GUIDANCE NOTES

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China Classification Society

GUIDELINES FOR SURVEY OF FIBER ROPES FOR OFFSHORE POSITION MOORING SYSTEM

2023

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Chapter1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 The Guidelines provide basis for the survey of fiber ropes used in the offshore position mooring systems.

1.1.1.2 For the position mooring systems with fiber ropes, the fiber ropes shall conform to the provisions in the Guidelines, the China Classification Society (CCS) codes and other acceptable standards, while the parts other than fiber ropes shall conform to the relevant CCS codes.

1.1.1.3 In addition, the relevant requirements of the competent authorities shall also be met.

1.1.2 Scope of application

1.1.2.1 The Guidelines only apply to the fiber ropes that extend freely at both ends in the position mooring systems of offshore floating installation and mobile offshore units.

1.1.2.2 The Guidelines apply to the fiber ropes made of polyethylene glycol terephthalate (polyester, PET), aromatic polyamide (aramid fiber, Aramid), and high-molecular-weight polyethylene (HMPE). For the other fiber ropes, the applicable requirements in the Guidelines can be referred to.

1.1.3 Equivalence and exemption

1.1.3.1 The design provisions that are inconsistent with the requirements in the Guidelines (including the requirements of the acceptable standards) can be accepted and used as the substitute for the corresponding requirements of the Guidelines, provided that those provisions have the safety level proven or indicated by written documents to be at least equivalent to that of the requirements in the Guidelines and have been agreed by all parties to the contract and CCS.

1.1.3.2 The fiber ropes with novel constructions and features may be exempted from any provision in the Guidelines if the application of these provisions may impede the application of its features or constructions severely, subject to agreement of CCS.

1.1.4 Application of risk assessment

1.1.4.1 If the owner, the operator, the designer or any other organization wishes to apply the risk assessment to the design, manufacturing or operation of the fiber ropes, the risk control plan and measures adopted in the risk assessment may completely or partially substitute the Guidelines, subject to the satisfactory review of the risk assessment documents by CCS.

Section 2 DEFINITION AND ABBREVIATIONS

1.2.1 Definition

1.2.1.1 Unless otherwise specified, the definitions in the Guidelines are as follows:

(1) Offshore floating installation: The building or unit that is moored at a location by means of non-rigid fixing, such as ropes, anchor chains or tension tendons or ballasts, for a long time and floats on the sea (including in submersible conditions). It is usually used in offshore oil and gas processing, storage and loading/unloading, fisheries and aquaculture, power generation or transformation, leisure and tourism, or other operation purposes;

(2) Mobile offshore unit: The offshore unit designed to be moved from one operating site to another as necessary;

(3) Permanent mooring system: The mooring system for continuous mooring operation over 5 years at the same operating site;

(4) Mobile mooring system: The mooring system for continuous mooring operation less than 5 years at the same operating site;

(5) Yarn: The generic term of a bundle of untwisted or twisted fibers.

(6) Dry rupture strength of yarns: The average rupture load measured during the dry rupture test of yarns;

(7)Jacket: The braided or plastic cover wrapped around the rope or subrope to protect the rope and hold the rope construction together;

(8) Termination: The mode in which the fiber ropes are connected to the assembly interfaces (e.g. splicing, potted jacks and wedge jacks);

(9) Polyester rope: The rope made of polyester fibers, which is widely used in the offshore mooring systems;

(10) HMPE rope: The rope made of high-molecular-weight polyethylene fibers, with higher strength and stiffness than the polyester rope;

(11) Aramid rope: The rope made of aromatic polyamide fibers;

(12) Minimum breaking strength: The indicator that must be obtained during the breaking tests specified in the accepted standards of fiber ropes;

(13) Linear density: The mass of a fiber rope in a unit length under preloads;

(14) Stiffness: The ratio of the tension change of a rope to its strain change;

(15) Static stiffness: The ratio of the tension change of a of rope to its strain change under the tension that changes slowly;

(16) Dynamic stiffness: The ratio between the tension change of a rope to its strain change under cyclic loading;

(17) Static-dynamic stiffness model: A type of stiffness model, in which the elongation under the average load and cyclic load is represented by the different slopes in loads and elongation.

(18) Axial compression fatigue: A failure mode of aramid ropes or other similar fiber ropes under low tension or compression;

(19) Creep: The permanent length increase under the continuous tension or cyclic loading;

(20) Creep failure: The failure of the fiber ropes that is caused by the unrecoverable elongation with the accumulation over time under loads;

(21) Torque matching method: The design method of fiber ropes that matches the torsional characteristics of wire ropes and other torque assemblies;

(22) Subropes (strands): The maximum assemblies of rope products.

1.2.2 Abbreviation

1.2.2.1 Unless otherwise specified, the abbreviations adopted for the purpose of the Guidelines are as follows:

ROV — The remotely operated underwater vehicle;

ISO — International Organization for Standardization.

1.2.3 Symbols

1.2.3.1 Unless otherwise provided, the definitions of the symbols adopted in the Guidelines are as follows:

EA — The stiffness;

$\triangle T$ — The load variation value;

$\triangle \varepsilon$ — The strain variation value;

K_r — The equivalent dimensionless stiffness;

C — The creep coefficient;

K_{rs} — The static stiffness;

K_{rd} — The dynamic stiffness;

N — The number of cycles;

R — The ratio of tension range to the minimum breaking strength.

Section 3 ACCEPTABLE STANDARDS

1.3.1 General requirements

1.3.1.1 In addition to meeting the requirements of the Guidelines, CCS also accepts the applicable parts of accepted standards for the design, manufacturing, installation, survey and test of fiber ropes.

1.3.1.2 Other standards, if adopted to substitute the standards listed in the Guidelines, shall be proven to have the safety level equivalent to that of the acceptable standard, and shall not be used until assessed and agreed by CCS.

1.3.1.3 Any inconsistency with the design standards, as well as any exemption and change of requirements in design standards, shall be explicitly stated in design documents, and shall be agreed by CCS.

1.3.1.4 The latest version of the standards since the effective date of the design contract shall be adopted; otherwise, explicit provisions shall be provided in the contract.

1.3.2 Acceptable standards

1.3.2.1 Main relevant standards of fiber ropes that are acceptable to CCS include:

(1) *Fiber Ropes for Offshore Stationkeeping Polyester* (ISO18692);

(2) *Fiber Ropes — Polyester — 3-, 4-, 8- and 12-Strand Ropes* (ISO1141);

(3) *Fiber Ropes — High Modulus Polyethylene — 8-Strand Braided ropes, 12-Strand Braided Ropes and Covered Ropes* (ISO10325);

(4) *Design and Analysis of Stationkeeping Systems for Floating Structures* (API RP 2SK);

(5) *Recommended Practice for Design, Manufacture, Installation, and Maintenance of Synthetic Fiber Ropes for Offshore Mooring* (API RP 2SM);

(6) *In-service Survey of Mooring Hardware for Floating Structure* (API RP 2I).

Chapter 2 SURVEYS OF PRODUCTS

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 This section provides the relevant requirements for product survey of the fiber ropes used for offshore position mooring systems, including the review of plans and information of product design, unit/batch survey and certificate issuance.

2.1.1.2 The applicant can apply for works approval and unit/batch survey after approval of fiber ropes used for offshore position mooring systems according to the requirements of CHAPTER 3, PART ONE of CCS *Rules for Classification of Sea-Going Steel Ships*.

2.1.1.3 The Guidelines can be referred to for implementation if the entrusting party applies for the certification surveys of the fiber ropes used for offshore position mooring systems.

Section 2 PLANS AND INFORMATION

2.2.1 Plans and information

2.2.1.1 In addition to the applicable documents listed in *CCS Rules for Classification of Mobile Offshore Units* and *Rules for Classification of Offshore Floating Installation*, the applicant shall submit the following documents to CCS for approval during the application for works approval by CCS:

(1) Technical conditions or enterprise standards for acceptance;

(2) Outlines for type test.

2.2.1.2 To apply for works approval by CCS for products, the applicant shall submit the following plans and information to CCS for reference:

(1) Standards adopted for fiber ropes;

(2) List of qualified suppliers of raw materials;

(3) Technical requirements of acceptance of raw materials, documentary evidence of quality of raw materials, and the re-survey reports (or records);

(4) Quality management documents and quality control documents;

(5) Profile of manufacturer, production history of ropes and the relevant descriptions;

(6) List of main equipment for production and test of fiber ropes;

(7) Survey personnel;

(8) Production process flow diagrams and production process documents for fiber ropes (including terminations), including but not limited to the following:

① Process of yarn assembly;

② Process of fiber rope assembly;

③ Process of strand assembly;

④ Processing technique of fiber rope jackets;

⑤ Processing technique of terminations;

(9) Formats of reports for approval and factory survey and test;

(10) Registration certificates of enterprise;

(11) Samples of product quality certificates of fiber ropes.

2.2.2.2 If there is any substantial modification or supplement to the reviewed documents, the applicant shall submit the modified or supplemented parts again for review.

Section 3 TYPE TEST

2.3.1 Survey of raw materials

2.3.1.1 The survey of the following items shall be conducted for each batch of materials used for the manufacturing of fiber ropes. Test methods and sampling requirements are shown in the following table. Survey results shall meet the relevant technical requirements indicated by the manufacturer of fiber ropes.

Survey items of yarns **Table 2.3.1.1**

Survey items	Standards	Sampling mode and amount
Dry breaking strength and elongation	ASTM D885	At least one sample per 5,000 kg fiber material
Yarn-on-yarn abrasion	ISO18692	At least one sample per 20,000 kg fiber material, at least one sampling test for each fiber rope order
Linear density	ISO18692	At least one sample per 5,000 kg fiber material
Content of marine finish	ASTM D2257	At least one sample per 20,000 kg fiber material, at least one sampling test for each fiber rope order.

2.3.2 Survey of fiber rope

2.3.2.1 Samples shall be taken from the fiber ropes that are made of the raw materials of the same batch number by the same process in the same construction and sizes. Generally, a section is cut off from the termination of each rope for the test sample.

2.3.2.2 The survey items of fiber ropes include the following contents:

(1) External visual survey: Visually check whether the ropes are twisted uniformly, or contain any broken strand or slack twist, whether there is any abrasion, scratch, cut or any other form of damage on appearance, and whether there is any greasy dirt and abnormal color variation on the appearance;

(2) Test of physical properties:

① Breaking strength test;

② Elongation and stiffness test;

③ Measurement of diameters;

④ Measurement and calculation of linear density;

(3) Particle ingress resistance test (if applicable);

(4) Subrope eye splice qualification test;

(5) Full rope cycle durability test;

(6) 3-T endurance test;

(7) Torque match with steel wire rope (if applicable);

(8) Axial compression fatigue test (if applicable);

(9) Creep rate verification test (if applicable).

Section 4 UNIT/BATCH SURVEY

2.4.1 Sampling

2.4.1.1 Sampling for unit/batch survey shall be implemented according to 2.3.2.1.

2.4.2 Unit/batch survey

2.4.2.1 Test items shall be implemented according to the requirements of 2.3.1.1 and 2.3.2.2 of this Chapter. Test methods shall be implemented based on the requirements of Chapter 4 in the Guidelines.

2.4.2.2 For the unit/batch survey after approval, if the diameter of the fiber rope is smaller than the sample diameter during approval, the exemption of some test can be accepted. See Table 2.4.2.2 for specific requirements.

Requirements for exemption of test Table 2.4.2.2

Test type	Exempted or not
Yarn test	Not exempted
Breaking strength test	Not exempted
Elongation and stiffness test	Only the test for dynamic stiffness can be exempted.
Particle ingress resistance test	Exemptible
Subrope eye splice qualification test	Exemptible
Full rope cycle durability test	Exemptible
3-T endurance test	Exemptible
Torque match with steel wire rope	Not exempted
Axial compression fatigue test	Exemptible
Creep rate verification test	Not exempted

2.4.2.3 For the tests in Table 2.4.2.2, exemption can be accepted only if the following conditions are met:

(1) The period of validity of batch approval does not exceed 4 years;

(2) One sample: for the fiber rope with the minimum breaking strength within ±20% of the sample;

(3) Two samples: for the fiber rope with the minimum breaking strength ranged between 80% of the smaller sample and 120% of the larger sample. However, such mode is not applicable to the dynamic stiffness test;

(4) Batch approval is only applicable to the fiber ropes of which the following design parameters are the same:

① The subrope construction;

② Type of yarn;

③ The number of layers of the eye structure;

④ D/d ratios of terminations;

⑤ The shape of the supporting surface of hardware;

⑥ The splicing length (the number of turns of stranded wires and conical turns)

⑦ Anti-wear materials and their application at eye splice locations;

⑧ Filtering materials of soil grains and design (only applicable to the “particle ingress resistance test”).

Section 5 MARKING AND QUALIFICATION CERTIFICATE

2.5.1 Marking

2.5.1.1 Each coil of completed rope is to be marked at a clearly visible position (such as protective jacket) with the rope name, diameter and length and the maker’s name (or brand name)..

2.5.1.2 The fiber ropes which have been accepted are to be identified with securely attached labels (lead sealing recommended) detailing at least the rope no., material, construction and additionally identified with CCS stamp at the termination of each rope..

2.5.2 Certificates of raw materials

2.5.2.1 The raw material manufacturer shall provide quality guarantees with the following performance parameters for each batch of raw materials used for rope manufacturing:

(1) Fiber designation or specifications;

(2) Linear density;

(3) Dry breaking strength and elongation of yarns;

(4) Yarn-yarn abrasion resistance test;

(5) Types of marine finish added and the relevant instructions (if any);

(6) Description of contents and water solubility of marine finish.

2.5.3 Certificates of fiber ropes

2.5.3.1 The manufacturer is to provide qualified fiber ropes with a qualification certificate detailing at least:

(1) product name, type and no.;
(2) materials of the fiber ropes;
(3) linear density of fiber ropes;
(4) length and diameter of a whole fiber rope coil;
(5) construction of fiber ropes;
(6) nominal breaking strength of fiber ropes and actual wet breaking strength;
(7) Manufacturing and survey dates;
(8) highest service temperature;
(9) shelf-life of product.

Section 6 CERTIFICATION FOR PRODUCTS

2.6.1 Certification for products

2.6.1.1 After works approval and product survey, CCS will issue the product certificate and/or equivalent certification document of the qualified fiber ropes used for offshore position mooring systems to the applicant.

Chapter 3 MATERIALS AND DESIGN

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 The fiber ropes used for offshore position mooring systems shall be designed with the methods in CCS *Rules for Materials and Welding*, *Rules for Classification of Mobile Offshore Units* and *Rules for Classification of Offshore Floating Installation*, etc.

3.1.1.2 The top and bottom of the mooring system with fiber ropes shall be provided with the anchor chains or wire ropes in appropriate lengths. The length of the upper anchor chain/wire rope shall be sufficient to ensure that the upper end of the fiber rope is kept at a depth that is not mechanically damaged by surface ships and offshore activities and not affected by ultraviolet radiation and marine organisms during its service life.

Section 2 MATERIALS OF FIBER ROPES

3.2.1 Raw materials

3.2.1.1 The fiber ropes for offshore position mooring systems are generally manufactured with polyethylene glycol terephthalate (polyester, PET), aromatic polyamide (aramid fiber, Aramid), high molecular weight polyethylene (HMPE), etc., of which the properties are listed in Table 3.2.1.1. If other materials are adopted, adequate data shall be provided to prove that their properties meet the requirements.

Parameters of raw materials of fiber ropes Table 3.2.1.1

Parameter	Type of fiber material		
	Polyester	**Aramid**	**HMPE**
Strength/weight ratio	Medium	High	High
Stiffness	Medium	High	High
Tension-tension fatigue damage	High	High	High
Axial compression fatigue damage	High	Low*	High
Abrasive resistance	High	Medium	High
Creep resistance	High	High	Low

Note: * means that the effects of this property depend on the composition of the mooring system and the application environment conditions.

3.2.1.2 The raw materials of fiber ropes used for offshore position mooring systems shall have good texture, uniform quality, corrosion resistance and aging resistance. The manufacturer should verify the material performance through the test in accordance with CHAPTER 4 in the Guidelines.

3.2.1.3 The marine finishes to make ropes are to comply with the following requirements:

(1) Marine finishes are not to be deleterious to the properties of fiber or fiber rope, and the treated fiber may increase the rope's service life by reducing yarn-to-yarn abrasion;

(2) Marine finishes are to remain effective during the rope's service life. The fiber supplier is to demonstrate the long-term durability of marine finishes.

3.2.1.4 The materials for rope jackets is to comply with the following requirements:

(1) The jacket is to be sufficiently flexible to permit the fiber rope assembly to be safely deployed over rollers or sheaves of diameter specified under the design deployment loads.

(2) Limiting bend radius based on jacket or rope bending rigidity is to be established for short periods during installation and for prolonged periods when wound onto the specified transportation drums.

(3) The selected jacket material is to be able to withstand low temperature to ensure adequate

protection of fiber ropes at low temperature.

3.2.2 Constructional design

3.2.2.1 Typical construction of fiber ropes include the parallel fiber ropes (parallel yarns, strands or subropes, etc.), braided-strand ropes (8 or 12 strands), etc.

3.2.2.2 The design of the jackets is to comply with the following requirements:

(1) The jacket is to be able to provide adequate protection for the rope during transportation, handling at installation or in service.

(2) The jacket is to be designed to provide adequate resistance to the ingress of sand or other hard foreign particles floating in seawater;

(3) The jacket can be in braided, extruded, wound or otherwise applied;

(4) The jacket shall be fixed tightly to the termination area to prevent the slippage of the jacket away from the termination;

(5) In regions exposed to fish bite, consideration may be given to hardening the jacket;

(6) Clearly visible marks shall be provided on the visible part of the jacket or fiber rope to facilitate the survey of the torsion of the fiber rope;

(7) The jacket shall be designed to ensure that water can completely fill the fiber rope construction to transfer heat and reduce heat accumulation during cyclic loading;

(8) The jacket shall be so elastic that no damage will be caused whenever the rope is under force.

3.2.2.3 The design of the terminations is to comply with the following requirements:

(1) The splicing termination is typically adopted for fiber ropes. For other terminations, the detailed design reports and test reports shall be submitted for approval according to the specific conditions;

(2) For the design of terminations, the termination weight, bending limit and heat accumulation shall be considered carefully;

(3) The minimum breaking strength indicated by the fiber rope manufacturer shall include the strength of the fiber rope and all the terminations. The fiber rope used in the sample test shall be consistent with the actually-used fiber ropes in the termination type and structural type;

(4) For the splicing terminations, the friction between the eye and the terminations hardware shall be minimized, and the wear resistance shall be maximized. Besides, the splicing terminations requires the hardware installed in eyes in the form of pins, bushes or collars to facilitate the terminations between the fiber rope and other assemblies in the mooring system.

3.2.3 Soil filter 3.2.3.1 The internal wear caused by water-borne particles (such as sand) is an important factor in the strength loss of fiber ropes. The fiber ropes shall not be used in areas with high turbidity unless suitable jackets or soil filter are adopted for protection to minimize particle penetration.

3.2.3.2 In order to prevent particles from entering, test shall be conducted for the jacket or soil filter according to the contents in CHAPTER 4, and the test conditions shall reflect the condition of fiber ropes exposed to particles.

Section 3 STRENGTH DESIGN

3.3.1 General requirements

3.3.1.1 For the selection of environmental conditions for the application of fiber ropes and their safety factors under the intact and damaged conditions, the relevant requirements in CHAPTER 4 of CCS *Rules for Classification of Offshore Single Point Moorings* shall be referred to.

3.3.1.2 Fiber ropes are generally made of viscoelastic materials, and their stiffness vary with load duration, load amplitude, load period, cycle times and load history. For the selection of stiffness models, refer to Section 4 of this chapter.

Section 4 STIFFNESS MODELS

3.4.1 General requirements

3.4.1.1 This section is mainly applicable to polyester ropes, and can also provide guidance for the stiffness of design and analysis of fiber ropes, such as HMPE and aramid fiber ropes.

3.4.2 Stiffness

3.4.2.1 On basis of engineering experience, simplified models are adopted to analyze the stiffness of fiber ropes. The upper/lower bound stiffness model and the static-dynamic stiffness model are commonly used in calculation.

3.4.2.2 HMPE has higher static and dynamic stiffness than either aramid or polyester, and its quasi-static stiffness mainly depends on the duration of the storm.

3.4.3 Upper/lower bound stiffness model

3.4.3.1 The upper/lower bound stiffness model defines the lower (installation stiffness) and the upper stiffness (storm stiffness) as the first approximation in calculation of mooring system. The lower and upper stiffness values are used to calculate the maximum displacement and maximum tension of mooring systems respectively. The upper/lower bound stiffness model is simple and widely used, but careful consideration is required for the determination and selection of upper and lower limits.

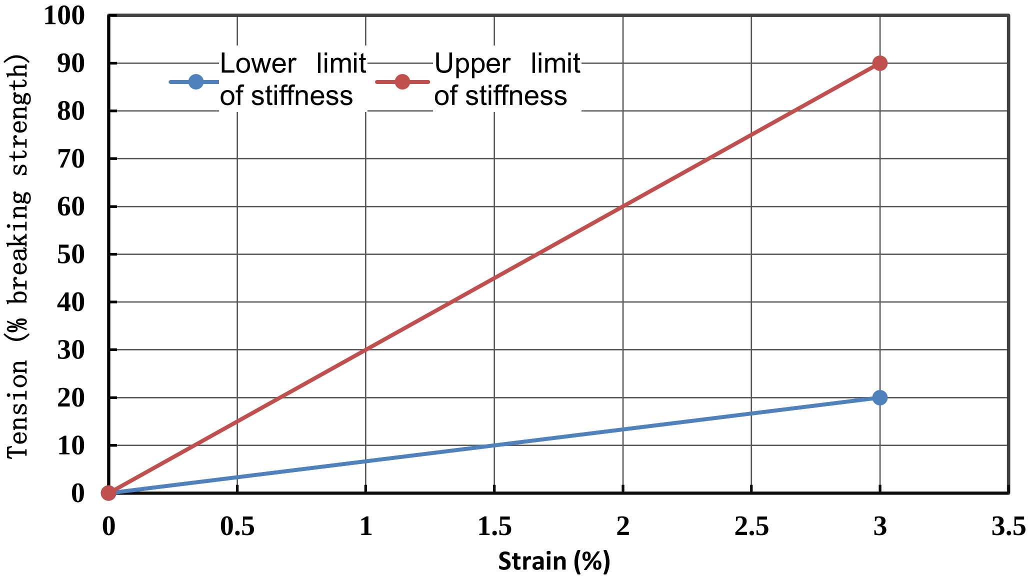


Figure 3.4.3.1 Upper/lower bound stiffness model of polyester ropes

3.4.4 Static-dynamic stiffness model

3.4.4.1 The elongation of polyester ropes largely depends on the macromolecular structure of the material. Static stiffness is the stiffness of tension members during slow loading; dynamic stiffness is the stiffness when tension members are under periodic loads. The existing test results and engineering projects indicate that the dynamic stiffness is 2–3 times of static stiffness. In order to accurately predict the displacement and mooring tension of the floating body, the above characteristics shall be considered through static-dynamic stiffness model in the calculation of floating body mooring.

3.4.4.2 In the static-dynamic stiffness model, static stiffness is used in the load curves from initial tension to average tension, and dynamic stiffness is used in the part of subsequent periodic loads.

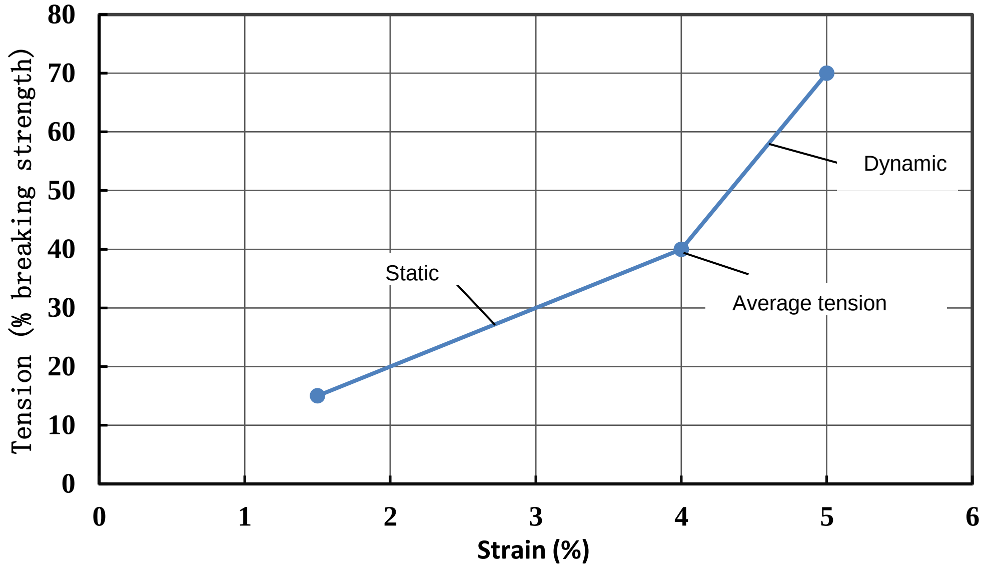


Figure 3.4.4.2 Static-dynamic stiffness model of polyester popes

The stiffness of polyester ropes is defined as:

$$EA = \frac{\Delta T}{\Delta \varepsilon} \quad \text{kN}$$

Where: ΔT — the load variation value, kN;

$\Delta \varepsilon$ — the strain variation value;

EA — the product of stiffness or elastic modulus and cross-sectional area of ropes, kN.

Equivalent dimensionless stiffness of polyester ropes, K_r, is defined as:

$$K_r = \frac{EA}{MBS}$$

Where, *MBS* is the minimum breaking strength of polyester ropes, *kN*.

3.4.4.3 On the basis of engineering experience, it is recommended to use quasi-static models to calculate the static stiffness. The quasi-static equation is defined as:

$$K_{rs} = \frac{T_2 - T_1}{\varepsilon_2 - \varepsilon_1 + C \times \log(t)}$$

Where, T_2 — the initial tension of test, typically the pretension of the fiber rope, kN;

T_1 — the end tension of test, typically the average storm tension of the fiber rope, kN;

ε_1 — the strain at the start point;

ε_2 — the strain at the end point;

C — the creep coefficient, determined through regression analysis;

t — the duration of environmental events.

The quasi-static stiffness test shall be conducted for ropes before installation, after installation and after use, if applicable. If other static stiffness models are used, appropriate data shall be provided through special tests and reviewed by CCS.

3.4.4.4 A three-parameter equation is recommended to be used as the dynamic stiffness equation, as follows:

$$K_{rd} = \alpha + \beta L_m + \gamma F + \delta \log(P)$$

Where, L_m — the percentage of average load to the minimum breaking strength;

F — the percentage of load amplitude to the minimum breaking strength;

P — the load period, s;

$\alpha, \beta, \gamma, \delta$ — the coefficients related to the above parameters, for which 3.4.5 can be referred to during initial design.

3.4.4.5 The three-parameter equation in the dynamic stiffness equation has the following effects on the dynamic stiffness:

(1) Influence of load amplitude: the following practices are recommended based on engineering experience,

① In the case of sinusoidal load, the maximum tension amplitude is taken as the value of F in the analysis of strength and fatigue;

② In the case of random loads, F is 0.5 times of the maximum tension;

③ F can be ignored in fatigue analysis under wave loads.

(2) Influence of load period: For the wave-frequency response, the load period is the period of the response peak; for low-frequency response and vortex-induced motion (VIM) response, the load period is the natural period of the mooring system.

(3) Influence of loading history: In order to study the influence of loading history, the state of ropes is divided into three types:

① Before installation: the rope is not pretensioned and has the lowest stiffness;

② After installation: the rope is pretensioned during installation, fulfilling the initial running-in;

③ Aging: In addition to pre-tensioning, the rope has undergone severe loads and reached the state of complete running-in.

The existing test data indicate a little difference between the stiffness of installed ropes and that of used ropes. Therefore, the stiffness of used ropes can be adopted conservatively.

3.4.5 Stiffness value in initial design

3.4.5.1 In the initial design of the mooring system using polyester ropes, it is necessary to use the approximate stiffness values because accurate stiffness values cannot be obtained based on test. This section can provide guidance for the determination of stiffness values in initial design. These data come from the test data of some permanent mooring systems using polyester ropes.

3.4.5.2 The three-parameter model method of dynamic stiffness (see 3.4.4.4) is derived from the existing data from polyester rope tests, as shown in Table 3.4.5.2. The upper limit value is conservative for tension, and the lower limit value is conservative for offset. This method needs the rough estimation of the influence of average tension, tension amplitude and loading period.

Dynamic stiffness coefficient in initial design **Table 3.4.5.2**

Coefficient	Upper limit value	Lower limit value
α	26.0	20.3
β	0.28	0.22
γ	-0.42	-0.33
δ	-0.97	-0.76

3.4.5.3 The quasi-static stiffness is measured based on the existing test data, and the test results indicate that the stiffness of the installed polyester rope differs greatly from the aged polyester rope, as shown in Table 3.4.5.3.

Quasi-static stiffness value in initial design **Table 3.4.5.3**

State of polyester rope	Stiffness level		
	Low (%MBS)	Medium (%MBS)	High (%MBS)
After installation	10	13	15
Aging	13	15	18

3.4.6 Other stiffness models

3.4.6.1 If other stiffness models are selected, it is necessary to ensure that these models can reflect the basic elongation of polyester ropes and obtain the reliable prediction results.

Section 5 FATIGUE DESIGN

3.5. 1 Tension-tension fatigue

3.5.1.1 For polyester ropes without reliable data available, the curve of "mean–two standard deviations" obtained by regression analysis can be used to analyze the fatigue of polyester ropes.

As polyester ropes have better fatigue resistance than anchor chains and wire ropes, fatigue evaluation usually focuses on the anchor chains and wire ropes with short fatigue lives.

The expression of the design curve is as follows:

$$NR^M = K$$

Where, N — the cycles;

R — the ratio of tension range to minimum breaking strength;

M — 5.2 (the slope of the T-N curve);

K — 25,000 (the intercept of the T-N curve).

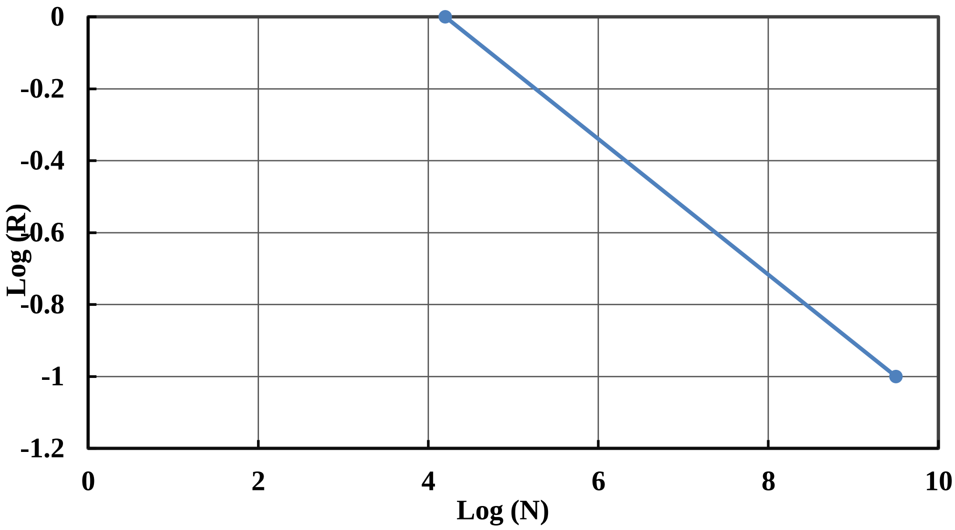


Figure 3.5.1.1 Fatigue design curve of polyester rope

3.5.1.2 For other types of fiber ropes, the designer shall determine the tension-tension fatigue life of the system through test or obtaining the fatigue data from the manufacturers.

3.5.2 Axial compression fatigue

3.5.2.1 Analysis of axial compression fatigue is not required for polyester ropes and HMPE. However, the aramid rope is prone to axial compression fatigue under low tension, which leads to failure. The following section mainly introduces the axial compression fatigue of aramid ropes.

3.5.2.2 Due to the failure mechanism of axial compression fatigue, the application of aramid ropes in mooring systems is not satisfactory. However, the long-term research of the industry indicates that such problem can be overcome by the following measures:

(1) Improving the design of terminations, marine finish and jackets;

(2) Establishing the appropriate minimum tension standard and analysis process;

(3) Carrying out the axial compression fatigue test to provide enough capability to resist the axial compression fatigue damage.

3.5.2.3 For the measures mentioned in (2) and (3) in 3.5.2.2, the recommended standards are:

(1) For a complete mooring in a strong storm environment (generally with a recurrence period of 100 years), the predicted minimum tension at the bottom of the aramid rope at the leeward shall be greater than the minimum breaking strength of 2%;

(2) The rope shall maintain the minimum residual strength of 95% of the minimum breaking strength after 2,000 dynamic load cycles (tension is ranged from 1% to 20% of the minimum breaking strength);

(3) If the aramid rope is hung with a buoy after pre-installation, a minimum tension of 2% of the minimum breaking strength shall be maintained.

3.5.2.4 The requirements in (1) and (2) of 3.5.2.3 can be modified according to the specific conditions of the project, but no significant deviation from the specific principles is allowed. In order to meet the review requirements, the designer shall provide the following information:

(1) Design standards of the minimum tension;

(2) Test steps of axial compression fatigue: tension range, the number of test cycles and frequency;

(3) Residual strength after test;

(4) Basis for design criteria and test procedures.

3.5.2.5 The time-domain analysis method shall be adopted in the analysis of the mooring system using aramid ropes; if the frequency-domain analysis method is adopted, the time domain analysis shall be adopted for verification at first.

3.5.3 Fatigue life

3.5.3.1 The fatigue safety factor of the position mooring system using fiber ropes is related to the detectable conditions and positions of the components, and the tension-tension fatigue safety factor of the fiber rope shall not be less than the specified values in Table 3.5.3.1.

Fatigue safety factors of fiber ropes **Table 3.5.3.1**

Position of component	Detectable component	Undetectable and key component
Ratio of fatigue life to design life	3	10

Section 6 CREEP DESIGN

3.6.1 General requirements

3.6.1.1 Creep failure (or creep rupture) is the result of cumulative, irreversible elongation of fiber ropes over time under load.

3.6.1.2 In the application of mooring systems, there will be no obvious creep in the polyester ropes and aramid fiber under load, but creep tendency is the main problem of HMPE. Therefore, analysis is mainly conducted for the creep failure of HMPE in this section.

3.6.1.3 Generally, the creep of fiber ropes needs to be considered in the permanent mooring system; there is less concern about the creep problem in the mobile mooring system as the duration of the operation is short.

3.6.1.4 The main factors affecting creep are average load, load duration, temperature, etc.

3.6.2 Influence factors of creep

3.6.2.1 Creep state is related to time. For the creep curve, its strain is a function of time, as shown in Figure 3.6.2.1 (1); its creep rate is the slope of the curve, as shown in Figure 3.6.2.1 (2). According to the different behaviors of creep rates, there are three types of creep state:

(1) Primary creep (Regime I): In this state, amorphous rearrangement occurs, and the high creep rate at the beginning reduces to a plateau level at the end. The strain is reversible when elastic and delayed elastic components are used;

(2) Steady-state creep (Regime Ⅱ): In this state, the molecular chain slides. The creep rate increases slightly, as the yarn stress actually increases slightly as creep continues under constant loads. The creep rate is regarded as a constant in this state. This strain is called as "plastic creep", and is irreversible;

(3) The tertiary creep (Regime Ⅲ): In this state, the molecular chain begins to rupture. High strain will lead to filament necking, and will increase local stress, accelerating the strain until rupture occurs.

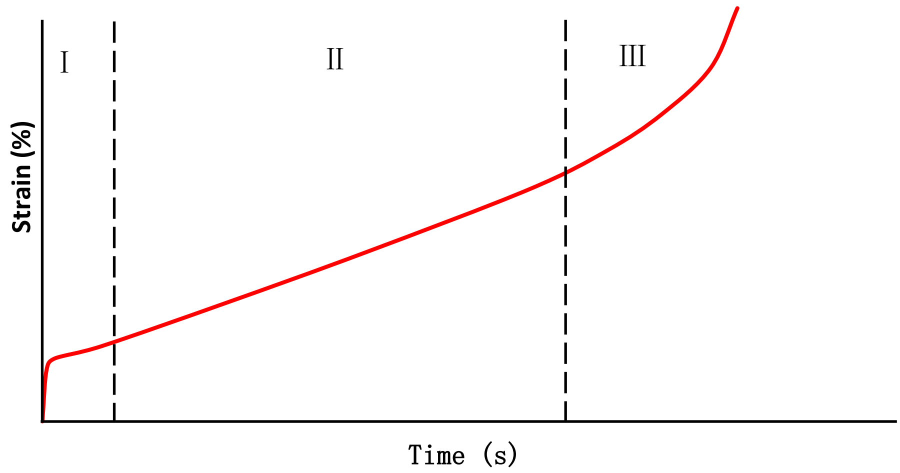


Figure 3.6.2.1 (1) Typical HMPE creep curve

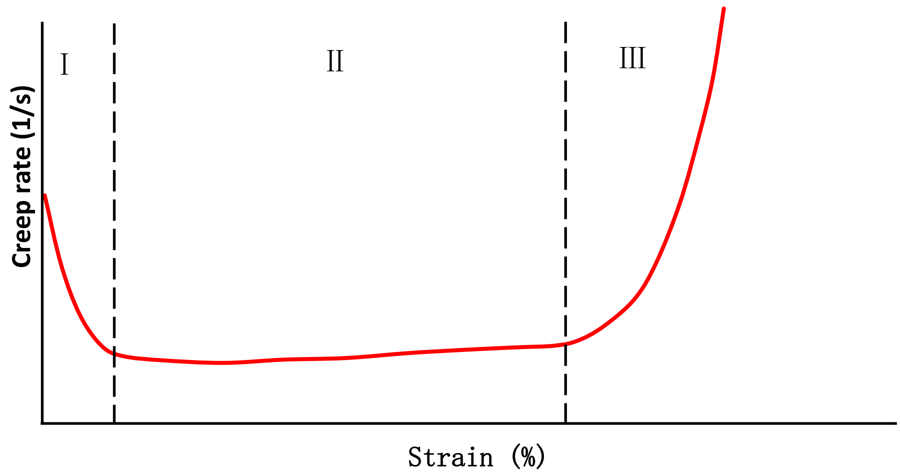


Figure 3.6.2.1 (2) Typical HMPE creep rate curve

3.6.2.2 The creep rate also depends on the applied load and temperature. Therefore, in order to avoid excessive creep, the HMPE rope shall be placed at an appropriate design water depth (temperature is sensitive to water depths).

3.6.3 Creep analysis

3.6.3.1 In order to estimate the creep strain during the design service life, the creep analysis shall be carried out for the mooring system. To simplify the analysis, the following assumptions are proposed:

(1) Compared with the design service life, as the duration of creep state I is short, the creep is negligible;

(2) The creep of state II is estimated using the constant creep rate with time, but its creep rate is still a function of load and temperature;

(3) The creep rate is a function of yarn stress and temperature, which can be obtained through yarn test and creep models;

(4) As the information related to rope design and unit mass is easy to obtain, yarn stress can be converted into rope tension (% of the minimum breaking strength) through the conversion factor of specific ropes;

(5) The strain in state II is defined as the irreversible plastic creep. Thus, such creep can be

accumulated. For a specific temperature, the annual cumulative creep strain G_t can be calculated by the following formula:

$$G_t = \sum h_i H_i$$

Where: h_i — the annual duration in the tension interval *i*;

H_i — the creep rate in the tension interval *i*.

3.6.3.2 The steps of creep analysis are as follows:

(1) Long-term environmental events can be expressed by several discrete design conditions. Each design condition consists of a reference direction and a reference sea state, with the characteristic parameters including the significant wave height, peak spectral period, crest factor, flow velocity and wind speed. The occurrence probability of each design condition shall be set;

(2) For each design condition, it is necessary to determine the average tension of all fiber ropes;

(3) Calculate the annual creep strain of a design condition (the sea state in one direction) through the calculation formula in 3.6.3.1 (5);

(4) Repeat step (3) to calculate the annual creep strain G_t of each sea state and direction, i.e., the sum of the creep strains of all sea states and directions;

(5) The total predicted creep strain of fiber ropes with the design service life of M is:

$$G = MG_t$$

Where, M — the design service life, in year.

3.6.4 Creep rupture analysis

3.6.4.1 In order to estimate the creep rupture life of mooring systems, creep rupture analysis shall be carried out for the mooring systems. If creep is monitored, the creep rupture life shall be more than 5 times of the design service life; if creep is not monitored, the creep rupture life shall be more than 10 times of the design service life. To simplify the analysis, the following assumptions are proposed:

(1) Compared with the design service life, as the duration of creep state III is short, it can be considered that creep rupture begins when state III occurs;

(2) The creep rate is a function of yarn stress and temperature, which can be obtained through yarn test and creep models;

(3) As information related to rope design and unit mass is easy to obtain, yarn stress can be converted into rope tension (% of the minimum breaking strength) through the conversion factor of specific ropes;

(4) The annual cumulative creep rupture damage ratio B can be calculated by the following formula:

$$B = \sum c_i / C_i$$

Where: c_i — the annual duration in the tension interval *i*;

C_i — the creep rupture time in the tension interval *i*.

3.6.4.2 The steps of creep rupture analysis are as follows:

(1) Long-term environmental events can be expressed by several discrete design conditions. Each design condition consists of a reference direction and a reference sea state, with the characteristic parameters including the significant wave height, peak spectral period, crest factor, flow velocity and wind speed. The occurrence probability of each design condition shall be set;

(2) For each design condition, it is necessary to determine the average tension of all fiber ropes;

(3) Calculate the annual creep rupture damage of a design condition (the sea state in one direction) through the calculation formula in 3.6.4.1 (4);

(4) Repeat step (3) to calculate the total annual creep rupture damage B_t in all sea states and directions, that is, the sum of creep strains in all sea states and directions;

(5) The predicted creep rupture life of fiber ropes is:

$$L = 1/B_t \quad \text{year}$$

Where, L — the creep rupture life, in year.

3.6.5 Creep model certification

3.6.5.1 The creep model that generates the design data for creep and creep rupture analysis shall be verified through the creep rate verification test of the rope under at least one load and one temperature according to the procedure specified in Section 11 of CHAPTER 4. If it is found that the design data used in the analysis are not conservative, the verification test results shall be used for adjustment, and the creep and creep rupture analysis shall be repeated. In order to adjust the design data correctly, additional test may be necessary for the creep rate of ropes.

3.6.6 Quasi-static stiffness

3.6.6.1 For HMPE rope, the equation in 3.4.4.3 shall be revised as follows:

$$K_{rs} = \frac{T_2 - T_1}{\varepsilon_2 - \varepsilon_1 + Ct}$$

The definition of parameters in the formula is consistent with that of 3.4.4.3.

Section 7 TORQUE COORDINATION DESIGN

3.7.1 General requirements

3.7.1.1 In the analysis of mooring systems, the torque coordination between fiber ropes and mooring assemblies (such as wire ropes) shall be considered.

3.7.1.2 There are two types of torque for mooring assemblies:

1) Torque components included: Torsion is included in the assemblies and transmitted between assemblies during installation or restoration;

2) Torque component excluded: The torsion is negligible. The fiber rope is generally not included in the torque component, but it can be regarded as a torque assembly during design.

3.7.2 Permanent mooring system

3.7.2.1 For a permanent mooring system, a torque-free fiber rope is usually used together with a torque-free steel assembly to obtain a torque-free fiber rope. If the torque steel assembly is used, the fiber rope shall have the same torsional characteristics in design, so as to ensure the matching with the steel assembly.

3.7.3 Mobile mooring system

3.7.3.1 As mobile mooring systems generally use torque steel assemblies, especially for the deep-water environmental conditions, special consideration shall be given to the mobile mooring systems.

3.7.3.2 For mobile mooring systems, the following two design methods are recommended in the industry:

(1) The torque matching method: Torque matching test is required, if adopted;

(2) Otherwise, if the dynamic torsion of steel assemblies can be restrained at the joints of fiber ropes and steel assemblies, the untwisted fiber rope can be used in the design of mobile mooring systems.

Section 8 EFFECTS OF OTHER ENVIRONMENTAL CONDITIONS

3.8.1 Anti-ultraviolet performance

3.8.1.1 During storage, transportation and installation, appropriate measures (such as using opaque covers) shall be taken to protect the fiber rope that is likely to be affected by ultraviolet light against damage caused by ultraviolet radiation.

3.8.2 Marine organisms

3.8.2.1 The strength of the fiber rope is basically unaffected by marine growth, but the marine growth will change the weight and towing load of the fiber rope in water. According to the engineering experience, the use of filters in the bearing part of fiber ropes can effectively prevent the growth of harmful marine organisms.

3.8.2.2 The marine organisms with hard shells will grow between the sleeve and the load-bearing core, causing wear and tear to the yarn. Soft marine organisms will adhere to the surface of the fiber rope, which will affect the inspection capability of the remotely operated underwater vehicle (ROV) for the fiber rope. Therefore, appropriate methods can be adopted to remove marine organisms, without damaging the fiber rope.

3.8.3 Rebound during failure

3.8.3.1 A considerable amount of energy is stored in the rope in an elastic mode, and the safety impact on the staff and equipment shall be considered during the formulation of installation procedures.

Section 9 CONSIDERATIONS FOR MOBILE MOORING SYSTEM

3.9.1 General requirements

3.9.1.1 This chapter is mainly applicable to the permanent mooring systems. For mobile mooring systems, most clauses are also applicable herein. However, in view of the differences between the permanent and mobile mooring systems, the following clauses shall be noted:

(1) Different requirements are specified for the anchor chain or wire rope at the top and bottom;

(2) The fiber rope of the mobile mooring system generally has no or small pre-tension, which may lead to great flexibility of the fiber rope in the early-stage use. However, the fiber rope will become hard with aging, which needs to be considered in stiffness test and mooring analysis;

(3) Dynamic stiffness and quasi-static stiffness depend on the parameters such as the average tension, tension amplitude, duration and natural period of the mooring system. However, these parameters are uncertain because of the short operation duration of the mobile mooring system, and they are generally determined through simple, conservative assumptions.

Chapter 4 TEST

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 This section provides guidelines for fiber rope tests, including fiber rope tests and yarn tests.

4.1.1.2 The performance characteristics of fiber ropes need to be documented and submitted to CCS to fulfill the expected purpose of products and meet service environment conditions.

4.1.2 Test regulations

4.1.2.1 Test sample requirements are summarized in Table 4.1.2.1.

Test sample requirements **Table 4.1.2.1**

Test Type	**Subrope Sample Allowed for Parallel Construction?**	**Same Splice as Production Rope Required?**	**Minimum Sample Length**
Breaking strength test	No	Yes	40D
Elongation and stiffness test	Yes	No	5 m
Particle ingress resistance test	No	Yes	40D
Subrope eye splice qualification test	Yes	Yes	5 m
Full rope cycle durability test	No	Yes	40D
3-T endurance test	Yes	Yes	5 m
Torque match with steel wire rope	No	Yes	Same length as steel wire rope
Axial compression fatigue test	No	Yes	40D
Creep rate verification test	Yes	No	5 m

Note: D is the nominal diameter of the rope.

4.1.2.2 Before the test (except yarn test, 3-T endurance test and particle ingress resistance test), the entire sample shall be soaked in fresh water for 4 hours (subrope) or 12 hours (full rope), and the test shall be carried out as soon as practical after being removed from the water.. If there is a delay of more than 16 hours after soaking, the sample should be soaked again.

4.1.2.3 The test machine is to comply with the following requirements:

(1) The test machine should have sufficient bed length, stroke, rate of loading, and force producing capacity to carry out the test;

(2) The test machine shall be equipped with a force measuring and recording device which is accurate to within ±1% of the estimated MBS for the rope sample. The force measuring and recording device shall be calibrated by a recognized independent calibration agency. This calibration shall be done within one year before testing. An original calibration certificate shall be available for examination, and a copy of this certificate shall be attached to the test report.

4.1.2.4 The sample internal temperature shall be monitored by suitable temperature measuring devices. For polyester, the sample internal temperature shall be kept below 40℃. HMPE rope properties are more sensitive to temperature and therefore sample temperature shall be recorded so the test results can be interpreted for application to the project. Aramid can tolerate higher internal temperature (70°C or even higher). When the rope temperature in the test (especially the dynamic load test) indicates a risk of overheating, the test shall be stopped, and then resumed after the temperature is lowered to an acceptable level.

Section 2 YARN TESTING

4.2.1 General requirements

4.2.1.1 Before manufacturing of fiber ropes, yarn testing shall be conducted.

4.2.2 Testing of yarn dry breaking strength and elongation

4.2.2.1 Four samples of basic yarn shall be taken and tested. The samples shall be conditioned to equilibrium at a temperature between 15° and 25℃ and a relative humidity between 60% and 70%.

4.2.2.2 The samples shall be loaded to break in accordance with the recognized standards (such as ASTM D885) or equivalent methods. The average yarn dry breaking strength and dry elongation shall be determined and recorded. The testing method to be used shall be identified in the rope design documentation. The same method is then to be used whenever the yarn is tested.

4.2.3 Yarn-on-Yarn abrasion resistance test

4.2.3.1 Yarn-on-yarn abrasion resistance test shall be conducted according to a recognized standard (ISO18692) or equivalent methods.

Section 3 BREAKING STRENGTH TEST

4.3.1 General requirements

4.3.1.1 All tests shall be carried out using the same loading procedures to maintain consistency. This includes any cycling procedures and load ranges.

4.3.1.2 The breaking strength test report shall contain the following information:

(1) Breaking force and the elongation;

(2) Load–elongation chart;

(3) The location and nature of breaking;

(4) Test conditions (such as ambient temperature, humidity and deviation).

4.3.2 Sample

4.3.2.1 At least 5 samples shall be selected for test.

4.3.2.2 The minimum free length of the sample shall be at least 40 times of the nominal diameter of the rope, and the sample shall be terminated in the same way as the production rope (including the jacket or sleeve). The sample shall neither be stretched to more than 5% of its design breaking strength before test nor be subjected to circulation or retention under tension. This method is not applicable to the test of used ropes.

4.3.2.3 Before the test, the sample shall be soaked in fresh water for at least 12 hours.

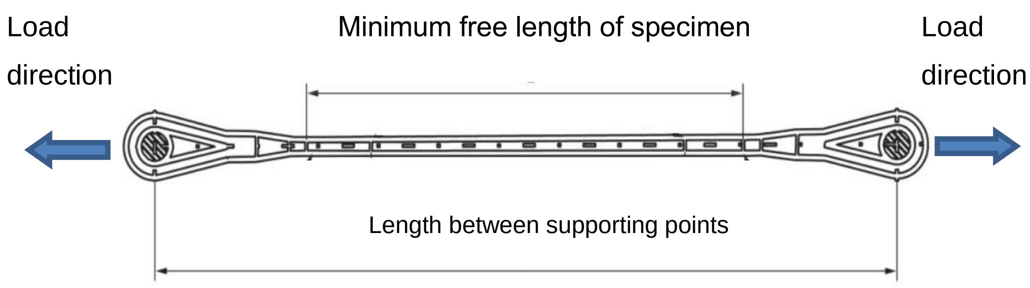


Figure 4.3.2.2 Setting of general test

4.3.3 Test procedure

4.3.3.1 The samples shall be tested in the following test procedures :

(1) A cycling tension between 1% and 50% of the rope MBS should be applied 10 times;

(2) On the eleventh cycle, apply force to the rope until it breaks;

(3) Record the breaking force (maximum force applied to the rope). Record the location where the rope broke (e.g., between splices, at end of a splice, at crotch of a splice, in back of an eye, or other breaking locations).

4.3.4 Description on acceptance of test results

4.3.4.1 Five full rope samples should be tested, and the MBS will be accepted if all 5 break loads are above the MBS.

4.3.4.2 If one break load is below the MBS, an investigation should be conducted to identify causes. If the investigation indicates an isolated event, two more samples can be tested, and the MBS will be accepted if both break loads are above the MBS.

4.3.4.3 If other test procedures are adopted, the documents supporting the reliability of test and data analysis methods shall be submitted in time and approved by the CCS Surveyor.

Section 4 ELONGATION AND STIFFNESS TEST

4.4.1 General requirements

4.4.1.1 All tests shall be carried out using the same loading procedures to maintain consistency. This includes any cycling procedures and load ranges.

4.4.2 Sample and test machine

4.4.2.1 At least 3 samples shall be selected for test.

4.4.2.2 The sample length shall be at least 5 m. The sample shall neither be stretched to more than 5% of its design breaking strength before test nor be subjected to circulation or retention under tension.

4.4.2.3 The sample shall be soaked in water for at least 4 hours before the test, and water shall be added during the test to keep the whole sample moist.

4.4.2.4 The test machine shall be equipped with an elongation measuring device and a data acquisition system to measure and record the elongation.

4.4.3 Installation pre-loading test

4.4.3.1 The test is carried out before the static stiffness test. The pre-loading operation can remove as much permanent elongation as possible during installation and to increase stiffness of the rope.

4.4.3.2 Detailed test procedure is as follows:

(1) Tension the rope to 1% MBS. Measure and record the initial rope length;

(2) Increase the tension to the specified pre-tension and hold at this tension for at least two hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(3) Increase the tension to the specified preload tension (the maximum installation tension) and hold it for 2 hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(4) Decrease the tension to pre-tension and hold at this tension for at least 6 hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(5) Decrease the tension to 1% MBS and hold it for at least 2 hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration.

Report the difference in length from the end of step (1) to the end of step (4) above. This is the permanent post-installation elongation.

4.4.4 Quasi-static stiffness for post-installation rope

4.4.4.1 This test shall be carried out on the test segment that has been tested in the installation pre-loading test.

4.4.4.2 Detailed test procedure is as follows:

(1) Increase the rope tension from 1% MBS to the pre-tension, and hold it for at least 100 minutes. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(2) Increase the tension from pre-tension to 30% MBS at a rate of approximately 10% MBS per minute and hold it for at least 2 hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(3) Increase the tension from 30% to 45% MBS at a rate of approximately 10% MBS per minute and hold it for at least 2 hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(4) Increase the tension from 45% to 60% MBS at a rate of approximately 10% MBS per minute and hold it for at least 2 hours. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration;

(5) Reduce the tension from 60% MBS to pre-tension at a rate of approximately 10% MBS per minute, and hold it for at least 200 minutes. Record the elongation at 1, 10, and 100 minutes, and at the end of the duration.

The data from this test may be used to determine quasi-static stiffness for the post-installation rope.

4.4.5 Quasi-static stiffness for aged rope

4.4.5.1 This test shall be carried out on the sample that has gone through the test for quasi-static stiffness for post-installation rope.

4.4.5.2 Detailed test procedure is as follows:

(1) Increase the tension from pre-tension to 65% MBS at a rate of approximately 10% MBS per minute and hold at this tension for 100 minutes. Record the elongation at 1, 10 and 100 minutes;

(2) Apply 1000 cycles of dynamic load with a tension range of 35% to 65% MBS and a period of 12 to 35 seconds;

(3) In the last cycle reduce the tension from 65% MBS to pre-tension at a rate of approximately 10% MBS per minute and hold at this tension for 100 minutes. Record the elongation at 1, 10, 100 minutes;

(4) The quasi-static stiffness test outlined in 4.4.4 should be repeated after above loading.

The data from this test may be used to determine quasi-static stiffness for aged rope.

4.4.6 Dynamic stiffness test

4.4.6.1 This test is used to determine the dynamic stiffness (under wave frequency (WF) and low frequency loading(LF)) of a bedded-in rope at different mean tensions and tension ranges.

4.4.6.2 The test shall be carried out on the sample that has gone through the test for quasi-static stiffness for aged rope outlined in 4.4.5.

4.4.6.3 Detailed test procedure is as follows:

(1) Cycle the rope 10 times between pre-tension and 55% MBS with a period of 12 to 35 sec. and then return to pre-tension and hold for at least 100 minutes;

(2) For each WF test case (12 to 35 sec. period), cycle the rope for 40 times between the minimum load and the maximum load in Table 4.4.6.3. Record the load and elongation with frequency of at least 1 Hz;

(3) For each LF test interval (250 sec. period), cycle the rope for 20 times at tension between the minimum load and the maximum load in Table 4.4.6.3. Record the load and elongation with frequency of at least 0.25 Hz;

(4) Polyester rope samples shall be tested with reference to the following testing matrix, which is suitable for a wide range of rope mooring applications:

Dynamic stiffness test matrix for general polyester rope mooring application

Table 4.4.6.3

No.	Average load (% MBS)	Load amplitude (% MBS)	Minimum load (% MBS)	Maximum load (% MBS)	Period (sec)	Number of cycles (times)
1	15	5	10	20	250	20
2	20	3	17	23	12–35	40
3	20	3	17	23	250	20
4	23	16	7	39	250	20
5	30	16	14	46	12–35	40
6	30	16	14	46	250	20
7	30	28	2	58	250	20
8	35	8	27	43	12–35	40
9	35	8	27	43	250	20
10	40	30	10	70	12–35	40
11	40	30	10	70	250	20
12	50	20	30	70	12–35	40
13	50	20	30	70	250	20
14	60	10	50	70	250	20

4.4.6.4 Dynamic stiffness is determined through the following methods:

(1) Dynamic stiffness shall be calculated by Equation 3.4.4.2 using the peak and trough points of the cycle, and the strain shall be based on the average rope length during the cycle;

(2) For each test case, calculate the dynamic stiffness for each cycle, and report the average stiffness of the last three cycles as the dynamic stiffness for the test case.

Section 5 PARTICLE INGRESS RESISTANCE TEST

4.5.1 General requirements

4.5.1.1 This test is required for rope preset on the seafloor and reuse of rope that has been accidentally dropped on the seafloor. Preventing the particles from entering the fiber rope is generally fulfilled by adopting jackets or sand barriers. This test is also applicable to the jacket and sand barrier.

4.5.2 Sample

4.5.2.1 At least 2 samples shall be selected for test.

4.5.2.2 The requirements of the sample are as follows:

(1) The sample shall comprise a typical fiber rope with a length of at least 40 times the diameter of the rope. If full-scale rope cannot be tested in the chamber, a scaled rope no less than half the diameter may be used;

(2) The circumferential surface of the sample shall be completely covered by the filter barrier material, applied in the same manner, and no thicker than used on the production ropes;

(3) The ends of the sample shall be sealed with a waterproof compound or with a watertight cap.

4.5.3 Test procedure

4.5.3.1 Detailed test procedure is as follows:

(1) The sample shall be placed in a hyperbaric chamber and totally immersed in water;

(2) After immersing the sample, it shall be kept at atmospheric pressure for 60 minutes;

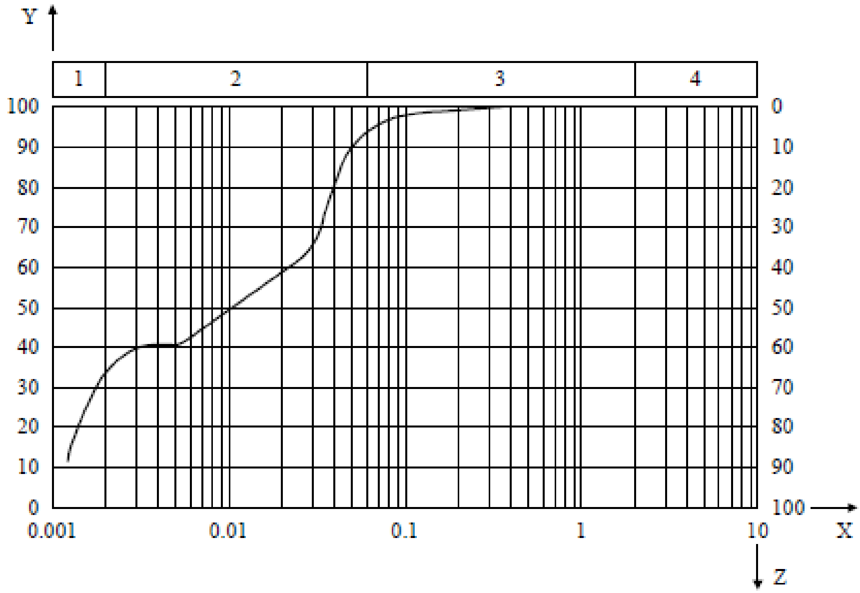
(3) Soil shall then be added to the water at a proportion of 25 % of water weight. The soil grading shall contain 30% to 40% clay (less than 2 microns) and 50% to 60% silt (2 to 63 microns). An example of soil grading is shown in Figure 4.5.3.1;

(4) Pressure shall then be increased to 10 Mpa. Horizontal (back and forth) and vertical (pick up and drop) movements (minimum 1 m) shall be imposed on the rope sample at least 20 times each to simulate rope movements during installation and impact of a dropped rope. After simulation, the rope shall be kept in the chamber for 72 hours.

(5) Pressure shall then be released and the sample shall be removed from the chamber;

(6) After the sample is taken out, the sample shall be carefully dissected to remove the jacket and the filter barrier. Photographic records of the dissection process should be taken.

(7) Samples from yarns on the surface of the load bearing cores of the rope shall be examined under a Scanning Electron Microscope (SEM) to detect the presence of soil particles. The yarn inside the rope shall not contain any soil particle with a diameter greater than 5 microns.



① Clay ≤2μm; ② Silt > 2μm and ≤63μm; ③ Sand > 63μm and ≤2 mm; ④ Gravel > 2mm and ≤ 63mm;

X: Particle size (mm); Y: Passing percentage (%); Z: Retained percentage (%)

Figure 4.5.3.1 Grading of Sand for Particle Ingress Resistance Test

Section 6 SUBROPE EYE SPLICE QUALIFICATION TEST

4.6.1 General requirements

4.6.1.1 The purpose of the subrope eye splice qualification test is to prove that the eye will not move after laying and will not be pulled out after being used for a long time. All tests shall be carried out using the same loading procedures to maintain consistency. This includes any cycling procedures and load ranges.

4.6.1.2 The report of eye splice qualification test shall include the following information:

(1) Test conditions (such as ambient temperature, humidity and deviation);

(2) Records about the tensile curves of the loads at the cycles 1–10, cycles 20, 50, 100, 200, 300, 400, 500, 600, 700 and 800 and cycles 900–1,000 and the "pin-to-pin distance”. If the test continues, cycles 1,100 and 1,200, etc. shall be recorded further until the test stops. In this case, every 100 cycles in a series shall be recorded;

(3) Records about the peak elongation of the cycle period, with the purpose of proving the asymptotic behavior, as shown in Figure 4.6.1.2;

(4) Photo files displayed by computer software of ropes and test equipment during the test.

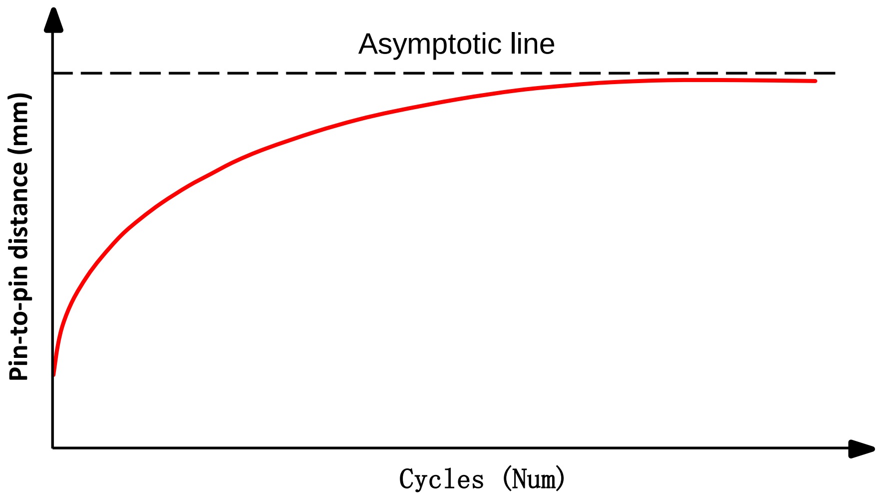


Figure 4.6.1.2 The asymptotic behavior in the "pin-to-pin distance" showing the eye splice locked during the rope cycle test.

4.6.2 Sample

4.6.2.1 Select at least 3 subrope samples for test, and the eye splice mode of the sample subrope shall be same as that of the full rope.

4.6.2.2 The sample shall be mounted on a smooth steel pin in the test machine.

4.6.3 Test procedure

4.6.3.1 Detailed test procedure is as follows:

(1) Load range of 5%–50% MBS for at least 1,000 cycles;

(2) If no asymptotic behavior is presented in the tensile curve of the load of the test rope and the "pin-to-pin distance" in the first 1,000 cycles, it is necessary to continue the cycle test;

(3) Record the tensile curve of load and "pin-to-pin distance" during the test.

4.6.4 Description on acceptance of test results

4.6.4.1 If the load of the test rope and the tangent of the tensile curve of "pin-to-pin distance" become gradually horizontal during the cycle, with an asymptotic behavior, the rope eye splice qualification test is completed.

4.6.4.2 If during the test cycle, the eye splice part of rope slips out, or the tensile curve of the load and "pin-to-pin distance" does not show any asymptotic behavior, the eye splice qualification test of the sample fails.

Section 7 FULL ROPE CYCLE DURABILITY TEST

4.7.1 General requirements

4.7.1.1 All tests shall be carried out using the same loading procedures to maintain consistency. This includes any cycling procedures and load ranges.

4.7.1.2 The report of the full rope cycle durability test shall include the following information:

(1) Test conditions (such as ambient temperature, humidity and deviation);

(2) Load ranges and cycle times;

(3) Load–elongation chart;

(4) After the test, the subrope condition inside the full rope: whether there is any adhesion or damage, etc.

4.7.2 Sample

4.7.2.1 At least one full rope sample shall be selected for test. Before the test, the rope shall be soaked in fresh water for at least 12 hours, and the sample shall be drenched to cool down during the test.

4.7.2.2 The length of the sample shall be at least 40 times of the nominal diameter of the rope, and the sample shall be terminated in the same way as the production rope (including the jacket or sleeve). The sample shall neither be stretched to more than 5% MBS before the test nor be subjected to the cycle or retention under tension. This method is not applicable to the test of used ropes.

4.7.3 Test procedure

4.7.3.1 The sample shall be tested as follows, and each of the following cyclic loads shall be applied within 1 minute:

(1) Tension range of 10% - 50% MBS for 17,000 cycles;

(2) Tension range of 5% - 55% MBS for 5,500 cycles;

(3) After the cycles, disassemble the full rope jacket and sand barrier, to check and record the fiber wear inside the rope.

4.7.4 Description on acceptance of test results

4.7.4.1 After the end of the test cycle, no fusing or severe adhesion damage of the subrope in the full rope is allowed; otherwise, the rope test fails.

Section 8 3-T ENDURANCE TEST

4.8.1 General requirements

4.8.1.1 The 3-T endurance test is to test the creep resistance of fiber ropes by measuring the period in which the load of the fiber rope maintains at a high level (the load is generally 90%–95% of the minimum breaking strength) before failure. All tests shall be carried out using the same loading procedures to maintain consistency. This includes any cycling procedures and load ranges.

4.8.2 Sample

4.8.2.1 For fiber ropes, at least 5 new subropes and 5 subropes extracted from the full rope cycle durability test are typically tested at two different tension levels.

4.8.2.2 If the test is conducted in air, the rope shall not be pre-soaked, so as to keep the temperature stable during the test. It is best to test in the water or air with temperature conditioned. For mooring applications, the recommended basic test temperature is 20℃.

4.8.3 Test procedure

4.8.3.1 Detailed test procedure is as follows:

(1) Install the sample on a test machine;

(2) Apply 10 cycles of load at 1% –50% MBS for the sample;

(3) Load the sample to the specified value, keep the load constant, and record the image of load and time;

(4) Measure the time from reaching the specified load to the rope breaking.

4.8.4 Description on acceptance of test results

4.8.4.1 In order to determine the slope of 3-T design curves, the breaking time under at least two loads is required.

4.8.4.2 It is suggested to select an appropriate high load to control the test time within 4 days.

4.8.4.3 Measure the time to obtain the rope rupture under different loads, and the time to rupture (TTR) under the constant load F for data processing shall be based on:

$$F = B - A \cdot \log_{10}\left(TTR\right) \quad \text{kN}$$

Where, F — the constant tension value, kN;

TTR — the time to rupture, *s*.

According to the above formula, the processing data are derived to obtain the coefficients A and B, so as to estimate the service life of the rope under high load.

Section 9 TORQUE MATCH WITH STEEL WIRE ROPE

4.9.1 General requirements

4.9.1.1 This test is required for fiber rope connected with a torque steel wire rope (6-strand or 8-strand) in a permanent mooring. The test is intended to demonstrate that the torque characteristics between the fiber rope and the steel wire rope are compatible.

4.9.2 Sample and test machine

4.9.2.1 The length of the fiber rope sample shall be equal to that of the wire rope.

4.9.2.2 The test machine shall be equipped with a rotation angle measuring device and a data acquisition system to measure and record the rotation angle.

4.9.3 Test procedure

4.9.3.1 Detailed test procedure is as follows**:**

(1) Equal length full rope samples of the fiber rope and the wire rope shall be connected and arranged in a test machine with both outer ends fixed;

(2) The samples shall be loaded to 2% of the wire rope MBS, and the length of each rope and the lay length of the wire rope shall be measured;

(3) The samples shall be cycled 10 times between 2% and 20% of wire rope MBS at a period of 20 to 30 sec.;

(4) The samples shall be held at the 20% wire rope MBS;

(5) The samples shall be cycled 10 times with a load range of 10% to 30% of wire rope MBS at a period of 20 to 30 sec., and the angular rotation of the termination for each cycle shall be recorded.

4.9.4 Description on acceptance of test results

4.9.4.1 The average cyclic degree of rotation per lay length of the wire rope shall be calculated and shall not exceed 5°.

Section 10 AXIAL COMPRESSION FATIGUE TEST

4.10.1 General requirements

4.10.1.1 This test is required for aramid rope and similar ropes and is intended to demonstrate that the aramid rope has adequate resistance against axial compression fatigue failure.

4.10.2 Sample

4.10.2.1 The length of the sample shall be at least 40 times of the nominal diameter of the rope.

4.10.3 Test procedure

4.10.3.1 Detailed test procedure is as follows:

(1) Cycle the rope from a trough tension of 1% of MBS to a peak tension of 20% of MBS at a period of less than 1 minute per cycle for at least 2,000 cycles;

(2) Tension the rope to break, using the test procedure of Section 4.3.3, to determine residual strength.

4.10.4 Description on acceptance of test results

4.10.4.1 If the residual strength is greater than 95% MBS, then the rope is considered to pass the axial compression fatigue test.

Section 11 CREEP RATE VERIFICATION TEST

4.11.1 General requirements

4.11.1.1 This test is required for HMPE rope only and is intended to demonstrate that the creep model generating creep data for HMPE creep analysis and creep rupture analysis (Section 6, CHAPTER 3) is appropriate.

4.11.1.2 Creep test shall be carried out under the condition of controlled temperature. During the test, the temperature shall be kept as constant as possible, and the temperature fluctuation range shall be controlled within 5℃.

4.11.1.3 The ambient temperature and humidity shall be recorded. For the test, the test temperature shall not exceed 25℃ and the tension shall not be greater than 55% MBS.

4.11.2 Sample

4.11.2.1 Generally, at least 4 new subropes shall be tested at two different tensions.

4.11.3 Test procedure

4.11.3.1 Detailed test procedure is as follows:

(1) The test shall be performed for a constant load and a constant temperature. The load level and temperature shall be selected to be relevant to the project where the rope will be applied, so that the creep rate in Regime II (3.6.2.1) can be established with confidence;

(2) The duration is such that the sample shows a constant creep rate with time for at least 24 hours, and the load level and temperature shall be kept as constant as possible within the duration. Load and elongation shall be recorded during the entire duration at least hourly;

(3) The creep rate is obtained from the strain versus time data over the end of the test period (e.g., the last 24 hours), which shall be compared with the creep rate generated by the creep model for the specific load and temperature;

(4) The total strain measured during Regime I of the test shall also be reported.

Chapter 5 SURVEYS OF OFFSHORE INSTALLATION

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 The storage, transportation and installation of fiber ropes shall be carried out in accordance with the approved documents and procedures. To prepare such documents and procedures, analysis, calculation and check shall be conducted according to the loads applied in each stage of the storage, transportation and installation process, so as to keep the loads and bending radius of fiber ropes in the range of design permission during operation and treatment.

5.1.1.2 The storage, transportation and offshore installation of fiber ropes shall not only meet the technical requirements of this chapter, but also comply with the relevant applicable provisions of Chapter 9 of API RP 2SM and Chapter 5 of API RP 2I.

5.1.1.3 During the storage and transportation, necessary measures shall be taken to prevent the fiber rope from being exposed to sunlight and getting wet, and the ambient temperature shall not exceed the allowable value of the fiber rope.

5.1.1.4 Fiber ropes are generally stored, transported and installed in the mode of drum winding, during which necessary measures shall be taken to prevent the fiber ropes from the damage caused by the friction between fiber ropes and the drum during winding and transportation.

5.1.1.5 It shall be noted that the bending radius at the termination shall not be less than the minimum allowable value specified by the manufacturer.

5.1.1.6 Metal termination fittings shall be wound or stored separately to avoid damaging the fiber ropes.

5.1.1.7 Foreign matter (gravel, etc.) shall be prevented from contacting the fiber rope.

5.1.1.8 The fiber rope of the mooring system shall comply with the relevant safety regulations of the sea area and region where the facility is located during offshore installation. Before installation, the installation procedures shall be submitted to Party A and the third party for review. The installation deviation shall be specified in the installation procedure, and shall be properly considered in design calculation.

5.1.1.9 The operation process of fiber ropes includes, but is not limited to, the transportation, loading, spring line operation, laying, tie-back and tensioning of fiber ropes.

Section 2 STORAGE AND TRANSPORTATION

5.2.1 General requirements

5.2.1.1 Care shall be taken to select the packaging, sea transportation and storage system of fiber ropes.

5.2.1.2 The designer shall pay special attention to the production process, onshore and offshore transportation and handling, storage and segmentation in the yard, installation and recovery (if applicable) of fiber ropes.

5.2.1.3 For the fiber rope, the operation instruction manual shall be provided, and the storage and transportation of the fiber rope shall be conducted according to the requirements of the instruction manual, so as to avoid damage to the fiber rope during storage and transportation. The storage and transportation instructions shall at least include the lifting requirements, winding requirements, transportation requirements and storage requirements.

5.2.1.4 The storage and transportation instructions shall specify in detail the handling restrictions (e.g. the restriction of the local and overall pressure on the rope) and the minimum bending radius (e.g. winding) of the fiber rope. For extra-long ropes with large diameters, it may be necessary to put the fiber ropes into special storage tanks.

5.2.1.5 Fiber ropes shall be stored in a flat, open place to prevent accidental movement and avoid being placed close to dangerous substances such as heat sources, fire sources and chemicals.

5.2.1.6 Each storage drum of fiber ropes shall be clearly marked with its contents and provided with traceability.

5.2.1.7 The finished fiber ropes shall be firmly packed with weatherproof materials.

5.2.1.8 During storage and transportation, the fiber ropes shall be protected against the effects of the damages caused by high temperature, chemical and ultraviolet radiation.

5.2.1.9 During the storage and/or winding of the fiber rope, it shall be avoided to use the metal pieces with sharp and/or protruding edges to scrape the fiber rope. Metal fittings of fiber ropes shall be packaged or stored separately to prevent abrasion of fiber ropes.

5.2.1.10 For the hoisting of the fiber rope drum, special hoisting poles and rigging are required. Before hoisting, the hoisting poles and rigging shall be carefully checked and installed correctly. Hoisting shall be fulfilled by trained and experienced hoisting operators to prevent the fiber rope drum from falling during hoisting.

Section 3 SURVEYS OF OFFSHORE INSTALLATION

5.3.1 General requirements

5.3.1.1 Generally, the contact between the fiber rope and the seabed shall be minimized. However, in some installation cases, it is necessary to lay the fiber rope in advance before connecting with the floating structure. If the fiber rope passes the particle ingress resistance test, it is allowed to pre-lay the fiber rope on the seabed.

5.3.1.2 A complete, detailed procedure for mooring system installation and recovery (if applicable) shall be formulated for the installation and recovery operation of fiber ropes.

5.3.2 Marine environmental condition

5.3.2.1 The offshore installation of the fiber rope mooring system is generally limited by sea state and weather, and the expected marine environmental condition in the operation area shall be evaluated in detail to ensure that there is enough window period for construction.

5.3.2.2 Offshore installation of the fiber rope mooring system involves many operations, each of which has its own allowable environmental conditions.

5.3.3 Investigation of construction site

5.3.3.1 Before installation, divers or remotely operated underwater vehicles shall survey the installation site and its nearby areas, and verify the seabed condition of the installation site, so as to confirm that there are no obstacles or debris. Emergency procedures for removing the obstacles on site shall also be provided. In the process of plan preparation, the relevant information about field investigation shall be fully considered.

5.3.4 Document review

5.3.4.1 For offshore installation operations, the documents to be submitted for review include but are not limited to:

(1) Installation operation plan;
(2) Quality survey plan;
(3) Risk analysis;
(4) Pre-survey procedures;
(5) Positioning procedures;
(6) Installation procedures;
(7) Post-survey procedures;
(8) Deck layout;
(9) Shipment layout;
(10) Layout of hoisting rigging;
(11) Calculation and analysis for shipment;
(12) Calculation and analysis for hoisting;
(13) Calculation and analysis for installation.

5.3.5 Data submission

5.3.5.1 After the installation is completed, relevant data shall be sorted out and submitted, including construction data, ROV image data, positioning data and completion reports, and the submitted data shall be complete and in compliance with the requirements.

5.3.6 Laying

5.3.6.1 The fiber rope laying procedure shall be submitted for review, including but not limited to the following contents:

(1) Loading and spring line operation plan of fiber ropes;

(2) Fiber rope laying plan;

(3) Fiber rope pre-tensioning plan (if applicable);

(4) Wet storage plan of fiber ropes;

(5) Analysis of fiber rope laying;

(6) Contingency plans.

5.3.6.2 Before laying the fiber rope according to the approved procedure, the following pre-investigation items shall be carried out:

(1) ROV carries out visual survey on all installed structures, such as anchor piles/suction anchors, quick female joints and completion conditions of mooring foundation;

(2) Check the status of existing subsea infrastructure, record any subsea infrastructure pre-installed on site, and verify the location, so as to ensure that there will be no collision during fiber rope laying;

(3) ROVs shall be used for visual investigation of fiber rope laying and wet storage routes, and sonar scanning shall be carried out along each laying and wet storage route. Any abnormality or debris found during the investigation shall be reported. Where feasible, these anomalies shall be drawn, recorded and eliminated.

5.3.6.3 Generally, the installation operation depends on the mooring system under installation, available installation equipment, weather and site conditions. During the laying of fiber rope mooring site, the following contents shall be carried out in sequence:

(1) Before on-site installation, mobilization of construction resources and test of equipment shall be carried out;

(2) After everything is ready, lay the fiber rope mooring system according to the approved procedures;

(3) During system laying, the following field tests and measurements shall be carried out (if applicable):

① Calibration and verification of the positioning and measuring system;

② Bottoming measurement of fiber ropes;

③ Torsion measurement of fiber ropes.

5.3.6.4 Offshore installation shall be carried out according to the instruction manual of fiber rope, so as to minimize the damage during loading, unloading and installation. During offshore laying, the following matters shall be noted:

(1) Before the spring line operation and laying of fiber ropes, all potential contact surfaces and sharp edges on the equipment and spring line of the fiber rope as well as the laying path shall be inspected to ensure that no damage may be caused to the fiber rope;

(2) Deck protection shall be provided for fiber ropes, and polyethylene ropes and/or PE foil shall be wrapped around drums and winches to protect fiber ropes against sharp edges;

(3) Generally, the contact between the fiber rope and the seabed shall be minimized, but in some installation cases, it is necessary to lay the fiber rope in advance before connecting with the floating structure. If the fiber rope passes the particle ingress resistance test, it is allowed to pre-lay the fiber rope on the seabed;

(4) The fiber rope laying route shall be arranged in such a way as to avoid damage caused by friction, cutting or excessive bending.

5.3.6.5 Post-laying investigation

ROVs shall conduct post-laying investigation for the pre-laid fiber rope mooring system, and record the route of fiber ropes on the seabed. ROVs shall investigate the torsion of fiber ropes. If the torsion exceeds the acceptance standard, countermeasures shall be taken to release the torsion of fiber ropes.

5.3.7 Tie-back

5.3.7.1 The procedures for fiber rope tie-back shall be submitted for review, including but not limited to the following contents:

(1) Unit limit plan;

(2) Fiber rope tie-back plan;

(3) Fiber rope tension plan;

(4) Calculation and analysis for unit limits;

(5) Calculation and analysis for fiber rope tie-back:

(6) Calculation and analysis for fiber rope tension;

(7) Contingency plans.

5.3.7.2 Before the connection with the unit, visual measurement and sonar scanning shall be used to investigate at the designated location, and complete pre-installation investigation reports shall be provided. The investigation contents include:

(1) As-built status of anchor piles, quick connectors (if applicable) and fiber ropes;

(2) Visual inspection of ROVs to all the installation items;

(3) The condition of the rigging for fiber rope fishing and retreating;

(4) Visual investigation by ROVs on the mooring connection routes of fiber ropes and sonar scanning along each fiber rope route;

(5) Marking and checking the position of any underwater infrastructure installed in advance on site to ensure no collision during fiber rope connection;

(6) Identification of any seabed anomalies or debris.

5.3.7.3 Before tie-back of the fiber rope mooring system, the following work shall be done:

(1) Enough weather window shall be reserved for the tie-back of some fiber ropes, enabling the unit to be in a safe and stable state;

(2) The unit limit test is required, and formal tie-back operation may be carried out only if the limit test meets tie-back requirements;

(3) Pre-tensioning operation shall be designed reasonably to obtain the permanent elongation and increase the rope stiffness as much as possible, and the pre-tensioning force, duration and elongation of each rope shall be recorded and compared with the design value;

(4) Installation and test shall be carried out for the construction equipment.

5.3.7.4 During the site tie-back of the fiber rope moorings, the weather and site conditions that meet the construction requirements shall be ensured, and the following contents shall be carried out in sequence:

(1) Tie back the fiber rope mooring system according to the approved procedures;

(2) After the tie-back of all fiber rope mooring is fulfilled for the first time, lifting and tensioning can be started. The unit shall be kept in a balanced state (with a small inclination) as much as possible in the process of lifting, and the diagonal lifting and tensioning are usually carried out by segmented lifting method.

5.3.7.5 After all the tie-back of the fiber rope mooring system is completed, the following surveys shall be carried out:

(1) Divers shall use inclinometers to measure the top chain inclination of all fiber ropes underwater, and record the draft of the unit, mooring center position and other data;

(2) ROVs investigate the fiber rope after tie-back, and record its key point coordinates, torsion number and underwater state.

Chapter 6 IN-SERVICE SURVEYS

Section 1 IN-SERVICE SURVEYS

6.1.1 General requirements

6.1.1.1 Generally, in-service surveys shall meet the relevant requirements of CCS *Rules for Classification of Mobile Offshore Units*, CCS *Rules for Classification of Offshore Floating Installation* and API RP 2I.

6.1.1.2 For the purpose of maintaining the validity of the classification certificate of offshore mooring system with fiber ropes, various surveys shall be carried out as specified in this section, as appropriate. Such surveys may be extended by CCS Surveyors at their professional judgment, and the owner is to provide appropriate survey conditions accordingly.

6.1.1.3 During the survey, if any damage or defect of fiber ropes for offshore position mooring systems is found and considered necessary to deal with immediately, the owner or his representative shall take the initiative to inform CCS.

6.1.1.4 It is the responsibility of the owner to apply to CCS for all surveys necessary for the maintenance of the validity of certificates and to make preparations and take safety precautions for surveys in accordance with the requirements.

6.1.1.5 The Guidelines may be referred to for the implementation if the entrusting party applies for the certification surveys of the fiber ropes used for offshore position mooring systems.

6.1.2 Annual surveys

6.1.2.1 All fiber ropes for the classed mooring systems shall be surveyed annually. The annual survey shall be carried out within 3 months before and after each anniversary date from the date of the initial classification survey or of the completion of the last special survey.

6.1.2.2 The annual survey shall include the following items:

(1) The Surveyor should review the records of anchor leg re-tensioning and confirm with designer that adequate chain/wire segments are available for further re-tensioning due to plastic deformation such that the bottom end of the fiber rope does not touch the ground, while the top end does not come into contact with the fairleads and stays below the water surface;

(2) The Surveyor shall verify that recorded values of creep are in accordance with the anticipated design values. Any deviance from design values shall be justified by the designer, and appropriate remedial action shall be taken accordingly;

(3) The Surveyor shall confirm that the pre-tension of mooring lines shall be within the designer recommended limits.

6.1.3 Special surveys

6.1.3.1 All fiber ropes for the classed mooring systems shall be specially surveyed. The special survey may be commenced at the annual survey prior to its expiry date and be progressed during the succeeding year with a view to completion by its expiry date. When the special survey is commenced before the annual survey prior to its expiry date, the entire survey is to be completed within 15 months from the date of commencement of the special survey if such work is to be credited to the special survey. Only in this case can be items executed at the start of the special survey be credited as an integral part of the special survey. For the fiber ropes used in mooring systems with unconventional design, laid-aside state or abnormal environment, the special survey shall be determined according to the specific circumstances.

6.1.3.2 Special survey shall include the following items:

(1) A special survey requires a detailed survey plan to ensure that quantitative information is available in case of emergency, and the surveyor shall also have a list of items to be surveyed. The special survey plan shall specify the specific methods and means used to survey the operating conditions of the mooring system;

(2) Special survey shall include a dry-docking or underwater inspection (ROV or diver), and all components of mooring system shall be examined to the satisfaction of the attending Surveyor;

(3) The re-tensioning record of the anchor leg of the fiber rope shall be reviewed and

confirmed with the designer that adequate lengths of chain/wire segments are available for further re-tensioning due to plastic deformation such that the fiber rope does not come into contact with the fairlead and stays below the water surface;

(4) The recorded values of creep are shall be confirmed in accordance with the anticipated design values. Any deviance from design values shall be justified by the designer, and appropriate remedial action shall be taken accordingly;

(5) The depth of the fiber rope from the water surface and the height from the seabed during underwater inspection shall be confirmed to meet the design approval drawings or the manufacturer's technical requirements;

(6) The torsional strength of fiber ropes during underwater inspection shall be confirmed to meet the design approval drawings or the technical requirements of the manufacturer;

(7) The pre-tension of fiber ropes shall be confirmed within the recommended design limit;

(8) For the survey of the appearance of fiber ropes, special attention shall be paid to the condition of fiber rope terminal;

(9) Foreign objects in the rope body or gap shall be checked and removed if any;

(10) Any marine organism affecting the condition of the rope shall be removed without damaging the rope.

6.1.4 Special event surveys

6.1.4.1 A special event survey is any survey which is not a periodical survey. A special event survey shall be requested by the owner or his agent of the mooring system in any of the following cases:

(1) Any damage, defect or failure of fiber ropes for mooring system occurs;

(2) If the special events occurred (such as severe storms or accidents including falling objects, collision, and contact interference of underwater objects) approaches or exceeds the design limit working condition of fiber rope, and/or the owner considers it is necessary to carry out targeted inspection or replace the parts of mooring anchor leg, it is necessary to apply to CCS for special event surveys;

(3) Postponement of surveys.

6.1.4.2 The scope of special event surveys for special events shall be determined according to the purpose of survey. For example, if the survey is carried out due to the falling of an object, the survey should be limited to the area where the object may be damaged.

6.1.4.3 Special event surveys shall be carried out at least according to the annual survey requirements after the special event of severe storms (that is, the working condition close to the design limit). When applicable, some survey measures with special survey requirements shall be considered.

6.1.4.4 In the patrol survey for underwater mooring systems, if any damage is found to the fiber rope, countermeasures shall be taken in time according to the scope and depth of the damage, including additional protection, repair and replacement.

Section 2 IN-POSITION SURVEY AND MAINTENANCE

6.2.1 General requirements

6.2.1.1 The owner or operator of the mooring system shall formulate the survey, maintenance and condition evaluation plan of the fiber rope. The plan shall be formulated jointly by the mooring system operator, the rope manufacturer and CCS, so that all parties can reach an agreement on the overall safety assessment of a given device.

6.2.1.2 During the operation, the tension or geometry of the fiber rope shall be monitored regularly, and if necessary, the fiber rope shall be adjusted to maintain the positioning performance.

6.2.2 In-position survey

6.2.2.1 In case of the following situations, an in-position survey shall be conducted:

(1) During the in-position service, if the tension change of mooring system under mild environmental conditions exceeds ±5% of the pre-tension;

(2) When the typhoon approaches the level considered in mooring system design.

6.2.2.2 If there is no typhoon, it is suggested to adjust the mooring system every five years to offset the relaxation of fiber ropes caused by creep.

6.2.2.3 Records shall be kept of in-position monitoring and test data during service.

6.2.3 In-position maintenance

6.2.3.1 Check the mooring system underwater. If any damage of the fiber rope is found, timely develop the countermeasures according to the scope and depth of the damage, including additional protection, repair and replacement decisions. The survey contents include:

(1) Overall maintenance: detect the growth state of marine organisms in the fiber rope and check the torsion state of the fiber rope;

(2) Eye maintenance: check whether the eye position of the fiber rope is damaged. Any damage found shall be reported to CCS, with the causes analyzed and the treatment measures formulated. Repair results shall also be reported to CCS;

(3) Jacket: check whether the jacket is damaged, and record the damage degree, if any; if the damage does not penetrate the jacket, and the subrope is intact, there is no need to repair the jacket; if the damage penetrates the jacket but does not penetrate the sand barrier, and the subrope is intact, appropriate repair measures shall be taken according to the damage degree of the jacket;

(4) Sand barrier: check whether the sand barrier is damaged. If the sand barrier is damaged but not penetrated, evaluation shall be conducted, and measures shall be taken accordingly;

(5) Subrope: If the sand barrier is damaged, check the subrope. Untie the jacket about 0.3 meters away from the damaged area, calculate and record the number of damaged subropes, record the identification marks of damaged subropes, and evaluate the damage degree of subropes, so as to determine whether to use the rope.

6.2.3.2 For maintenance operations at sea, it is necessary to ensure perfect facilities and equipment and strictly follow the procedures prescribed by authoritative organizations. The repair procedure shall include:

(1) Describe the maintenance of the rope, and the in-line splicing or terminal splicing technology that can be used to restore the strength of the rope;

(2) Describe the repairable damage of the outer jacket and sand barrier, and the repair requirements of various facilities and equipment;

(3) Record the situation of the damaged area in detail;

(4) Remove the obviously worn part in the load-bearing part of the rope;

(5) Prevent the wear particles from further entering the load-bearing part of the rope;

(6) Ensure that the rope will not be further damaged after rearrangement.

The quality control procedures of all rope repair, in-line joints and terminations shall be maintained same as those of new ropes.