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6-5-6 PERFORMANCE EVALUATION OF MECHANICAL JOINTS OF REINFORCING BARS

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SUMMARY

Introduced in this paper are rebar joints developed recently in Japan. They are classified based on the stress transfer mechanism. The last Recommendation to evaluate the performance of mechanical joints of rebars is outlined emphasized on the Unit Testing Method. The applicability of rebar joints is judged considering the performance grade of joints, the spot to use and the effect by concentration of joints. The test results of jointed rebars and several concrete specimens reinforced with jointed rebars are also presented.

INTRODUCTION

In the past 20 years, various types of rebar joints have been developed in Japan in addition to the conventional lap splicing and gas pressure welding joints. However, there were no common standards to evaluate the performance of those joints in those days, so that the performance of respective joint was investigated by testing concrete specimens reinforced with jointed rebars subjected to several kinds of forces and conditions. Through the experience on the tests and evaluations for the respective rebar joint, a simpler method to evaluate the performance with the test results only on jointed rebars was highly demanded. The RPCJ Committee in the Building Center of Japan studied the rebar jointing technology and completed the 1st Recommendation for Evaluation of Joint Performance of Rebars in 1974 and the 2nd Recommendation in 1975.

In the field of public works engineering, Japan Society of Civil Engineers proposed "Recommendations for Evaluation of Joints in Reinforcing Bars" in 1979. Then the Building Material Testing Center completed "the Basic JIS Recommendation for Rebar Joints" in 1980, which was a mutully agreeable standard for both building and public works engineerings.

In 1981, a part of Building Standard Law was revised and the ductility of structures has been taken concretely into structural calculation in the aseismic design. In addition precast reinforced concrete structures must be sometimes jointed in the member ends where sufficiently ductile capacity is required, so that the more definite standard of performance evaluation on rebar joints not only for strength and rigidity but also for ductility has become necessary. This "3rd Recommendation for Evaluation of Joint Performance of Rebars" has been completed by Concrete Structure Appraisal Committee, with Y. Kanoh as Chairman, in the Building Center of Japan in 1982.

KINDS OF REBAR JOINTS

Rebar joints available are classified from view-points of stress transfer mechanism into lap splicing joint, threaded joint, swaged sleeve joint, filled sleeve joint, heated pressure joint, welding joint, and butt contact joint. Threaded joint, swaged joint and filled sleeve joint are called in general mechanical joints.

There are two types of threaded joints, one is the joint for screwlike hot rolled bars and the other is the joint for end-threaded bars. Since there is a gap between the coupler and rolled screw, several ways to fix the gap were developed, such as locking nut type, epoxy resin or cement mortar grouting type, swaged coupler type and swaged nut type. In the end-threaded joints, there are several types to provide screws at the ends of bars, such as cutting or swaging male screws and swaging female screws to the ends.

Swaged sleeve joints include intermittently dise-swaged sleeve joint, continuously squeezed sleeve joint and explosively swaged sleeve joint.

Heated pressure joints include gas pressure welding joint and electric resistance pressure welding joint. The former joint is most popular in jointing medium sizes of bars not thicker than D25, whose nominal diameter is 25 mm, in the cast-in-place reinforced concrete structures.

Among welding joints, there are butt welding joint, lap welding joint and lapped steel plate welding joint. In the butt welding joint, the ends of bars were butted with a gap and covered almost with specific metal pieces and welded. The last two joints are commonly used to joint the bars of precast concrete members.

The butt contact joint is effective only for compression, but it is not allowed to be used in Japan to avoid mistakes and confusions at construction sites.

THE 3RD RECOMMENDATION FOR EVALUATION OF JOINT PERFORMANCE OF REBARS

(1) Scope of Applicability This recommendation shall be applied for mechanical rebar joints to be used in reinforced concrete structures excluding conventinal gas pressure welding joint and lap splicing joint. However, it may not be applied for the specific joint which is based on the special study and research.

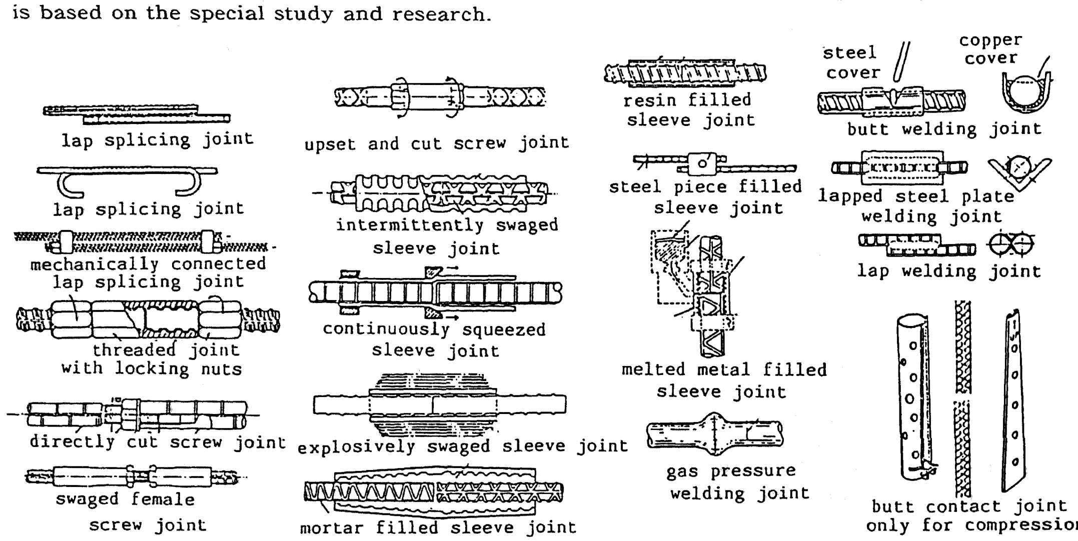


Fig.1 Classification of Rebar Joints

(2) Classification of Joint Performance   The performance of joints is classified into the follwing four grades. In Grade SA Joint the strength, rigidity and ductility are almost equivalent to those of rebars to joint. In Grade A the strength and rigidity are almost equivalent to, but the ductility is slightly inferior than of rebars. In Grade B the strength is almost equivalent to, but other characteristics are inferior than those of rebars. In Grade C the strength, rigidity, etc. are inferior than those of rebars.

(3) Judgement of the Performance of Joints

(3. 1) The judgement of the performance of joints shall be accordant to the following Unit Testing Method or Member Testing Method.

(3. 2) The Unit Testing Method shall take up Monotonous Tensile Test, Elastic Cyclic Test and Plastic Cyclic Test.

(3. 3) In the Member Testing Method, repeated loading tests of structural members reinforced with jointed rebars shall be taken up as well as Monotonous Tensile Test and Repeated Tensile Test in the Unit Testing Method. The results of member tests shall be judged if it is satisfactory to require the performance according to the applied conditions.

(3. 4) The judgement on the performance of the joint for precast concrete structures shall be based on the Member Testing Method as a rule.

(3. 5) When judging the performance of joints, the performance of the joints in actual structures presumed by the quality control standard, specifications and summary for design and practice of works, etc. shall also be taken into consideration.

(4) Performance Test

(4. 1) In order to evaluate the performance of joints, necessary tests out of Monotonous Tensile Test, Repeated Tensile Test, Elastic Cyclic Test and Plastic Cyclic Test shall be applied in accordance with the Unit Testing Method or the Member Testing Method regulated in (3).

(4. 2) The test piece shall be the joint with two rebars jointed to the both ends and the joint must be located at the center as a rule.

(4. 3) The rigidity, deformation, average strain and slipping grade of the joint shall be checked for the specific length of the test piece. However, in case that the specific length of the test piece is shorter than 50 cm, the longer test length than the specific length may be used, provided that it is not more than 50 cm.

(4. 4) The specific length of the tested joint with rebars at both ends shall be the sum of the length of joint itself plus 1/2 of the diameter of each bar or 20 mm at both ends, whichever is the longer.

(4. 5) The loading rule for testing joint units shall be as in Fig. 2.

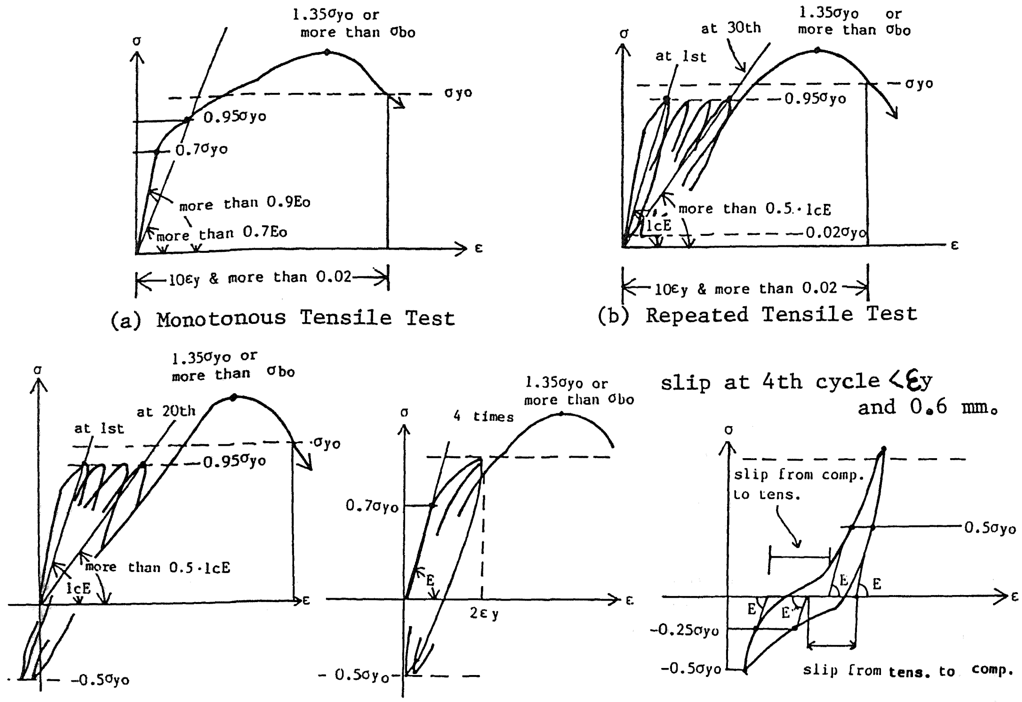
(4. 6) The Member Test shall be made in such a way that the applicability of the joint can be judged with regards to the strength, rigidity, hysteresis damping characteristics and ductility in accordance with the grade of joint performance shown in Fig. 2.

(4. 7) The Member Test shall be made for reinforced concrete specimens where all the joints of rebars are concentrated at one critical portion as a rule.

(5) Performance Evaluation Criteria   The performance evaluation for the test results of joint units shall be based on the criteria shown in Fig. 2.

(6) Applicability for Structural Design

(6. 1) Whether the joint is applicable or not and how the structure is effected with or without joints shall be considered depending on the respective structural member such as column, girder, wall, etc.



(a) Monotonous Tensile Test (b) Repeated Tensile Test

(c) Elastic Cyclic Test (d) Plastic Cyclic Test

Fig. 2 Criteria of Grade A Joint

(6. 2) The effect by concentration of joints shall be considered in the cases of full jointing and partial jointing.

(6. 3) In case of designing in accordance with Calculation Routes 1, 2a, 2b, and 2c or wall structures based on the Official Announcement from the Ministry of Construction, the applicable sorts, positions and concentration of joints shall be as shown in Table (herein omitted).

(6. 4) In case of designing in accordance with Calculation Routes 3, the applicable sorts, positions and concentration of joints shall be as shown in Table 1.

(6. 5) When using Table 1 for the composite strutures of steel and reinforced concrete, it may be regarded as partial jointing even if all rebars are fully jointed.

(6. 6) In case that the length of the joint is longer than the depth of the member, Grade SA Joint shall be regarded as Grade A Joint as a rule.

(6. 7) At the jointing part the required space between rebars and the thickness of cover concrete shall be also secured as a rule.

TEST RESULTS OF CONCRETE SPECIMENS REINFORCED WITH JOINTED REBARS

Influence of Rebar Joints on Flexual Behavior The main rebars of beam specimens were screwlike hot rolled. The rebars were jointed with couplers and locking nuts. Different grades of rebars joints were produced by giving different torque to the nuts. The specimens with the joints at the critical sections were simply supported and repeated loads were applied, as shown in Fig. 3 (a).

Table 1 Applicable and Non-Applicable Joint Sorts & Spots (for Route 3)

spot to use	sort of member	Grade SA F	Grade SA P	Grade A F	Grade A P	Grade B F	Grade B P	Grade C F	Grade C P
a. main bars at central region of girders, bending bars in beams and slabs		O	O	O	O	I	I	I	I
b. main bars at member-end region where yield hinge is formed in asesimic design	FA	O	O	L	L	L	L	X	X
	FB	O	O	L	O	L	L	X	X
	FC	O	O	O	O	L	O	X	X
	FD	O	O	O	O	O	O	X	X
	WA, WB	O	O	O	O	L	O	X	X
	WC, WD	O	O	O	O	O	O	X	X
c. main bars at other member -end region	FA	O	O	O	O	I	I	X	X
	FB	O	O	O	O	I	O	X	X
	FC	O	O	O	O	O	O	X	X
	FD	O	O	O	O	O	O	X	X
	WA, WB	O	O	O	O	I	O	I	I
	WC, WD	O	O	O	O	O	O	I	I
d. other bars	FA	O	O	O	O	I	O	I	I
	FB	O	O	O	O	I	O	I	I
	FC	O	O	O	O	O	O	I	O
	FD	O	O	O	O	O	O	O	O
	WA, WB	O	O	O	O	O	O	I	O
	WC, WD	O	O	O	O	O	O	O	O

Remarks :
F = Full Jointing.
P = Partial Jointing.
O = Usage of Joint is allowed.
X = Usage of Joint is not allowed.
I = Usage of Joint is allowed increasing the quantity of rebars.
L = Usage of Joint is allowed in case designed assuming the lower grade of member sort marked O.
Marks FA, FB, ·····, WD for sorts of member performance denote those shown in the Minister's Order No. 96 in 1981 based on the Official Announcement No. 1792—1.

The relationship between force and deflection are shown in Fig. 3 (b). The elastic stiffnesses, cracking loads, yielding loads and envelope curves are almost similar. But in Specimen L2 with Grade A Joints, a considerable slip is observed every time after yielding when from unloading to opposite loading, but little slip in Specimen LN without no joints.

Influence of Very Rigid and Long Joints on Inelastic Behavior

Extremely rigid and long joints have been considered struturally bad to be located at yielding zones since they may cause concentration of strain in main rebars near joints. Three beam-column assemblage specimens with and without mortar sleeve joints, which were most rigid among available joints in Japan, were tested as shown in Fig. 4 (a). Specimen SJN had no joints. But in Specimen SJB the main rebars of beams were jointed at the faces of the column, and in Specimen SJP they were jointed in the beam-column intersection.

The test results showed in Fig. 4 (b) that cracking loads, yielding loads and damage patterns were almost similar. However, two Specimens SJB and SJP with joints showed higher maximum loads and less reduction of loads after yielding than those of Specimen SJN without joints. It is considered that in Specimen SJB the rigidity and strength of joints have

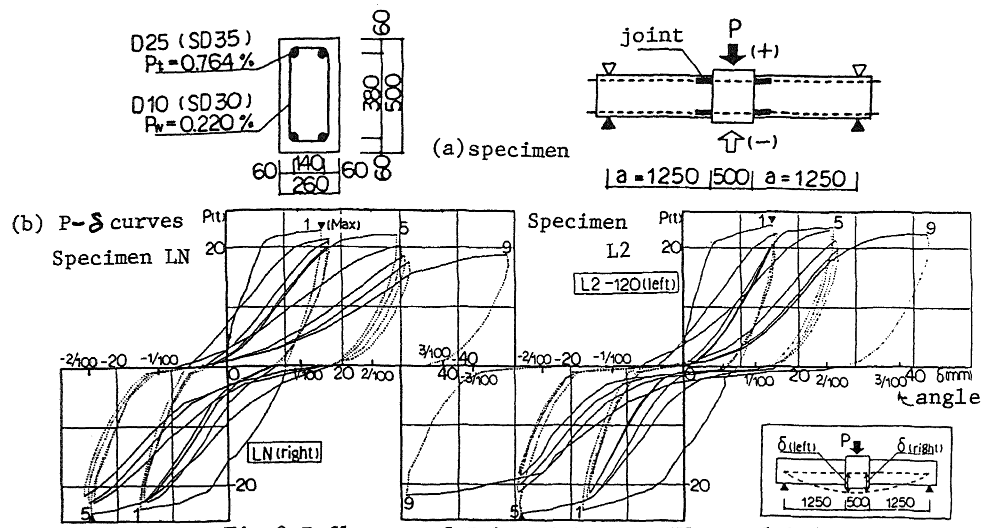


Fig.3 Influence of Rebar Joints on Flexural Behavior

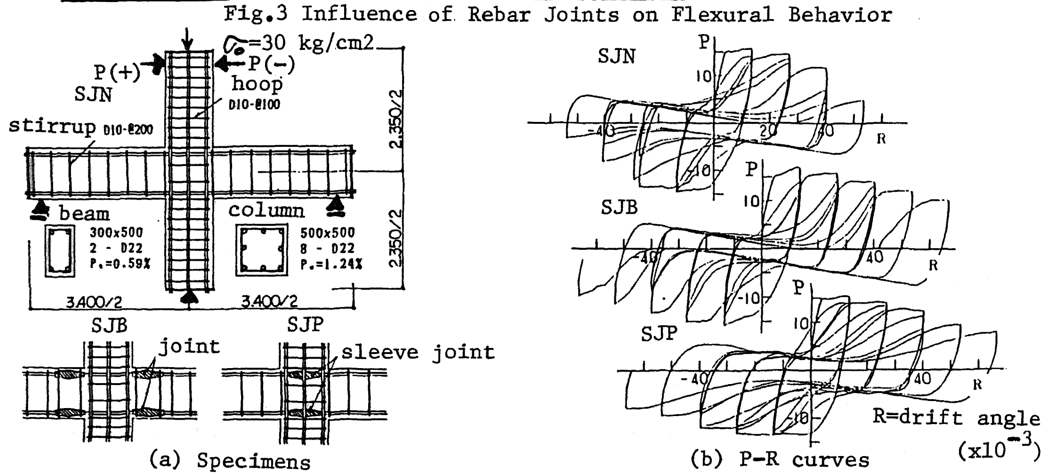


Fig.4 Influence of Very Rigid and Long Joints

reinforced the concrete and prevented the main bars from buckling at the compressive side of yielding zones and that in Specimen SJP the larger section of bars has played a role to prevent the beam bars from slipping from the damaged concrete at the intersection.

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