8.8-9.4	8.4-9.0
Maximum dry density (g/cm^3)	2.34-2.71	2.18-2.21	2.13-2.17
Modified CBR (%)	78-135	170-204	152-186
Coefficient of permeability (cm/s)	10^{-2} -10^{-3}	10^{-2} -10^{-3}	-
Angle of shear resistance (°)	40-50	_	_

10.2.5 Recently, hydration-hardened steel- slag is used as a civil engineering material for port facilities, such as for deformed blocks, foot protection blocks, and dumping blocks. For details, may be determined by referencing to the appropriate foreign standards.

10.3 Crushed Concrete

10.3.1 Crushed concrete has mainly been used as a base course material for pavement so far, but recently it has become difficult to obtain good quality aggregate so there are attempts to also use concrete as an aggregate.

10.3.2 When using crushed concrete as a material for aggregate, the properties such as the angle of shear resistance vary depending on mother concrete. Thus, under present circumstances it is difficult to give the standard values of their properties. Therefore, the properties of crushed concrete can be determined by referring to it.

10.4 Dredged Soil

10.4.1 Dredged soil has been used as a landfill material for industrial areas, residential areas… When there is no demand to use or when no landfill area, can be transported to the ocean. However, in any case, the implementation must be permission from the management agency and ensure the requirements on environmental protection

Encourage research into appropriate disposal solutions for use dredged soil an effective way to reduce construction spending.

10.4.2 When dredged soil is cohesive soil becomes a very soft ground with a high water content, so soil improvement is required after reclamation. In practice, can apply soft soil reinforcement methods such as vertical drainage preloading PVD, vacuum consolidation, soil cement column…

11. Other Materials

11.1 Plastic and Rubber

11.1.1 When using plastics and rubbers, material shall be selected appropriately in view of the location and purpose of use, environmental conditions, durability, and cost.

11.1.2 The following are examples of applications of plastic and rubber in port construction.

11.1.2.1 Geosynthetics

Geosynthetics is a general term that includes the geotextiles, namely polymer material products in the form of permeable sheets, as well as geomembranes, which are nonpermeable films.

1) Permeable materials

Permeable materials may be woven or non-woven. Woven types, geowovens, are woven into a matrix with perpendicularly crossing warps and woofs. Non-woven types, non-woven geotextiles, are textiles created by adhesion of fibers, interlocking adhesion, or both.

2) Water sealing materials

The following are examples of applications of geosynthetics in port construction.

3) Embankment reinforcing

When laying good-quality soils over a land reclaimed with dredged clay, a sheet or net of geosynthetics is spreaded directly over the surface. Its purpose is to ensure the passage of heavy machinery, while preventing subsidence of good-quality soils.4) The net method has often been used in recent reclamation works with soft ground.

4) Preventing washing out and scouring

When used as a filter material with the aim of preventing sand washing out, a sand invasion prevention cloth is often laid out on the surface of backfill stone or on the back of rubble mound of the quaywall, and under the entire bottom of the rubble mound, or under the part of the sea side of the mound. It is also used as a measure to scouring prevention.

11.1.2.2 Joint sealing materials

These include seal plates, joint boards, and grouting materials used in/on the joint sections of concrete structures.

11.1.2.3 Expanded polystyrene

This is used for buoys, pontoon floats, and other civil engineering structures, on account of its lightness. Expanded polystyrene (EPS) blocks and EPS beads are used as civil engineering materials. Generally, EPS blocks are used to reduce earth pressure, to counter settlement in embankments on soft ground, and to form the foundations of temporary roads. EPS beads are mixed with cement or another cementing material together with soils and used as a lightweight material in backfilling, in order to reduce settlement and earth pressure.

11.1.3 The standards for sand invasion prevention cloth and plate, and rubber mats normally used to prevent scouring**,** piping or infiltation in port and harbor facilities are as follows:

1) Sand invasion prevention cloth

Sand invasion prevention cloth used to prevent invasion of soil into the backfill will normally be determined in consideration of the constructions conditions such as the placing method of backfilling, the residual water level, and the leveling precision of backfilling.

The cloth that is laid under the bottom of rubble mounds to prevent washing out of the subsoil will normally be determined in consideration of the natural and construction conditions such as the wave height, tidal current, and rubble size.

Tables 11.1 (a) and (b) list the minimum standards for woven and nonwoven materials under favorable execution conditions.

Table 11.1 (a) Minimum Standards for Sand Invasion Prevention Sheets (Nonwoven)

Type	Thickness	Tensile strength	Elongation	Mass
Nonwoven cloth	≥ 4.2 mm	≥ 880 N/5cm	≥ 60%	≥ 500 g/m^2

Note: The thickness of 4.2 mm or greater is applied for the cloth under loading of 2 kN/m2 according to JIS L 1908. With no loading, the thickness should be 5 mm or greater.

Table 11.1 (b) Minimum Standards for Sand Invasion Prevention Sheets (Woven)

Type	Thickness	Tensile strength	Elongation
Woven cloth	≥ 0.47 mm	≥ 4,080 N/5cm	≥ 15%

2) Sand invasion prevention plates

The standard thickness of the plates used to prevent scouring and that used for the vertical joints of caisson 5 mm. The plates should meet the standards listed in **Table 11.2.** In cold regions, rubber plates are sometimes used. In this case, the values listed in **Table 11.3**

Table 11.2 Standards for Sand Invasion Prevention Plates (Soft Vinyl Chloride)

Test item	Method Tensile direction	Giá trị chuẩn
Tensile strength	Lateral	≥ 740N
Tear strength	Longitudinal	≥ 250N
Elongation	Lateral	180%
Seawater resistance Tensile strength residual ratio	Lateral	≥ 90%
Seawater resistance Elongation residual ratio	Lateral	≥ 90%
Specific gravity	-	1.2-1.5
Stripping strength	Longitudinal	30 N/cm

Table 11.3 Standards for Sand Invasion Prevention Plates (Rubber)

Test item	Tensile direction	Standard values
Tensile strength	-	≥ 4.400N/3 cm

3) Rubber mats

Rubber mats used for enhancing friction may be made of brand-new or recycled rubber. The quality is commonly as listed in **Tables 11.4** and **11.5**.

Table 11.4 Quality of Recycled Rubber

Test item			Performance
Physical test	Before aging	Tensile strength Tear strength Hardness Elongation	≥ 4.9 MPa ≥ 18 N/mm 55-70 vạch ≥ 160%
	After aging	Tensile strength Tear strength Hardness Elongation	≥ 3.9 Mpa Within ± 8 of pre-aging value ≥ 140%

Table 11.5 Quality of Brand-New Rubber

Test item			Performance
Physical test	Before aging	Tensile strength Tear strength Hardness Elongation	≥ 9,8 MPa ≥ 25 N/mm 70 ± 5 vạch ≥ 250%
	After aging	Tensile strength Tear strength Hardness Elongation	≥ 3.9 Mpa Within ± 8 of pre-aging value ≥ 140%
	Compressive permanent strain		≤ 45 %

11.2 Painting Materials

11.2.1 The following items should be considered when selecting painting materials:

- The purpose of the painting
- The properties and characteristics of the painted surface
- The performance and composition of the painting material
- Cost

11.3 Grouting Materials

11.3.1 General

1) The grouting methods shall be selected by examining the site conditions and performed in consideration of the influence on the surrounding environment.

2) The grouting methods are employed to strengthen the ground or to cut off the ground water flow by filling crevices in rocks or subsoils, vacant spaces in or around structures, or voids of coarse aggregate with grouting materials. Various grouting materials are used according to the characteristics of the object to be grouted.

11.3.2 Properties of Grouting Materials

1) Grouting materials shall be selected in view of the required performance for the subsoils to be grouted.

2) The basic properties required of grouting materials are the efficiency of seepage, filling and coagulation, the strength and impermeability of the stabilized body. Suitability with the grouting object is particularly affected by the seepage efficiency of the material. **Fig. 11.1** shows the seepage limits of various grouting materials for subsoils in view of grain-size

distribution.

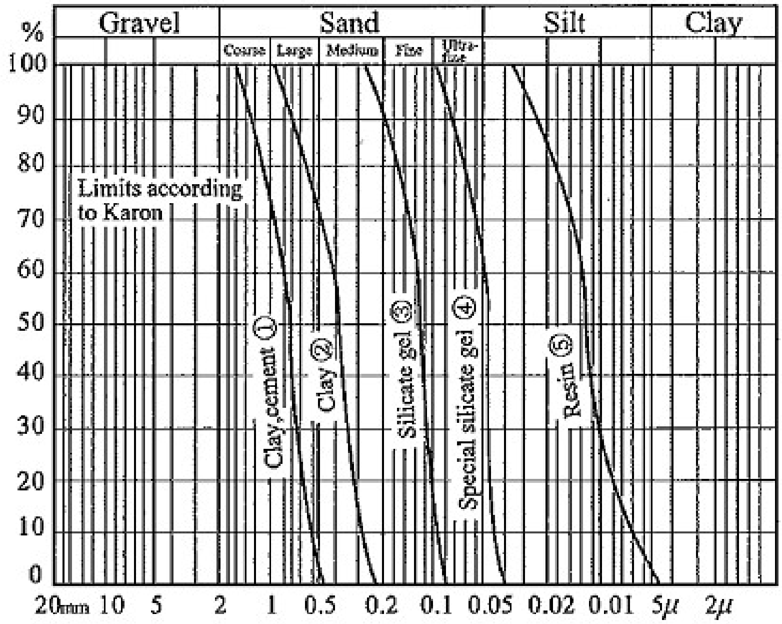

Fig. 11.1 Seepage Limits of Grouting Materials for Subsoils in View of Grain-size Distribution

11.4 Asphalt Concrete Mass

1.4.1 Asphalt concrete mass is often collected from many different places, so it has various properties. The quality of recycled asphalt mixtures shows more variation than that of brand-new mixtures. Therefore, to have the desired needle penetration, one typically adds brand- new asphalt or additives when recycling.

1.4.2 Recycled asphalt mixtures that are used for the foundation layer or surface layer can be handled the same way as asphalt mixtures that are purely brand-new material.

11.5 Oyster Shell

Crushed oyster shell with a size of at most 30 mm when mixed with sand in a ratio of 2 to 1 in volume can be used to improve ground materials. The strength of soil improvement pile with mixed-in oyster shell is evaluated as about the same as that of improvement pile composed of sand. However, characteristics such as water content ratio and compression index vary based on the particle sizes when the oyster shell is crushed and on the mixing ratio with sand, so the use of oyster shell requires sufficient investigation, such as by soil test.

12. Friction Coefficient

12.1 For the friction coefficient of a material when the frictional resistance force against the sliding of a facility is calculated, the static friction coefficient can be used. In this case the friction coefficient of the material should be appropriately specified by considering factors such as the characteristics of the facility and the characteristics of the material.

12.2 For the characteristic values of the static friction coefficient for the performance verification of port facilities it is generally possible to use the values given in **Table 12.1**. Consideration is needed as there usually is a large variation when the friction coefficient is repeatedly measured under the same conditions. The values shown in **Table 12.1** are kind of values used from the past experience, and if a value is not shown here then it is preferable to perform experiments to determine it.

12.3 The values shown in Table 9.1 are values used to verify the stability of facilities against sliding, and cannot be used for purposes such as for determining the friction coefficient between the surface of a pile and the soil when calculating the bearing capacity of a pile, or the friction coefficient for verifying the stability of a sloping breakwater, or the friction coefficient used to calculate the launching of a caisson on slope, or the friction angle of a wall to calculate earth pressure. The values shown in Table 9.1 are the static friction coefficients when a static actions occur, but there are no appropriate references for when dynamic motions occur, such as through seismic forces, so in fact these values are also used in such cases.

Table 12.1 Characteristic Values for the Static Friction Coefficient

Concrete and concrete 0.5	0,5
Concrete and base rock	0,5
Underwater concrete and base rock	0,7 đến 0,8
Concrete and rubble	0,6
Rubble and rubble	0,8
Timber and timber	0,2 (wet) to 0,5 (dry)
Friction enhancement mat and rubble	0,75

Note 1: Under standard conditions the value 0.8 may be used for the case of underwater concrete and base rock. However, in situations such as if the bedrock is brittle or has many cracks, or if there are places where the movement of the sand that covers the bedrock is significant, the coefficient can be lowered under such conditions to about 0.7.

Note 2: Can be referred to for the friction coefficient in the performance verification of cellular blocks.

12.4 Friction Coefficient for Friction Enhancement Mats

In the performance verification of port facilities, if a material such as a bituminous material or rubber is used as a friction enhancement mat then the friction coefficient may be taken as 0.75, as shown in **Table 12.1**.

12.5 Friction Coefficient for In-Situ Concrete

The friction coefficient for in-situ concrete must be appropriately specified by taking into account factors such as the characteristics of the material and the natural conditions.

12.6 Sliding Resistance between Base Rock and Prepacked Concrete

As for friction coefficient between base rock and prepacked concrete, the values of **Table 12.1** can be used. It is also possible to similarly treat other types of underwater concrete other than prepacked concrete.

(Draft)

APPENDIX A

(Refer)

Standards of Japan

A.1 Standards for steel used in facilities port

- JIS G 3101	Rolled steels for general structure
- JIS G 3106	Rolled steels for welded structure
- JIS G 3114	(Hot-rolled atmospheric corrosion resisting steels for welded structure.
- JIS G 3444	Carbon steel tubes for general structure
- JIS A 5528	Hot rolled steel sheet piles
- JIS G 3191	Steel bar
- JIS G 3112	Steel bar for reinforced concrete
- JIS G 3192	Shaped steel
- JIS G 3193	Steel plate and steel Strips
- JIS G 3194	Flat steel
- Coastal Development Institute of Technology	Manual for corrosion protection and maintenance work for port steel facilities, iron slug hydration hardener - revised Edition) 200x
- JIS B 1180	Hexagonal head bolts
- JIS B 1181	Hexagonal shape nuts
- JIS B 1186	Sets of high strength hexagonal head bolt for friction grip joints
- JIS G 3117	Recycled steel bar for reinforced concrete
- JIS G 3536	PC steel wire and strands
- JIS G 3109	PC steel bars
- JIS G 3525	Wire rope
- JIS F 3303	Electrically welded anchor chairs
- JIS G 3551	Welded wire mesh

A.2 Standards for concrete

- JSCE 2002	Standard Specification for Concrete Structures,Construction
- JIS A 5372	Precast reinforced concrete products
- JIS A 5373	Precast prestressed concrete products

A.3 Other standards:

- Standard Specification for Port Contruction Work , Japan Port Association , 2005
- Recommendation for Limit State Design of Timber Structurre (Draft), Architectural Institute of Japan, 2003.
- Japan Road Association, Specifications for Highway Bridges (Vol II Steel Bridge, 2004)
- Manual on Corrosion Prevention and Repair for Port and Harbor Steel Structures (revised edition), published by the Coastal Development Institute of Technology in Japan.
- Technical Manual for iron slug hydration hardener (englarged Edition), Coastal Development Institute of Technology, 2006.
- Limit State Design Guide for Wood Structures, Architectural Institute of Japan (hereafter, the Recommendation - Draft)
- Hydration- Hardened Steel-Slag Technical Manual (Supplementary Edition).
- JIS A 5006. Rubbles
- JIS K 6723. Plasticized polyvinyl chloride compounds; JIS K 6773. Polyvinylchloride waterstop; JIS K 7112. Plastics -- Methods of determining the density and relative density of non-cellular plastics; JIS K 6256. Rubber, vulcanized or thermoplastic - Determination of adhesion test; JIS K 6328. Rubber Coated Fabrics; JIS K 6251. Rubber, vulcanized or thermoplastics - Determination of tensile stress-strain properties; JIS K 6252. Rubber, vulcanized or thermoplastic - Determination of tear strength; JIS K 6253. Rubber, vulcanized or thermoplastic - Determination of hardness; JIS K 6257. Rubber, vulcanized or thermoplastic - Determination of heat ageing properties; JIS K 6262. Rubber, vulcanized or thermoplastic - Determination of compression set at ambient, elevated or low temperatures.
- JIS L 1908. Test methods for geotextiles

APPENDIX B

(Refer)

Standards of ASTM

B.1 Standards for steels

- ASTM A6/A6M	Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- ASTM A36/A36M (2008)	Standard Specification for Carbon Structural Steel
- ASTM A53/A53M (2012)	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc- Coated, Welded and Seamless
- ASTM A106/A106M	Standard Specification for Seamless Carbon Steel Pipe for High- Temperature Service
- ASTM A123/A123M (2012)	Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
- ASTM A153/A153M	Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- ASTM A185/A185M (2007)	Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
- ASTM A252	Standard Specification for Welded and Seamless Steel Pipe Piles
- ASTM A325	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
- ASTM A416/A416M (2012)	Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete
- ASTMA 501	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
- ASTM A563	Standard Specification for Carbon and Alloy Steel Nuts.
- ASTM A615/A615M (2012)	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
- ASTM A648	Standard Specification for Steel Wire, Hard-Drawn for Prestressed Concrete Pipe
- ASTM A656/A656M	Standard Specification for Hot-Rolled Structural Steel, High-Strength Low- Alloy Plate with Improved Formability.
- ASTM A690/A690M	Standard Specification for High- Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments

- ASTM A722/A722M (2012)	Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete
- ASTM A829/A829M	Standard Specification for Alloy Structural Steel plates
- ASTM A1007	Standard Specification for Carbon Steel Wire for Wire Rope

B.2 Các tiêu chuẩn đối với vật liệu bê tông và bitum

- ASTM C33/C33M	Standard Specification for Concrete, aggregates
- ASTM C94/C94M	Ready-mixed Concrete
- ASTM C150/C150M (2012)	Standard Specification for Portland Cement
- ASTM C330/C330M	Standard Specification for Lightweight Aggregates for Structural Concrete
- ASTM C478	Standard Specification for Precast Reinforced Concrete Manhole Sections
- ASTM C494/C494M (2012)	Standard Specification for Chemical Admixtures for Concrete
- ASTM C595/C595M	Standard Specification for Blended Hydraulic Cements
- ASTM C618 (2012)	Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
- ASTM C913	Standard Specification for Precast Concrete Water and Wastewater Structures
- ASTM C989/C989M (2012)	Standard Specification for Slag Cement for Use in Concrete and Mortars
- ASTM C1240 (2012)	Standard Specification for Silica Fume Used in Cementitious Mixtures
- PCI MNL-116 (1999)	Manual for Quality Control for Plants and Production of Structural Precast Concrete Products, 4th Edition
- ASTM D242	Standard Specification for Mineral Filler For Bituminous Paving Mixtures
- ASTM D1187/D1187M	Standard Specification for Asphalt-Base Emulsions for Use as Protective Coatings for Metal
- ASTM D1139/1139M	Standard Specification for Aggregate for Single or Multiple Bituminous Surface Treatments
- ASTM D5106	Standard Specification for Steel Slag Aggregates for Bituminous Paving Mixtures
- ASTM D6373	Standard Specification for Performance Graded Asphalt Binder

(Draft)

APPENDIX C

(Refer)

British Standards

C.1 Standards for steel

-	BS	4		1980	Structural steel sections
-	BS	143	1256	1986	Specification for malleable cast iron and cast copper alloy threaded pipe fittmgs
-	BS	497	Part l:	1976	Coat iron and cast steel
-	BS	970		-	Specification for wrought steels for mechanical and allied engineering purposes
-	BS	1052		1980	Specification for mild steel wire for general engineering purposes
-	BS	1449	Part l:	1983	Carbon steel plate, sheet and strip
-	BS	1452		1990	Specification for flake graphite cast iron
-	BS	2569	Part1:	1965	Protection of iron and steel by aluminium and zinc against atmospheric corrosion
-	BS	3100		1976	Specification for steel casting for general engineering puiposes
-	BS	3601		1974	Steel pipes and tubes for pressure purposes: carbon steel with specified room temperature properties
-	BS	3692		1967	Specification for ISO metric precision hexagon bolts, screws and nuts
-	BS	4165		1984	Specification for electrode wires and fluxes tor the submerged arc welding of carbon steel and medium-tensile steel
-	BS	4190		1967	ISO metric black hexagon bolts, screws and nuts
-	BS	4320		1968	Metal washers for general engineering purposes
-	BS	4360		1990	Specification for weldable structural steels
-	BS	4395		-	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering
-	BS	4449		1988	Specification for carbon steel bars for the reinforcement of concrete
-	BS	4482		1985	Cold reduced steei wire for the reinforcement, of concrete
-	BS	4483		1985	Steel fabric for the reinforcement of concrete
-	BS	4486		1980	Specification for hot rolled and processed high tensile

				alloy steel bars for the prestressing of concrete
-	BS	4604	-	Use of high strength friction grip bolts in structural steelwork
-	BS	4848	-	Hot rolled structural steel sections
-	BS	5135	1984	Metal-arc welding of carbon and carbon manganese steels
-	BS	5896	1980	High tensile steel wire and strand for the prestressing of concrete
-	BS	5950	-	Structural use of steelwork in buildings
-	BS	6263		Seamless and welded steel tube for general engineering purposes
-	BS	7361	-	Cathodic Protection

C.2 Standards for Concrete and Bitum

-	BS	12	1989	Specification for ordinary and rapid hardening Portland cement
-	BS	594	1985	Rolled asphalt (hot process) for roads and other paved areas
-	BS	882	-	Aggregates from natural sources for concrete (including granolithic)
-	BS	1200	1976	Building sands from natural sources
-	BS	3148	1980	Methods of tests for water for making concrete (including notes on the suitability of the water)
-	BS	3690	1970	Bitumens for building and civil engineering
-	BS	4027	1980	Specification for sulphate-resisting Portland cement
-	BS	5075	-	Concrete admixtures
-	BS	6073	-	Precast concrete masonry units
-	BS	8110	-	Structural use of concrete

(Draft)

APPENDIX D

(Refer)

Corrosion rate of steel in the marine environment

D.1 The value about the corrosion rate of steel in the marine environment shown in Table D-1 was obtained according to the data observed in Japan

Table D-1 Standard Values of Corrosion Rates for Steel

Corrosive environment		Corrosion rate (mm/year)
Seaside	HWL or higher	0,3
	HWL-LWL -1m	0,1- 0,3
	LWL -1m - seabed	0,1 – 0,2
	Under seabed	0,03
Seaside	Above ground and exposed to air	0,1
	Underground (residual water level and above)	0,03
	Underground (residual water level and below)	0,02

D.2 However, the values in **Table D-1** are the average ones, and the actual corrosion rate may exceed them depending on the environmental conditions of the steel material. Therefore, when determining the corrosion rate of steel, the results of corrosion surveys under similar conditions should be referred to. It should also be noted that the values in **Table D-1** refer to the corrosion rate for only one side of the steel section. Thus, when the both sides of steel section are subject to corrosion, the sum of the corrosion rates of the both sides estimated on the basis of the values in **Table D-1** should be employed.

D.3 The values for “HWL or higher” in Table 5.11 refer to the corrosion rate immediately above HWL. The corrosion rate between the HWL and the seawater sections should be determined by referring to actual corrosion rates in the properties of sea water around the structures. This is because past corrosion surveys have shown that the corrosion rate varies depending on the properties of sea water and the depth of water. The values in Table 5.11 are listed as references with a range of variation. In general, the corrosion in the intertidal zone should be dealt with separately from that in the submerged zone because of the differences in the environmental conditions. The appropriate boundary between them is around 1.0 m below LWL. In cases of the concentrated corrosion, the corrosion rate greatly exceeds the values listed in Table 5.11, and thus these values are not applicable to such cases