CONCRETE LIBRARY OF JSCE VOL.1, JULY 1983

RECOMMENDED RULES FOR JOINTS IN REINFORCING BARS

(Reprint from the CONCRETE LIBRARY No.49 published by JSCE, February 1982)

JSCE Concrete Committee on Joints of Reinforcing Bars

Masatane KOKUBU, Chairman　　Shoji IKEDA, Secretary

Committee Members

Katsuhito AONO	Tetsuo KUNIHIRO	Kazuo TSUNO	Ziro MURATA
Hirotoshi ABE	Katsumi KODAMA	Takeshi TERAO	Masaaki YACHIDA
Tadao IINO	Kazusuke KOBAYASHI	Tsutomu NOGUCHI	Jun YAMAZAKI
Kohei IKEDA	Yukimasa GOTO	Takeshi HIGAI	Yasuhiko YAMAMOTO
Hiroshi UEKI	Michiyuki KOHNO	Yoshiro HIGUCHI	Tsutomu YANAGIDA
Kozo EGUCHI	Tokio KONDO	Yoshio FUJITA	Yukio YOKOMIZO
Tsunehiro OHUCHI	Shozo SAITO	Minoru FUNAKOSHI	Iwao YOSHIDA
Nobuyuki OHKADO	Motohiro SUZUKI	Yasuro MAKI	Hirotomo YOSHIDA
Tsutomu OHAGI	Shigetsugu SEINO	Atsuhiko MACHIDA	Kiyohiro YOSHIMURA
Minoru OHTA	Hiroshi SEKI	Yoshiji MATSUMOTO	Akira WATANABE
Kiyoshi OKADA	Hiromasa TANAKA	Kiyoshi MIYAKE	Takeshi WATANABE
Hajime OKAMURA	Yoneyoshi TAIDO	Yoichi MIMAKI	
Akiyoshi KAWAI	Isamu TAKUWA	Kiyoshi MIYAMOTO	
Hiroshi KANEMITSU	Osamu TAMAKI	Shinichi MUGURUMA	

Committee Members from trusters

Katsumi ADACHI	Kiyomi SHINOZAWA	Manji NISHIMURA	Kanehisa MORIYAMA
Yoshiyuki ISHIBASHI	Hiroshi SHIMOMURA	Yoichi NOJIRI	Yukio YAMAGAMI
Tohru IWAI	Minoru SUGITA	Shozo FURUTSU	Ikuo YAMAGUCHI
Katsuhiro UNO	Eiichi TAZAWA	Tatsuo MOGAMI	Kouichi YAMAMOTO
Takayuki UENO	Shigeo TAKANO	Masashi MOCHIZUKI	
Nariyuki KUMAGAI	Yoshio TANI	Hiromasa MOCHIZUKI	
Hidemasa SAKAI	Ken NIKAIDO	Iwao MORI	

CONTENTS

SYNOPSIS

The Committee on Concrete in the Japan Society of Civil Engineers (JSCE) organized Subcommittee on Joints of Reinforcing Bars when JSCE was entrusted to make researches for the joints of reinforcing bars by related corporations in 1979. After the subcommittee had made extensive researches, Recommended Rules for Joints of Reinforcing Bars were proposed. The rules consist of two recommendations. One is a comprehensive and basic rules for design and construction of joints of reinforcing bars which specified detailed instructions for reinforced concrete structures including bar joints. The other proposed the classification and evaluation of various types of bar joints which became a basis of the draft of the corresponding Japan Industrial Standards (JIS). Other than the recommendations and the commentaries here presented, recommendations for design and construction of the specific joints such as pressed sleeve joints, threaded reinforcement joints, threaded joints, metal-filled sleeve joints, mortar filled sleeve joints, automatic gas-pressure welding joints were proposed.

Masatane KOKUBU
(Chairman)

Shoji IKEDA
(Secretary)

Masatane KOKUBU is professor of civil engineering at Musashi Institute of Technology and professor emeritus of the University of Tokyo. He was chairman of the Committee on Concrete in Japan Society of Civil Engineers from 1960 to 1982. He is honorary member of the Japan Society of Civil Engineers and of the American Concrete Institute. He is member of Executive Committee of I.A.B.S.E.

Shoji IKEDA is professor of civil engineering at Yokohama National University. He is member and secretary of the Committee on Concrete in JSCE.

RECOMMENDATIONS FOR FUNDAMENTALS IN DESIGN AND FABRICATION OF JOINTS IN REINFORCING BARS

CHAPTER 1 GENERAL

Section 1 Extent of applicability

This Recommendation shall apply as a basis for design and fabrication of joints in reinforcing bars to be used in reinforced concrete structures in general.

The items not specified in this Recommendations shall be ruled by JSCE "Recommendations for evaluation of joints in reinforcing bars 1981" (abbreviated as "Recommendations for Evaluation") and JSCE "Standard specifications for unreinforced and reinforced concrete, 1980" (abbreviated as "RC Specifications").

CHAPTER 2 DESIGN OF JOINT PORTIONS

Section 2 Locations of joints

(1) The locations of joints shall avoid the member cross sections subject to high stresses as much as possible.

(2) The locations of joints shall be staggered but not be aligned in a single member cross section as a rule. As for the distances between the staggered two joints in the axial direction, a standard length shall be equal to a joint length plus twenty five bar diameters.

(3) When the requirements in the item (2) are not met, the allowable stresses for the joints shall be reduced according to Section 9 (2).

(4) The locations of the joints shall be shown on the design drawings as a rule.

Section 3 Spaces between joints

(1) The spaces between a joint and an adjacent joint or bar shall be greater than the maximum size of coarse aggregate.

(2) When the joints are to be fabricated after placing reinforcing bars, enough spaces must be left for installation of jointing machines.

Section 4 Concrete protection for reinforcement in joint portions

The minimum concrete cover for joint portions shall satisfy Section 23 of the RC Specifications.

Section 5 Joints of the bars of different diameters

When jointing the bars of different diameters the following requirements shall be met.

(1) When the degree of concentration of the joints is less than 1/2, the ratios of the cross sectional areas of the two different bars shall be greater than 1/2 as a rule.

(2) When the degree of concentration of the joints is greater than 1/2, the ratios of the cross

sectional areas of the two different bars shall be greater than 3/4 as a rule.

(3) The requirements for the locations of joints and the considerations against shear shall follow the intent of Section 21 (3) of RC Specifications.

Section 6 Joints of different grade of steel

When jointing the bars of different grade of steel, it must be ensured that the difference in the grade of steel does not have adversary effect on joint performance.

Section 7 Mixed use of joints

The mixed use of joints in a single member cross section shall preferably be avoided in the members subject to effect of fatigue by repeated loads.

Section 8 Lap splices

(1) The lap lengths in lap splices in tension reinforcement shall be greater than length 1 as calculated by the following equation and twenty bar diameters.

$$1 = \frac{\sigma_{sa}}{4\,\tau_{oa}}\,\phi$$

where, σ_{sa} : allowable tensile stress in reinforcement
τ_{oa} : allowable bond stress for concrete
ϕ : bar diameter

(2) The portions of lap splices in tensile reinforcement must be sufficiently reinforced with transverse reinforcement.

Section 9 Allowable stresses

The allowable stresses for the joints shall be in general as shown below when the joint performance is evaluated by the Recommendations for Evaluation and the fabrication is controlled as specified.

(1) The allowable tensile stress for joints shall be respectively less than 100, 80 and 60 percent of the allowable stresses of the bars jointed for the class A, class B and class C for the static strength performance as specified by the Recommendations for Evaluation.

(2) When the degree of concentration of joints is greater than 1/2, the allowable tensile stress for joint portions shall be reduced as appropriate depending on the type of the joints and taking into account of the degree of reliability depending on the fabrication and other causes as specified in the Recommendations for Evaluation.

(3) For the joints qualifying for the strength performance in high stress repetition as specified in the Recommendations for Evaluation the increase of allowable stresses in special load conditions shall be permissible according to Section 68 (2), (3) of the RC Specifications.

(4) The allowable tensile stresses for the joints for which the strength performance in fatigue is assured by the Recommendations for Evaluation shall be in general less than the values specified in Section 67 (1) (b) of the RC Specifications.

CHAPTER 3 SELECTION OF JOINTS

Section 10 Selection of the types and methods of joints

The types and methods of joints must be appropriately selected depending on the types of reinforcing bars, bar diameters, stresses, locations of the joints, and the performance required for the joints.

Section 11 Selection of joint performance

(1) In structural members the joints classifying as class A for static strength performance by the Recommendations for Evaluation shall be used as a rule. However, the joints of class B may be used where approved as appropriate. The joints of class C may be used by the direction of the Engineer in the portions of the structural members outside the regions of primary importance.

(2) For the joints where the effect of high stress repeated loading is remarkable the joints to be used must be those qualifying for the strength performance in high stress repetition as specified by the Recommendations for Evaluation.

(3) For the joints where the effect of repeated loads under service state is remarkable the joints to be used must be those qualifying for the strength performance in high cycle repetition as specified by the Recommendations for Evaluation.

CHAPTER 4 FABRICATION OF JOINTS

Section 12 Confirmation of the evaluation of joint performance

The joints to be employed in construction projects must be confirmed of qualifying for the required performance according to the Recommendations for Evaluation in advance to the initiation of the construction. In this occasion the situation where the evaluation is made must be maintained as the conditions for the joint performance.

Section 13 Manual for fabrication of joints

In fabrication of joints a manual for fabrication of the joints must be prepared and approved by the Engineer.

Section 14 Control of fabrication of joints

In fabrication of joints the control of fabrication must be made so that the joints of required performance are obtained through attendance and inspection for the items specified in advance.

COMMENTARY ON RECOMMENDATIONS FOR FUNDAMENTALS IN DESIGN AND FABRICATION OF JOINTS IN REINFORCING BARS

CHAPTER 1 GENERAL

Section 1 Extent of applicability

This Recommendation indicates fundamental items concerning design and fabrication of the joint portions in reinforcing bars to be used in ordinary reinforced concrete structures.

For jointing reinforcing bars the lap splices and gas pressure welded joints have been broadly in use. Also, among the joints recently developed are: the joint by press forming a steel tube "to be referred as sleeve" enclosing the joint portion of the bars by hydraulic pressure at ambient temperature, "pressed joint," the joint by a steel coupler inside wall of which are threaded to match the threaded surface configuration hot rolled on the reinforcing bar, "thread lugged bar joint," the joint by a coupler threaded on the threads machined on the bar ends hot upset and swelled, "threaded joint," the joint by infilling the gap between the bars and a metal sleeve with molten metal, "molten metal infilled joint," the joint by infilling a similar arrangement with high strength non-shrinkage mortar grout, "mortar infilled joint," the joints by automatic process of gas pressure welding, "automatically gas pressure welded joint," and so on. The experience of application of these joints to practice have been progressive. This Recommendation is intended to cover these joints, and indicates common fundamental items in design and fabrication of joints when those joints are to be used. Each of those joints has its unique characteristics, and the mechnism for stress transfer of each type of joints also differs. Consequently, when the stage of design and fabrication of a certain type of joint is arrived, one of the other Recommendations for design and fabrication written for each type of joint shall be referred, in addition to this Recommendation.

This Recommendation, also, is intended to cover the joints in reinforcing bars in ordinary reinforced concrete structures. Hence, if the joints are to be designed or fabricated in special structures, such as, the structures subject to special loadings, or the structures subject to special environment, it shall be examined whether or not some modifications of the requirements set forth in this document are necessary, so that the requirements are suitable for such a structure.

Even though this Recommendation is intended mainly for joints in reinforcing bars subject to tension, this can be applicable to the joints subject to compression also.

CHAPTER 2 DESIGN OF JOINT PORTIONS

Section 2 Location of joints

1.– In general, the joints in reinforcing bars tend to become weak spots, and could become responsible for weakening the strength of the structural member containning the joints, if the joints are placed in the region subject to high stresses. Consequently, it is preferable for the joints to avoid the cross section subject to high tensile stresses such as the neighborhood of midspan sections in beams.

2.– If the joints are concentrated in one section and if the joints should have been weakend, the structural member would be jeopardized, and in other occasions, some type of joint when congested in one area may inhibit compaction of concrete. Therefore, it was made a principle to stagger the locations of the joints. The reason for the joints to be staggered by a distance of 25

bar diameters comes from the consideration that with this manner of positionning the joints, even if all joints should fail, some strength can be expected of the member by virtue of the bond effect. In general, with this much of staggering the adverse effect on compaction of concrete is considered to be minor.

3.– Even though the practice in accord with the item 2 of this section is desirable, sometimes it could be inevitable to concentrate joints in one section as in the case where prefabricated reinforcement cages are to be joined. For such cases adverse effects on the structural member due to concentration of the joints are safeguarded by reducing the allowable stresses according to the reliability governed by the fabrication method and other conditions, as specified by item (2), Section 9 of the Commentary.

Section 3 Spaces between joints

1.– The minimum space between a joint and an adjacent joint or a bar was required mainly for placing concrete. This requirement which is more liberal than the requirements in Section 22 of RC Specifications resulted from the practical consideration not to require too wide spaces between joint portions as to cause proportioning of the member difficult in design. When the length of joint portion is not very long, and if these joints are positioned per item (2) of Section 2 and the spaces specified in this section are maintained, there will be little concern of poor compaction of concrete or reduced bond strength. However, three are conditions where compaction of concrete tends to be poor, such as, when the joints are concentrated in one section, the cross section of the concrete member is too small, the joints are located in the area where placing of concrete is difficult, or when the joint portion is considerably long in size. Therefore, it is advisable to reserve as much space as possible between joint portions.

Also, it is preferable to maintain greater spaces between joint portion and adjacent bars for lap splices than the value shown in Section 22 of RC Specifications.

2.– When the joints are to be fabricated only after the reinforcing bars were placed, spaces are required to be considerably greater than the maximum size of aggregate in general for installation of jointing machine. Hence, it is important to consider the method and timing of fabrication of joints in design stage to avoid conflict in later stages.

Section 4 Concrete protection for reinforcement in joint portions

The steel components for joint such as sleeves or couplers need to be securely contained in concrete just as reinforcing bars, and the requirements are given in this section.

It shall be noticed that the requirements for concrete cover have to meet the requirements of Section 23 of RC Specifications even for the ties or stirrups placed on that side of the joint portion closer to the surface of concrete.

Section 5 Joints of bars of different diameters

This section specifies to limit the variation in the amount of reinforcement within one quarter at a section where the bars of different diameters are jointed, in principle.

Jointing the bars of gradually smaller diameters facilitates convenient tapering off of the amount of steel, if there is steel more than required in the section where joints are to be made. However, an abrupt change in the amount of steel at the joints tends to cause flexural cracks which may eventually transform themselves into diagonal cracks and thus to reduce shear strength of the concrete member.

The limitation placed on the rate of change in the amount of steel at a section where joints are to be made was derived from such consideration, and further, an additional mirgin of shear strength of the concrete member was recommended to be reserved for safety. Also, reducing the amount of steel by jointing reinforcing bars of decreasing diameters should affect the concrete

member behavior as would the anchoring of the bars in tensile zone of the concrete member, and therefore, the locations for joints need careful considerations. Thus, the design of the joints of the bars of different diameters was made to follow items (1) and (2) of this section and also the intent of item (3) of Section 21 of RC Specifications.

Section 6 Joints of different grade of steel

This provision is to consider that for some method of jointing, required performance may not be obtained if the reinforcing bars of different grade of steel are to be jointed. Especially, when the reinforcing bars are heated or melted as in the case of welded splices or gas pressure welded joints the performance of joints may be affected by the difference in grade of steel or difference in manufacturer of steel. Therefore, thorough study by test is necessary for such cases. On the other hand, when the steel sleeves are used for jointing bars as in the pressed joint, it shall be noted that the required sleeve length may vary with the surface deformation of the reinforcing bars, even if the grade of steel is the same.

Section 7 Mixed use of joints

This requirement was set forth to consider possible distress in the concrete member due to overstressing of some of the joints in a same cross section of the concrete member, such overstressing possibly resulting from difference in stiffness or fatigue resistant performance among different types of joint mixed in one cross section.

Section 8 Lap splices

1. and 2.– Lap splices are easy to fabricate but their safety could be impaired grossly if compaction of concrete was imperfect, or separation of ingredients of concrete occurred, or the concrete surrounding the joints deteriorated. Also, without sufficient amount of lateral reinforcement, and if subject to high tensile stress or repeated high stresses, the surrounding concrete of the lap splices may split along the reinforcing bars causing brittle failure. Therefore, the joints need to be positioned in the area only subject to lower stresses, and the joint zone need to be sufficiently reinforced by lateral reinforcement. Further, the reliability of lap splices can be improved by providing hooks at the tails of the bars, by porviding spiral reinforcement or linkage divice, or by making the lap length longer than required minimum.

The lap length specified in this section is equal to the length calculated by item (4), Section 20 of RC Specifications. In this connection, even though it is supposed to use for allowable tensile stress of reinforcing bars the values in Table 7 (c) of Section 67 of the RC Specifications, it is desirable instead to use 60 percent of the specified yield stress for safety. On the other hand, if the safety of the lap splices was to improve by some means of reinforcing, and if the effect was confirmed by tests, the lap length may be reduced.

The lap splices designed per this section and fabricated under sufficient control can classify as class A for static strength performance by the Recommendations for Evaluation.

Section 9 Allowable stresses

This section was set forth based on the Recommendations for Evaluation and also referencing Section 67 of RC Specifications as well as the results of tests of joint performance. The values for allowable stresses shown in this section are applicable to the joints the performance of which is evaluated by the Recommendations for Evaluation, and are subject to specified control of fabrication. However, when the effect of cracking in concrete is particularly grave, the values of allowable stresses shown here shall be reduced appropriately, as in the case of Section 67 of the RC Specifications.

1.– The allowable stresses shown here were specified so that under service loads the joints

of any classification should behave approximately equivalently to the reinforcing bars, basing on the static strength performance defined by the Recommendations for Evaluation. The values for allowable stresses shown here need not be modified in relation to the reliability governed by the fabrication method and other conditions, provided the number of the joints in the tensile zone of a cross section of the concrete member is less than 1/2 the number of the bars passing through that section.

2.– If the number of the joints in the tensile zone of the concrete member cross section is greater than 1/2 the number of the bars, the influence of the reliability of the joints on the safety of the concrete member is considered to be significant, and hence, in such cases, it is considered appropriate to reduce the values of allowable stresses shown in item (1) of this section to 90 percent, 80 percent and 70 percent respectively for the group I, group II, and group III defined in Section 6 of the Commentary on Recommendations for Evaluation.

3.– The joints qualifying for the strength performance in high stress repetitions are to maintain soundness under repetition of a stress equal to 95 percent of the specified yield stress of the reinforcing bar used, and hence, it was permitted to apply here the increase of allowable stresses as indicated in items (2) and (3), Section 68 of the RC Specifications.

4.– The joints are considered to qualify for the fatigue resistant performance by the Recommendations for Evaluation, if the durable stress range for two million cycles of loading is greater than 10 kg/mm^2, and the residual deformation is less than 0.2 millimeters. The allowable stresses shown here apply to the joints in ordinary concrete members subject to the effect of repeated loads. The allowable stresses for the case where especially severe fatigue is expected need to be examined taking into account of the number of repetition and stress range. Further, if the stiffness of the joints under service load is considerably different from the stiffness of the reinforcing bars, it is necessary to confirm the fatigue strength of the reinforced concrete member by tests, since higher stresses may be attracted to the joints when the joints are positioned dispersedly.

CHAPTER 3 SELECTION OF JOINTS

Section 10 Selection of the types and methods of joint

The intent of this section is the same as item (1), Section 20 of the RC Specifications.

The use of a certain type of joints may be restricted by the type of the structure or member, arrangement of reinforcement and condition of construction, even if the joint performance and requirements are satisfied. Also, if the method of fabrication differs for the same type of joint, the range of applicability or joint performance may vary. Such shall be considered in selection of the type and the method of fabrication of the joints.

Section 11 Selection of joint performance

1.– The static strength performance of the joints of class A classified by the Recommendations for Evaluation is almost equivalent to that of reinforcing bars, and therefore, it was made a principle to use the joints of this class in structures from a view point of ensuring structural behavior of the members and simplicity, convenience and rationality of design and construction. However, for certain types of members, the joints of class B are not merely satisfactory but also a better selection, and in such cases the joints of class B can be used. Also, in the portions of the members where high stresses are not expected, the joints of class C can be used by the direction of the Engineer.

2. and 3.– A guideline was given for selecting the joints based on the joint performance in accordance with the Recommendations for Evaluation.

CHAPTER 4 FABRICATION OF JOINTS

Section 12 Confirmation of the evaluation of joint performance

This section specifies that the joints to be used shall be those the performance of which was confirmed by the Recommendations for Evaluation.

The confirmation of the performance may be based on available and reliable test results, nevertheless, it is advisable to confirm by test at least for static strength performance, before a large number of joint is to be used. Also, the performance of joints of the same method of fabrication could vary with the variation in category of specification of reinforcing bars, diameter or surface configuration of the reinforcing bar, or the conditions of construction. Therefore, if change should occur in condition from where the evaluation was made, the joint performance is not necessarily considered confirmed any more, and hence, the joint performance shall be examined with reference to the conditions where the evaluation was made.

Section 13 Manual for fabrication of joints

In advance to fabrication of joints a manual for the fabrication of joints shall be written and approved by the Engineer. The manual shall specify: specifications of capability and criteria for maintenance of the machinery needed to make the joints of required performance depending on the type of reinforcing bars, location and orientation of joints and conditions of fabrication, criteria for labor, fabrication sequence for the areas where reinforcement is congested, items and method for inspection for examining proper completion of fabrication, and procedures for correction of defects. It is extremely important for producing ensured joints to proceed with fabrication conforming to such a manual.

Section 14 Control of fabrication of joints

The items and frequency for attendance and inspection appropriate for each type and method of fabrication of joints shall be determined in advance, and shall be followed for control of fabrication, so that the joints of required performance can be obtained. The items necessary for inspection vary with the type and method of fabrication of joints, but in general include: inspection of materials used, machinery, skill of worker, whether or not the fabrication was correctly completed, and confirmation of joint performance.

Among those are the following items of inspection to be made after completion of fabrication.

a) inspection of appearance
b) detailed inspection of appearance (measurement of dimension, visual inspection of cracks, etc)
c) inspection by non-destructive tests
d) inspection by failure tests on model test specimens
e) inspection by failure tests on cut out test specimens

The application of the various items of inspection listed here to various types of joints shall be selective. Also, a certain item of inspection may be possible for all joints, whereas some items of inspection might have to be made by sampling some of the joints. Usually, the ratio of the number of sampling to the total number of the joints varies according to how the items of inspection are combined to use. It is important to decide on the items of inspection appropriate for the type of joints taking into account of those considerations.

Particularly, it is advisable to include the inspection of strength by the tests to failure on cut out test specimens among the items of inspection, as the situation requires, in a significant construction project, since such inspection is extremely effective for control of fabrication of joints.

RECOMMENDATIONS FOR EVALUATION OF JOINTS IN REINFORCING BARS

Section 1 Extent of applicability

This Recommendation shall be applied for evaluation of the performance of the joints in reinforcing bars to be used in reinforced concrete structures in general.

The joints to be evaluated shall be those subject to tension mainly, and of such types as pressed joints, thread-lugged bar joints, threaded joints, molten metal infilled joints, mortar infilled joints, gas pressure welded joints, lap splices and other similar kinds. The bars to be joined shall be hot rolled deformed bars (SD24, SD30, SD35, SD40, SD50) and shall conform to the specifications of JIS G 3112–1975 "Reinforcing bars for concrete."

Section 2 Performance of joints

The performance of joints in reinforcing bars shall be evaluated in terms of whichever performance considered necessary and selected from those itemized below.

(1) Static strength performance.
(2) Strength performance in high stress repetition.
(3) Strength performance in high cycle repetition.
(4) Reliability governed by fabrication method.
(5) Others. (e. g. Low temperature performance)

Section 3 Static strength performance

Static strength performance shall be classified into the items (1), (2) and (3) shown below. The modulus of elasticity of the bars in axial stressing shall not be taken less than 1.9×10^6 kg/cm^2 when evaluating the stiffness of joints in axial stressing.

(1) The joints to classify as class A shall satisfy the following values for strength and axial stiffness in static tensile test.

Strength: Higher than 135 percent of the specified yield stress of the bar, or higher than specified tensile strength of the bar.

Axial stiffness: Greater than that of the bar at a stress equal to 70 percent of the specified yield stress of the bar, or greater than 90 percent of that of the bar at a stress equal to 95 percent of the specified yield stress of the bar.

Residual deformation: Less than 0.3 mm when the stress is reduced to less than 2 percent of the specified yield stress of the bar, after loaded to the stress equal to 95 percent of the specified yield stress of the bar.

(2) The joints to classify as class B shall be those satisfying the following values for strength and axial stiffness in the test described above, but do not conform to (1).

Strength: Same as (1)

Axial stiffness: Greater than 90 percent of that of the bar at a stress equal to 70 percent of the specified yield stress of the bar, and greater than 70 percent of that of the bar at a stress equal to 95 percent of the specified yield stress of the bar.

Residual deformation: Less than 0.3 mm when the stress is reduced to less than 2 percent of the specified yield stress of the bar, after loaded to the stress equal to 95 percent of the specified yield stress of the bar.

(3) The joints to classify as class C shall be those satisfying the following values for strength and axial stiffness in the test described above, but do not conform to (1) or (2).

Strength: Greater than the specified yield stress of the bar.

Axial stiffness: Greater than 90 percent of that of the bar at a stress equal to 50 percent of the specified yield stress of the bar, and greater than 50 percent of that of the bar at a stress equal to 95 percent of the specified yield stress of the bar.

Residual deformation: Not specified.

Section 4 Strength performance in high stress repetition

The joints to qualify for the strength performance in high stress repetition shall satisfy the condition that at the thirtieth loading the line connecting the origin and the point corresponding to the maximum deformation on the stress versus strain curve has a slope greater than 85 percent of the slope of the curve for the first loading, where the lower limit of the stress is maintained less than 2 percent of the specified yield stress of the bar and the upper limit of the stress is maintained higher than 95 percent of the specified yield stress of the bar during repeated loading.

Section 5 Strength performance in high cicle repetition

The joints to qualify for the strength performance in high cycle repetition shall have the strength greater than 10 kg/mm^2 in terms of the varying stress range in 2 millions cycles and shall have a residual deformation less than 0.2 mm in the fatigue test. The fatigue test shall be conducted according to the methods specified in the (Appendix) "Recommended method of fatigue test of joints in reinforcing bars".

Section 6 Reliability governed by fabrication method

The reliability governed by the fabrication methods and other conditions shall be evaluated based on a degree for the various performances of the joints to lower due to the deviation in fabrication procedures from the standard procedure, and on a degree of reliability due to the mechanisms characteristic to each jointing method.

Section 7 Method of evaluation for the performance of joints

The method of evaluation for the performance of joints shall be based on such items specified in Table 1 as (1) classification for static strength performance, class A, class B and class C, (2) classification for strength performance in high stress repetition, (3) classification for strength performance in high cycle repetition, (4) evaluation of reliability governed by fabrication, and (5) other classifications considered necessary.

Table 1 Classification of joint performance

Evaluation items		Classification of evaluation[1)]	Conditions for performance	Symbols
(1)	static strength performance	class A	when satisfies Section 3 (1)	A
		class B	when satisfies Section 3 (2)	B
		class C	when satisfies Section 3 (3)	C
(2)	strength performance in high stress repetition	qualifies	when satisfies Section 4	S
		does not qualify	when does not satisfy Section 4	S_N
(3)	strength performance in high cycle repetition	qualifies	when satisfies Section 5	F
		does not qualify	when does not satisfy Section 5	F_N
(4)	reliability governed by fabrication and other causes	———	judged by Section 6	–
(5)	Others [2)]	———	performances other than (1) through (4)	–

Note: 1) When the classification is not applicable, it shall be noted.
2) This shall be applied for the evaluation of the performance in special cases such as evaluation of performance at extremely low temperatures or strength in high cycle repetition severer than Section 5, and others.

Section 8 Test and record

1. Test specimens

The test specimens to be used for performance test of joints in reinforcing bars shall be fabricated of the same material and by the same method of fabrication as employed actually in construction sites, and shall be those considered to be medium and to represent the performance of the joints. The test specimens must not be subject to stresses before tests.

2. Test methods

The performance tests of joints in reinforcing bars shall be conducted according to the methods specified below.

(1) The test of reinforcing bars shall be conducted following the intent of JIS Z 2201 "Tensile test specimens of metalic materials" and JIS Z 2241 "Method of tensile tests for metalic materials."

(2) The tests for static strength performance shall be conducted following the intent of JIS Z 2241 "Method of tensile tests for metalic materials" and using the test specimens specified in (1). As for the loading, according to necessity, after loading to a stress equal to 95 percent of the specified yield stress of the reinforcing bar, loading shall be reduced to a stress lower than 2 percent of the same, where the residual deformations shall be measured, and then, loading shall be applied again. The number of test specimens shall be three.

(3) The tests for strength performance in high stress repetition shall be conducted with a loading speed appropriate for measurement of loads and deformations accurately, and within a loading range specified in Section 4. The number of test specimens shall be three.

(4) The tests for strength performance in high cycle repetition shall be conducted by the test for fatigue resistant characteristics or the test for assurance of fatigue strength specified in (Appendix) "Recommended method of tests for fatigue strength of the portions of joints in reinforcing bars."

(5) The values of strengths to be used for evaluation shall be the minima of the test results.
(6) The values of axial stiffnesses or deformations to be used for evaluation shall be the averages of the test results.
(7) The measurements of deformations shall be made by the instruments capable of measuring one hundredth of a millimeter.

3. Test lengths of joints

The test lengths for measurements of stiffnesses or residual deformations shall be defined as the region between the two points located 20 mm or one half the bar diameter, whichever is greater, farther apart from each end of the joint. A length of the portion of the bar pulled out from the ends of the joint may be directly measured if appropriate methods are available.

4. Record

The results of performance tests of joints shall be surely recorded according to the manners shown below.

(1) Characteristics of test specimens:– The record shall include the classification of the materials according to the specifications and test values, the brand names and surface deformations of the reinforcing bars, the names and model identifications of the machine used for fabrication of the joints, and the situation where the joints were fabricated.
(2) Test results of performance of joints:– The test results of performance of joints shall be recorded in the form of a table of the results, stress-strain curves and description of the situation of the tests and so on, and in the sequence of the test of reinforcing bars, the test for static strength performance of the joints, the test for strength performance in high stress repetition, the test for strength performance in high cycle repetition, and so on.

COMMENTARY ON RECOMMENDATIONS FOR EVALUATION OF JOINTS IN REINFORCING BARS

Section 1 Extent of applicability

This Recommendation specifies standards for the methods of evaluation for the performance of the joints in reinforcing bars mainly subject to tension. The reason for the tension joints to be considered as main objective is because the joints in reinforcing bars are in general jointed mainly for tension, and for the various types and methods of joint performance to be required is that in tension. Even though there are joints subject to compression only, such joints are not covered here.

The mechanical characteristics of the joints in reinforcing bars vary according to the types and methods of fabrication, and hence, there may exist a difficulty in evaluating the performance by a common standard. For example, in the case of the gas pressure welded joints there is no problem of residual deformation, while in the case of lap splices the performance of joints develops only when embedded in concrete. However, the fundamental function required as the performance of joints in reinforced concrete is in common, and therefore, this Recommendation aims to become one to be applied to various joints in general. That is, it was intended to relate the evaluation of performance and actual design and fabrication of joints by evaluating the performance of joints of reinforcing bars on the same ground. Because of this, some of the items for evaluation may be satisfied by nature for certain types of joints, on the other hand, such evaluation may be possible only by means of a particular method of test for other types of joints.

Since the method for evaluation of reinforcing bars was made generally applicable, it may be applied to all types of deformed reinforcing bars conforming to JIS G 3112–1975 "Reinforcing bars for reinforced concrete."

Particularly, the primary objective of this Recommendations is intended that this to be used for a general evaluation of performance of each method of jointing reinforcing bars, but it is not intended that the tests specified herein to be applied to the quality control or inspection for a certain construction project.

In writing this Recommendation, reference was made to "Recommended standards for judgement of performance of joints in reinforcing bars" by the Committee RPCJ of Japan Architecture Center and numerous test results compiled.

Section 2 Performance of joints

Even though it will be most desirable for the performance of joints in reinforcing bars to be equal to that of reinforcing bars, it is in general difficult to attain. Therefore, the evaluation of the performance of joints was itemized into (1), (2) and (3) in terms of the mechanical properties required for the joints in relation to the fundamental requirements for the reinforcing bars when embedded in concrete, and the mechanical properties of reinforcing bars. Further, the item (4) was included in evaluation of performance of joints, since a method of joint may not be practicable if the reliability governed by the fabrication method is poor, even if other performances are satisfied.

In this connection, even though the ease of fabrication and the economy are also important factor for evaluation of performance of joints, it is usually difficult to evaluate by a general standard, and hence, the evaluation in this document is limited to that for mechanical performance.

The item (1) is the most fundamental among various criteria for the performance of the joints,

and is to evaluate static strength performance in terms of strength and stiffness in comparison to the reinforcing bars. The axial stiffness referred here means an apparent Young's modulus in tension and relates to crack widths and deformation behavior of reinforced concrete members.

The item (2) is to evaluate the strength and stiffness for the joints to have in order for the structual members to maintain soundness when subject to repeated loads causing high stresses such as would occur during earthquakes.

The item (3) is to evaluate the fatigue resistant performance when the members of the railroad structures are subject to the effect of repeated loads of high cycles due to train loads, and is to evaluate not only strength but also residual deformation.

The item (4) is to evaluate the reliability of joints related to quality control and fabrication control during construction project.

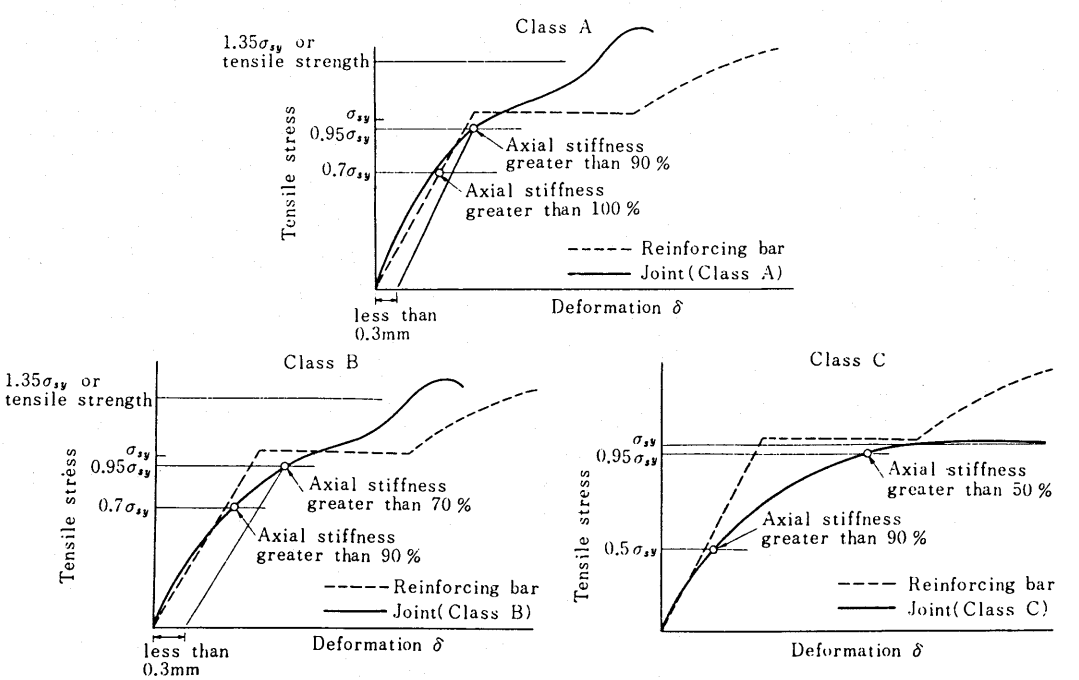
The item (5) is to evaluate whatever performance required when the structure is exposed to unusual environmental conditions, such as the case when the joints are used in the extremely low temperatures.

The evaluation needs to be made only for those items necessary according to the types of structures where the joints are used and the state of the loading.

Section 3 Static strength performance

This section is to evaluate the statis strength performance of joints which is the most fundamental item for ths joints in reinforcing bars, and to classify the joint performance into three classes in relation to the reinforcing bars.

The items for evaluation include those relate to stiffness and residual deformation from consideration of the soundness and cracking of reinforced concrete members under service loads, and those relate to strength in connection with ultimate strength and safety. The reason for



Commentary Fig. 1

classifying into three classes is because the performance required of joints in structural members is not necessarily identical, and hence classification into one or two classes was considered to be uneconomical.

The classification (1) is the case where the joint performance is considered to be approximately equal to that of the reinforcing bars, when the inevitable inaccuracies in tensile tests are taken into account.

The classification (2) represents the joint performance practicable to the case where the stresses in joint portion are lower than that for the classification (1) under service loads. Even in this case the strength related to the ultimate strength is equal to the case for the ciassification (1).

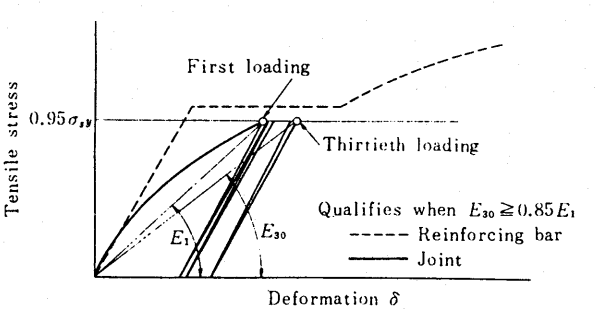
The classification (3) represents the joint performance practicable for the case where the stresses in joint portion are relatively low under service loads, but the strength is specified to be higher than the specified yield stress of the reinforcing bar to ensure the safety of the members.

The schematic representation of the concept of the performance is given in Commentary Fig. 1.

Section 4 Strength performance in high stress repetition

This section is to evaluate the performance required for the joins when high stresses are induced repeatedly as in the case where the joints are subject to the effect of earthquakes. The reason for the repeated load test to be conducted by the one directional repeated load test is because the performance of the joints subject to reversing stresses due to earthquakes is considered to be possible to be evaluated by one directional repeated load test for usual cases, and hence, such tests which are simpler to perform than load reversal tests were called for. The loading of thirty cycles at the stress equal to 95 percent of the yield stress of the reinforcing bars is specified assuming the state of loading during severe earthquakes. The schematic representation of the concept of this performance is given in Commentary Fig. 2.

However, in the case of the joints utilizing threads and tightening lock nuts, where the effect of compressive stresses is significant, it is preferable to ensure the behaviors of the joint portion subject to compressive stresses of 50 percent of the specified yield stress. When the residual deformations occur in contraction side, it is recommendable to apply twenty cycles of reversing loads (Static stress repetition between the compressive and tensile stress limits respectively 50 percent and 95 percent of specified yield stress), and to ensure that the slope of the line connecting the point representing the maximum deformation in tension at the twentieth loading and the origin on the stress-strain diagram is greater than 85 percent of the slope at the first loading. It is advisable, however, to call for the stress reversal repeated load tests only if particularly necessary, since such methods of testing are considerably cumbersome.



Commentary Fig. 2

Section 5 Strength performance in high cycle repetition

The requirements of this section cover the fatigue resistant property of reinforcing bars in the structures subject to repeated variable loads mainly such as train loads, and where the effect of fatigue is not particularly severe. The limit for the strength was specified by taking into account that the fluctuating stress seldom exceeds 10 kg/mm^2 in the structures where the ratio of the dead and live loads is typical of railroad structures. A reason for specifying the value of the residual deformation after two million cycles of loading is because the loads causing fatigue actually occur unlike the case of the earthquake loads and the effect accumulates by nature.

Section 6 Reliability governed by fabrication method

The strength and axial stiffness of the joints considerably depend on the state of fabrication, and some types of the joints are sensitive to the skill of work man, the control of materials, or quality of concrete. However, when the performance of joints can be easily confirmed by inspections or tests, the reliability of joints is considerably assured, and hence, the reliability of the joints was considered to be able to be evaluated in conjunction with the ease of control of fabrication. The reliability may also differ with the mechanisms of stress transfer which are proper to each type of joints from structural point of view. However, since it is not necessarily easy to evaluate the reliability for each method of fabrication of joints, it is advisable to take into account of the method of control of fabrication referring to the items listed below. Namely, when there is reliability of joints governed by the method of fabrication and other causes, and if the evaluation is to be made by classification into three graduated groupes I, II and III, the criteria for evaluation could be as shown below.

Group I : The case where the reliability governed by the method of fabrication and other causes is high, and the joint can develop the expected performance by usual control of fabrication.

Group II : The case where the joint performance could be affected by weather, or the inspection is not necessarily easy, but in general the expected joint performance is obtainable and the reliability of the joint is high.

Group III : The case where the joint performance is affected to a certain extent by the control of the fabrication at the site, but the expected joint performance is obtainable if subjected to appropriate control.

Section 7 Method of evaluation for the performance of joints

The method of evaluation of joint performance was set forth here to evaluate the joint performance based on classification of each specific criterion for performance defined in Section 3 through Section 6. However, the items to be selected for evaluation are only those considered necessary in view of the type of the structure, nature of the loading and the state of the stresses.

Evaluation for the items (1), (2) and (3) is to be based on the tests specified in Section 8, or to be based on the test results available, and the evaluation shall be made according to the classification shown in Table 1.

The evaluation item (4) relates to the reliability of the joints governed by the fabrication methods and other conditions, and should idealy be specified for each individual type or fabrication method of joints, and is a highly important item in evaluating the joint performance. However, each individual type and fabrication method of joints has its characteristics, and is influenced by the construction environment and the method of control of fabrication, and therefore, it is difficult to specify a common specification for such evaluation. Hence, it is recommendable to evaluate this when considered necessary in reference to Commentary Section 6. Furthermore, when this evaluation is actually to be made, it is advisable to take into consideration of the ex-

perience of fabrication, test results, and the methods of control of fabrication and inspection, as appropriate.

The evaluation item (5) relates to the joint performance in the extremely low temperatures, or the joint performance in high cycle stress repetition where joints are subject to stress repetitions grossly in excess of two million cycles, and for such cases appropriate performance test shall be made, or reference shall be made to available test results for evaluation.

One example of the designation for the results of evaluation is shown below.

(Example) xxx method of joint: A S F_N
* ** ***

Note: * indicates joint performance (1), statis strength performance.
** indicates joint performance (2), strength performance in high stress repetition.
*** indicates joint performance (3), strength performance in high cycle stress repetition.

The symbols to be used are given in Table 1. The items not been evaluated are indicated by a symbol "–."

The joint performance (4) "Reliability governed by the fabrication method and other conditions" and the joint performance (5) "Others", shall be described in the parentheses following the series of the symbols.

According to this convention of designation the xxx method of joint in this example is shown to classify as class A for joint performance (1), qualifies for the joint performance (2), does not qualify for the joint performance (3), and also it is shown that no evaluation was made of the joint performance (4) and (5).

Section 8 Test and record

1.– The performance of joints is highly dependent on the type of the materials used and the method of fabrication employed, and hence, the test specimens shall be fabricated of the material and by the fabrication method equivalent to those employed at the construction site, and shall be such that represent the average joints. Also the test specimens shall be free from any loading history before the test, because otherwise the stiffness of the joint might have changed and proper results may not be obtained.

2.– Included in the performance tests of joints in reinforcing bars is the static tensile test of the reinforcing bar for the purpose of comparison, in addition to the tests of the joints for static strength performance, the strength performance in high stress repetitions, and the strength performance in high cycle repetition. For the static tensile test of the reinforcing bars the requirements for the test specimens are specified in JIS Z 2201 "Tensile test specimens of metallic materials" and the requirements for test method in JIS Z 2241 "Method of tensile tests for metallic materials." Also, for the test for the strength performance in high cycle repetition the method of test was specified in the (Appendix) "Recommended method of fatigue test of joints in reinforcing bars," and the test shall be conducted in accordance with it. For the static tensile test and the test for strength performance in high stress repetition of joints the effect of loading speed was considered to be small, and hence, it was recommended that the test method shall be as specified in JIS Z 2241 "Method of tensile tests for metallic materials."

In this connection, in both tests the reference length required for measurement of deformation was defined in the item 3 of this section. Also, for the case of the lap splices the results of flexural tests on reinforced concrete beam specimens may be substituted with the note to this effect being attached.

3.– The deformation of the joint portion is to be measured on a reference length (distance between the reference points) on the jointed part in principle. However, in general it is not necessarily easy to measure the deformation on the reference length on the jointed part only, and hence, it was permitted to establish the reference points at appropriate locations on the bar

and in the vicinity of the both ends of the jointed part. In this case the distance between one of the reference points and the closest end of the jointed part shall be the smaller of 20 millimeters or one half the bar diameter, because, if the length in this region is too long, the measurement would neither properly evaluate the deformation of the joint, the axial stiffness of the jointed part and the reinforcing bar being different, nor it is practicable to grasp the influence of the reinforcing bar in the region between the reference point and the end of the jointed part. The length of the bar pulling out from the end of the jointed part may be directly measured to obtain the deformation, if such measurement is feasible.

4.– The record of the results of the tests for the performance of the joints in reinforcing bars shall include the test results of the reinforcing bar, the characteristics of test specimens of the joints, the test results of the performance of the joint portion, and the results of the evaluation following this Recommendation. Furthermore, it is recommendable to include in the record the photographs showing the fabrication of test specimens and the testing.

A sample of the form of the record of the results of the test and the evaluation is shown in what follows.

REPORT ON TEST RESULT FOR EVALUATION OF PERFORMANCE OF JOINTS IN REINFORCING BARS (A SAMPLE FORM)

"Designation of type and method of joint"

1. Objective of test (To be described within approximately one page)
2. Particulars of test specimens
   (1) Date of test
   (2) Place of test
   (3) Specification, manufacturer, surface configuration and mechanical properties of reinforcing bars
   (4) Conditions of joint portion (dimensions, date of fabrication, method of fabrication, name of equipment, photograph of fabrication, etc.)
3. Test of reinforcing bars
4. Test for static strength performance
   (1) Method of test (name of testing machine, test length, photograph of test in progress, name of person incharge, etc.)
   (2) Test results and judgement

(Example)

Designation of test specimens	Strength	Axial stiffness		Residual deformation
	Rupture stress (kg/mm²)	Apparent modulus of elasticity (×10⁴ kg/mm²)		(mm)
		at 0.7 σ_y	at 0.95 σ_y	at 0.95 σ_y
1	58.8 (Rupture in bar)	2.52*(1.26)	2.24 (1.12)	0.06
2	61.1 (")	2.67 (1.34)	2.23 (1.12)	0.07
3	58.1 (")	2.45 (1.23)	2.16 (1.08)	0.08
Average	59.3	2.55 (1.28)	2.21 (1.11)	0.07
Judgement	Class A (58.1 kg/mm²>1.35×35 kg/mm², 1.28>1.00, 1.11>0.90, 0.07mm<0.3 mm)			

Note) * Numbers in ( ) are the ratios of module of elasticity of joint portion and reinforcing bar.
◎ Diagrams shall be attached.

5. Test for strength performance in high stress repetition
   (1) Method of test (name of testing machine, test length, photograph of test in progress, name of person in charge, etc)
   (2) Test results and judgement

(Example)

Designation of test specimens	Axial stiffness, or apparent modulus of elasticity ($\times 10^4$ kg/mm^2)	
	at 0.95 σ_y of first loading	at 0.95σ_y of thirtieth loading
1	2.21	2.14 (0.97)
2	2.65	2.54 (0.96)
3	1.81	1.71 (0.94)
Average		(0.96)
Judgement	Qualifies for the strength performance (0.96>0.86)	

© Diagrams shall be attached.

6. Test for strength performance in high cycle repetition
   (1) Method of test (name of testing machine, test length, photograph of test in progress, name of person in charge, etc)
   (2) Test results and judgement

(Example)

Designation of test specimens	Total stress range (kg/mm^2)	Consequence of 2 million cycles of loading	Residual deformation (mm)
1	12	Did not rupture	0.10
2	12	"	0.12
3	12	"	0.11
Average	12	–	0.11
Judgement	Qualifies for the strength performance (12 kg/mm^2 >10 kg/mm^2, 0.11 mm<0.2 mm)		

7. Reliability governed by the method of fabrication and other conditions
8. Tests for other items of performance
9. Summary of evaluation

(Example)

Items	Judgement	Symbols	Conditions or special notes
Static strength performance	Class A	A	
Strength performance in high stress repetition	Qualifies	S	
Strength performance in high cycles repetition	Qualifies	F	
Reliability governed by method of fabrication and other conditions	–	–	
Other items for performance	–	–	

10. Name and title of the person in charge of test and report.
11. Record of measurements in test (test data).

(Appendix) Recommended method of tests for fatigue strength of joint portion in reinforcing bars

1. Quality of test specimens

The test specimens to be used for fatigue test of the joints in reinforcing bars shall be fabricated of the same material and by the same method of fabrication as employed actually in construction sites, and shall be such that represent the average joints. The test specimens shall not be subject to stresses before tests.

2. Record of particulars of test specimens

On sampling the test specimens clear record shall be made of the classification of specifications and the test values of the materials used, name and model identification of the machine used for fabrication of the joints, and the conditions where the joints were fabricated.

3. Method of loading

The lower limit of stress shall be equal to 3 kg/mm^2, and the upper limit shall be varied for the specimens so that the faitgue strength can be determined. The frequency of loading shall be maintained constant and in the range of approximately 3 Hz and 10 Hz. The loading shall be in axial tension as a rule.

4. Number of cycles

The upper limit for the number of cycles shall be, in general, two million cycles.

5. Measurement of residual deformation

The residual deformation shall be measured of the joint portion of the test specimens which did not fail after 2 million cycles of repeated load. The measurement shall be taken by an instrument capable of reading 1/100 millimeters. The test length shall be the range between two points each being located at the nearer of 20 millimeters of 1/2 the bar diameters farther apart from each end of the joint, in principle. Whereas, the length of the portion of the bar pulling out from the joint may be directly measured, if such measurement is possible. The test value shall be an average of the test results under the same loading.

6. Test for fatigue resistant characteristics

To evaluate the fatigue resistant performance of joints by test values of fatigue strengths, the test shall be conducted according to what follows, and the results may be considered as the fatigue resistant characteristics which are standard to that method of jointing. Nevertheless, when tests are to be made in relation to a certain construction project, the items (a) through (c) shall be adopted to suit that construction project.

(a) Grade of steel: SD35

(b) Diameter of the reinforcing bars:
For D41 through D51, one of the diamterrs in the range
For D29 through D38, 〃
For D16 through D25, 〃

(c) Surface deformation of the bars: One type. The description of the surface deformation and the name of the manufacturer shall be given.

(d) Number of test specimens: Shall be eight, in principle. Further, two tests shall be made for a stress under which the S–N curve becomes asymptotic to the horizontal.

(e) Determination of S–N curve: Shall be made in reference to JIS Z 2273 (1974) "General rule for the method of test for fatigue strength of metallic materials"

7. Test for assurance of fatigue strength:

If all the specimens did not fail after 2 millions cycles of an equal and constant stress range, that stress range can be considered as the assured fatigue strength of that joint. The conditions for the test shall be based on the items 6. (a), (b), (c), in general, if the test is not intended for a particular construction project.

8. Evaluation of fatigue resistant performance

The fatigue resistant performance of joint portions shall be evaluated using the results of either items 5. and 6., or, items 5. and 7. For the criteria for evaluation, in general, a joint can be evaluated as qualifying for the fatigue resistant performance, if the durable stress range, determined either by the S–N curve as specified in item 6., or by the test for assurance of fatigue strength as specified in item 7., is greater than 10 kg/mm^2, and the residual deformation is less than 0.2 millimeters.