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# Concrete Placing Methods and Fatigue of Shear Studs

Mise en place du béton et fatigue des goujons soumis à l'effort tranchant

Einfluss der Betoneinbringung auf das Ermüdungsverhalten von Schubdübeln

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## SUMMARY

In many steel-concrete composite applications, other than ordinary beams and girders for bridges or buildings, water "bleeding", in the fresh concrete, has an important effect on fatigue and static strength of shear studs. This strength behaviour is discussed with relation to the means and direction of concrete placing and examined by way of push-out tests.

## RESUME

Dans de nombreuses constructions mixtes acier-béton, autres que les poutres ordinaires utilisées dans les ponts ou les bâtiments, l'eau de resuage dans le béton frais a une influence importante sur la résistance statique et à la fatigue des goujons soumis à un effort tranchant. Ce comportement de la résistance est discuté en relation avec la mise en place du béton et est examiné au moyen d'essais "push-out".

## ZUSAMMENFASSUNG

In vielen Anwendungsbereichen der Verbundbauweise hat das Ausscheiden von Wasser aus frischem Beton einen grossen Einfluss auf die dynamische und statische Festigkeit der Schubdübel. Eine Ausnahme bilden dabei gewöhnliche Balken und Träger des Brücken- und Hochbaus. Der Einfluss der Art und Richtung der Betoneinbringung auf das Festigkeitsverhalten wird aufgezeigt und mit "Push-Out" Versuchen untersucht.

## 1. INTRODUCTION

Since 1956, many valuable results of studies on the design of the stud shear connectors have been reported [1]. The purpose of these studies is mainly to facilitate the application of stud shear connectors for the ordinaly composite steel beams or girders in bridges and buildings, and as matter of cource, the problems of the effect of water bleeding in concrete to the bearing surface of stud connectors were not discussed ( only in the push-out tests by J.W.Fisher et al. [2], the effect was considered ). When the stud connectors are applied in various steel-concrete composite constructions such as the concrete encased steel beams and girders or columns, and in steel-concrete mixed structural systems [ see Fig.1 ], the problems of the above effect become very important. In these cases, because, there are several placing directions of concrete relating with the shearing directions of stud connectors. In this paper, therefore, the static and fatigue behaviors of studs in relation to the placing directions of concrete are studied.

## 2. TEST SPECIMENS AND CONDITIONS

The specimens were of the push-out type. As shown in table 1, the specimens were classified into four types denoted by A, B, C and D. To unify the properties of concrete for four types of the specimens, it was necessary to make all type specimens at a time. The web plate of H-shape steel in A and B type were separated at the time of concrete placing. In order to ensure the natural bond between concrete and flanges of H-shape steel, the steel surfaces were not covered with a layer of cup grease which was employed in the previous studies [1], prior to concrete placing. Fig. 2 shows details of specimens, in which four studs are embeded in each slab.

The push-out tests of each type were carried out dividing into five series. Dimensions of studs and properties of concrete in each series are listed in table 2. Experimental parameters in series 1 to 3 and series 3 to 5 are heights of stud and strengths of concrete, respectively. H-shape steel and stud materials of all specimens were structural carbon steel of SS41 designated by JIS.

In static loading tests, the load was intermittently released to observe the residual slips. Slip between H-shape steel and concrete portions was measured by four dial gages ( 1/1000 mm ) and four displacement meters ( 1/100 mm ) at the level of the studs. On the other hand, in fatigue tests, the frequency of repeated loading was 5.5 Hz., and minimum shear stress level of stud was kept constant of 15 N/mm$^2$. Relative slip between steel and concrete was observed by two non-contact type displacement meters.

## 3. STATIC TEST RESULTS AND PROPOSED DESIGN FORMULAE

Load-residual slip curves of push-out specimens are shown in Fig. 3. In this figure, it is clearly indicated that the residual slips for C-type specimens are extremely large in comparison with the specimens of other types at early stage of loading. This seems to be influenced by the bleeding of water in concrete to the bearing surface of studs.

The measured values of the ultimate loads of studs are protted in Fig. 4, and the design values in AASHTO, BS and DIN are also illustrated. On the ultimate loads of the 100 mm height studs, the values by the AASHTO specification give good agreement with test data.

From the static test results, the static strength of studs are proposed as

follows:
The nominal static strength of the stud at the ultimate limit state is given by;

For all-types, $P_d = 0.126\ d\ h \sqrt{f_{ck}}$ ( kN ) (1)

And the static strength at the serviceability limit state is given by;

For A, B and D-types, $P_s = 0.50\ P_d$ ( kN ) (2)

For C-type, $P_s = 0.35\ P_d$ ( kN ) (3)

These formulae can be applied in the range of $h/d = 3.0$ to $5.0$. The coefficient in equations (2) and (3) were determined on an assumption that a serviceability limit state of studs is defined as the load at a residual slip of 0.5 mm. Where , the load-residual slip relationship generally became nonlinear as shown in Fig. 3.

## 4. FATIGUE TEST RESULTS AND CONSIDERATIONS

Fig. 5 shows a typical example of the relationship between number of cycles of loading and relative slip at the stress range of 150 $N/mm^2$ in series 3. Fatigue life of B-type is extremely short than the other types, and fatigue failure occurs when relative slip reaches about 1.0 mm.

$\Delta\tau$-N relationships in five test series are summarized in Fig. 6. In all test series, it is recognized that the fatigue lifes of B-type specimens are clearly shortest. But in series 5, namely, at high level of concrete strength as 40 $N/mm^2$, these tendency is not so remarkable. As the reason of decrease of the fatigue life on B-type specimens, it is considered that water bleeding in fresh concrete gives bad effects at the contact surface between the H-shape steel flanges and the slabs, especially around the bottom of the welded studs.

From the test results, the fatigue strengths of all type studs at cycles of $N = 2 \times 10^6$ are estimated, and are protted in Fig. 7. As the matter of course, the correlation between the fatigue strength and the concrete strength is observed. It can be observed that the stud heights have no effect to fatigue strength.

$\Delta\tau$-N relations of each type specimens included from series 1 to 3 are shown in Fig. 8. The recommended design values of CEB-ECCS-FIP-IABSE Joint Committee on Composite Structures [7] are also illustrated in Fig. 8. The code gives very conservative values to the studs such as A-type specimens. But, it satisfactorily coincides with the B-type studs.

For the reliability analysis of the studs under the repeated loading, the coefficients of $\Delta\tau$-N relations and parameters of Weibull distribution of each type stud in series 1 to 3 are given in table 3. Design ranges of shear stress of the studs under constant amplitude loading can be calculated from the equations in table 3 if the reasonable probability of fatigue failure and the number of load cycles are specified. On the other hand, the fatigue life of the studs subject to random loading can be also determined by Miner's linear cumulative damage rule.

## 5. CONCLUSIONS

Throughout the push-out tests by using forty specimens in static and eighty specimens in fatigue, some remarkable results which support the assumption were obtained. The conclusions are as follows:

1) Water bleeding in fresh concrete gives a bad effect both to C-type studs in static behavior and to B-type studs in fatigue strength.

2) In standard push-out test method such as British Standards, the placing direction of concrete at the time of making the specimens should be noted.

3) One of the reason of the scatter of fatigue test results in previous studies [1]-[3] is considered due to the difference of concrete placing directions.

In the future, it is necessary to test also the studs have the height of 100 mm over. And the interaction problems of the studs under the shear and tension would be the subject for further study.

## ACKNOWLEDGEMENTS

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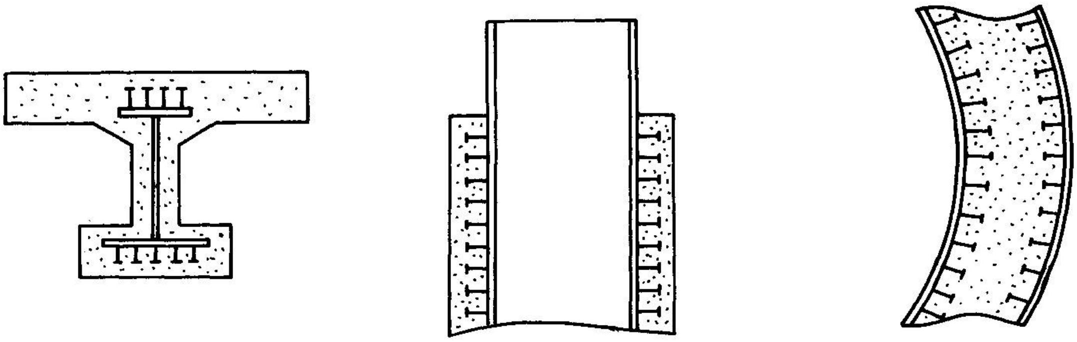
## NOTATIONS

$P_d$ = design shear strength at ultimate limit state, ( kN )
$P_s$ = design shear strength at serviceability limit state, ( kN )
$d$ = diameter of the stud, ( cm )
$h$ = overall height of the stud, ( cm )
$f_{ck}$ = characteristic cylinder strength of concrete at age considered ( $N/cm^2$ ).

## REFERENCES

[1] for examples,
Viest, I.M.: "Investigation of Stud Shear Connectors for Composite Concrete and Steel T-Beams," Journal of the ACI, Vol.27, No.8, 1956, pp.875-891,
Thürlimann, B.: "Composite Beams with Stud Shear Connectors," Bulletin No. 174, Highway Research Board, 1958, pp.18-38,
Thürlimann, B.: "Fatigue and Static Strength of Stud Shear Connectors," Journal of the ACI, Vol.30, No.12, 1959, pp.1287-1302,
King, D.C., Slutter, R.G. and Driscoll, Jr. G.C.: "Fatigue Strength of 1/2-Inch Diameter Stud Shear Connectors," Highway Research Record, No.103, 1965 , pp.78-106.
[2] Fisher, J.W. et al.: "Shear Strength of Stud Connectors in Lightweight and Normal-Weight Concrete," AISC Engineering Journal, Vol.8, No.2, 1971, pp.55-64.
[3] Mainstone, R.J. and Menzies, J.B.: "Shear Connectors in Steel-Concrete Composite Beams for Bridges; Part 1: Static and Fatigue Tests on Push-Out Specimens," Concrete, Vol.1, No.9, 1967, pp.291-302.
[4] AASHTO: "Standard Specifications for Highway Bridges," 12th ed., 1977.
[5] BSI: "BS 5400, Part 5, The Design of Composite Bridges," 1979.
[6] DIN: "Richtlinien für Stahlverbundträger," 1980.
[7] ECCS: "Composite Structures," The Construction Press, 1981.



(a) Preflexed beam (b) Composite column (c) Composite shell

Fig. 1 Applications of stud shear connectors in various steel-concrete composite constructions

Table 1 Classification of specimens

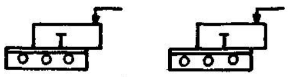
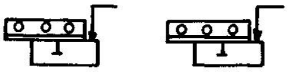
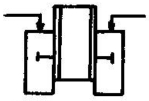
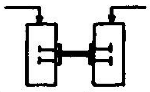
| Type | Placing direction of concrete |
|---|---|
| A |  |
| B |  |
| C |  |
| D |  |

Table 2 Dimensions of studs and properties of concrete in five test series

| Series | Stud | | | Concrete | |
|---|---|---|---|---|---|
| | Height h (mm) | Diameter d (mm) | h/d | Ave. Slump (cm) | Ave. Strength ($N/mm^2$) |
| 1 | 40 | 19 | 2.11 | 16 | 34.2 |
| 2 | 70 | 19 | 3.68 | 18 | 32.2 |
| 3 | 100 | 19 | 5.26 | 17 | 31.3 |
| 4 | 100 | 19 | 5.26 | 15 | 37.7 |
| 5 | 100 | 19 | 5.26 | 12 | 46.0 |

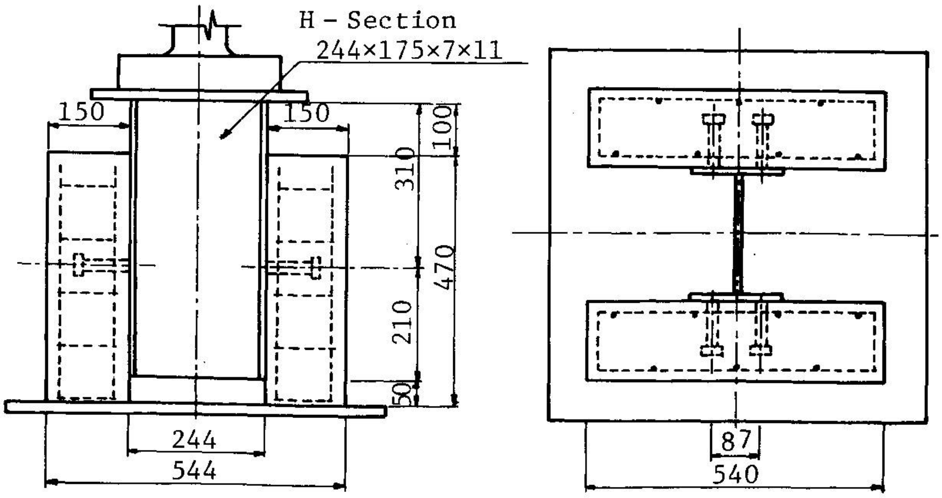
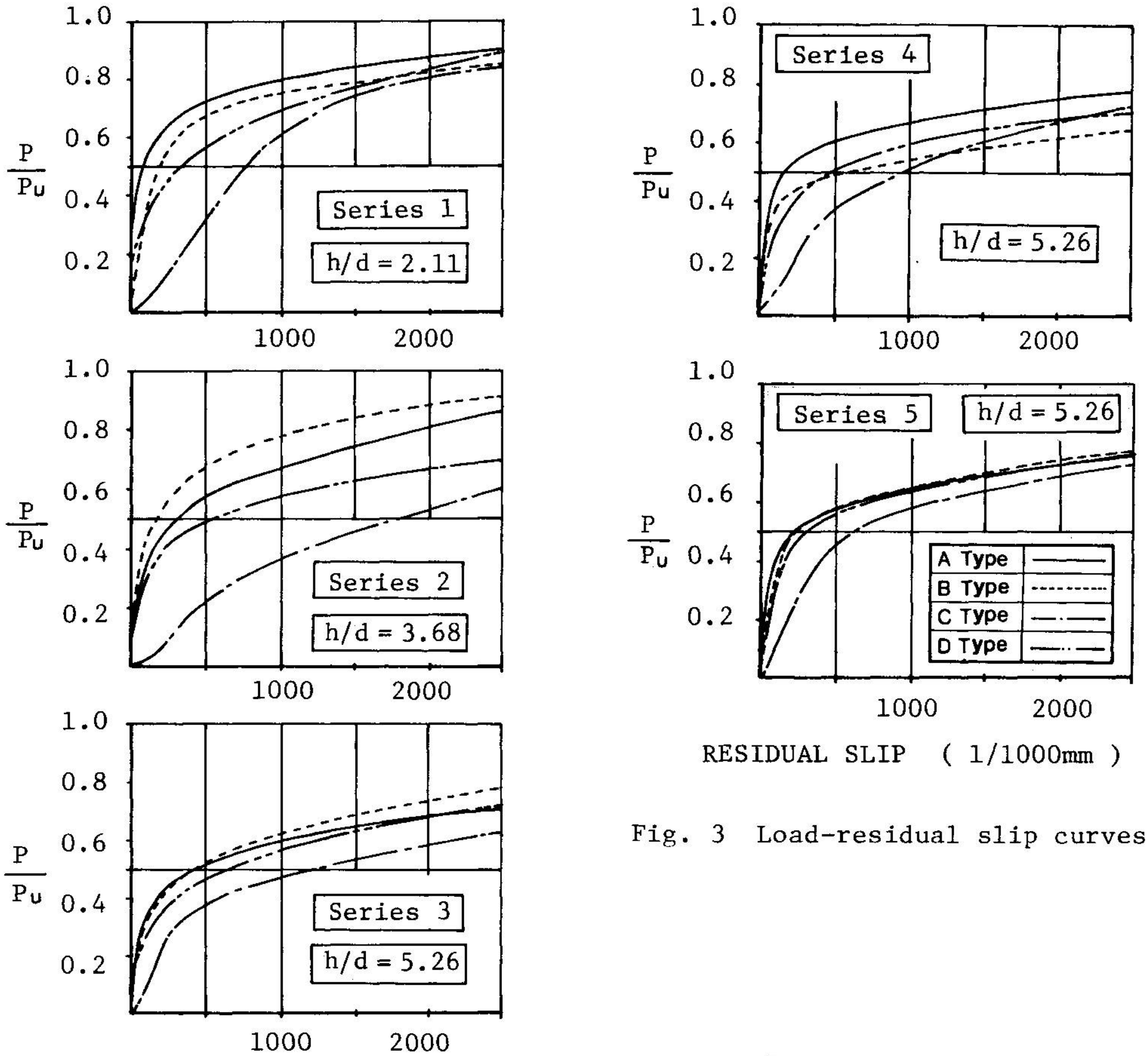


Fig. 2 Details of specimens



RESIDUAL SLIP ( 1/1000mm )

Fig. 3 Load-residual slip curves

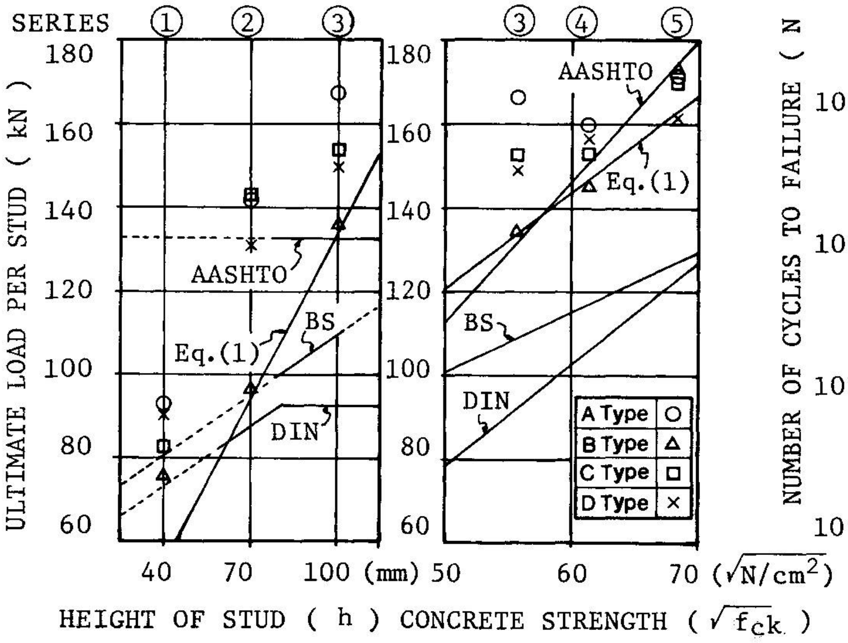


Fig. 4 Ultimate load versus height of stud and concrete strength

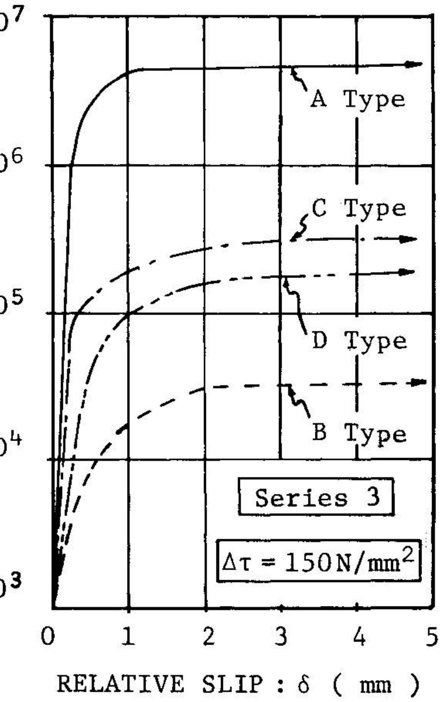


Fig. 5 N-δ curves

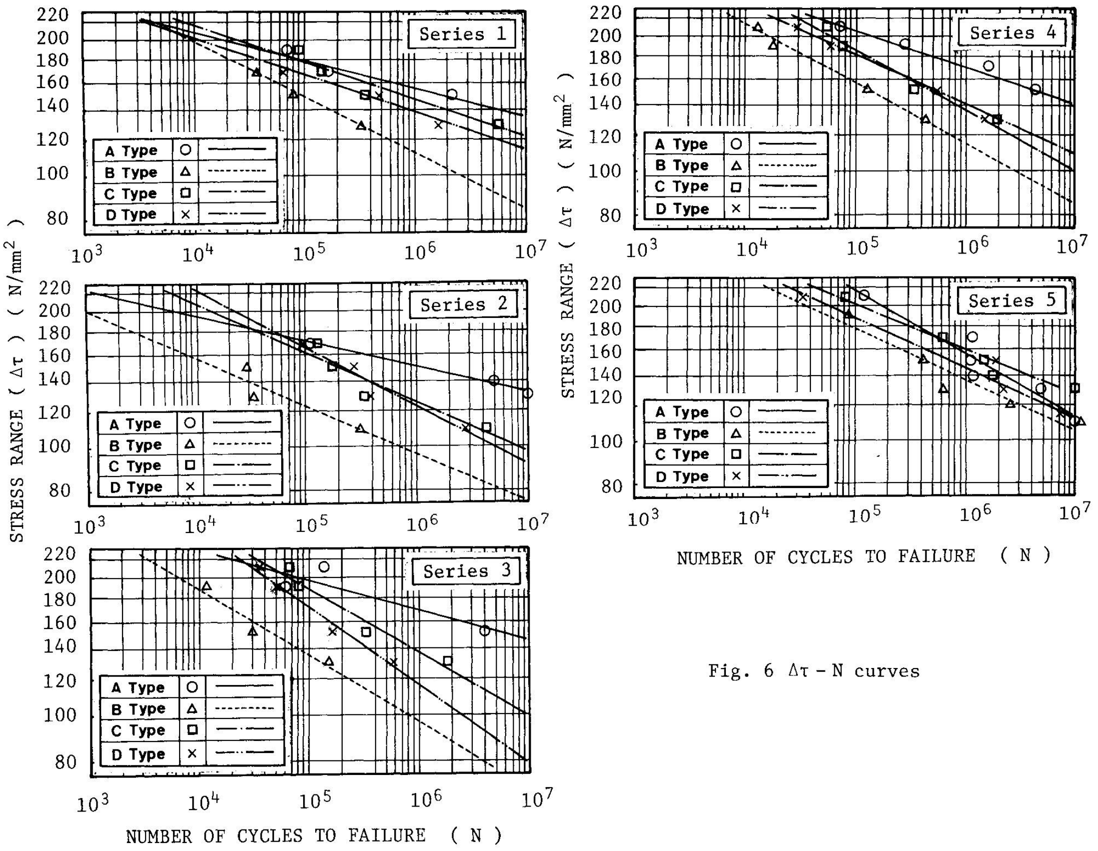


Fig. 6 Δτ - N curves

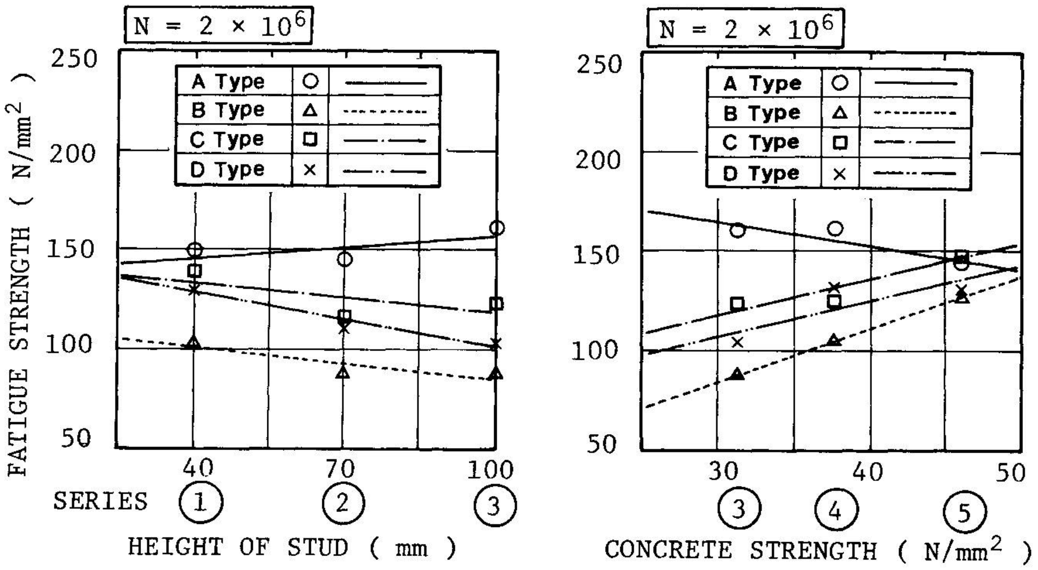


Fig. 7 Estimation of fatigue strength at $N = 2 \times 10^6$

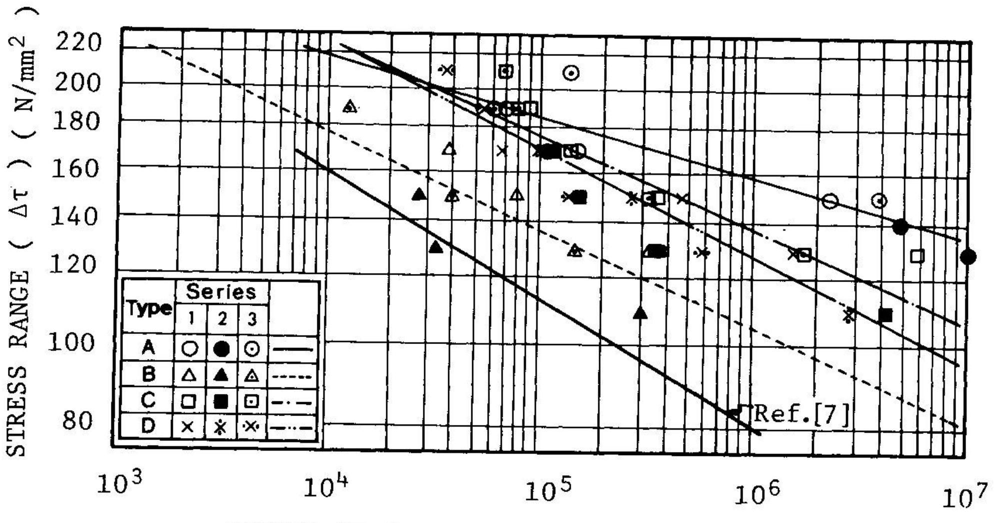


Fig. 8 Δτ - N relations in series 1 - 3

Table 3 Statistical properties in series 1-3

| Type | Δτ-N Relation | | Probability of failure | | |
|---|---|---|---|---|---|
| | Coefficient | | Parameter | | |
| | a | b | Shape(m) | Scale(β) | Loca-tion($\chi_0$) |
| A | 37.621 | 14.384 | 3.706 | 1.596 | -1.446 |
| B | 23.672 | 8.749 | 3.784 | 1.222 | -1.109 |
| C | 25.375 | 9.073 | 3.803 | 1.271 | -1.154 |
| D | 22.658 | 7.918 | 4.814 | 0.972 | -0.900 |
| Re-mark | $\log_{10} N = a - b\log_{10}\Delta\tau$<br>Δτ : Stress range | | $P = 1.0 - \exp\{-[(\chi-\chi_0)/\beta]^m\}$<br>P : Probability of failure<br>χ : Deviation | | |