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RECOMMENDATION FOR DESIGN AND CONSTRUCTION OF CONCRETE STRUCTURES USING EPOXY-COATED REINFORCING STEEL BARS

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SYNOPSIS

The Japan Society of Civil Engineers (JSCE) formed the Epoxy-Coated Reinforcing Steel Bars Research Subcommittee when it was entrusted to research epoxy-coated reinforcing steel bars by sixteen companies; five companies from poducers of reinforcing steel bars, nine companies from producers of epoxy powder coating material, and one coating company.

The **"Recommendation for Design and Construction of Concrete Structures using Epoxy-Coated Reinforcing Steel Bars"** was drawn up in 1986 by the research subcommittee on the basis of the results of research and actual applications in construction work. The recommendation includes standard specification for epoxy-coated reinforcing steel bars, manufacturing manual for epoxy-coated bars, specification of rebars, coating material and patching paint, specification of reinforcing bars for coated bars, and method of tests for coated bars and coating material.

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(Chairman)

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RECOMMENDATION FOR DESIGN AND CONSTRUCTION OF CONCRETE STRUCTURES

USING EPOXY-COATED REINFORCING STEEL BARS

CHAPTER 1 GENERAL PROVISIONS

Article 1 Scope of Application

This recommendation shall provide the general standards regarding the design and construction of reinforced concrete structures using epoxy-coated reinforcing steel bars. Matters not specified in this recommendation shall conform to the "Standard Specifications for Non-Reinforced and Reinforced Concrete (1980)" of the Japan Society of Civil Engineers.

(Comments)

In properly designed and constructed concrete structures, the reinforcing steel bars (rebars) in the concrete seldom corrode under normal conditions of application due to the low permeability of the concrete and the large quantity of calcium hydroxide generated by the hydration of portland cement. However, when a structure is located in a corrosive environment, or a high salt content sea sand is used, or excess cracking occurs in the concrete, the durability of the concrete structure may be significantly reduced as a result of corrosion of rebars.

Epoxy-coated reinforcing steel bars (coated bars) are used to prevent deterioration of concrete members due to the corrosion of rebars, as mentioned above. Such coated bars have the special feature that even for concrete structures subject to salt penetration, such as those used in the splash zone of a marine structure, in the floor slabs of bridges on which de-icing salt is used, or in structures exposed to high chloride levels, such as reservoirs for waterworks, etc., no increase in the concrete cover is required, and they can be used effectively as a part of or a section of the members.

However, when coated bars are used, there are various conditions that must be considered regarding the quality and the methods of use, as the corrosion resistance of the rebars afforded by the epoxy coating varies greatly depending upon the quality and the thickness of the coating, and whether or not there is any damage to the coating. This recommendation deals with matters particularly relating to the use of coated bars when they are used in structures mainly exposed to chlorides.

As the durability of concrete structures is greatly affected, not only by the corrosion resistance of the rebars, but also by the suitability of the design and the quality of the concrete, the design conditions for the members, the concrete mix, the method of construction, etc., when epoxy-coated rebars are used, the "Standard Specifications for Non-Reinforced and Reinforced Concrete (1980)" of JSCE (hereinafter to be referred to as "Specifications for RC") must be adhered to, as in the case of ordinary reinforced concrete.

Article 2 Definition

In this recommendation, the words and expressions used are defined as follows:

(1) Non-coated bar: Reinforcing steel bar without epoxy resin coating.
(2) Coated bar: Reinforcing steel bar with epoxy resin coating applied by the electrostatic spray method.
(3) Coating film: The film of epoxy resin formed on the surface of the coated bar using electrostatic spray method.
(4) Thickness of coating: Thickness of the coating film formed on the surface of coated bar, measured vertically from the surface at the plane between the ribs on the bar.
(5) Holiday: A part of coated film where the film is discontinuous or where the thickness of the film is extremely small compared with the sound part of the coated bar.

(Comments)

Non-coated bar: In this recommendation, reinforcing steel bar without epoxy resin coating are called non-coated bars. The definitions for reinforcing steel bars shall conform to "Specifications for R.C.".

Coated bar: There are two methods of applying epoxy resin coating, the electrostatic spray method and the fluid immersion method, each of which has its own special features. As the coated bars require high corrosion resistance and because there are restrictions due to configuration and the fact large quantities of rebars are to be coated effectively, this recommendation deals with those which are epoxy coated using the electrostatic spray method.

The process for coating using the electrostatic spray method consists of surface preparation, preheating, spray coating, baking, cooling, finishing, inspection, etc.. Even though the rebars are heated to as high as 200 degrees Centigrade when the coating is applied, the effect on the physical properties of the rebar to be coated is little.

The rebar for coating shall conform to the "Standard Specification of Reinforcing Steel Bars for Epoxy-Coated Bars" of JSCE. Epoxy resin coating may be applied to ordinary round steel bars also, but sufficient care must be exercised in fixing and jointing as the bond between the bars and concrete will become extremely low.

Coating Film: In the case that the coating is performed using the electrostatic spray method, the coating film is formed on the heated rebars as the sprayed epoxy powder is melted and adheres to the surface of the rebars.

Thickness of coating: The corrosion resistance of coated bars increases as the thickness of coating increases, while the adhesion of the coated film on rebar decreases, causing the film to peel off easily from rebar when bending the bars as well as to lower the bond between the concrete and the bars. Therefore, approximately 200 microns of coating thickness is considered to be suitable under normal conditions.

Holiday: Holiday occurs mainly as a result of defects, such as scratches, small holes, sharp edges, etc., on the surface of the rebars to be coated, and improper manufacturing processes. Some holidays can be distinguished visually, while others can be detected only by instruments. In this recommendation, therefore,

all the insulting defects that can be detected by a test performed using a holiday detector in accordance with the "Test for Holidays of Epoxy-Coated Reinforcing Steel Bars" of JSCE shall be defined as holidays.

Existence of holidays in a coated bar reduces its corrosion resistance, and the number of such defects can be used as a criterion for the suitability of coated bars for use. Though it is desirable that the number of such defects to be zero, it is recommended that the number of holidays per meter of a bar shall not exceed 5 for D19 or smaller bars and 8 for D22 or larger bars, when tested with a 1000V D.C. holiday detector as specified above.

CHAPTER 2 COATED BARS

Article 3 Quality and Test Method of Coated Bars

(1) The coated bars shall conform to the "Standard Specification for Epoxy-Coated Reinforcing Steel Bars" of the Japan Society of Civil Engineers.
(2) The tests of epoxy-coated reinforcing steel bars shall be performed in accordance with the following methods of testing as provided for in the Standards of the Japan Society of Civil Engineers:

1) Test for holidays of epoxy-coated reinforcing steel bars
2) Test for thickness of coating of epoxy-coated reinforcing steel bars
3) Test for impact resistance of epoxy-coated reinforcing steel bars
4) Test for bendability of epoxy-coated reinforcing steel bars
5) Test for bond strength of epoxy-coated reinforcing steel bars
6) Test for alkali resistance of epoxy-coated reinforcing steel bars
7) Test for corrosion resistance of epoxy-coated reinforcing steel bars

(Comments)

Item (1): Although various types of coated bars are available, having different coating material, methods of coating, bar shapes, etc., the coated bars as provided for in this recommendation shall conform to the "Standard Specification for Epoxy-Coated Reinforcing Steel Bars" of JSCE.

For the coating material and rebars to be coated, the following standards of JSCE are provided:

1) "Standard Specification of Coating Material for Epoxy-coated Reinforcing Steel Bars"
2) "Standard Specification of Steel Bar for Epoxy-coated Reinforcing Steel Bars"

The coated bars shall be manufactured by blasting the above mentioned rebars in accordance with the "Standard Specification for Blasting of Epoxy-Coated Reinforcing Steel Bars" of JSCE and coating them with epoxy resin powder specified in the above mentioned standard using the electrostatic spray method.

Item (2): There are seven methods provided for the testing of coated bars in the standards of JSCE, as shown above. The following methods are also provided in the standards of JSCE to test the material for coating and for repair of coated bars:

1) Visual test of epoxy-coating

2) Adhesion test of epoxy-coating
3) Test for impact resistance of epoxy-coating
4) Test for flexibility of epoxy-coating
5) Test for abrasion resistance of epoxy-coating
6) Test for hardness of the epoxy-coating
7) Test for corrosion resistance of epoxy-coating
8) Test for chemical resistance of epoxy-coating

Article 4 Inspection of Coated Bar at Place of Manufacturer

(1) Coated bars shall be inspected at the place of the manufacturer before shipment in accordance with the instructions of the purchaser to ensure that they meet the requirements.
(2) The inspections performed at the place of the manufacturer shall be in accordance with the instructions of the purchaser and, in principle, the "Manufacturing Manual for Epoxy-Coated Reinforcing Steel Bars" of the Japan Society of Civil Engineers.

(Comments)

Item (1): Coated bars shall be used after confirming that they conform to the "Standard Specification for Epoxy-Coated Reinforcing Steel Bars" of JSCE. Therefore, the coated bars are to be inspected in accordance with the instructions of the purchaser to ensure that their quality meets the requirements of the standards of JSCE. In general, it is suggested that the results of the tests performed at the place of the manufacturer be confirmed as well as performing the visual inspection, etc..

The following locations of coating are considered to be susceptible to damage before delivery of the coated bars to the construction site:
1) The lifting points of the coated bars
2) The edges of the coated bars where they contact each other when tied in a bundle
3) At the points where the contact is made with a fulcrum when they are being transported

Item (2): Even though the inspection of the coated bars at the place of manufacturer shall be performed in accordance with the method as provided in the "Manufacturing Manual for Epoxy-Coated Reinforcing Steel Bars" of JSCE, the inspector may change the items of inspection, the frequency and the number to be inspected, etc.. Particularly if the coated bars are to be used in members in the splash zone of a marine structure, holidays, thickness of coating, corrosion resistance, etc. and, if they are to be constructed in winter, the bendability, shall be thoroughly inspected.

Article 5 Handling, Storage and Transporting of Coated Bar at the Place of Manufacture

(1) Coated bars shall be handled with care so as not to damage the coating on the surface of the coated bars.
(2) Coated bars shall be stored in a location where the sunshine does not fall directly upon them for a long period of time, and care shall be exercised not to pile them up too high to prevent the coating from being damaged.
(3) When transporting coated bars, measures shall be taken to prevent the coating from being damaged, and they must be secured in such a way that no

collapse of the cargo can occur.

(Comments)

Item (1): Since the coating can be easily damaged by sharp edges, etc., care shall be exercised when transporting, and storing coated bars. When transporting from the place of manufacture, prior consideration must be given to the use of nylon sling, but also to the height of the storage, method of lifting, prevention of collapse, etc..

Item (2): Damage is likely to occur to the coating if coated bars are stacked to more than 6 ties. If several bars are to be picked up from a pile of the bars, the uppermost bars must be picked up first, and they should be picked up horizontally, only after confirming that the edges are not in contact with other bars. If the edge rubs against other bars, it tends to damage the coating of other bars.

Since the coating of the coated bars deteriorates when they are exposed to the ultraviolet rays, they should not be stored in a location where the sunshine falls directly upon them. If the coating deteriorates due to the direct sunshine, in many cases the bendability and the impact resistance will be reduced.

Item (3): When transporting coated bars from the place of manufacture to the construction site, prior consideration must be given to the method of shipment so as not to damage the coating during transportation. If they are to be loaded with other cargo, care must be taken so as not to come into contact with other cargo.

CHAPTER 3 CONCRETE MATERIAL

Article 6 General Provisions

(1) The qualities of concrete materials shall be confirmed before use.
(2) The allowable limit of chlorides to be contained in the concrete at the time of mixing shall be determined by the engineer in charge, taking into consideration the type of concrete structure, the environmental conditions and others.

(Comments)

Item (1): Even when the coated bars are used, the quality of concrete is important, and, therefore, the quality of the materials used to produce the concrete must be confirmed beforehand to obtain the required quality of concrete.

Item (2): Coated bars are generally used in structures located in corrosive environments and subject to chloride penetration in concrete from the splashing of sea water, the use of de-icing salt, etc.. The amount of chlorides accumulated as the they penetrate concrete is far greater than the amount contained in the concrete during mixing. The chloride content of the concrete during mixing has no effect on the corrosion resistance of the coated bars. However, since the salt content of the concrete during mixing can affect not only the quality of concrete, such as lowering of the long-term strength, increase in the heat of hydration, acceleration of the setting, etc., but also, the durability of the

structure, the engineer in charge should determine acceptable chloride levels considering all conditions relating to the structure.

Article 7 Cement

(1) Ordinary portland cement, high-early strength portland cement, moderate-heat portland cement, sulphate-resistant portland cement, blastfurnace slag cement and flyash cement shall conform to JIS R 5210, JIS R 5211 and JIS R 5213, respectively.
(2) In the case that cement other than specified in (1) above is used, the quality thereof shall be confirmed and the method of use thoroughly examined and prior approval shall be obtained from the engineer in charge.

(Comments)

In selecting a cement to be used for construction, the type of structure, the environmental conditions, the other material used, the time of construction, the construction period, the method of construction, etc. must be taken into account so as to select a cement capable of producing concrete of the required quality.

Article 8 Water

The water used shall not contain noxious chemicals which affect the quality of the concrete, such as oil, acid, salts, organic matters, suspended solid, etc..

(Comments)

The water used for mixing concrete shall not contain noxious chemicals as provided for in Article 75 of the "Specifications for R.C.". Where it is difficult to obtain the required water for the mixing of concrete for special structures, such as a lighthouse on a detached island, etc. seawater may be used provided all the rebars used are coated bars and prior approval of the engineer in charge is obtained. However, it must be confirmed that the quality of concrete will not be ill-affected by use of seawater by performing relevant tests prior to the commencement of construction.

Article 9 Aggregate

(1) The aggregate used shall conform to the provisions of the "Specifications for RC".
(2) The allowable limit of chlorides in the sea sand used shall be determined by the engineer in charge.
(3) Testing of chloride content of the sea sand shall be performed in accordance with the "Method of Testing Chloride Content of Sea Sand" of JSCE Standards.
(4) Where crushed sand, fine aggregates of blastfurnace slag, etc. are used, they shall conform to JIS A 5004 and JIS A 5012, respectively.

(Comments)

Item (1): The aggregate used shall be clean, hard and suitably graded, and shall not have ill effect on the quality of the concrete. Therefore, the provisions of "Specifications for RC" shall apply to the selection of materials.

Item (2): The corrosion resistance of the coated bars will not be affected by

the chlorides mixed into the concrete when sea sand is used as an aggregate. However, as the chloride content of sea sand increases, it may affect the quality of concrete and alkali aggregate reaction, etc.. Therefore, the engineer in charge will determine the allowable limit of chlorides contained in the seasand in conformity with Item (2) of Article 6 of this recommendation.

Article 10 Admixture

(1) Admixtures used shall conform to the Standards of JSCE or JIS.
(2) Admixtures other than those specified above shall be subject to confirmation of their quality and their effect on the quality of concrete, and the method of use shall be thoroughly reviewed and their use shall be subjected to the approval of the engineer in charge.

(Comments)

To improve the workability for placing and compaction by increasing the fluidity of the concrete, use of a suitable amount of an air entraining agent, water reducing agent, superplasticizers, etc., is an effective method from the point of preventing the coated bars from being damaged by the use of a vibrator.

CHAPTER 4 MIX PROPORTION OF CONCRETE

Article 11 Water-Cement Ratio

(1) The water-cement ratio of concrete shall conform to Article 95 of the "Specifications for RC".
(2) The water-cement ratio of concrete determined by the required durability of concrete used for marine structures shall conform to Article 234 of the "Specifications for RC".

(Comments)

The durability of the structures will be improved considerably by using coated bars, but even so, the importance of the quality of concrete cannot be ignored. Therefore, the water-cement ratio of the concrete in which the coated bars are to be used shall be determined in accordance with the provisions of the "Specifications for RC"

Article 12 Consistency

The consistency of the concrete shall be such that the slump is as small as possible within the range suitable for placing and compaction .

(Comments)

The criterion shall be that the slump of the concrete be as small as possible within the range suitable for operation in accordance with Article 99 of the "Specifications for RC", even when coated bars are used. As mentioned in Article 10 (Comments) of this recommendation, however, it will be effective from the viewpoint of preventing the coating from being damaged to improve the workability of the concrete by increasing the slump through the suitable use of a

superplasticizers, etc.. When the slump is made larger than necessary when using liquified concrete, though the concreting operation will become easier, considerable segregation of materials is likely to occur, suggesting that the quality of concrete may be adversely affected. Therefore, sufficient care must be exercised when liquifying the concrete.

CHAPTER 5 REINFORCEMENT WORK

Article 13 Receiving of Coated Bars

(1) When receiving coated bars at the construction site, they shall be checked for the required quality.
(2) When uncrating a shipment of coated bars, the method used shall be such that no damage should occur to the coating.

(Comments)

Item (1): The quality inspection to be performed at the time of delivery of the coated bars to the site shall include confirmation of the required quality by using the performance test results of the coated bars, together with the test results of coating material, repair material, steel bar, etc..

Item (2): It is suggested that tools such as clippers, etc., be used for uncrating the delivery so as not to cause damage to the coating.

Article 14 Transportation and Storage of Coated Bars

(1) A suitable method shall be used for transporting coated bars so as not to cause any damage to the coating.
(2) A suitable method shall be used for storing coated bars so as not to cause damage to the coating.

(Comments)

Item (1): Coated bars are subject to coating damage caused by contact with other bars during transportation, unloading, abrasion of wire ropes, extreme bending deformation, etc.. To prevent the coated bars from such damage, the bars shall be securely bound together using a buffer material as required so that the bars do not rub against each other during transporting, and it is desirable that the bent bars be supplied with a canvas cover, etc. so as to prevent the coating of the bars from being damaged due to the contact with the edges of other bars. Also, it is desirable to have a buffer material on the bed of the transporting truck. When loading and unloading coated bars, it is preferable to lift them at either two or three points, to avoid bending deformation. To prevent the wire rope from making direct contact with the steel bars, it is necessary to use a lifting material (e.g. nylon sling, etc.) and to place them on buffer material instead of placing them directly on the ground. If damage occurs to the coating during transportation, it must be repaired as provided for in Chapter 7 of this recommendation before rusting occurs.

Item (2): It is preferable to store the coated bars on buffer material placed at suitable intervals instead of placing them directly on the ground, to avoid

damaging the coating, and to supply them with a canvas cover to avoid exposure to direct sunshine. It is not desirable to store coated bars by piling them on top of one another. If they are to be stored by piling, buffer materials, such as wood, rubber, jute sack, etc. should be used to separate the layers. However, the number of layers allowed shall be limited to maximum of five, even for large diameter bars.

Article 15 Cutting and Bending of Coated Bars

(1) Coated bars shall be cut and bent using a method that does not damage the coating and the quality of the steel bars.
(2) Coated bars shall, in principle, be bent at ambient temperatures higher than 5 degrees Centigrade. The shape shall conform to Article 28 of this recommendation.
(3) If any damage is caused to the coating during cutting and bending, the damaged portion shall be promptly repaired in accordance with Chapter 7 of this recommendation.

(Comments)

Item (1): The basic procedure for cutting and bending of coated bars is similar to Article 138 of the "Specifications for RC", but particular attention must be paid to the following points:

1) Care must be taken not to damage the coating when cutting and bending coated bars. For this reason, at the point of drive roll and back-up barrel of the bending machine, use of urethane roller, lined with material that will not damage the coating, is recommended. If any damage is incurred during bending, the cause must be examined and measures (improvement of bending machine, repair coating, etc.) be taken immediately before further continuing the work.
2) In cutting coated bars, a jig that will not damage the coating must be used. When a shear cutter is used, buffer material must be used at the point of contact between the bars and the shear.

Item (2): The coating of coated bars will resist cracking during bending above a temperature of 5 degrees Centigrade. The properties of coated bars will not change up to about 200 degrees Centigrade considering the manufacturing process. Therefore, it was determined that the cutting and bending are, in principle, to be performed at an atmospheric temperature of more than 5 degrees Centigrade. If the cutting and bending must be performed at an ambient temperature of less than 5 degrees Centigrade, it is desirable to take measures to raise the temperature of the coated bar.

Item (3): Since coated bars are coated after blasting steel bars, any damaged portion of the coating tends to rust. For this reason, it is suggested that the damaged portion be repaired by coating before rusting occurs. In principle, the method of inspection for damage to the coating shall be visual.

A damaged area larger than 10 to 15mm^2 may be considered to be requiring repair. ASTM A 775-81 defines the limiting value to be 0.1in^2 (about 65mm^2) and similarly, ASTM D 3963-82 defines it to be 6x6mm (36mm^2). However, the results of domestic research indicate that if the damaged portion exceeds 25mm^2 in area, it tends to rust in a corrosive environment. Also, even if each of these damaged parts falls within the limiting value, the existence of several such parts may be harmful. ASTM D 3963-82 defines that the total area of damage

should not exceed 2% of the total surface are, and that bars for which this value is exceeded cannot be used.

Article 16 Assembly of Coated bars

(1) The coated bars shall not be subject to impact during assembly.
(2) The coated bars shall be tied solidly, avoiding damage due to rubbing.
(3) After assembly, the coated bars shall be inspected again and the damaged portion shall be repaired using the material for repair as specified in Chapter 7 of this recommendation.

(Comments)

Item (1): As the coating of the coated bars is susceptible to damage from impacts, when the bars are dragged or dropped, they may sustain damage that reaches the base metal. When being assembled, coated bars shall be handled with care.

Item (2): For the ties of coated bars, use of soft iron wire with diameter of larger than 0.9mm with vinyl insulation is recommended. When vinyl covered iron wire is used, solid assembly of coated bars may become difficult to achieve, due to the slippery surface of the coating. For this reason, it is suggested that the bars be tied in a cross or at a large number of places.

Avoid using the assembled bars as a ladder, etc., as damage to the coating may result. If a fixing method other than binding is used, the approval of the engineer in charge must be obtained.

Item (3): After the assembly of the coated bars has been completed, inspection in accordance with Article 139(4) of the "Specifications for RC" as well as inspection for damage to the coating shall be performed. As repair of the damage may be difficult once the bars have been assembled, the inspection should be performed during assembly wherever possible. If the coating is damaged as a result of rubbing against other bars in a binding, care must be taken to check the surrounding area for damage. If slight rusting has already occurred on the surface of the bars, the repair work shall be performed only after removing the rust with sand paper, etc..

In the case that the bars will be exposed to direct sunshine for more than 3 to 6 months after assembly, the bending workability of the coating may be reduced. When performing rebending, etc., the bars shall be inspected for damage to the coating near the bending location, and repairs carried out as required.

Article 17 Joints of Coated Bars

(1) The type and method of joints of coated bars shall be selected depending on the type of bars, diameter, stress condition, position of joint, performance requirement for the joint, etc..
(2) The method and position of joints of the coated bars shall be determined in accordance with Article 29 of this recommendation, and constructed after the approval of the engineer in charge has been obtained.
(3) The joints of the coated bars shall be in accordance with the design drawings with regard to position and dimension, and shall be fabricated in such a way that the performance of the joint is not impaired.

(Comments)

The joints of the coated bars can be classified into lapped splices, mechanical joints, welded joints, etc.. Since these joints are specified in the "Specifications for RC", the "Recommendations for Design and Fabrication of Joints in Reinforcing Bars" (Concrete Library No.49) and the "Standard Specification for Welded Joints of Reinforcing Steel Bars", matters not provided for in this recommendation shall be determined in accordance with the suitable guideline for the type of joints stated elsewhere.

The lap splice shall conform to Article 140 of the "Specifications for RC". The mechanical sleeve joints filling the gap with epoxy resin shall conform to the "Recommendations for Design and Fabrication of Joints in Reinforcing Bars".

It has been confirmed that in the gas-pressure welded joint, if the end surface and perphery of the weld are coated with epoxy-resin, the surface of the weld will not be completely compressed, being left as a flat fracture. Therefore, the coating on the end surface to be welded must be completely removed prior to the welding. During the fabrication of gas-pressure welded joints, noxious fumes may be generated from the resin. Therefore, measures shall be taken to ensure the safety of the working environment, etc..

In principle, the enclosed arc-welded joint shall conform to the "Recommendations for Design and Fabrication of Joints in Reinforcing Bars". It is confirmed that static strength of enclosed arc-welded joint meet the values specified in the recommendations mentioned above even when the coating on the end surface is not removed. However, noxious fumes may be generated from the combustion of the resin as in the case of the gas-pressure welded joint. Therefore, measures shall be taken to preserve the safety of the working environment, etc..

In the case of mechanical joints with couplers, couplers and locknuts coated by electrostatic spray method shall be used. In particular, the locknut must also be internally coated. There could be a case where the screwed torque may not meet the specified value, depending on the thickness of the coating, hardness, etc.. During the fabrication of the joints, therefore, it is desirable to confirm the torque coefficient prior to the commencement of the fabrication by testing.

The fabrication of the grip joints shall conform to "Recommendations for Design and Fabrication of Joints in Reinforcing Bars".

Article 18 Repair of Joints

(1) When a joint other than a lapped splice or mechanical sleeve joint filling the gap with epoxy resin is used, damage to the coatings on the surface of the coated bars or the joint material cannot be avoided. The damaged coating and the joint must be securely repaired.
(2) The material and the method used to repair the joint shall conform to Article 23, 24 and 25 of this recommendation, respectively.

(Comments)

The lapped splice and mechanical sleeve joint filling the gap with epoxy resin will not require repair as application of an external force that may damage the coating of the coated bars and the joint material is not required.

The coating of the gas-pressure welded joint and the enclosed arc-welded joint may be damaged due to the heat applied. Therefore, the damaged coating film tends to peel off and must be removed with a wire brush. In the case of the gas-pressure welded joint, the coating at the point where the setscrew fitting contacts the coated bars may be damaged, in which case repair will be required. The range within which the coating is affected due to the heat applied varies depending on the diameter of the coated bars. However, assuming that the coating incurs damage at around 200 degrees Centigrade, the range is about 70 to 180 mm from the location of the joint. The range within which the damage will be incurred by the setscrew fitting, holder, etc. varies depending on the method used, but it may extend up to about 180 mm from the location of the joint. Taking into account these conditions and easiness of the work, repair will be required within the range of 180 mm from the location of the joint regardless of the diameter of the bars.

The mechanical grip joint shall be repaired after construction by coating the joint with a repair coating or by using a method conforming with Articles 23,24 and25, respectively of this recommendation, as plastic deformation occurs on the surface of joint sleeve. If the repair is to be performed using a method other than the above, prior approval of the engineer in charge must be obtained.

It shall be confirmed after construction of the mechanical grip joint or the joints with screwed couplers, that no gap exists between the coated bars and the joint material, and the damaged outer surfaces of the joint material and damaged coated bars shall be repaired. The finished thickness of the repair coating shall be from 200 to 300 microns.

CHAPTER 6 PLACING OF CONCRETE

Article 19 General Provisions

When placing concrete, care shall be taken not to damage the coating of the coated bars.

(Comments)

Since the rebars are epoxy-coated to protect them from corrosion, it is necessary that the placing of concrete be performed with attention paid to prevent the coating from being damaged.

Aricle 20 Consolidation

(1) Consolidation of concrete for the concrete structure in which the coated bars are used shall, in principle, be performed using an internal vibrator.
(2) The internal vibrator shall be used so as to prevent the coating of the coated bars from being damaged as much as possible.

(Comments)

Item (1): Consideration given to the consolidation of concrete when coated bars are used is similar to that provided in Article 125 of the "Specifications for RC" to the extent that the concrete must be placed and thoroughly consolidated

so as not to reduce the bond strength of the coated bars. For this reason, the use of the internal vibrator is specified as a general rule. Where compaction may be difficult using an internal vibrator, a form vibrator may be used simultaneously.

Item (2): The coating of the coated bars is considered to sustain damage that reaches the base material within about 10 seconds if it comes into contact with internal vibrator. Therefore, the use of an internal vibrator coated with urethane is recommended.

Article 21 Construction Joint

When removing laitance from a construction joint on the surface of the placed concrete, care shall be taken not to damage the coating of the coated bars.

(Comments)

Although the construction joint is required to be constructed as provided for in Articles 131 to 136, respectively of the "Specifications for RC", special attention shall be paid when removing the laitance on the surface of the concrete placed at the horizontal construction joint.

If mortar or concrete has adhered to the coated bars at the construction joint, it shall be removed by water jets or wiping it with waste rags before it hardens, care being taken not to damage the coating. Wire brushes should not be used to clear away hardened mortar or concrete adhered to the coated bars.

To remove laitance at the construction joint, a method that prevents the coating from being damaged shall be used, e.g. water jet, etc., as sand blasting tends to damage the coating.

Article 22 Formwork

When erecting formworks, the method used shall be such that no damage is caused to the coating of the coated bars.

(Comments)

Although the erection of the formwork shall be performed in accordance with the provisions of Article 146 of the "Specifications for RC", care must be taken of the following points when erecting the formwork for structures using coated bars.

1) The spacers used to maintain spaces between the face of the formwork and the coated bars shall be of a material that does not damage the coating and the spacers themselves shall be made of non-corrosive material or treated therewith.
2) The tie bars used for formworks shall receive corrosion protective treatment. Repair coating material may be used for the treatment. After stripping the formwork, the screw part of the tie bar exposed in the holes of the wooden plugs shall receive rust preventive treatment with the repair coating material, etc..
3) When welding is performed to install tie bars for formworks, care shall be taken that sparks from the welding do not fall on the coated bars.
4) The end formwork used to construct a vertical construction joint shall be

erected so as not to damage the coating of the coated bars.

CHAPTER 7 REPAIR OF COATED BARS

Article 23 General Provisions

Where the coating is damaged as a result of cutting or where a part has deteriorated or been damaged as a result of welding, it shall be thoroughly cleaned and repaired with repair coating material before the concrete is placed.

(Comments)

Even though care is taken during the construction as provided for in both Chapters 5 and 6 in this recommendation, using coated bars of the required quality, for which tests have been performed and confirmed by inspecting them as provided in Chapter 2, there may be cases where the coating sustains damage, such as cuts, scratches or damage from impact, in the process of unloading, transportation, fabrication or in some cases fractures due to bending. Also, at the section of cutting or welded part, the coating may be broken off or deteriorate. These defects shall be cleaned by removing dirt, oil and the damaged film due to heat, etc. and repaired.

The method used for repair shall be by applying the repair coating with brushes or with a spray gun, or repairing them with hot-melt material, rust-preventive tape, etc.. Any of these methods may be used as long as the quality and the method of repair conform to the provisions of Articles 24 and 25 of this recommendation, respectively, which must be decided depending on the type of defects and work environment. Appropriate care must be taken to plan the construction schedule so as to incorporate repair operation of assembled coated bars for visual inspection and repair.

Article 24 Material for Repair

(1) Material used for repair shall, in principle, conform to the "Standard Specification of Patching Paint for Repair of Epoxy-Coated Steel Reinforcing Bars" of JSCE.
(2) Where the materials other than the above are used for repair, the quality of the material shall be thoroughly confirmed and prior approval shall be obtained from the engineer in charge.

(Comments)

Item (1): Materials for repair of coated bars include patching paint, hot-melt material, heat shrinkable material, corrosion protective tape, etc.. However, the patching paint conforming to the "Standard Specification of Patching Paint for Repair of Epoxy-Coated Reinforcing Steel Bars" shall be used in principle, considering its good adhesion properties to rebars and coated bars, good chemical and corrosion resistance, and the quality having been confirmed thoroughly in comparison with other materials. In selecting the repair coating material, the compatibility with the coating film of the coated bars must be considered.

Item (2): Among the materials used for repair other than the patching paint

mentioned above, hot-melt material, heat shrinkable material and corrosion protective tape are advantageous in some aspects compared with the patching paint, as they require no time for drying. Since some of these materials, however, have not yet confirmed their workability, durability, etc., when using them, the quality shall be thoroughly confirmed and the approval of the engineer in charge obtained.

Article 25 Method of Repair

(1) Method used for repair of the coating shall be suitable to the type of patching paint used.
(2) When repair materials other than the patching paint mentioned above are used, the method of repair shall be thoroughly reviewed and the prior approval of the engineer in charge obtained.

(Comments)

Item (1): Depending on the type of patching paint, the mix ratio of main agent and hardening agent, time allowed for use, time required for drying, etc. will vary. Therefore, specification for the patching paint used must be adhered to.

When applying the patching paint, the following treatments shall be performed depending on the condition of the defective portion of the coated bars. Cross section of the coated bars after cutting and harmful defects, caused in the process of transportation, fabrication and assembly, shall be cleaned up by removing foreign matters, such as oil, dirt, etc. using wet cloth with a solvent. When rust has already formed, it shall be removed with sandpaper, etc. prior to repair coating. Where weld joint, gas-pressure welded joint, etc. are used, the deteriorated portion of the coating due to the heat must be removed completely. To remove such deteriorated coating or mill scale that appears on the base rebar, blasting is preferable. When difficulties are involved in using blasting, a power tool, such as a sander, or wire brushes may be used.

Patching paint shall be applied as soon as the above pretreatment has been completed, using brushes, sprays, etc.. Scratches or abrasion, which are comparatively small in area, may be repaired suitably using brushes, etc. and defects, such as the cross section of the coated bars after cutting or welded portion, may be repaired with brushes, sprays, etc.. The thickness of the repair coated film shall be about 200 to 300 microns. As it takes time to dry the repair coated film, care shall be taken to avoid touching the wet coating or exposing it to rain, etc..

Item (2): When using material other than patching paint, the properties of the material must be well understood, selecting the most suitable method taking into account the condition of the defect and working environment, and the approval of the engineer in charge shall be obtained.

CHAPTER 8 ALLOWABLE STRESS

Article 26 Allowable Bond Stress

The allowable bond stress between the deformed coated bars and concrete shall,

in principle, be 80% of the value specified in Article 66 (4) of the "Specifications for RC".

(Comments)

The maximum bond strength between deformed coated bars and concrete varies depending on the type and diameter of the coated bars. The maximum bond strength being specified to be greater than 80% of the value for the non-coated bars in the "Standard Specification for Epoxy-Coated Reinforcing Steel Bars", the allowable bond stress shall, in principle, be 80% of the value specified for the non-coated deformed rebars. However, in the case of the small diameter bars, the shape of the ribs become much smoother because of the coating film, making the bonding strength smaller. When using small diameter bars, it is recommended either to reduce the allowable bond strength further or to confirm the bond strength by performing the bond strength test.

The bond between coated non-deformed rebars and concrete may, in general, be neglected.

Article 27 Allowable Tensile Stress

The allowable tensile stress of the coated bars shall conform to the provision of Article 67 of the "Specifications for RC".

(Comments)

As the mechanical properties of the coated bars must conform to the corresponding specified values of the rebars before they are coated, the value specified for the non-coated bars as specified in Article 67 of the "Specifications for RC" may be used for the allowable tensile stress of the coated bars.

Even in the case which the cracks formed in concrete are specially harmful to the corrosion protection of the non-coated bars and the allowable bond stress is required to be reduced, such measures need not be taken in general for coated bars, subject to approval of the engineer in charge. However, where the cracks must be controlled strictly from the view point of water-tightness, the reduction of the allowable tensile stress must be considered as in the case of the non-coated bars.

CHAPTER 9 STRUCTURAL DETAILS

Article 28 Bending Radius of Coated Bars

The bending radius of the coated bars shall conform to the provisions of Article 18 of the "Specifications for RC".

(Comments)

The coated bars are required to satisfy the conditions given in "Section 5.5, Bendability" of the "Standard Specification for Epoxy-Coated Reinforcing Steel Bars". Even if minor damage is caused to the coating due to handling, there would be no practical problems if it is repaired using the method specified in

Chapter 7 of this recommendation. Therefore, it was determined that the bending radius of the coated bars may be the same as in the case of the non-coated bars.

Article 29 Joints of Coated Bars

(1) The joint used in the major sections shall be A class joint as specified in the "Recommendations for Evaluation of Joints in Reinforcing Bars" of JSCE.
(2) The location of the joint, the lap lengths in lapped splice, etc. of the coated bars shall be determined in conformity with the "Recommendations for Fundamentals in Design and Fabrication of Joints Splices in Reinforcing Bars" of JSCE. However, the allowable bond stress of concrete used to calculate the lap length shall be in conformity with Article 26 of this recommendation.
(3) Where the joints other than the lap splice or the mechanical sleeve joint filling the gap with epoxy resin are used, it should be confirmed beforehand that the joint may be securely repaired if damaged.

(Comments)

The joint of coated bars includes, lap splice, mechanical grip joint, welded joint, etc., but the joints other than the lap splice or the mechanical sleeve joint filling the gap with epoxy resin inevitably cause damage to the coating when constructing the joint. Worse still, in some cases, depending on the condition, the damaged coating at the joint cannot be repaired at the site. Therefore, where the joints other than the joints mentioned above are used, it should be confirmed beforehand that the joint may be securely repaired if damaged.

Article 30 Concrete Cover

(1) The concrete cover of the coated bars shall in general be greater than the value specified for "General Environment" used for non-coated bars in the "Specifications for RC".
(2) Where special consideration is given, the concrete cover of the coated bars may be reduced to the diameter of the bars used.

(Comments)

Either in an ordinary environment or in a corrosive environment, the coated bars almost never corrode. Therefore, when determining the cover of the coated bars, it is not necessary to consider the extra cover due to environmental conditions as long as it is greater than the diameter of the bars used.

In consideration of the tolerance in the construction and damage to the coating, the cover should be greater than that used in the case when non-coated bars are used in the general environment. The value for the general environment means the equivalent value as specified in Article 23 of the "Specifications for RC" where it says "for large and important structures or the structure exposed to wind and rain".

If it is required to reduce the concrete cover, however, the tolerance in the construction must be separately considered and thorough care should be taken that the coating has no holidays or damage exceeding their limits. In addition, special consideration must be given to the part that wears due to floating ice, etc. of the structure that requires to be fire resistant, etc..

STANDARD SPECIFICATION FOR EPOXY-COATED REINFORCING STEEL BARS

1. Scope of Application

This specification covers plain and deformed epoxy-coated reinforcing steel bars (coated bars) manufactured using epoxy powder and coated by the electrostatic spray method.

2. Material

2.1 The epoxy coating material shall conform to the "Standard Specification of Coating Material for Epoxy-Coated Reinforcing Steel Bars" of the Standard of the Japan Society of Civil Engineers.

2.2 The reinforcing steel bars (rebars) to be coated shall conform to the "Standard Specification of Steel Bars for Epoxy-Coated Reinforcing Steel Bars" of the Standards of the Japan Society of Civil Engineers.

2.3 The rebars to be coated shall, in principle, be straight without any bends.

3. Surface Preparation of Rebars before Coating

3.1 The surface of rebars to be coated shall be blasted, in conformity with the "Standard Specification for Blasting of Epoxy-Coated Reinforcing Steel Bars" of the Standards of the Japan Society of Civil Engineers.

3.2 The blasted surface of the rebars to be coated shall be free from detrimental defects, such as scratches, which may result in defects after epoxy-coating.

4. Coating of Rebars

Coating of the blasted rebars shall be performed by the electrostatic spray method in accordance with the specifications for the epoxy powder coating material used.

5. Requirements of Coated Bars

The quality of coated bars shall satisfy the followings:

5.1 Appearance: The coated film shall be uniform and shall be free from drooping, projection, or adhering foreign matter.

5.2 Holiday: The number of holidays per meter obtained by the "Test for Holidays of Epoxy-Coated Reinforcing Steel Bar" of the Standards of the Japan Society of Civil Engineers shall be within 5 for nominal diameter of D19 or smaller bars and within 8 for nominal diameter of D22 or larger bars.

5.3 Thickness of Coated Film: The thickness of coated film obtained by the

"Test for Thickness of Coating of Epoxy-Coated Reinforcing Steel Bar" of the Standards of the Japan Society of Civil Engineers shall be within the range of 200 ± 50 microns and the frequency exceeding this range shall be not larger than 10%.

5.4 Impact Resistance: The impact resistance of coated bar shall be tested at the strength of 30 kg-cm as prescribed by the "Test for Impact Resistance of Epoxy-Coated Reinforcing Steel Bars" of the Standards of the Japan Society of Civil Engineers. It shall be verified that 80% or more tested coated bars have no holes in the coating after the test.

5.5 Bendability: The test shall be performed by the "Test for Bendability of Epoxy-Coated Reinforcing Steel Bars" of the Standards of the Japan Society of Civil Engineers, and the following conditions shall be satisfied:

(1) The test shall be performed on the conditions as shown in Table 1 at the condition of 20±2 degrees Centigrade, and the frequency of cracking, peeling off, etc. caused on the coating shall be not larger than 20%.

(2) The test shall be performed with the inner radius of 3d (d:diameter of the coated bar) to 180 degrees at the temperature of 5±1 degrees Centigrade (SD 50 shall be bent to 90 degrees), and the frequency of cracking, peeling off, etc. caused on the coating shall be not larger than 20%.

Table 1 Bending Conditions

type	inner radius of bending	bending angle
SD 24	2 d	180 degree
SD 30	2 d	180 degree
SD 35	not larger than D41 : 2 d	180 degree
	not smaller than D51: 2.5 d	180 degree
SD 40	2.5 d	180 degree
SD 50	not larger than D25 : 2 d	90 degree
	not smaller than D29: 2.5 d	90 degree

5.6 Bond Strength: The coated bars shall be tested by the "Test for Bond Strength of Epoxy-Coated Reinforcing Steel Bars" of the Standards of the Japan Society of Civil Engineers, and the maximum bond stress shall be not smaller than 80% of that of the non-coated steel reinforcing bars.

5.7 Alkali Resistance: The coated bars shall be tested by the "Test for Alkali Resistance of Epoxy-Coated Reinforcing Steel Bars" of the standards of the Japan Society of Civil Engineers, and the coating shall have no softening, swelling, bulging and peeling off, etc..

5.8 Corrosion Resistance: The coated bars shall be tested by the "Test for Corrosion Resistance of Epoxy-Coated Steel Reinforcing Bars", of the Standards of the Japan Society of Civil Engineers, and the average corroded area shall be not larger than 1%.