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GB 50728-2011

Technical code for safety appraisal of engineering structural strengthening materials

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the People's Republic of China;**

**General Administration of Quality Supervision,
Inspection and Quarantine of the People's Republic of
China.**

Foreword

This Code is prepared by Sichuan Institute of Building Research and China Huashi Enterprises Co., Ltd in collaboration with the relevant organizations, in accordance with the requirements of Construction Standard [2001] No. 87 issued by the former Ministry of Construction - *Notice on Printing and Distributing the "Development and Revision Plan of National Engineering Construction Standards from 2000 to 2001"*.

In the course of compilation of this Code, the compilation group carried out special studies on the methods for safety appraisal of various engineering structural strengthening materials and products, performed extensive investigation and analysis as well as verification tests and test trials on key projects, summarized the experience in performance design, quality control and engineering application of China's strengthening materials and products over the past 20 years, and made comparative analysis and reference to foreign advanced standards and norms. On this basis, the opinions of the relevant organizations and the general public were widely solicited in various ways and tested, and the test results were evaluated. Accordingly, the main provisions have also been repeatedly revised and finalized after review.

This Code comprises 12 chapters and 19 annexes, with the main technical contents as follows: general provisions, terms, basic requirements, structural adhesives, injection grouting for cracks, cement-based grouting for structural strengthening, polymer modified cement mortar for structural strengthening, fibre reinforced polymer, steel wire ropes, synthetics modified concrete and mortar, steel fibre concrete, and post-installed fastenings.

The provision(s) of this Code printed in bold type is (are) mandatory one(s) and must be enforced strictly.

The Ministry of Housing and Urban-Rural Development of the People's Republic of China is responsible for the administration of this Code and the interpretation of mandatory provisions. The Sichuan Provincial Department of Housing and Urban-Rural Development is responsible for the daily administration of this Code. The Sichuan Institute of Building Research is responsible for the interpretation of specific technical contents. In order to fully improve the quality of codes, all relevant organizations are kindly requested to sum up and accumulate experience and data in actual engineering practices during the process of implementing this Code. The relevant opinions and advice, whenever necessary, can be posted or passed on to the Administration Committee of Codes for Building Appraisal and Reinforcement of the Ministry of Housing and Urban-Rural Development at No. 55, Third North Section of the

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1 General provisions

1.0.1 This Code is formulated with a view of strengthening the quality control and technical management of relevant materials and products used in the engineering structural strengthening to ensure the quality and safety of the engineering structural strengthening projects.

1.0.2 This Code is applicable to the safety inspection and appraisal of materials and products used in structure strengthening engineering.

1.0.3 The conclusions on the safety appraisal of application of engineering structural strengthening materials and products shall be taken as the basis for the selection of materials for engineering strengthening, and shall not be used for replacing the sampling of strengthening materials and products at the construction site for re-inspection.

1.0.4 The safety appraisal of application of engineering structural strengthening materials and products shall be accepted by the inspection and appraisal institutions with corresponding qualifications approved by the competent authorities of the nation.

1.0.5 This Code shall be used in conjunction with the following current national standards, namely GB 50367 *Code for design of strengthening concrete structure*, GB 50702 *Code for design of strengthening masonry structures*, GB 50550 *Code for acceptance of constructional quality of strengthening building structures*, etc.

1.0.6 Not only the requirements stipulated in this Code, but also those in the current relevant standards of the nation shall be complied with, during the safety inspection and appraisal of application of engineering structural strengthening materials and products.

2 Terms

2.0.1 Appraisal

A set of work activities carried out for demonstrating the reliability (including the safety, suitability and durability) of a strengthening material or product in involvement of load-bearing members of engineering structure under stress.

2.0.2 Verification test

A test to prove whether the properties of a strengthening material or product meet the specified requirements.

2.0.3 Sampling

The process of randomly selecting or composing samples according to certain rules.

2.0.4 Sample

One or more individuals taken from the population in the prescribed manner, for providing information about the population as a basis for the determination of a particular feature of the population.

2.0.5 Characteristic value of a material property

Basic representative value of material properties. This value shall be determined based on a certain quantile of the probability distribution of material properties that meet the specified quality. Normally, this quantile is taken as 0.05 in the engineering structure.

2.0.6 Substrate

In the bonding engineering, both strengthening member and existing structure member are adherents. However, the two are different in properties. For ease of differentiation, the existing structure member or the portion to be adhered thereto is referred to as a substrate.

2.0.7 Structural adhesive

An adhesive that is used for bonding of load-bearing structures or members and is able to withstand long-term design stress and environmental effects, referred to as structural adhesive.

2.0.8 Primer

Cement mortar prepared using modified polymer for improving the bonding properties.

2.0.16 Grouting material

A high-flow injection material with good plasticity. The grouting materials for engineering structures shall have the physical properties of non-delamination, non-differentiation, minimal curing shrinkage and stable volume, along with the bonding and mechanical properties that meet the specified requirements. Normally, grouting materials are divided into modified epoxy grouting materials and modified cement-based grouting materials.

2.0.17 Injection grouting for cracks

A series of grouting material, mainly used for concrete cracks and masonry cracks with a pressure injection width of 1.5mm to 5.0mm. Due to the use of no coarse aggregate, grouting material is renamed as “injection grouting” to show the difference with the general grouting material.

2.0.18 Fibre reinforced polymer

Composite materials prepared using specially treated high strength or high modulus continuous fibres arranged in accordance with certain rules, with the fibre-reinforced effect.

2.0.19 Fibre concrete

Composite materials prepared by mixing staple fibres distributed evenly in irregular directions in cement-based concrete. When mainly used for improving the strength of concrete, it is called fibre-reinforced concrete. When mainly used for improving the crack resistance or toughness of concrete, it is generally called fibre modified concrete.

2.0.20 Stainless-steel fibre reinforced concrete

It refers only to the stainless-steel staple fibre produced by melt extraction, mixed with nickel and chromium components. It is suitable for concrete or mortar layer strengthening, and is generally applied to important structures with strict requirements for corrosion protection and heat resistance.

2.0.21 Stainless wire ropes

Steel wire ropes using metal strands made of fine stainless-steel wires, with no grease coated on the inside and the outside. In the engineering structural strengthening projects, they are generally used for the reinforcement of polymer

3 Basic requirements

3.0.1 Any engineering structural strengthening materials and products involved in engineering safety must pass the safety appraisal according to the requirements of this Code.

3.0.2 The strengthening materials or products applying for safety appraisal shall meet the following conditions:

- 1 Have the ability to supply in batches;
- 2 Basic experimental research data is complete, and pilot projects or engineering trials have been carried out;
- 3 Toxicity and combustion properties of materials or products have passed the inspection and appraisal by the hygiene department and the fire department, respectively.

3.0.3 The sampling for safety appraisal of strengthening materials or products shall meet the following requirements:

- 1 Samples for safety appraisal shall be composed of the samples taken by the independent appraisal institutions from the inspection lots according to certain rules. Under no circumstances shall we use specially prepared or selected samples or use the ones taken by the entrusting party.
- 2 The samples (or specimens, similarly hereinafter) required for each property item shall be taken from at least 3 inspection lots. At least one set of samples shall be taken from each lot. The number of samples per set shall meet the following requirements:
 - 1) When the inspection results are expressed as a mean value, the number of effective samples shall not be less than 5;
 - 2) When the inspection results are expressed as a characteristic value, the number of effective samples shall not be less than 15.

3.0.4 Inspection of safety appraisal and sorting of inspection results shall meet the following requirements:

- 1 When to be processed into specimens, the samples drawn according to the requirements of Article 3.0.3 in this Code shall be processed in accordance with the requirements of inspection methods and criteria. In addition, conditioning shall be carried out before inspection.
- 2 The test methods used for safety appraisal shall meet the requirements of Annex A in this Code.

4 Structural adhesives

4.1 General requirements

4.1.1 The structural adhesives for strengthening of engineering structures shall be divided into adhesive for concrete, adhesive for structural steel, adhesive for masonry and adhesive for timber, according to different adhesive substrates. Each adhesive shall be divided into room temperature curing, low temperature curing and high-wet surface (or underwater) curing structural adhesives, according to different field curing conditions. If necessary, it shall be distinguished into general purpose structural adhesive, temperature resistant structural adhesive and medium corrosion resistant structural adhesive, according to different service conditions. During safety appraisal, sampling, inspection and assessment shall be carried out, respectively.

4.1.2 The highest service temperature category of room temperature curing structural adhesives shall be indicated in the manual, according to the following requirements. The corresponding conformity assessment criteria are set out in the sections of this chapter:

- 1 The applicable temperature range for Class I is -45°C to 60°C;
- 2 The applicable temperature range for Class II is -45°C to 95°C;
- 3 The applicable temperature range for Class III is -45°C to 125°C.

4.1.3 As for structural adhesives for engineering structures, the design working life shall meet the following requirements:

- 1 It should be 30 years when used in the strengthening of existing buildings;
- 2 It should be 50 years when used for new construction (including the strengthening and retrofitting of new construction);
- 3 When the structural adhesive reaches the design working life, if its adhesive ability has not been appraised as significant degradation, its working life may be allowed to be extended properly. However, the extended life shall be tested by the appraisal agency and jointly determined with the building property owner.

4.1.4 The structural adhesive passing the safety appraisal, where it is found to change the binder, curing agent, modifier, additives, pigments, fillers, carriers, mix proportion, manufacturing process, curing conditions, etc., shall be regarded as the unidentified adhesive.

4.1.5 During the application for safety appraisal, a copy of the operation manual with title, number and date shall be provided along with the research report. The manual shall include at least the following items:

- 1 basic chemical composition and carrier type of the structural adhesive;
- 2 preparation instructions, including the components, ratio, feeding sequence, environmental control required for adhesive preparation, and working life (operable time) of prepared structural adhesive;
- 3 recommended substrate surface treatment method and its detailed description;
- 4 construction environment control against adhesive;
- 5 detailed description on the operations and requirements of coating or pressure injection process;
- 6 curing procedures, including the description on typical time, temperature, pressure and limits of each parameter;
- 7 storage requirements and storage life.

4.2 Structural adhesive for concrete substrates

4.2.1 During safety appraisal of the structural adhesives using concrete structural members as the substrates for steel, fibre reinforced polymer and anchor bonding, and the primer and putty that need to be used in conjunction with the structural adhesives, the requirements of this section shall apply.

4.2.2 As for room temperature curing structural adhesives for concrete substrates, the safety appraisal shall include the basic property appraisal, long-term property appraisal and appraisal of resistance to medium corrosion. During appraisal, the following requirements shall be complied with:

- 1 The basic properties of structural adhesives shall meet the requirements of Table 4.2.2-1, Table 4.2.2-2 or Table 4.2.2-3, respectively.
- 2 The long-term property appraisal of structural adhesives shall meet the following requirements specified in Table 4.2.2-4:
 - 1) The structural adhesives with a design working life of 30 years shall be tested for damp heat ageing resistance ability;
 - 2) The structural adhesives with a design working life of 50 years shall be tested for damp heat ageing resistance ability and long-term stress resistance ability;
 - 3) The structural adhesives bearing dynamic loads shall be tested for fatigue resistance ability;
 - 4) The structural adhesives used in cold regions shall be tested for freeze-thaw resistance ability.
- 3 The medium corrosion resistance ability of structural adhesives shall meet the requirements of Table 4.2.2-5.

Table 4.2.2-1 -- Criteria for basic property appraisal of structural adhesives for concrete substrates, designed for steel bonding

5 Injection grouting for cracks

5.1 General requirements

5.1.1 The injection grouting for sealing and filling concrete and masonry cracks shall be divided into modified epoxy-based injection grouting and modified cement-based injection grouting, in accordance with different bonding materials in use. There are two types of modified epoxy-based injection grouting, namely room temperature curing and low temperature curing. Cement-based injection grouting can be used at both room temperature and high temperature. During safety appraisal, sampling, inspection and appraisal shall be carried out, respectively.

5.1.2 The design working life of the injection grouting for cracks in compliance with the safety requirements of this Code shall meet the following requirements:

- 1 For modified epoxy-based injection grouting for cracks, the requirements of Article 4.1.3 in this Code shall apply.
- 2 The modified cement-based injection grouting for cracks used at room temperature shall be designed with a design working life of not less than 50 years. The injection grouting for cracks used at high temperature shall be designed with a working life of not greater than 30 years. The working life shall be agreed upon by the user and the design organization.

5.1.3 The injection grouting for cracks passing the safety appraisal, where it is found to change the materials, mix proportion or process, shall be regarded as the unidentified injection grouting.

5.2 Safety appraisal of injection grouting for cracks

5.2.1 The test items and acceptable indices for safety appraisal of modified epoxy-based injection grouting for cracks shall meet the requirements of Table 5.2.1.

Table 5.2.1 -- Criteria for safety appraisal of modified epoxy-based injection grouting for cracks

Test item		Test condition	Acceptable indices for appraisal
Grout properties	Splitting tensile strength (MPa)	CARRY out 7 days of curing after grout casting.	≥ 7.0
	Flexural strength (MPa)	PERFORM the testing at $(23 \pm 2) ^\circ\text{C}$ under the condition of $(50 \pm 5) \%RH$ at a loading speed of 2mm/min	≥ 25 , and must not be disintegrated
	Compressive strength (MPa)		≥ 60

6 Cement-based grouting material for structural strengthening

6.1 General requirements

6.1.1 During safety appraisal of cement-based grouting material for structural strengthening, the requirements of this chapter shall apply.

6.1.2 When the test items and acceptable indices for safety appraisal given in different standards are below the requirements of this Code, the requirements of this Code must be enforced for cement-based grouting material for engineering structural strengthening.

6.1.3 Cement-based grouting material in use shall meet the safety requirements of this Code. The working life after structural strengthening shall be determined according to Item 2 of Article 5.1.2 in this Code.

6.1.4 The grouting material passing the safety appraisal, where it is found to change the material compositions, mix proportion or process, shall be regarded as the unidentified grouting material.

6.2 Safety appraisal of cement-based grouting material

6.2.1 The test items and acceptable indices for safety appraisal of cement-based grouting material for engineering structural strengthening shall meet the requirements of Table 6.2.1-1 and Table 6.2.1-2.

Table 6.2.1-1 -- Criteria for safety appraisal of cement-based grouting material for structural strengthening

Test item	Age (d)	Test condition	Acceptable indices
Compressive strength (MPa)	1	USE cube specimens with a side length of 100mm.	≥ 20.0
	3	PERFORM the testing at $(23 \pm 2) ^\circ\text{C}$ under the condition of $(50 \pm 5) \%RH$ according to the method specified in GB/T 50081.	≥ 40.0
	28		≥ 60.0
Splitting tensile strength (MPa)	7	USE cylindrical specimens with a diameter of 100mm.	≥ 2.5
	28	PERFORM the testing in accordance with the method specified in GB/T 50081.	≥ 3.5
Flexural strength (MPa)	7	USE 100mm × 100mm × 400mm specimens. PERFORM	≥ 6.0

7 Polymer modified cement mortar for structural strengthening

7.1 General requirements

7.1.1 The polymer modified cement mortar for engineering structural strengthening is divided into polymer latex modified cement mortar and polymer dry-mixed modified cement mortar, in accordance with the state of polymer materials. Polymer latex modified cement mortar shall be used for the strengthening of important structures. Polymer materials used in polymer modified cement mortar shall be modified epoxy, modified acrylate, modified styrene-butadiene or modified neoprene polymer. Polyvinyl alcohol, styrene-acrylic and chlorinated polymers as well as ethylene-vinyl acetate copolymer must not be used.

7.1.2 The engineering structural strengthening projects using polymer modified cement mortar should be determined with a design working life of 30 years. When the user requires a design working life of 50 years, the certificate for qualification of long-term stress resistance shall be provided.

7.1.3 Grade I and Grade II polymer modified mortar, used for the strengthening of load-carrying structures, shall be used in accordance with the following requirements, respectively:

- 1** For concrete structures:
 - 1)** When the concrete strength grade of existing structural members is not lower than C30, Grade I polymer modified cement mortar shall be used;
 - 2)** When the concrete strength grade of existing structural members is lower than C30, Grade I or Grade II polymer modified cement mortar shall be used.
- 2** For masonry structures: In case of no special requirements, Grade II polymer modified cement mortar may be used.

7.1.4 The ambient temperature for long-term use of polymer modified cement mortar shall not be higher than 60°C.

7.1.5 The polymer modified cement mortar passing the safety appraisal, where it is found to change the material compositions, mix proportion or process, shall be regarded as the unidentified polymer modified cement mortar.

8 Fibre reinforced polymer

8.1 General requirements

8.1.1 Fibre reinforced polymers for engineering structural strengthening include the carbon fibre reinforced polymer, glass fibre reinforced polymer and aramid fibre reinforced polymer. For toughening purposes, it is permitted to use part of the basalt fibres either as a blend or as an overlay, but not basalt fibre reinforced polymer alone.

8.1.2 The fibres of the fibre reinforced polymer must be continuous fibres; the way in which they are forced must be designed to withstand only tensile stress.

8.1.3 The characteristic value for tensile strength of fibre reinforced polymer shall be determined according to the confidence level stipulated in Article 3.0.5 of this Code and the requirements of 95% strength assurance rate.

8.1.4 The safety appraisal of fibre reinforced polymer must be carried out simultaneously with that of the selected supporting structural adhesive. If this brand of fibre is intended to be used in conjunction with other brands of structural adhesive, the following items shall be re-tested for adaptability, respectively:

- 1 tensile strength of fibre reinforced polymer;
- 2 tensile bond strength of fibre reinforced polymer and concrete; and
- 3 interlaminar shear strength of fibre reinforced polymer.

8.2 Carbon fibre reinforced polymer

8.2.1 For carbon fibres for the strengthening of load-carrying structures, the material variety and specifications must meet the following requirements:

- 1 For important structures, polyacrylonitrile (PAN)-based small-tow fibres with a tow size of 12k or less must be used. Large-tow fibres must not be used.
- 2 For general structures, in addition to the use of PAN-based small-tow fibres with a tow size of 12k or less, if there is a suitable structural adhesive, PAN-based carbon fibres with a tow size of not greater than 15k are still acceptable.

8.2.2 Carbon fibre reinforced polymer is divided into Grade I, Grade II and Grade III according to its properties. During safety appraisal, the inspection shall be carried out according to the grade reported by the entrusting party. The

9 Steel wire ropes

9.1 General requirements

9.1.1 During the steel wire production of steel wire ropes for structural strengthening and the safety appraisal of steel wire ropes, the requirements of this chapter shall apply.

9.1.2 The steel wire ropes for engineering structural strengthening are divided into high-strength stainless wire ropes and high-strength zinc-coated steel wire ropes. During selection, the following requirements shall apply:

- 1** In the case of important structures, or in the event that structures are in a corrosive medium environment, humid environment and open air, high-strength stainless wire ropes shall be used;
- 2** For general structures in an indoor environment with normal temperature and humidity, when high-strength zinc-coated steel wire ropes are used, effective anti-rust measures shall be taken;
- 3** No grease shall be applied to the inside and outside of the steel wire ropes for structural strengthening.

9.2 Steel wire for rope making

9.2.1 When using high-strength stainless wires for rope making, high-quality stainless-steel with a carbon content of not greater than 0.15%, a sulfur content of not greater than 0.025% and a phosphorus content of not greater than 0.035% shall be used for rope making.

9.2.2 When using high-strength zinc-coated steel wire for rope making, high-quality carbon structural steel with a sulfur content and a phosphorus content of not greater than 0.30% shall be used for rope making. Mass of zinc coatings and quality of galvanization shall, in accordance with the importance of structures, meet the requirements for Grade A or Grade AB of the current national standard GB/T 15393 *Zinc coatings for steel wire*, respectively.

9.2.3 The safety appraisal of steel wires is divided into chemical composition appraisal and mechanical property appraisal, and shall be based on the quality certificate issued by the manufacturer of steel wires. The safety appraisal agency is only responsible for reviewing the credibility and validity of the certificate.

10 Synthetics modified concrete and mortar

10.1 General requirements

10.1.1 During the safety appraisal of synthetics modified concrete or mortar prepared by using polyacrylonitrile fibres, modified polyester fibres, polyamide fibres, polyvinyl alcohol fibres and polypropylene fibres, the requirements of this chapter shall apply.

10.1.2 When other varieties of synthetics are used as the substitute, the indices of safety appraisal thereof shall not be lower than those of the replaced fibre.

10.1.3 In the engineering structural strengthening projects, synthetics modified concrete or mortar is mainly used for the following occasions:

- 1 To prevent new concrete or mortar from early-age plastic shrinkage and cracking;
- 2 To limit the shrinkage cracks and temperature cracks in the use of new concrete or mortar;
- 3 To enhance the flexural toughness, impact and fatigue resistance abilities of new concrete or mortar;
- 4 To improve the impermeability and frost resistance of concrete or mortar.

When used for structural toughening and strengthening, polyacrylonitrile fibres, modified polyester fibres, polyamide fibres and polyvinyl alcohol fibres shall be used. When used only for crack control, polypropylene fibres may also be used.

10.2 Safety appraisal of synthetics modified concrete and mortar

10.2.1 For synthetics for structural strengthening, the meso-structural and geometric characteristics shall meet the requirements of Table 10.2.1.

Table 10.2.1 -- Morphological identification and geometric size control requirements of synthetics

Test item	Identification marks and control indices				
	Polyacrylonitrile fibre (Acrylic fibre)	Modified polyester fibre (Polyester fibre)	Polyamide fibre (Nylon fibre)	Polyvinyl alcohol fibre (PVA fibre)	Polypropylene fibre (PP fibre)
Fibre morphology	Bunchy, vertically textured	Bunchy	Bunchy, easily dispersed into filaments	Bundles	Monofilament or split

Annex A

Suitable test method standards for safety appraisal

A.0.1 For determination of colloidal properties of structural adhesives, the following test method standards shall apply:

- 1 current national standard GB/T 2918 *Plastics - Standard atmospheres for conditioning and testing*;
- 2 current national standard GB/T 2567 *Test methods for properties of resin casting body*;
- 3 Annex E of this Code, *Determination method for splitting tensile strength of filler-rich adhesive colloid and polymer modified cement mortar*;
- 4 Annex P of this Code, *Determination method for shrinkage of adhesive casting (colloid)*.

A.0.2 For determination of bonding capacity of structural adhesives, the following test method standards shall apply:

- 1 current national standard GB/T 7124 *Adhesives - Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*;
- 2 current national standard GB/T 6329 *Adhesives - Determination of tensile strength of butt joints*;
- 3 current national military standard GJB 444 *Test method for strength properties of adhesives in shear by tension loading at high temperatures (metal to metal)*;
- 4 Annex F of this Code, *Determination method and evaluation criteria for T impact peeling length of structural adhesive*;
- 5 Annex G of this Code, *Laboratory determination method and evaluation criteria for tensile bond strength of adhesive material agglutinate strengthening material and substrate*;
- 6 Annex K of this Code, *Determination method for bond strength of adhesive agglutinate steel bar and concrete substrate in pull-out constraint condition*;
- 7 Annex N of this Code, *Determination method and evaluation criteria for compressive shear strength of concrete-to-concrete bonding*.

A.0.3 For determination of environmental and long-term stress resistance abilities of structural adhesives, the following test method standards shall apply:

- 1 Annex C of this Code, *Quick determination of wedge for bond durability*;

- 2 Annex J of this Code, *Determination method for damp heat ageing of structural adhesive and polymer modified cement mortar*;
- 3 Annex L of this Code, *Determination method for heat ageing resistance of structural adhesive*;
- 4 current national military standard GJB 3383 *Test methods for durability of adhesive bonding* (Method 105);
- 5 Annex M of this Code, *Determination method for fatigue stress resistance ability of specimens connected with adhesive*;
- 6 current national standard GB/T 50329 *Standard for methods of testing of timber structures*.

A.0.4 For determination of physical and chemical properties of structural adhesives, the following test method standards shall apply:

- 1 current national standard GB/T 7123.1 *Determination for working life of adhesives*;
- 2 current national standard GB/T 1634.2 *Plastics - Determination of temperature of deflection under load*;
- 3 current national standard GB/T 13477.6 *Test method for building sealants - Part 6: Determination of flow*;
- 4 Annex H of this Code, *Determination method of non-volatile matter content in structural adhesive*;
- 5 Annex Q of this Code, *Determination method for initial viscosity of structural adhesive*;
- 6 Annex R of this Code, *Determination method for thixotropic index of structural adhesive*.

A.0.5 For determination of properties of injection grouting and grouting materials for cement substrates, the following test method standards shall apply:

- 1 Annex A of current national standard GB/T 50448 *Technical code for application of cementitious grout*;
- 2 Annex C of current national standard GB 50119 *Code for concrete admixture application*;
- 3 Annex S of this Code, *Determination method for flexural strength of polymer modified cement mortar and grouting material*;
- 4 current industry standard YB/T 2206.2 *Test method for thermal shock resistance of castable refractory - Water quenching*;
- 5 current industry standard DL/T 5150 *Test code for hydraulic concrete*.

A.0.6 For determination of properties of fibre reinforced polymer, the following test method standards shall apply:

- 1 current national standard GB/T 3354 *Test method for tensile properties of oriented fiber reinforced plastics*;

Annex C

Quick determination of wedge for bond durability

C.1 Scope of application and application conditions

C.1.1 This method is applicable to rapid re-test and assessment for durability of structural adhesives.

C.1.2 The structural adhesive using this method for durability test shall meet the following conditions:

- 1 Such structural adhesive has passed the tests of colloidal properties, bonding capacity, ageing resistance and long-term stress resistance;
- 2 Samples to be tested are derived from random sampling of structural adhesives produced from mass production.

C.2 Instruments, equipment and tools

C.2.1 The applicable instruments, equipment and tools shall include:

- 1 damp heat ageing test chamber;
- 2 tool microscope or 5x ~ 30x magnifier;
- 3 vernier caliper, with a precision of 0.002;
- 4 wedge propulsion device, at a required constant speed of (30 ± 5) mm/min;
- 5 scribe that shall be able to draw significant scratches on the stainless-steel surfaces;
- 6 copper mallet;
- 7 vise (if necessary).

C.2.2 The properties of the damp heat ageing test chamber shall meet the requirements of current national standard GB/T 10586 *Specifications for damp heat testing chambers*. The environmental conditions of the damp heat testing chamber shall be (50 ± 2) °C and $(95 \sim 100)$ %RH.

C.3 Wedge preparation

C.3.1 Materials for making wedges shall not be electrolyzed, corroded, or chemically reacted with structural adhesives.

C.3.2 This method recommended the use of 2Cr13 stainless-steel wedges. With experience in use, it is also allowed to use LY12CZ aluminum alloy wedges. Form and size of the wedge specimen are illustrated in Figure C.3.2. Stainless-

Annex D

Determination method for interlaminar shear strength of fibre reinforced polymer

D.1 Scope of application

D.1.1 This method is suitable for determining the interlaminar shear strength of wet lay-up and room temperature curing unidirectional fibre fabric composites. It may also be used for determining the interlaminar shear strength of laminated and room temperature curing multi-layer preformed plates.

D.1.2 The interlaminar shear strength of fibre reinforced polymer, determined by using this method, can be used for the evaluation of suitability of fibre materials and adhesives.

D.2 Specimen forming mold

D.2.1 The preparation of specimen forming molds shall meet the following requirements:

- 1 The forming mold consists of a pair of bright and clean steel plates of size 400mm × 300mm × 25mm, one of which is used as a pressing plate and the other of which is used as a formwork for fabric ply. A pair of 10# or 12# channel steel with a length of 500mm is provided on the top and bottom of the mold, respectively. DRILL screw holes with a diameter (D) of 18mm on the end of channel steel, equipped with 4 screws with a diameter (d) of 16mm for tightening and pressing, nuts and pressure strings fitted on the screws, as a pressing tool for bonding fabrics to specimens.
- 2 The steel plates for the forming mold shall be milled on a milling machine after planning. The surface finish of finished surfaces shall be of Grade .
- 3 The forming mold shall still be equipped with two steel plates, 300mm long, 20mm wide and 4mm thick, for controlling the standard thickness of fabric ply that shall be reached after pressing.

D.2.2 Auxiliary tools and materials shall meet the following requirements:

- 1 4 adjustable torque-indicating wrenches;
- 2 several pieces of 0.1mm thick polyester film, with a plane size of 500mm × 400mm;

- 2) Pressure forming process: After the top layer is covered with a polyester film, a steel press plate shall be installed to prepare to enter the pressure forming process. The overall pressure forming process shall also be carried out at room temperature. At this point, the steel backing plates specified in Item 3 of Article D.2.1 in this Annex shall be placed on both ends of the length of the steel formwork to control the laminate thickness. Then INSTALL the steel press plate, channel steel and screws. After checking, TIGHTEN the screws for pressing, so as to reduce the laminate thickness until the steel press plate touches the steel backing plates at both ends. LET stand for 24h under pressure.
 - 3) Curing process: After taken out from the forming mold, the specimens shall be continued for 144 hours of curing. The curing temperature shall be controlled at $(23 \pm 2) ^\circ\text{C}$. Artificial high-temperature curing method must not be used. Neither disturbance or mechanical processing nor exposure to the sun, rain or moisture shall be allowed during curing.
- 2 Preparation of preformed plate specimens shall meet the following requirements:
- 1) Each specimen shall be prepared from three adhesive laminated strip plates;
 - 2) During preparation, the forming mold above may be used for gluing, pasting, pressing (with no backing plate) and curing;
 - 3) Pressing and curing time shall meet the requirements of Item 3, Paragraph 1 of this Article.

D.4 Specimen fabrication

D.4.1 Specimens shall be cut from the middle of the sample. The outermost specimen shall not be less than 30mm from the edge of the sample. A diamond turning tool shall be used for specimen processing. It is advisable to perform sawing, planning or polishing after water lubrication. The edges of each specimen shall be smooth, flat and parallel to each other. Specimen processing personnel shall wear safety goggles against dust, protective clothing and masks to prevent dust adhesion to the skin.

D.4.2 Under normal circumstances, the specimen length, l , shall be taken as $30\text{mm} \pm 1\text{mm}$; the specimen width, b , shall be taken as $6.0\text{mm} \pm 0.5\text{mm}$. The thickness of the specimens made of fabrics shall be determined by mold pressing, that is, $h = 4\text{mm} \pm 0.2\text{mm}$. For specimens bonded by preformed plates, if the thickness thereof is greater than 4mm, it will be permissible to fine-tune the thickness to 4mm on one side on a machine tool (Figure D.4.2). The number of specimens in each group shall not be less than 5. If it is necessary to determine the standard deviation of the test results, the number of specimens

D.6.1 Prior to the test, the specimen appearance shall be inspected. The appearance quality shall meet the requirements of current national standard GB/T 1446 *Fiber-reinforced plastics composites - The generals for determination of properties*.

D.6.2 The specimen shall be placed in the center of the test device. The span, L , shall be regulated to 20mm. The error shall not be greater than 0.3mm. The axis of the loading indenter shall be centered between the two supports, and shall be parallel to the axis of the supports.

D.6.3 CARRY out continuous loading at a loading speed of (1 ~ 2) mm/min until the specimen fails. RECORD the maximum load, P_b , and the specimen failure mode.

D.6.4 In the event that one of the following circumstances occurs during the test, it is confirmed that the specimen has failed and the test may be stopped immediately:

- 1 Load readings have dropped 30% from the peak;
- 2 The travel of the loading indenter has exceeded the nominal thickness (4mm) of the specimen;
- 3 The specimen has separated into two pieces.

D.7 Test results

D.7.1 The interlaminar shear strength of the specimen shall be calculated according to the following formula:

$$f_s = \frac{3P_b}{4bh} \quad (\text{D.7.1})$$

Where:

f_s - Interlaminar shear strength (MPa);

P_b - Maximum load (N) during specimen failure;

b - Specimen width (mm);

h - Specimen thickness (mm).

D.7.2 The failure modes of specimens and the normality determination thereof shall meet the following requirements:

- 1 Typical failure modes of specimens (Figure D.7.2):
 - 1) interlaminar shear failure (Figure D.7.2a);

Where:

f_{ct} - Test value (MPa) of cylindrical splitting tensile strength;

F - Specimen failure load (N);

d - Diameter (mm) of the specimen on the splitting plane;

l - Specimen length (mm).

2 The RMS of cylindrical splitting tensile strength shall be determined according to the following requirements:

- 1)** TAKE the arithmetic average of 5 measurements as the effective strength value of this set of specimens;
- 2)** If there is a maximum or minimum in a set of measurements, when the difference between the maximum or minimum and the median is greater than 15%, the median will be taken as the effective strength value of this set of specimens;
- 3)** In the event that the differences between the maximum and the median, and between the minimum and the median are greater than 15%, this set of test results will be invalid, requiring a re-test.

E.5.2 When it is necessary to calculate the standard deviation and coefficient of variation of the splitting tensile test results, there shall be at least 15 effective strength values.

E.5.3 The test report shall include the following contents:

- 1** origins, varieties, models and lot numbers of the materials to be inspected;
- 2** sampling rules and sample size;
- 3** preparation methods and curing conditions of specimens;
- 4** numbers and dimensions of specimens;
- 5** temperature and relative humidity of the test environment;
- 6** models and ranges of test equipment, and date of verification;
- 7** loading mode and loading speed;
- 8** failure load and failure modes of specimens;
- 9** test result finishing and calculation;
- 10** sampling, test and verification personnel, and test date.

Annex F

Determination method and evaluation criteria for T impact peeling length of structural adhesive

F.1 Scope of application

F.1.1 This Code is suitable for determining the T impact peeling length, an important sign of toughness of room temperature curing structural adhesive.

F.1.2 The requirements for toughness of structural adhesive used for building strengthening in the seismic fortification zones may be tested and conducted with conformity assessment according to this Code.

F.2 Principle

F.2.1 Each T impact peeling specimen is prepared by bonding a pair of mild steel sheet with adhesive. Under the prescribed conditions, impact force is applied to the un-bonded end of the specimen, causing the specimen to peel along its glue line. For structural adhesives at different levels of toughness, the peeling length varies significantly, from which the level of toughness can be identified.

F.2.2 By measuring the peeling strength of the specimen and comparative analysis of test data of different models of adhesives, a simple and practical conformity assessment criteria for toughness of structural adhesives may be worked out, with the peeling length as an index.

F.3 Test device

F.3.1 A free-fall impact peeling test device shall be used, as shown in Figure F.3.1.

F.3.2 The impact peeling test device shall be made of 45# steel, and shall be conducted with surface treatment against rusting.

F.3.3 The parts processing of the test device shall meet the following requirements:

- 1** The free-fall impact block shall be made of 45# steel, with a mass of 900^{+5}_0 g;

Annex G

Laboratory determination method and evaluation criteria for tensile bond strength of adhesive material agglutinate strengthening material and substrate

G.1 Scope of application

G.1.1 This method is suitable for determining the tensile bond strength of cohesive, adhesion or mixed failure under uniform tensile stress, when the structural adhesive, interfacial adhesive (agent) or polymer modified cement mortar is used as the adhesive material for bonding (including coating, spraying, casting, etc.) the following strengthening materials and substrates:

- 1** fibre reinforced polymer and concrete substrate;
- 2** steel plates and concrete substrate;
- 3** polymer modified cement mortar and concrete substrate for structures;
- 4** interfacial adhesive (agent) and concrete substrate for structures.

G.2 Test equipment

G.2.1 The force range of the tensile testing machine shall be selected to ensure that the failure load of the specimen is between 20% and 80% of the full load for calibration of this machine. The indication error of the force values shall not be greater than 1%.

G.2.2 The structure of the testing machine's clamp holder shall be able to fix the specimen perpendicular to the center, without producing eccentricity and torsion.

G.2.3 Specimen fixture shall consist of a steel clamp with a tie rod and a steel standard block with a screw, and shall be made of 45# carbon steel. Its shape and main dimensions are shown in Figure G.2.3.

G.6 Test results

G.6.1 The tensile bond strength shall be calculated according to the following formula, accurate to 0.1MPa:

$$f_{ti} = P_i / A_{ai} \quad (\text{G.6.1})$$

Where:

f_{ti} - Tensile bond strength (MPa) of the specimen i ;

P_i - Load value (N) during the failure of specimen i ;

A_{ai} - Adhesive surface area (mm²) of the standard metal block i .

G.6.2 Specimen failure modes and corresponding normality determination:

- 1 Specimen failure modes shall be divided according to the following requirements:
 - 1) Cohesive failure: It shall be divided into cohesive failure of concrete substrates and cohesive failure of inspected binding materials. The latter can be seen in situations where low-performance and poor-quality adhesives (or polymer mortar and composite mortar) are used.
 - 2) Adhesion failure (interlaminar failure): It shall be divided into interfacial failure between the adhesive layer or mortar layer and the substrate, and interfacial failure between the adhesive layer and the fibre reinforced polymer or steel plate.
 - 3) Mixed failure: The adhesive surface is in two or more failure modes.
- 2 Normality determination of the failure modes shall meet the following requirements:
 - 1) In the case of cohesive failure of concrete substrates, or in the event that despite of the emergence of two or more mixed failure modes, the area of the cohesive failure of concrete substrates accounts for more than 85% of the adhesive surface area, it will be determined as the normal failure;
 - 2) In the case of adhesion failure, or in the event that the area of the cohesive failure of binding materials or the cohesive failure of concrete substrates is less than 85% of that of the mixed failure, it shall be determined as the abnormal failure.

Note: The interfacial failure between the steel standard block and the high-strength and fast-curing adhesive for inspection belongs to a technical problem of inspection. Bonding shall be carried out again. Such failure shall not be involved in the normality assessment of the failure modes.

Annex H

Determination method of non-volatile matter content in structural adhesive

H.1 Scope of application

H.1.1 This method is suitable for determining the non-volatile matter content in room temperature curing modified epoxy and modified vinyl ester structural adhesives.

H.1.2 The determination results of this method may be used for determining whether the tested adhesive is mixed with the volatile components that affect the properties and quality of structural adhesives.

H.2 Instruments and equipment

H.2.1 The instruments and equipment for determining the non-volatile matter content in adhesive shall meet the following requirements:

- 1** Electrothermal blast drying oven (drying oven), with a temperature fluctuation of not greater than $\pm 2^{\circ}\text{C}$.
- 2** Thermometer shall be prepared in two kinds, with the measuring ranges of 0°C to 150°C and 0°C to 250°C .
- 3** An aluminum weighing box or a temperature-resistant weighing bottle shall be used as the weighing container. The diameter and height should be 50mm and 30mm, respectively.
- 4** An analytical balance shall be used as the weighing scales, with a sensibility of 1mg and a maximum capacity of 200g.
- 5** No less than 4 glass dryers with seal covers shall be used. Each of them shall be filled with allochroic silica gel (blue gel).
- 6** Adhesive sampler, there shall be no chemical reaction between the sampler materials and the raw materials of the adhesive.

H.3 Preparations before testing

H.3.1 Equipment calibration requirements: The analytical balance and the oven temperature control system shall be regularly verified according to the verification procedures of the national metrology department. Do not use the equipment that has exceeded the validity of the test.

H.3.2 Silica gel drying requirements: TAKE the amount of silica gel required for two dryers. DRY silica gel in a drying oven at 200°C for about 8h. TAKE it

Annex J

Determination method for damp heat ageing of structural adhesive and polymer modified cement mortar

[Translator Note: Annex I is not existed]

J.1 Scope of application and application conditions

J.1.1 This method is applicable to the verification test for ageing resistance of structural adhesive and polymer modified cement mortar.

J.1.2 Structural adhesive and polymer modified cement mortar using this method for ageing test shall have passed the safety test of other items.

J.2 Test equipment and test water

J.2.1 Ageing of specimens shall be carried out in a programmable constant temperature and humidity testing machine. The temperature and relative humidity in the ageing chamber of this machine shall be automatically controlled, continuously recorded and remain stable. The air velocity inside the chamber shall be able to maintain at 0.5m/s to 1.0m/s. Condensation water on the chamber wall and roof shall be automatically removed and shall not drip onto the specimens.

J.2.2 Water for the testing machine shall be distilled or deionized water. Unpurified condensate water must not be reused. Water for the arbitration testing machine shall also require the resistivity of not less than $500\Omega \cdot m$. The wet-bulb system shall also use water with the same water quality. Prior to each test, wet bulb gauze and remaining water shall be replaced. The use-by date of gauze shall not exceed 30 days.

J.2.3 The testing machine shall be powered by a dual power supply, and shall be able to automatically switch when the working power supply is off. Short-term power outage caused by any reason shall be recorded on file for future reference.

J.3 Specimens

J.3.1 For the determination of the ageing properties of structural adhesives, steel-to-steel tensile shear specimens shall be used and prepared in accordance with the requirements of current national standard GB/T 7124 *Adhesives - Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*. The metal test pieces for bonding shall be made of 45# steel. The adhesive surfaces thereof shall be treated by sandblasting. For the

K.3 Specimens

K.3.1 The test specimens consist of inspected adhesive and hot-rolled ribbed bars implanted into the concrete blocks. There shall not be less than 5 specimens in each set.

K.3.2 The nominal diameter of hot-rolled ribbed bars shall be 25mm. The grade of steel bars shall not be lower than Grade 400. The surface shall be free of rust, oil stain and dust pollution. The appearance shall be straight with no bending. The relative rib area shall be between 0.055 and 0.065. The length of the steel bar shall be determined according to its burial depth and fixture size as well as the detector's jack height. The depth of rebar implantation shall be 150mm (6 times the steel bar diameter) for C30 concrete blocks, and 125mm (5 times the steel bar diameter) for C60 concrete blocks.

K.3.3 The inspected adhesives shall be obtained through random sampling from the materials supplied in batches by the independent inspection institution. The packaging and marking shall be intact and shall not be tested with outdated adhesives.

K.4 Bonded rebars

K.4.1 Prior to rebar bonding, TEST the moisture content in the drilling positions of concrete blocks. The test results shall meet the requirements of the test design.

K.4.2 Drilling diameter and its measured deviation shall meet the requirements of the adhesive manual.

K.4.3 A special borehole cleaning device shall be used for borehole cleaning before rebar bonding. However, the number of borehole blowing and brushing shall be reduced by half the number of times specified in the adhesive manual. If it is required to blow twice and brush once in the manual, it will only blow once without brushing in the actual operation. If the borehole cleaning methods and frequency are not specified in the manual, do not clean boreholes during the test.

K.4.4 Glue preparation for bonded rebars and adhesive injection method shall be in strict accordance with the requirements of the adhesive manual.

K.4.5 Steel bars shall be inserted immediately in the holes injected with glue. ROTATE the steel bar while inserting in a clockwise direction, until it reaches the specified depth.

K.4.6 After rebar bonding, LET stand for 7 days of curing. The curing conditions shall be in accordance with the requirements of the manual. The pull-

out test shall be performed immediately upon the expiration of curing. The delay for any reason shall not exceed 1 day.

K.5 Pull-out test

K.5.1 The test shall be performed at $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$, with a relative humidity of not greater than 70%. If the inspected adhesives are sensitive to humidity, the relative humidity shall be controlled within the range of 45% to 55%.

K.5.2 The test procedures shall meet the following requirements:

- 1 INSTALL the hollow jack of the bond strength detector on the steel backing plate on the surface of the concrete block after passing through the steel bars. USE the upper fixture to clamp the bonded rebar specimen. MAKE alignment carefully. CLAMP firmly afterwards.
- 2 START the controllable throttle to evenly and continuously apply loads. CAUSE specimen failure within 2min to 3min.
- 3 RECORD the load value and failure mode during failure.

K.6 Test results

K.6.1 The bond strength in pull-out constraint condition, $f_{b,c}$, shall be calculated according to the following formula:

$$f_{b,c} = N_u / \pi d_0 l_b \quad (\text{K.6.1})$$

Where:

N_u - Pull-out failure load (N);

d_0 - Nominal diameter (mm) of the steel bar;

l_b - Anchorage depth (mm) of the steel bar.

K.6.2 The failure modes shall be in accordance with the following circumstances. In case of reinforcement yielding, CHECK the causes, and REMAKE the specimens for testing.

- 1 adhesion failure of adhesive and concrete bonding surface;
- 2 adhesion failure of adhesive and steel bar bonding surface;
- 3 mixed failure.

K.6.3 The test report shall include the following contents:

- 1 varieties, models and lot numbers of the adhesives to be inspected;
- 2 sampling rules and sample size;
- 3 methods for drilling, borehole cleaning and rebar bonding;

Annex L

Determination method for heat ageing resistance of structural adhesive

L.1 Scope of application and application conditions

L.1.1 This method is applicable to the verification test for heat ageing resistance of structural adhesive.

L.1.2 Structural adhesive using this method for heat ageing test shall have passed the safety test of other items.

L.2 Test equipment and test water

L.2.1 Heat ageing of specimens shall be carried out in a programmable constant temperature test chamber. The temperature in the ageing chamber shall be automatically controlled, continuously recorded and remain stable. The air velocity inside the chamber shall be able to maintain at 0.5m/s to 1.0m/s.

L.2.2 The testing machine shall be powered by a dual power supply, and shall be able to automatically switch when the working power supply is off. Short-term power outage caused by any reason shall be recorded on file for future reference.

L.3 Specimens

L.3.1 For the determination of the heat ageing properties, steel-to-steel tensile shear specimens shall be used and prepared in accordance with the requirements of current national standard GB/T 7124 *Adhesives - Determination of tensile lap-shear strength of rigid-to-rigid bonded assemblies*. The metal test pieces for bonding shall be made of 45# steel. The adhesive surfaces thereof shall be treated by sandblasting.

For the determination of the heat ageing properties of polymer modified cement mortar, the steel sleeve specimens in use shall meet the requirements of Annex R in the national standard GB 50550-2010 *Code for acceptance of constructional quality of strengthening building structures*.

L.3.2 There shall not be less than 15 specimens. They shall be randomly divided into three groups, one of which is control group, and the other two of which are ageing test groups.

L.3.3 After specimen bonding, LET stand for 7 days of curing.

requirements of current national standard JGJ 52 *Standard for technical requirements and test method of sand and crushed stone (or gravel) for ordinary concrete*.

- 4 Mixing water shall be drinking water.
- 5 The mix proportion of concrete shall be determined according to the strength grade of C40.
- 6 During each preparation of concrete, a set of test blocks of standard size shall be made for testing its strength grade.

N.3.2 After casting, the test pieces shall be covered with plastic films for curing. The curing system and formwork dismantling time shall meet the requirements of current national standard GB/T 50081 *Standard for test method of mechanical properties on ordinary concrete*. The test blocks made during concrete preparation shall be cured along with the test pieces under the same conditions.

N.3.3 After dismantling the formwork of test pieces, CHECK the appearance quality. All the test pieces with cracks, pockmarks, holes and defects shall be discarded.

N.3.4 During the determination of compressive shear bond strength of interfacial adhesive (agent), the specimen preparation shall meet the following requirements:

- 1 PLACE a shear loading device immediately upon the expiration of test piece curing. LOAD in a compression testing machine, until the protruding part of the test piece is completely cut off.
- 2 DISCARD the protruding part of the test piece. The prismatic part left is used as the substrate for coating interfacial adhesive (agent).
- 3 CLEAR loose aggregate and dust on the shear plane of substrate.
- 4 According to the requirements of the manual of the interfacial adhesive (agent), APPLY interfacial adhesive (agent) to and EMBED original steel mold into the shear plane of substrate.
- 5 When the applied glue is dry tack-free, USE newly prepared fine stone concrete to fill the vacancy of the original protruding part in the steel mold (for the bonding test of mortar layers and concrete substrates, polymer modified cement mortar shall be used instead to fill vacancies). The convex specimens reformed after tamping are the specimens used in this test method.
- 6 Newly formed specimens shall be cured according to the requirements of N.3.2 in this Annex.

N.3.5 During the determination of compressive shear strength for underwater or high wet bonding of structural adhesives, the specimen preparation shall meet the following requirements:

P.2.3 Bubbles generated in the glue casting process shall be removed using a vacuum degassing device or a vibration table. If there are only a few bubbles in the glue, the needle poking method may be used for bubble removal.

P.2.4 The gauges for measuring the net length of the mold cavity and the specimen length shall have a measurement accuracy of 0.01mm. The gauges shall be verified by the metrology department, and shall be used within the effective verification cycle.

P.3 Specimens

P.3.1 Specimens for measuring unconstrained linear shrinkage shall be cuboids formed by casting, with a size of 12mm × 12mm × 120mm. The accuracy of the specimen size is guaranteed by the machining accuracy of the mold cavity, not otherwise specified. There shall not be less than 5 specimens in each set.

P.3.2 Specimens shall be prepared by casting, and shall meet the following requirements:

- 1 The mold for preparing casting specimens shall be placed in an environment of $(23 \pm 2) ^\circ\text{C}$ and $(50 \pm 5) \%RH$ (standard environment) for 24 hours of equilibrium in advance. The net length of the mold cavity, L_0 , shall be measured immediately in this temperature and humidity environment upon the expiration. Accurate to 0.01mm. After checking, PLACE the mold in a standard environment for standby application.
- 2 The outer surface and cavity surface of the mold shall be carefully coated with high-quality parting agent. The quality of coatings shall be checked and approved by the special personnel.
- 3 The glue for specimen casting shall be prepared according to its manual. The mixing speed shall be under control to prevent the generation of bubbles.
- 4 Well-mixed glue shall be carefully injected into the mold. Throughout the casting process, attention shall be paid to prevent bubble generation in the glue. If any, measures shall be taken accordingly. After the mold is fully injected with glue, a squeegee shall be used for smoothing the surface of the casting body. Any discovered defects such as pockmarks, etc., shall be tightly filled in time.
- 5 After casting, the specimen shall be placed together with the mold in a standard environment for 2 days. DISMANTLE the formwork afterwards. Then, PLACE the specimen opened on a plane. CARRY out another 19 days of curing with no constraint under the same temperature and humidity conditions.

P.4 Shrinkage measurement

PLACE the beaker or container in thermostatic water bath to accurately control the glue temperature. If the specimen contains bubbles, they shall be completely removed before injection.

Q.5.2 INSTALL the guard on the instrument. Be familiar with the direction of rotation before installing.

Q.5.3 SELECT rotor number and speed (r/min) according to the range table (mPa · s) given in the instrument manual.

Q.5.4 FOLLOW the operating instructions and procedures specified in the instrument manual. First, ROTATE the lifting assembly so that the rotor will slowly dip into the glue, until the rotor's liquid level mark and the liquid level are on the same horizontal line. Then, START the motor. TURN the variable speed knob to align the selected RPM with the RPM indication point. At this point, the rotor starts to rotate in glue. READ the value immediately when the pointer tends to be stable. Then, TURN off the power. RESTART the instrument afterwards for the second and third readings.

Q.5.5 If the pointer reading is not between 30 grids and 90 grids, REPLACE the rotor number and speed. RE-PREPARE specimens for testing. The original glue specimen shall be discarded, and shall not keep using. If viscosity still cannot be measured after the replacement of rotor number and speed, CHANGE to a coaxial double-cylinder rotary viscometer for testing.

(B) Glue with an estimated viscosity value of greater than $8 \times 10^4 \text{mPa} \cdot \text{s}$

Q.5.6 SELECT the drum, speed and fixed cylinder according to the specified shear rate. INSTALL the instrument according to the procedures and methods specified in the instrument manual.

Q.5.7 Carefully INJECT the prepared glue (specimen) into the outer cylinder of the instrument, according to the specimen amount specified in the dimension table of the instrument measuring system. The rotor's working height must be completely immersed in glue. It would be better if a small amount of glue overflowed into the upper groove of the rotor. After injection, LET stand for a while to eliminate bubbles. A small clean metal needle may also be used for breaking bubbles to accelerate degassing, if necessary.

Q.5.8 CONNECT the instrument to a thermostatic apparatus that has been preheated up to 23°C, so that the inner and outer cylinder systems are immersed in water at a constant temperature.

Q.5.9 TURN on the power. START the motor to rotate the drum. After the pointer is stable, READ the value for the first time. TURN off the power afterwards. If the readings are between 20% and 90% of the full scale of the

Annex R

Determination method for thixotropic index of structural adhesive

R.1 Scope of application

R.1.1 This method is suitable for determining the thixotropic index for the thixotropic properties of structural adhesives characterized by dynamic viscosity ratios at different speeds.

R.1.2 For brushing-type structural adhesives for construction at room temperature, the thixotropy required for technical properties may be assessed by determining the thixotropic index.

R.2 Instruments and equipment

R.2.1 Rotary viscometer: When a Newtonian fluid viscometer is in use, the rotor speed shall be 6r/min or 60r/min. When a non-Newtonian fluid viscometer is in use, if the rotor speed settings are different, it will be allowed to replace with 5.6r/min and 65r/min.

Note: For adhesives mixed with fillers, NXS-11A viscometers shall be used.

R.2.2 Constant temperature bath (thermostatic bath): It shall be adjustable within the range of 20°C to 100°C. In addition, the error of constant water temperature shall not be greater than 0.2°C.

R.2.3 The division value of the thermometer shall be 0.1°C.

R.2.4 The shape and size of the container shall be determined according to the manual of the rotary viscometer in use.

R.3 Specimens

R.3.1 The components of structural adhesive shall be randomly selected from the inspection lot, and shall be placed in the laboratory for not less than 24h. Before the test, the components shall be stirred and mixed evenly at a room temperature of 23°C ± 0.5°C as the specimen for determining the glue viscosity, according to the mix proportion specified in the adhesive manual.

R.3.2 Specimens shall be uniform, with consistent color and no lumps.

R.3.3 The sample size shall be able to meet the testing requirements of the rotary viscometer.

Annex S

Determination method for flexural strength of polymer modified cement mortar and grouting material

S.1 Scope of application

S.1.1 This method is suitable for determining the flexural strength of polymer modified cement mortar and grouting material for structural strengthening.

S.1.2 This method is not suitable for determining the flexural strength of low-strength ordinary cement mortar.

S.2 Test devices and equipment

S.2.1 The mold for specimen casting shall meet the following requirements:

- 1 It shall be a detachable steel mold. The steel should be 45# carbon steel. The inner surface finish of the mold shall be up to .
- 2 The net size in the mold shall be 30mm × 30mm × 120mm and 40mm × 40mm × 160mm. The allowable deviation thereof shall meet the following requirements:
 - 1) The dimension deviation of each side of the net section in the mold shall not exceed 0.20mm. The deviation of the net length in the mold shall not exceed 1mm.
 - 2) After assembly, the angle between the adjacent planes in the mold shall be 90°. The non-perpendicularity thereof shall not exceed ±0.5°.
 - 3) For the upper surface of each side of the mold, the flatness deviation shall not exceed 1.5% of the length of the short side.
- 3 The disassembled structure of the mold shall not cause damage to the specimens during operation.

S.2.2 When the specimen castings need to be compacted by jolting, the technical properties and quality of the jolting table shall meet the requirements of current industry standard JC/T 682 *Jolting table for compacting mortars specimen*.

S.2.3 A hydraulic compression testing machine, with a measurement accuracy of ±1.0%, shall be used in the flexural test. The testing machine shall be able to uniformly and continuously apply loads at a controllable speed. The failure load of specimens shall be between 20% and 80% of the full load for

S.4.1 Shape and dimensions of the specimen: In the case of determining the flexural strength of polymer mortar and composite mortar, prismatic specimens of size 30mm × 30mm × 120mm shall be used. In the case of determining the flexural strength of grouting material, prismatic specimens of size 40mm × 40mm × 160mm shall be used.

S.4.2 Specimens shall be made, casted, tamped and cured in a mold conforming to the requirements of Article S.2.1 in this Annex. The curing system and formwork dismantling time shall be determined according to the manual of this inspected material. However, for the specimens providing design and construction basis for structural strengthening, the curing time shall be subject to 28 days.

S.4.3 If the normality of grout strength increase needs to be evaluated, the number of sets of specimens may be increased. The formwork will be dismantled 1 day, 3 days and 7 days after casting for strength test.

S.4.4 After formwork dismantling, CHECK the specimen surface for defects. All the specimens with cracks, pockmarks, holes and defects shall be discarded.

S.5 Test procedures

S.5.1 CARRY out the test in time upon the expiration of specimen curing. If it is necessary to postpone the test for some reason, the test shall not be delayed for more than 1 day.

S.5.2 When the specimen is installed in the testing machine (Figure S.2.5), the specimen molding side shall be taken as the load-carrying surface. In addition, the specimen shall be centered on the front and back of the testing machine. If found to be in loose or unstable contact with the support or force point, the specimen shall be leveled.

S.5.3 Specimen loading shall be uniform and continuous. Specimen failure shall be controlled to be performed within 1.5min to 2.0min. During failure, in addition to recording the load indication of the testing machine, failure point positions and failure modes shall also be recorded. When the failure point of the specimen is located between two concentrated load lines, the failure is normal. When the failure point is located between the concentrated load line and the support, the failure is abnormal. CHECK the cause of the occurrence. After rectification, REMAKE the specimens for testing.

S.6 Test results

S.6.1 For specimens in normal failure mode, the flexural strength value, f_b , shall be calculated according to the following formula. Accurate to 0.1MPa.

$$f_b = Pl_b / bh^2 \quad (\text{S.6.1})$$

Where:

P - Failure load (N) of the specimen;

l_b - Specimen span (mm);

b and h - Width and height of the specimen section.

S.6.2 The flexural strength value of a set of specimens shall be determined in accordance with the following requirements:

- 1 When a set of specimens are in normal failure mode, the flexural strength value shall be expressed as the arithmetic mean of the whole set of measurements.
- 2 When only one in a set of specimens is in abnormal failure mode, this measurement shall be discarded. The flexural strength value shall be expressed as the arithmetic mean of the three remaining measurements.
- 3 When there is more than one abnormal failure value in a set of specimens, the test for this set is invalid.

S.6.3 The test report shall include the following contents:

- 1 origins, varieties, models and lot numbers of the materials to be inspected;
- 2 sampling rules and sample size;
- 3 preparation methods and curing conditions of specimens;
- 4 numbers and dimensions of specimens;
- 5 temperature and relative humidity of the test environment;
- 6 models and ranges of the equipment, and date of verification;
- 7 loading mode and loading speed;
- 8 failure load and failure modes of specimens;
- 9 test result finishing and calculation;
- 10 sampling, test and verification personnel, and test date.

The sectional dimensions of the specimen shall be 100mm × 100mm. The specimen shall be 350mm long and designed as a beam specimen. The calculation span of the beam shall be 300mm. There shall not be less than 10 specimens in each set, 5 of which are conducted with the flexural strength test, and the other 5 of which are conducted with this test.

T.3.2 The concrete strength grade of the specimen shall be determined according to the test design, but not lower than C25.

T.3.3 Proper feeding, casting and vibrating methods shall be adopted to make the fibres evenly distributed in irregular directions during the concrete mixing process.

T.3.4 Concrete specimens shall be conducted with 7 days of standard curing, then cured according to the general requirements. The test shall be carried out on the 28th day of general curing.

T.4 Test procedures

T.4.1 After measuring the specimen dimensions, PLACE a 12mm thick stainless-steel cushion block on the bottom of the beam specimen.

T.4.2 INSTALL the beam specimen with a backing plate and a loading device in the testing machine. APPLY loads at a loading rate of (0.5 ± 0.1) mm/min, until the deflection reaches 0.20mm. At this point, if the specimen has been cracked, you may uninstall the specimen and remove the stainless-steel backing plate. If the specimen cracking is not within three points, the test results of this specimen will be invalid.

T.4.3 For the beam specimen with the steel backing plate removed, CONTINUE to apply loads at a loading rate of 0.1mm/min. The full curve of residual load-deflection will be measured then.

T.4.4 On the full curve of residual load-deflection, USE a measuring scale to find the load values (in “N”) corresponding to the deflection of 0.5mm, 0.75mm, 1.0mm and 1.25mm on the graph. CALCULATE the mean value of these four load values according to the Formula (T.4.4).

$$P_r = (P_{0.5} + P_{0.75} + P_{1.0} + P_{1.25})/4 \quad (\text{T. 4. 4})$$

T.4.5 CALCULATE the residual strength value of this beam specimen, f_r , according to the Formula (T.4.5). Accurate to 0.01MPa.

$$f_r = P_r l / b h^2 \quad (\text{T. 4. 5})$$

U.3.2 For the production of concrete blocks, the mix proportion shall be designed according to the required strength grade. After casting, the blocks shall be conducted with 28 days of standard curing. During curing, concrete shall be kept wet to prevent early cracking.

U.4 Requirements of instruments and equipment

U.4.1 A special pull-out apparatus or self-assembled pull-out device may be used as the loading device for testing. However, the following requirements shall be met:

- 1** The device's loading capacity shall be at least 20% greater than the expected load value for testing. The device shall be able to operate continuously and steadily at a controllable speed.
- 2** The machine error of the device's force measuring system shall not exceed $\pm 2\%$ of the full scale. The system shall have peak storage function.
- 3** When the device's hydraulic loading system maintains the load in a short period ($\leq 5\text{min}$), the load drop value shall not be greater than 5%.
- 4** The device's clamp holder shall be able to maintain alignment of the force line with the anchor axis.
- 5** The net spacing between the bearing point of the device and the bonded rebar shall not be less than $6d$ (d refers to the diameter of bonded rebar or anchor), and shall not be less than 125mm. The net spacing between the bearing point of the device and the anchor shall not be less than $2h_{\text{ef}}$ (h_{ef} refers to the effective burial depth).

U.4.2 When the entrusting party requires to test the load-displacement curve for the anchor connection of important structures, the on-site displacement measuring device shall meet the following requirements:

- 1** The instrument range shall not be less than 50mm. The measurement error shall not exceed $\pm 0.02\text{mm}$.
- 2** The displacement measuring device shall be able to work synchronously with the force measuring system and record continuously, measure the vertical displacement of the anchor relative to the concrete surface, and plot the entire load-displacement curve.

U.4.3 If subject to conditions, the dial indicator is allowed to be used for segmented recording by manual operation. At this point, before reaching the peak load, the specimen's displacement record points shall be above 12.

U.4.4 The instruments and equipment for on-site inspection shall be regularly submitted to the verification institution for verification. Under one of the following circumstances, re-verification shall be carried out in time:

List of quoted standards

National standards

- 1 GB 50010 *Code for design of concrete structures*
- 2 GB 50017 *Code for design of steel structures*
- 3 GB 50119 *Code for concrete admixture application*
- 4 GB/T 50329 *Standard for methods of testing of timber structures*
- 5 GB 50367 *Code for design of strengthening concrete structure*
- 6 GB/T 50448 *Technical code for application of cementitious grout*
- 7 GB 50550 *Code for acceptance of constructional quality of strengthening building structures*
- 8 GB 50702 *Code for design of strengthening masonry structures*
- 9 GB/T 1634.2 *Plastics - Determination of temperature of deflection under load*
- 10 GB/T 2568 *Test method for tensile properties of resin casting body*
- 11 GB/T 2569 *Test method for compressive properties of resin casting body*
- 12 GB/T 2570 *Test method for flexural properties of resin casting body*
- 13 GB/T 3098 *Mechanical properties of fasteners - Bolts, screws and studs*
- 14 GB/T 3354 *Test method for tensile properties of oriented fiber reinforced plastics*
- 15 GB/T 3356 *Test method for flexural properties of unidirectional fiber reinforced plastics*
- 16 GB/T 3366 *Test method for fiber volume content of carbon fiber reinforced plastics*
- 17 GB/T 4883 *Detection and treatment of outliers in the normal sample*
- 18 GB/T 6329 *Adhesives - Determination of tensile strength of butt joints*
- 19 GB/T 7123.1 *Determination for working life of adhesives*

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