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Comparative effect of remolding methods on the vane shear strength of Yellow Sea sediment

by

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ABSTRACT

A laboratory test program was designed and implemented to evaluate the effect of different remolded vane shear test methods. Sediment used in this study was obtained from the Yellow Sea. Two basic remolding methods were used: (1) thorough kneading of the sediment sample by hand, which, in theory, completely breaks down any structure and homogenizes the material, and (2) rotating the blade of the vane shear device in the sample, which preferentially destroys the existing sediment structure along the shear planes whose resistance will be measured in the test.

A lower remolded shear strength was produced by: (1) vane remolding than by hand remolding, and by (2) turning the vane through additional revolutions prior to strength determination. In order to obtain a measured remolded vane shear strength that approaches a residual value, the vane should be rotated in place through at least four revolutions after the peak strength is measured.

INTRODUCTION

Laboratory vane shear testing is a relatively quick and easy method to determine undrained shear strengths of fine-grained (i.e., cohesive) marine sediment that has been obtained by sampling or coring. The vane shear tests can be performed in the ends of the core sections and/or perpendicular to the core axis after the core has been split longitudinally. By performing the tests on split cores, a detailed subbottom shear strength profile can often be constructed for the sediment at that site.

From a geotechnical engineering standpoint and to infer how past geologic processes have affected a particular portion of the seafloor, sediment shear strength is a very useful physical property. Sediment shear strengths are important to understand: (1) how the sea floor will behave under engineering loadings such as from pipelines, offshore platforms, tracks or wheels from remotely-operated-vehicles, or ship anchors; (2) how deep projectiles or other objects will penetrate below the mudline; (3) what effort will be needed to uncover buried fill deposits or to extract economically important minerals; (4) whether slopes are stable, marginally stable, or likely to fail under dynamic forces; (5) how resistant an area of seafloor is to scour or storm-induced-erosion; and (6) what geologic forces may have been applied to that area in the past.

Laboratory vane shear tests are typically performed according to the following procedure: the vane is inserted into the core such that the amount of sediment above the vane is equal to at least one vane height, the vane is rotated until a peak torque is obtained from which the largest sediment shear strength is calculated assuming that the vane turns a cylinder of sediment just equal to the included volume of the vane. Then the vane is rotated through one or more revolutions to remold the sediment on and near the shear surface, and another torque reading is measured from which the remolded strength is calculated. Often, a sensitivity value, which is related to the amount of strength loss an undisturbed sample would experience upon remolding, is calculated by dividing the peak strength by the remolded strength. Highly sensitive material can lose most of its strength upon remolding and can flow like a viscous fluid.

Although there may be a preferred natural sediment fabric, that fabric is probably randomly oriented with respect to the final shear surface created by the vane shear test. The interparticle bonds between clay particles in the sediment are also in their natural state. These two factors account for why the measured shear strength is highest during the first vane rotation. After initial failure, the particles adjacent to the shear surface have progressively more interparticle bonds broken and the particles become more parallel to the shear surface. Therefore, strength continues to decrease as disturbance increases, until remolding is complete and a limiting lower-bound residual strength value is reached.

METHODS

Kasten cores (Kuehl and others, 1985) were obtained at nine stations in the Yellow Sea (Fig. 1) and were split longitudinally. Shipboard miniature-vane shear tests were performed at approximately 0.25-m intervals down-core with a 12.7-mm-diameter by 12.7-mm-high four-bladed vane that had a rotation rate of approximately 82 degrees per minute at the top of the Wykeham-Farrance machine's weakest spring (Lee, 1985; Winters, 1988). After a peak torque was measured, the sediment was remolded by quickly rotating the vane through one revolution and a second torque was measured and recorded. The peak undrained vane shear strength, S_u, and the remolded vane shear strength, S_r, were calculated from the equation:

$$S_u \text{ or } S_r = \frac{4T}{2\pi d^2 h + 0.667\pi d^3}$$

where: T = measured torque (determined from equipment calibration),
d = diameter of vane, and
h = height of vane.

After each vane shear test was performed, a subsample, centered around the vane shear test location, was obtained and placed into a labeled plastic bag. That bag was then put into another plastic bag. All of the subsamples were shipped to the U.S. Geological Survey's marine geotechnical testing laboratory in Woods Hole, Massachusetts where they were stored at a temperature of approximately 4°C prior to additional testing.

Laboratory vane shear tests were performed on 73 of these remolded sediment subsamples in November 1985 using the following technique: each subsample was thoroughly remolded by hand-kneading within the plastic bag, then carefully (without entrapping air bubbles) transferred into either a 100-ml or 250-ml glass beaker. A 25.4-mm-high by 25.4-mm-diameter vane was inserted into the sediment and a remolded shear strength [LAB S_r (Hand)] was determined before 90° of rotation occurred (Table 1); the vane was quickly rotated through one revolution (rev) and another torque reading was recorded and used to obtain S_r (+ 1 rev). Another rotation of the vane was made and a third laboratory strength was calculated [S_r (+ 2 rev)]. This procedure was repeated until a fourth and fifth torque were measured and their strengths calculated. Only one sample exhibited any rotation within the beaker during laboratory tests. The above procedure was repeated with the 12.7-mm vane.

RESULTS AND DISCUSSION

The shipboard [S_r (+ 1 rev)] versus laboratory [S_r(+1 rev)] remolded vane shear strengths (Table 1) were plotted in Figure 2 to show if a correlation existed between the strengths measured on the same sediment samples at sea and in the laboratory. The effect of the vane size on the hand remolded laboratory strength is shown on Figure 3. The effects that the methods of remolding had on the shear strengths are illustrated in Figures 4 - 9, typically, to portray the loss in strength after additional remolding. Strength data obtained from the hand kneading versus the fourth revolution remolding methods are plotted in Figures 4 and 5 for the 12.7-mm and the 25.4-mm vanes, respectively. Hand remolding versus the first revolution vane method are plotted in Figures 6 and 7. Strengths obtained from remolding after one revolution are plotted versus the fourth revolution in Figures 8 and 9.

A number of findings are apparent from the vane shear strength data. Surprisingly, no correlation exists between the remolded strength data obtained on the ship and the values determined in the laboratory after one vane rotation (Fig. 2). Because of the additional remolding, the laboratory-tested sediment strengths should have been lower then the shipboard remolded strengths. None of the lab strengths exceeded 1.6 kPa and some shipboard strengths were much higher than the corresponding lab strengths; however, approximately 80 percent of the shipboard strengths were lower than the laboratory data. That may be an artifact of differences in operating procedure or from changes in sediment properties, such as a decrease in the moisture content of the sediment due to water migration to or through the sides of the plastic bags. In 38 percent of the tests, the laboratory hand-remolded strengths [S_r (Hand)] were greater than the shipboard natural vane shear strengths, S_u (Table 1).

The y-intercept of the best-fit linear regression line for the data in Figure 3 indicates that the 25.4-mm vane is more sensitive than the 12.7-mm vane in measuring weak, lower sediment-resistance values. That is because the larger vane requires a greater amount of spring rotation or torque to shear the sediment. Because equipment errors are proportionally much greater for small spring rotations, the larger-sized vane probably produces more accurate strength data for very soft sediment. However, since the smaller-sized vane was used after the larger vane, the comparison was biased; additional remolding imparted to the sediment prior to retesting may have produced weaker sediment.

The method of remolding greatly influences the vane shear strength. Figures 4 and 5 show that hand remolding produces strengths that are more than two times greater than those measured after four revolutions of the vane (including intermediate strength tests). Clearly, remolding by rotation produces lower shear strengths than remolding by hand. Most of the remolded strength loss occurs during the first vane rotation (indicated by the low slope of the regression lines on Figures 6 and 7). Relatively little additional strength loss is produced by subsequent rotations (indicated by the steeper slope of the regression lines in Figures 8 and 9). For each additional vane rotation, a proportionately smaller amount of strength is lost. In 60 percent of the strengths measured with the 12.7 mm vane and in 90 percent of those measured with the larger vane, less than a 10-percent strength decrease occurred between the third and fourth vane revolution. Those data indicate that the 25.4-mm vane may be more effective than the smaller vane in remolding the sediment, because a residual strength value was approached quicker.

Although few data exist for some cores, Table 2 and Figures 10 and 11 imply that the differences in strength loss between the hand- and vane-remolding methods decrease for sediment with a higher plasticity index. If so, the method of remolding may be less important for more plastic sediment. Plasticity index, equal numerically to the liquid limit minus the plastic limit (Atterberg limits), represents a range of water contents within which the remolded sediment behaves plasticly. The potential for plastic behavior increases with the plasticity index.

We do not know why the vane-remolding techniques produces a lower strength than the hand-remolding procedure. However, there are three possibilities. First, remolding by hand may not adequately break all of the bonds between particles. Secondly, hand remolding would not be expected to fully align adjacent particles into an arrangement that was parallel to the final shear surfaces. Remolding by vane rotation may be more effective in performing both of those necessary functions for measuring residual strength (Lambe and Whitman, 1969, p. 312). The third possibility requires that remolding with the vane may somehow change a physical characteristic of the sediment, which would invalidate the test if a similar phenomenon doesn't occur in situ. For example, water or air may be drawn to the sediment-failure surface during rotation.

A more detailed study, possibly involving microfabric analysis, might determine why one method consistently produces lower strength measurements than the other method. Until additional information is available, rotation through at least four revolutions with the vane should be the preferred test method. That technique will produce a more conservative (i.e., lower) remolded strength as well as a higher sensitivity value (S_u/S_r) for the sediment.

The natural water content of the sediment samples ranged from 32 to 144% (ave. 68%), liquid limits ranged from 32 to 102% (ave. 58%), plastic limits ranged from 18 to 36% (ave. 25%), and plasticity indexes ranged from 11 to 71% (ave. 33%). Refer to Booth and Winters (1989) for further descriptions of the geotechnical properties of the sampled sediment.

SUMMARY

The type of remolding method used greatly affects the strength measurements recorded from a miniature-vane shear test. Remolding by rotating the vane, the preferred method, produces lower strength values than does physically remolding the sediment by hand. However, the differences between strengths exhibited by the two techniques may decrease as the plasticity index of the sediment increases.

The discrepancies between the shipboard and laboratory measurements may not only highlight the importance for standardized testing procedures and for shipping and storage requirements that are adequate to insure that sediment characteristics don't change; they may also point to the inherent range in uncertainty of the vane shear test if used on extremely weak sediment.

The larger-size vane can be used for very soft to soft sediment consistencies (S_u < 24 kPa) and should be used if testing extremely weak sediment (Su < ~4 kPa) because of its more accurate determination of low shear strength. However, since the edge of the vane should be at least one vane diameter or height away from any sample surface boundary, its use is not always possible. The size of the vane should always be noted when recording results because radial-shear-rate effects between different size vanes may produce different results.

Further laboratory investigations, possibly utilizing microfabric studies, are necessary in order to determine why different remolding techniques produce consistently different strength values.

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REFERENCES

Booth, J.S., and Winters, W.J., 1989, Geotechnical description of Yellow Sea sediments with some preliminary geological interpretations: U.S. Geological Survey Open-File Report 89-149, 265 p.

Kuehl, S.A., Nittrouer, C.A., DeMaster, D.J., and Curtin, T.B., 1985, A long, square-barrel gravity corer for sedimentological and geochemical investigation of fine-grained sediments: Marine Geology, v. 62, p. 365-370.

Lambe, T.W., and Whitman, R.V., 1969, Soil mechanics: New York, Wiley, 553 p.

Lee, H.J., 1985, State of the art: laboratory determination of the strength of marine soils: in Chaney, R.C., and Demars, K.R., eds., Strength testing of marine sediments: laboratory and in-situ measurements: American Society for Testing and Materials, Special Technical Publication 883, Philadelphia, ASTM, p. 454-472.

Winters, W.J., 1988, Geotechnical testing of marine sediment: U.S. Geological Survey Open-File Report 88-36, 52 p.

Table 1 YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC1a	0.75-0.80			12.7	250	44	1.97	0.83	0.31	0.21	0.21
				25.4	250		1.97	1.09	1.02	0.96	0.97
	1.00-1.05			12.7	250	44	2.17	0.83	0.62	0.62	0.72
				25.4	250	44	2.12	1.28	1.01	1.00	1.00

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC1b	0.55-0.60	2.2/3.0	-	12.7	250	54	0.93	1.20	1.10	0.93	1.00
				25.4	250	55	1.20	1.15	1.07	1.01	0.97
	0.80-0.85	6.2	3.9	12.7	100	55	0.72	0.41	0.31	0.10	-
				25.4	100	56	1.09	0.78	0.67	0.63	0.61
	1.05-1.10	6.3	2.8	12.7	250	54	0.41	0.41	0.31	0.41	0.21
				25.4	250	55	0.78	0.70	0.67	0.62	0.58
	1.30-1.35	1.9	-	12.7	250	48	0.62	0.62	0.62	0.52	0.52
				25.4	250		0.89	0.62	0.53	0.49	0.44
	1.55-1.60	5.1	1.4	12.7	100	42	1.34	1.24	0.83	0.62	0.62
				25.4	100	41	1.45	1.00	0.83	0.75	0.76
	1.80-1.85	4.9	1.9	12.7	100	42	0.93	0.83	0.72	0.72	0.62
				25.4	100	43	1.27	0.98	0.98	0.92	0.91

\- Denotes negligible shear strength (< 0.1 kPa).

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC-4	0.55-0.60	1.2	0.4	12.7	100	102	0.41	0.31	0.31	0.21	0.21
				25.4	100	103	0.78	0.67	0.66	0.61	0.60
	0.80-0.85	0.6	-	12.7	250	104	0.52	0.31	0.31	0.31	0.31
				25.4	250	101	0.60	0.52	0.49	0.47	0.44
	1.05-1.10	2.3	-	12.7	100	88	0.62	0.52	0.31	0.31	0.21
				25.4	100	91	0.58	0.41	0.35	0.31	0.28
	1.30-1.35	3.3	0.6	12.7	250	69	0.62	0.52	0.52	0.52	0.52
				25.4	250	69	0.84	0.62	0.58	0.56	0.56
	1.55-1.60	3.7	-	12.7	250	81	0.62	0.52	0.52	0.41	0.41
				25.4	250	81	0.93	0.87	0.83	0.80	0.74
	1.80-1.85	3.7	-	12.7	250	34	5.79	3.18	3.18	2.89	2.89
				25.4	250	35	3.62	1.88	1.52	1.45	1.34
	2.05-2.10	6.6	3.3	12.7	250	36	2.48	1.24	0.93	0.83	0.72
				25.4	250	36	2.20	1.15	0.82	0.66	0.62
	2.30-2.35	4.3	-	12.7	100	32	2.59	1.14	0.72	0.52	0.41
				25.4	100	32	2.94	1.97	1.83	1.64	1.71

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC-5	0.55-0.60	0.4	-	12.7	250	101	1.04	0.93	0.62	0.62	0.72
				25.4	250	103	1.14	0.98	0.93	0.85	0.83
	0.80-0.85	1.7	0.1	12.7	100	89	0.83	0.62	0.52	0.41	0.41
				25.4	100	88	1.17	0.91	0.88	0.85	0.84
	1.05-1.10	0.4	-	12.7	250	96	0.93	0.62	0.62	0.52	0.52
				25.4	250	99	1.17	1.00	0.96	0.95	0.91
	1.30-1.35	0.7	0.2	12.7	250	99	0.83	0.62	0.52	0.41	0.41
				25.4	250	98	1.07	0.95	0.89	0.87	0.84
	1.55-1.60	0.7	-	12.7	250	91	1.04	1.24	1.14	1.04	0.93
				25.4	250	90	1.05	0.76	0.45	0.34	0.27
	1.80-1.85	2.1	-	12.7	100	94	0.83	0.62	0.62	0.52	0.41
				25.4	100	96	1.05	0.96	0.93	0.91	0.87

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC-6	0.55-0.60	-	-	12.7	250	111	0.62	0.52	0.41	0.31	0.41
				25.4	250	115	0.88	0.79	0.75	0.73	0.69
	0.80-0.85	0.2	-	12.7	250	106	0.83	0.41	0.83	0.41	0.41
				25.4	250	105	1.01	0.96	0.92	0.89	0.85
	1.05-1.10	0.1	-	12.7	250	113	0.52	0.62	0.93	0.62	0.72
				25.4	250	114	0.83	0.79	0.69	0.67	0.63
	1.30-1.35	1.9	0.7	12.7	250	110	0.41	0.31	0.31	0.31	0.31
				25.4	250	114	0.82	0.74	0.69	0.67	0.66
	1.55-1.60	1.3	0.1	12.7	250	102	0.93	0.72	0.72	0.21	0.41
				25.4	250	101	1.39	1.23	1.11	1.07	1.05
	1.80-1.85	2.3	0.3	12.7	250	103	0.83	0.72	0.72	0.93	1.14
				25.4	250	106	1.14	0.98	0.93	0.95	0.87
	2.05-2.10	2.2	0.1	12.7	250	94	1.76	0.83	1.24	0.72	0.83
				25.4	250	94	1.72	1.26	1.11	1.09	1.05
	2.30-2.35	3.2	-	12.7	250	102	1.04	1.24	1.14	1.14	1.14
				25.4	250	102	1.41	1.17	1.14	1.10	1.07
	2.55-2.60	3.8	1.9/0.1	12.7	250	96	1.04	0.72	0.62	0.62	0.62
				25.4	250	96	1.46	1.19	1.10	1.07	1.06
	2.80-2.85	4.0	2.3/0.1	12.7	100	98	1.14	1.24	1.14	1.04	1.04
				25.4	100	107	1.37	0.98	0.78	0.74	0.71

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	Shipboard S_u (kPa)	Shipboard S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	S_r(+ 1 rev) (kPa)	S_r(+2 rev) (kPa)	S_r(+3 rev) (kPa)	S_r(+4 rev) (kPa)
KC-7a	0.55-0.60	-	-	12.7	250	43	1.14	0.62	0.62	0.52	0.62
				25.4	250	44	1.55	1.15	1.05	1.02	1.01
	0.80-0.85	0.1	-	12.7	250	40	1.66	0.72	0.41	0.31	0.21
				25.4	250	41	2.15	1.48	1.04	0.91	0.82
	1.05-1.10	0.6	-	12.7	250	43	1.04	0.62	0.41	0.31	0.31
				25.4	250	43	1.39	1.26	1.13	1.27	0.97
	1.30-1.35	1.6	-	12.7	250	40	1.76	0.83	0.52	0.52	0.41
				25.4	250	41	2.02	1.41	0.35	0.28	0.23
	1.55-1.60	3.6	0.1	12.7	250	41	1.45	1.04	0.93	0.72	0.72
				25.4	250	41	1.79	1.23	0.74	0.66	0.60

Table 1 (cont.) YS-85-08 Vane Shear Test Results

		SHIPBOARD					LABORATORY				
CORE	Subbottom Depth (m)	S_u (kPa)	S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	S_r(Hand) (kPa)	S_r(+ 1 rev) (kPa)	S_r(+2 rev) (kPa)	S_r(+3 rev) (kPa)	S_r(+4 rev) (kPa)
KC-7b	0.55-0.60	3.9	-	12.7	250	41	1.55	0.83	0.52	0.41	0.41
				25.4	250	42	1.64	0.92	0.78	0.74	0.67
	0.80-0.85	4.1	-	12.7	250	39	1.97	1.04	0.72	0.62	0.41
				25.4	250	41	2.12	1.99	1.89	1.80	1.76
	1.05-1.10	4.0	0.9	12.7	250	38	2.69	1.24	0.93	0.93	0.93
				25.4	250	39	2.49	1.57	1.41	1.30	1.30
	1.30-1.35	2.7	-	12.7	100	39	2.17	1.04	0.93	0.72	0.41
				25.4	100	40	2.20	2.06	1.36	1.13	0.97
	1.55-1.60	4.3	-	12.7	250	37	3.00	1.45	1.24	1.04	0.93
				25.4	250	38	2.56	1.86	1.79	1.70	1.70
	1.80-1.85	2.5	-	12.7	250	35	5.79	2.03	1.45	1.16	1.16
				25.4	250	35	5.13	2.86	1.92	1.70	1.66
	2.05-2.10	4.4	-	12.7	250	36	5.28	1.35	0.72	0.62	0.62
				25.4	250	36	3.51	2.01	1.57	1.49	1.48
	2.30-2.35	2.1	-	12.7	100	36	3.52	0.62	1.14	0.93	0.83
				25.4	100	36	3.03	1.49	1.02	0.95	0.98
	2.55-2.60	5.9	-	12.7	250	36	3.21	0.83	0.62	0.62	0.62
				25.4	250	36	3.08	1.32	0.84	0.73	0.66
	2.80-2.85	5.1	-	12.7	100	39	2.07	1.04	0.72	0.62	0.52
				25.4	100	39	2.15	1.49	1.30	1.27	1.24

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	S_r(+ 1 rev) (kPa)	S_r(+2 rev) (kPa)	S_r(+3 rev) (kPa)	S_r(+4 rev) (kPa)
KC-8	0.55-0.60	0.2	-	12.7	250	45	1.14	0.72	0.62	0.62	0.62
				25.4	250	45	1.33	1.02	0.80	0.70	0.60
	0.80-0.85	2.2	-	12.7	250	41	1.97	1.45	0.93	0.62	0.52
				25.4	250	42	2.24	2.03	1.86	1.64	1.24
	1.05-1.10	2.5	-	12.7	250	45	1.55	1.34	1.55	1.04	0.93
				25.4	250	46	1.76	1.32	1.23	1.20	1.13
	1.30-1.35	1.4	-	12.7	100	48	0.83	0.62	0.52	0.52	0.41
				25.4	100	51	0.87	0.66	0.51	0.34	0.32
	1.55-1.60	2.1	-	12.7	250	47	1.86	1.35	1.14	1.14	1.04
				25.4	250	47	2.10	1.61	1.46	1.36	1.32
	1.80-1.85	0.9	-	12.7	250	46	1.04	0.62	0.41	0.41	0.31
				25.4	250	46	1.40	1.30	1.24	1.13	1.05
	2.05-2.10	3.3	-	12.7	250	44	1.55	0.83	0.72	0.52	0.41
				25.4	250	46	1.53	0.80	0.49	0.43	0.38
	2.30-2.35	5.0	0.8	12.7	250	44	1.97	1.55	1.14	0.93	0.93
				25.4	250	45	1.74	1.62	1.57	1.50	1.41
	2.55-2.60	4.0	-	12.7	250	42	2.07	1.14	1.14	0.41	0.31
				25.4	250	45	2.31	2.16	1.99	1.86	1.83
	2.80-2.85	3.6	-	12.7	100	45	1.86	1.24	1.04	0.93	0.93
				25.4	100	45	1.72	1.15	1.01	0.95	0.89

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC-9	0.55-0.60	-	-	12.7	250	86	1.24	0.72	0.41	0.41	0.41
				25.4	250	86	1.81	1.53	1.41	1.36	1.32
	0.80-0.85	0.5	-	12.7	100	92	0.62	0.31	0.21	0.10	0.10
				25.4	100	96	0.92	0.78	0.70	0.63	0.61
	1.05-1.10	-	-	12.7	250	105	0.52	0.41	0.31	0.31	0.21
				25.4	250	104	0.88	0.65	0.63	0.61	0.58
	1.30-1.35	-	-	12.7	250	82	1.66	1.04	0.72	0.62	0.62
				25.4	250	79	2.25	1.33	1.18	1.22	1.35
	1.55-1.60	2.0	-	12.7	250/100	98	0.52/0.52	0.41/0.41	0.41/0.41	0.31/0.31	0.31/0.21
				25.4	250/100/250	-	1.14/1.00/1.07	0.96/0.88/0.95	0.91/0.88/0.92	0.87/0.83/0.89	0.83/0.83/0.87
	1.80-1.85	2.7	0.1	12.7	100	98	0.72	0.72	0.83	0.72	0.72
				25.4	100	95	1.07	0.89	0.85	0.80	0.78

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	LABORATORY S_r(+ 1 rev) (kPa)	LABORATORY S_r(+2 rev) (kPa)	LABORATORY S_r(+3 rev) (kPa)	LABORATORY S_r(+4 rev) (kPa)
KC-10	0.55-0.60	0.1	-	12.7	100	52	1.45	0.83	0.62	0.62	0.62
				25.4	250/100/250	55	1.41/1.41/1.49	0.85/1.31/1.05	0.74/1.33/0.96	0.61/1.20/0.92	0.61/1.15/0.91
	0.80-0.85	0.1	-	12.7	250	42	3.00	1.24	0.93	0.72	0.62
				25.4	250	43	2.93	1.04	0.79	0.60	0.54
	1.05-1.10	0.1	-	12.7	100	51	0.72	0.52	0.41	0.31	0.31
				25.4	100	58	1.20*	1.09	1.06	1.04	1.01
	1.30-1.35	-	-	12.7	250	45	1.24	1.14	1.04	1.04	0.83
				25.4	250/100/250	46	1.26/1.20/1.18	0.62/1.05/0.97	0.32/0.98/0.89	0.22/0.93/0.83	0.18/0.89/0.79
	1.55-1.60	1.9	-	12.7	250	41	2.90	1.45	1.14	0.93	-
				25.4	250	41	2.68	1.66	1.59	1.32	1.23
	1.80-1.85	3.8	-	12.7	250	38	2.79	1.14	0.72	0.62	0.62
				25.4	250	38	2.84	1.37	1.26	1.33	1.32
	2.05-2.10	3.2	0.6	12.7	100	43	0.52	0.83	0.83	0.72	0.62
				25.4	100	43	1.15	1.04	0.88	0.82	0.74

* Sample rotated minutely within beaker during the test.

Table 1 (cont.) YS-85-08 Vane Shear Test Results

CORE	Subbottom Depth (m)	SHIPBOARD S_u (kPa)	SHIPBOARD S_r(+ 1 rev) (kPa)	Vane Size (mm)	Beaker Size (ml)	Water Content (%)	LABORATORY S_r(Hand) (kPa)	S_r(+ 1 rev) (kPa)	S_r(+2 rev) (kPa)	S_r(+3 rev) (kPa)	S_r(+4 rev) (kPa)
KC-11	0.55-0.60	1.7	-	12.7	250	58	0.41	0.41	0.21	0.21	0.10
				25.4	250	60	0.80	0.71	0.69	0.66	0.63
	0.80-0.85	0.5	-	12.7	250	51	0.62	0.41	0.41	0.31	0.41
				25.4	250	52	1.00	0.83	0.70	0.65	0.62
	1.05-1.10	5.2	-	12.7	100	47	0.72	0.93	0.83	0.72	0.83
				25.4	100	47	1.13	0.82	0.66	0.70	0.69

Table 2. Average laboratory strength decrease from S_r (hand) to S_r (+1 rev) and average plasticity indices for each core.

Core	Average Plasticity Index (%)	Plasticity Index Range (%)	Average Vane Shear Strength Decrease (12.7 mm Vane) (%)	Average Vane Shear Strength Decrease (25.4 mm Vane) (%)
KC7b	17	15-19	60	35
KC7a	18	16-19	45	25
KC8	19	17-22	31	21
KC10	21	17-32	41	30
KC1a	23	23-24	60	42
KC1b	23	19-27	12	21
KC4	24	11-44	33	27
KC11	27	25-32	17	18
KC5	52	46-61	24	17
KC9	53	48-58	27	19
KC6	59	52-71	30	15

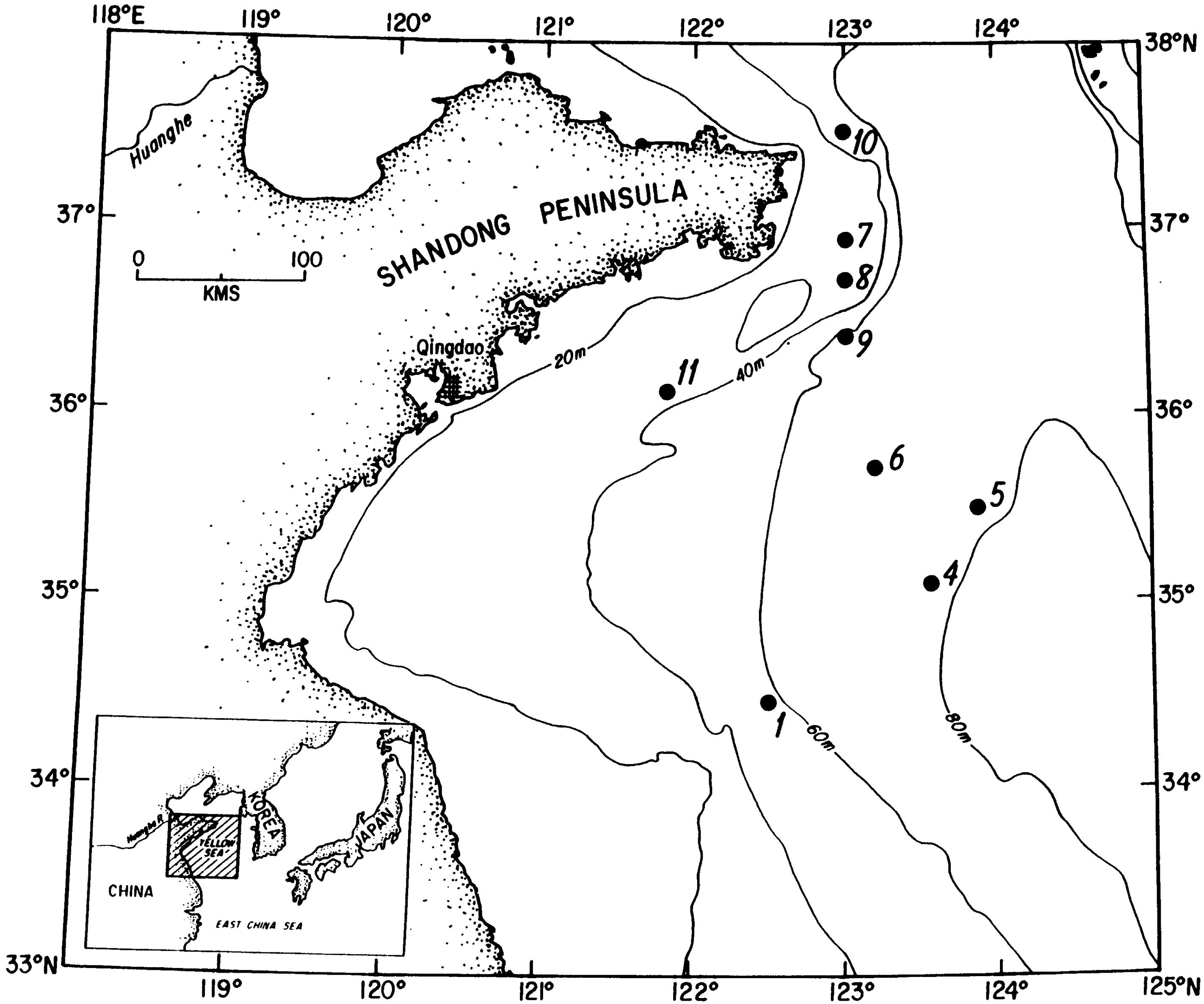

Fig. 1. Station location map.

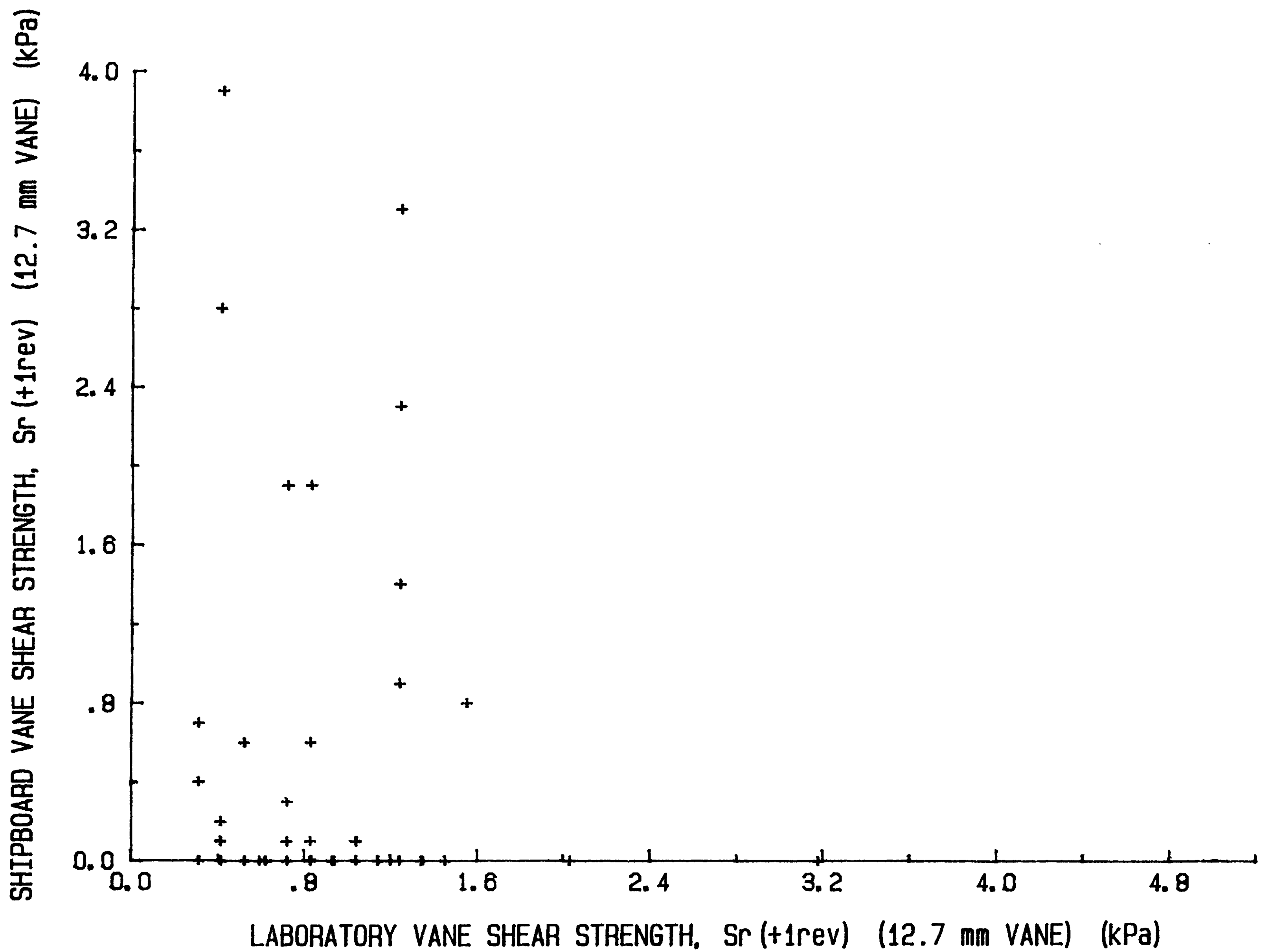

Fig. 2. Shipboard remolded vane shear strengths, S_r (+1 rev) (12.7 mm vane) versus laboratory vane shear strengths, S_r (+1 rev) (12.7 mm vane).

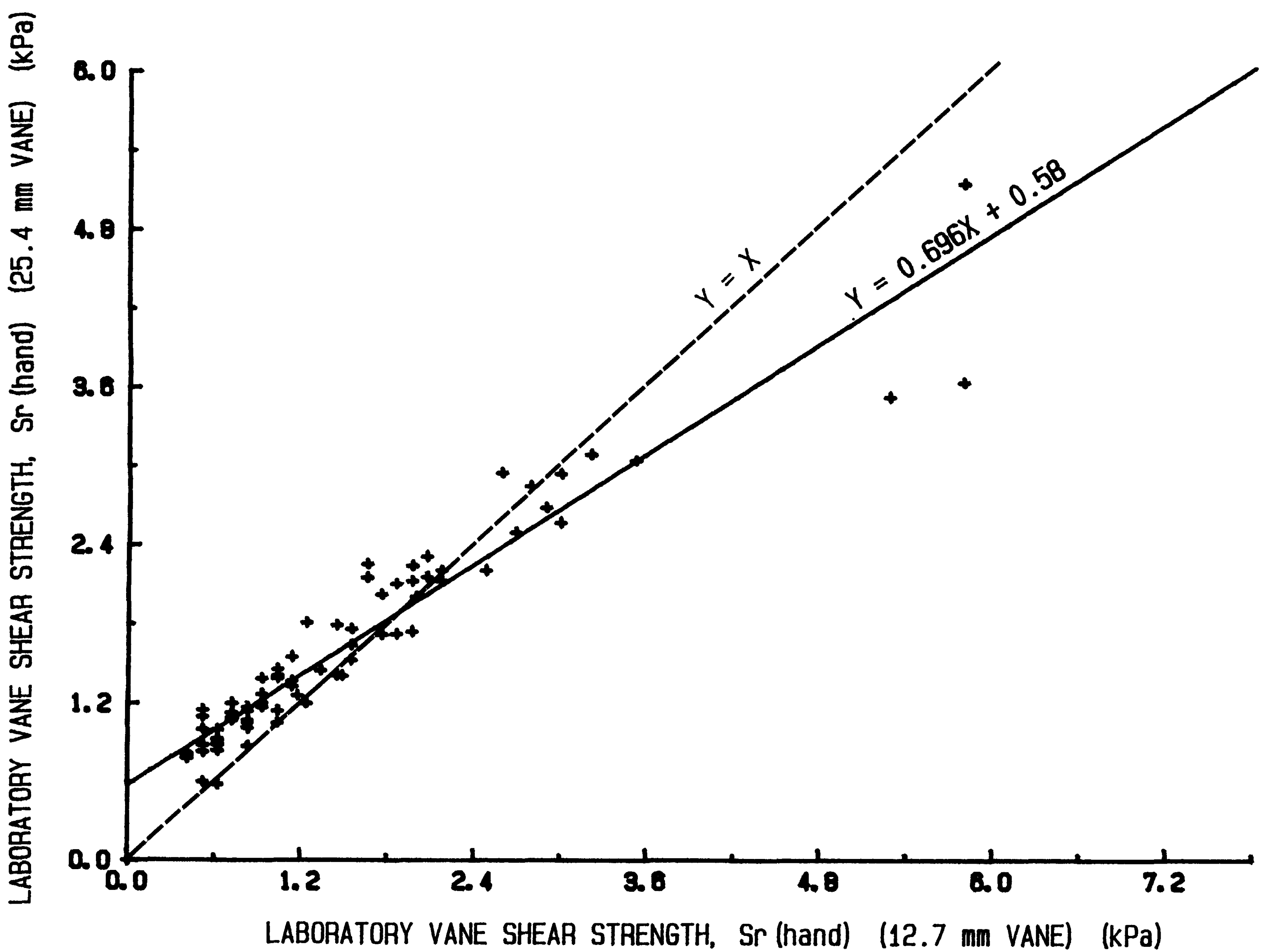

Fig. 3. Laboratory vane shear strengths, S_r (hand) (25.4 mm vane) versus laboratory vane shear strengths, S_r (hand) (12.7 mm vane).

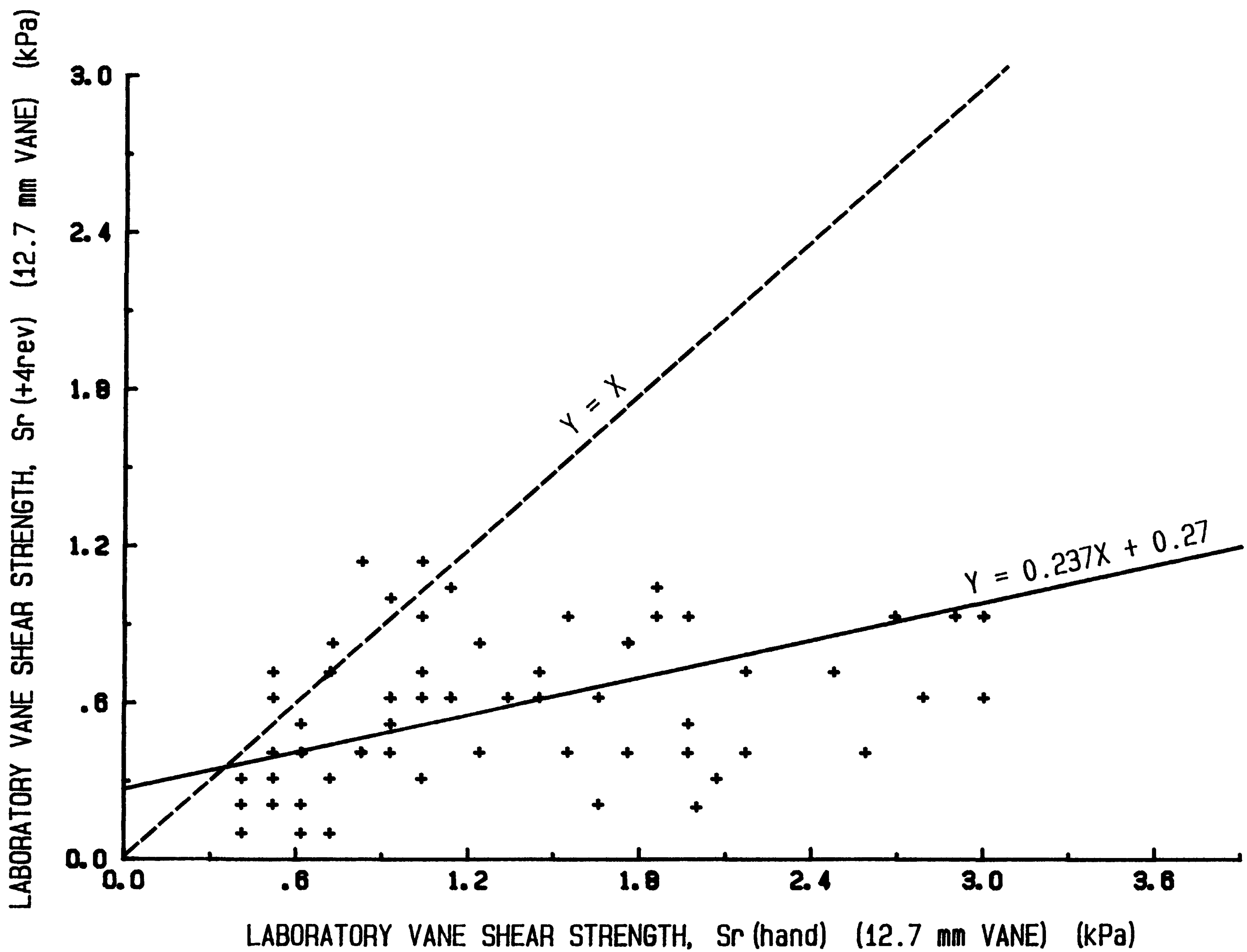

Fig. 4. Laboratory vane shear strengths, S_r (+4 rev) (12.7 mm vane) versus laboratory vane shear strengths, S_r (hand) (12.7 mm vane).

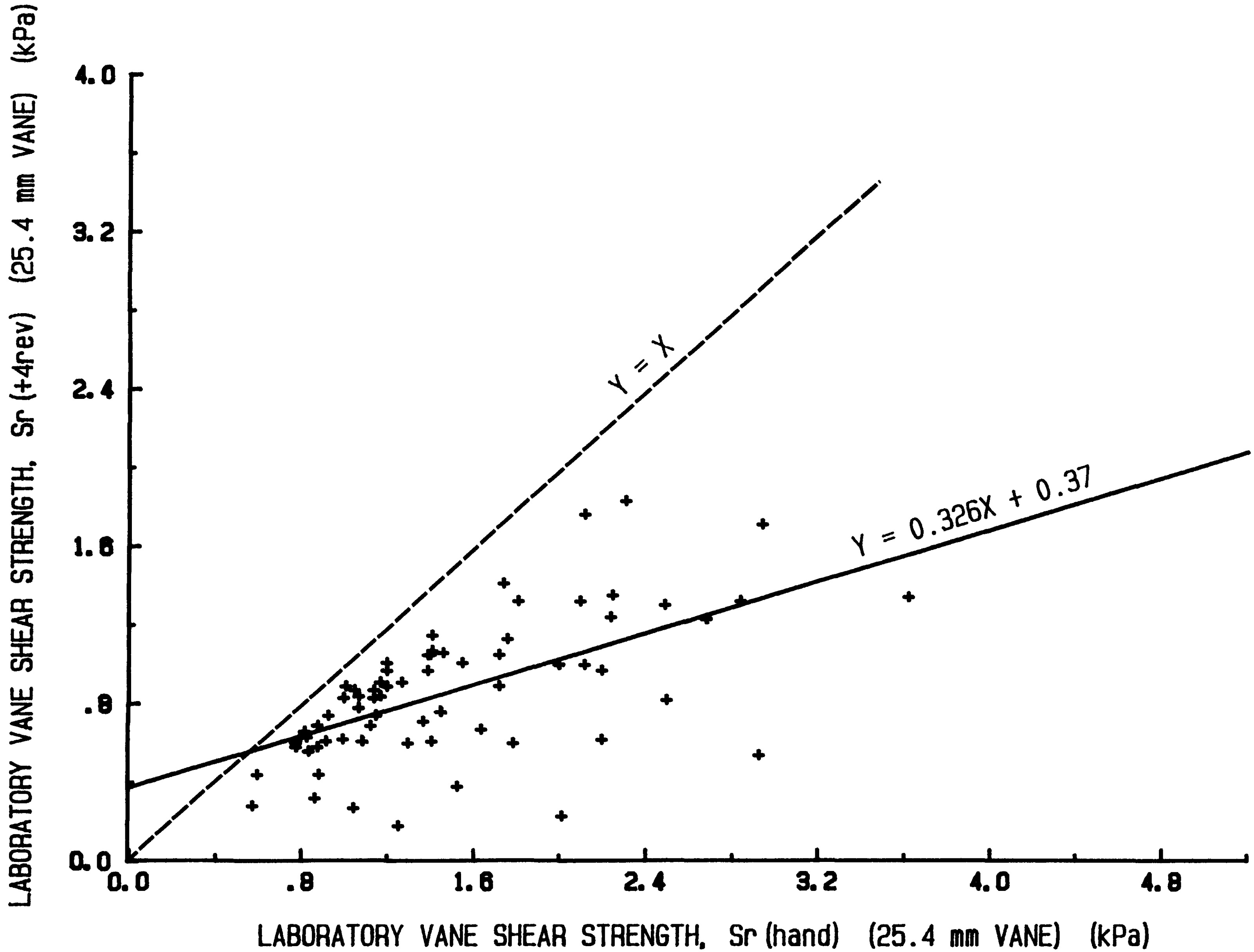

Fig. 5. Laboratory vane shear strengths, S_r (+4 rev) (25.4 mm vane) versus laboratory vane shear strengths, S_r (hand) (25.4 mm vane).

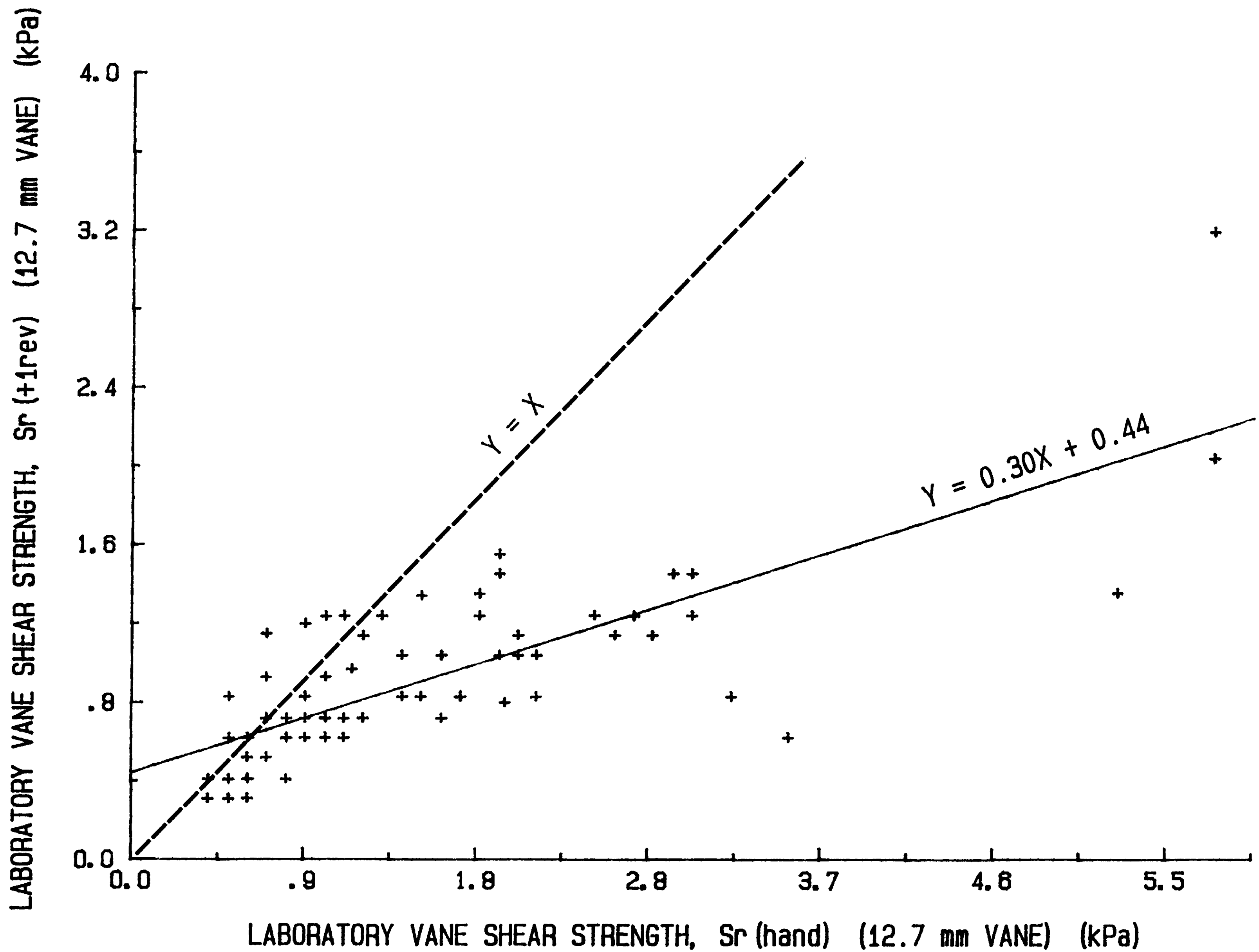

Fig. 6. Laboratory vane shear strengths, S_r (+1 rev) (12.7 mm vane) versus laboratory vane shear strengths, S_r (hand) (12.7 mm vane).

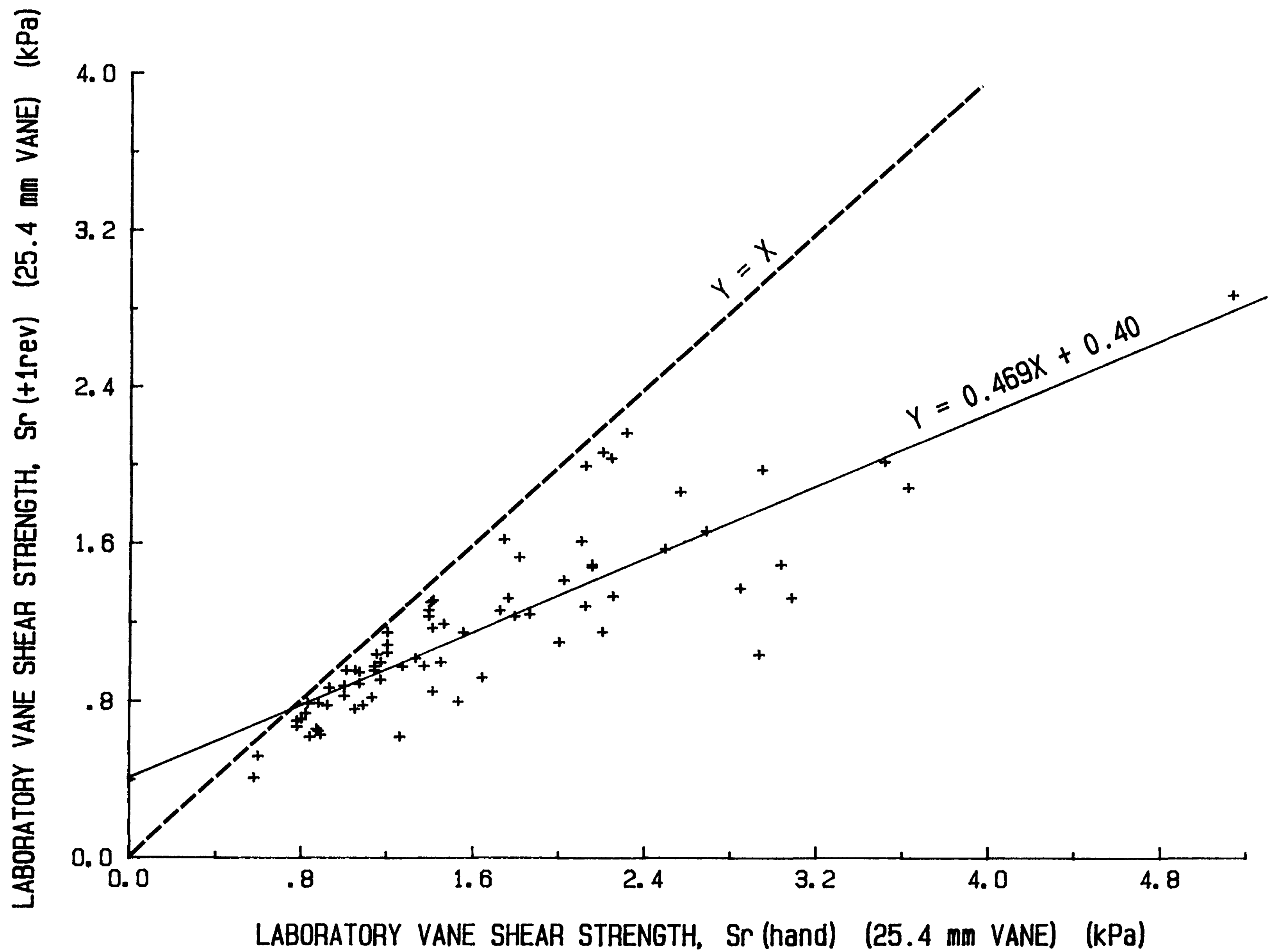

Fig. 7. Laboratory vane shear strengths, S_r (+1 rev) (25.4 mm vane) versus laboratory vane shear strengths, S_r (hand) (25.4 mm vane).

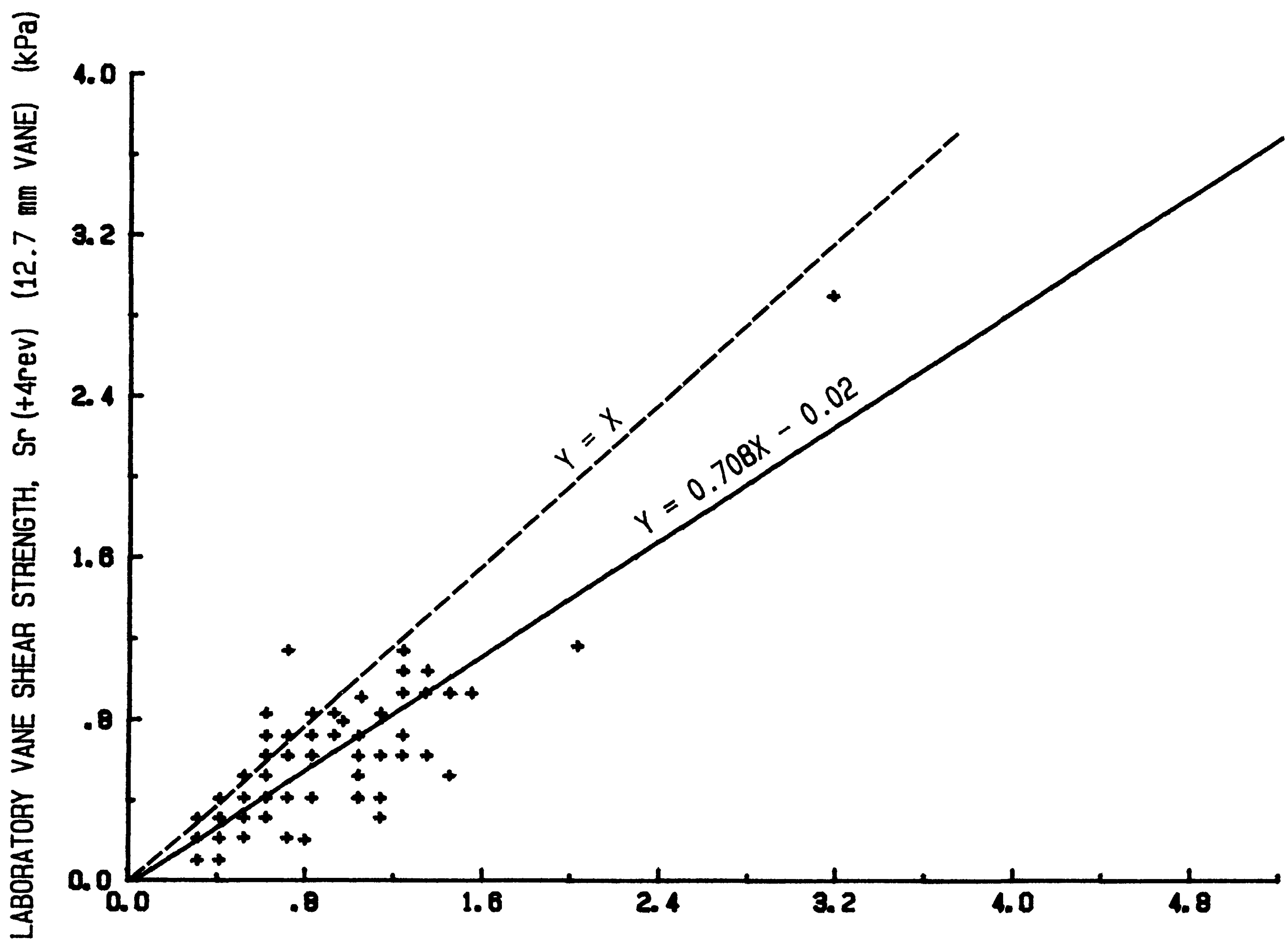

Fig. 8. Laboratory vane shear strengths, S_r (+4 rev) (12.7 mm vane) versus laboratory vane shear strengths, S_r (+1 rev) (12.7 mm vane).

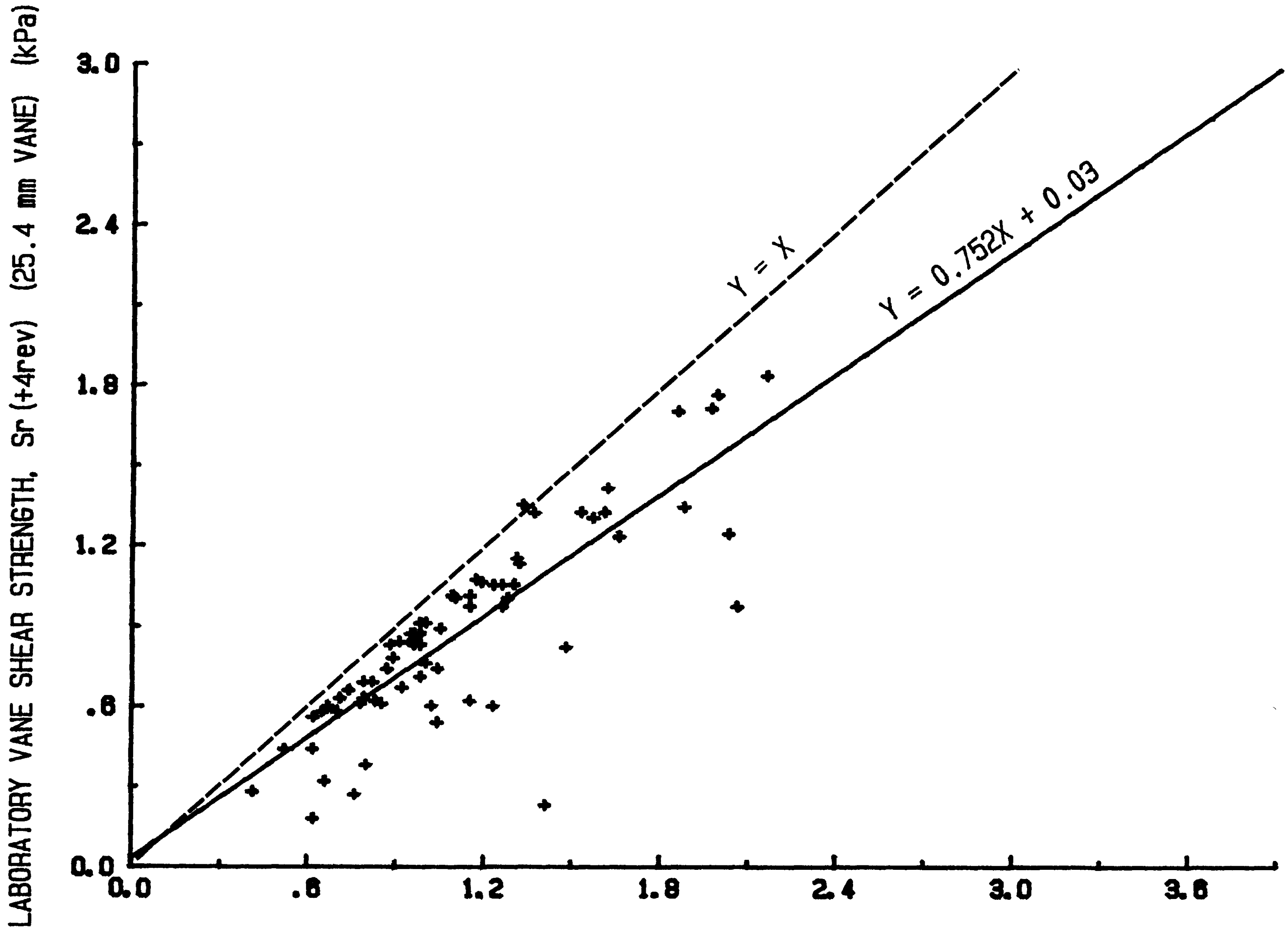

Fig. 9. Laboratory vane shear strengths, S_r (+4 rev) (25.4 mm vane) versus laboratory vane shear strengths, S_r (+1 rev) (25.4 mm vane).

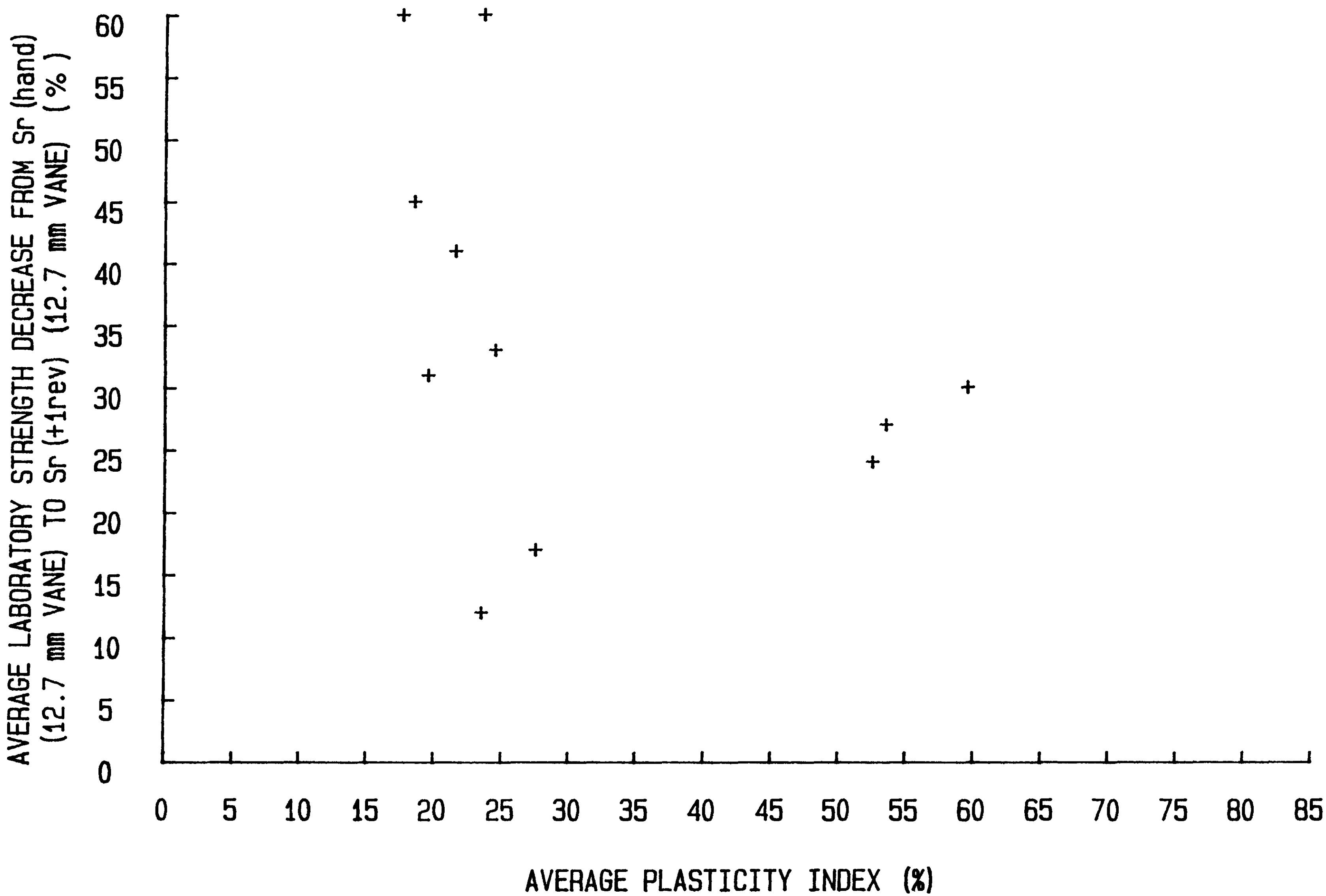

Fig. 10. Average laboratory strength decrease from S_r (hand) (12.7 mm vane) to S_r (+1 rev) (12.7 mm vane) versus average plasticity index for each core.

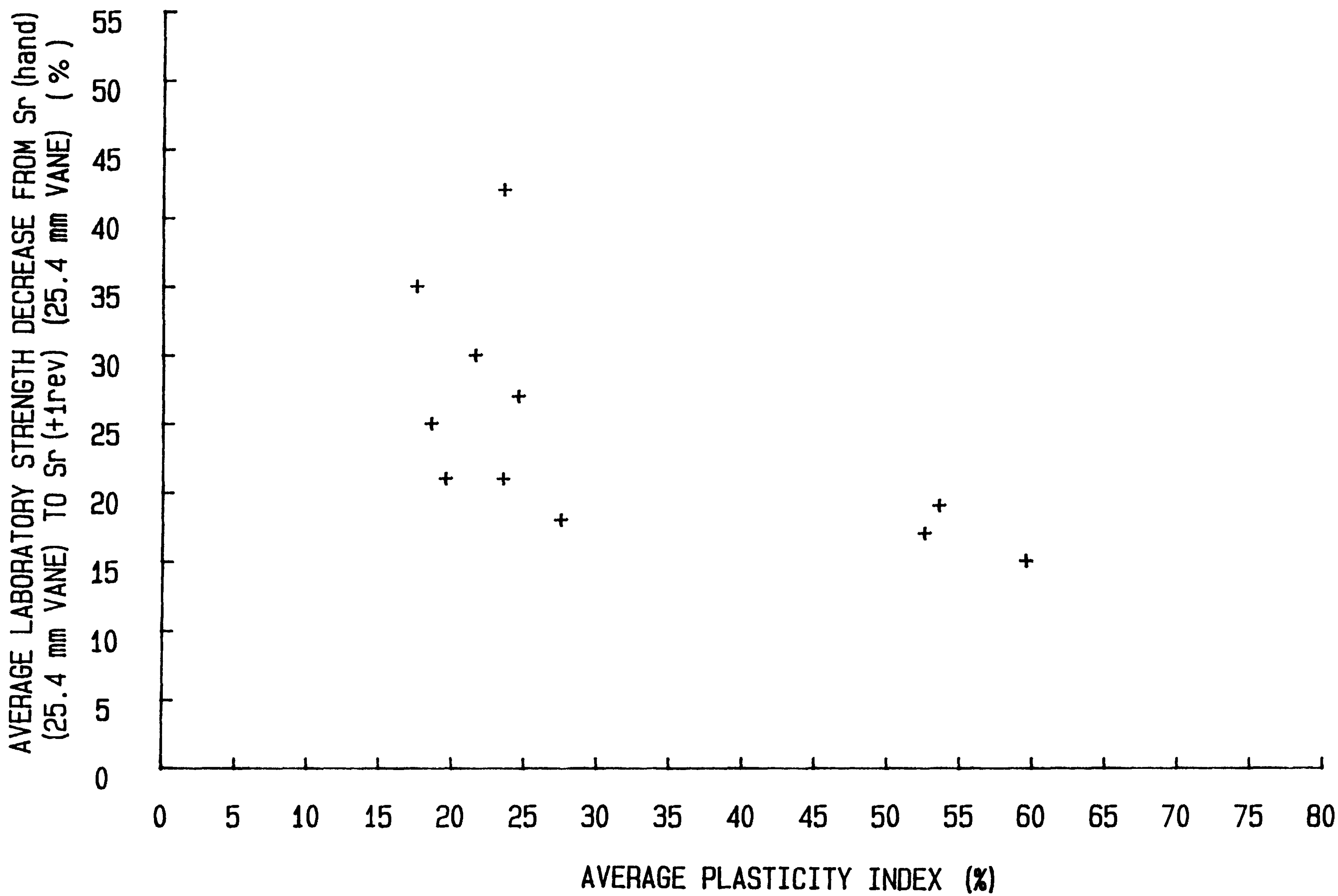

Fig. 11. Average laboratory strength decrease from S_r (hand) (25.4 mm vane) to S_r (+1 rev) (25.4 mm vane) versus average plasticity index for each core.