Energy, Mines and Resources Canada

Énergie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology

Centre canadien de la technologie des minéraux et de l'énergie

Mining Research Laboratories

Laboratoires de recherche minière

[redacted]

testing
mechanical properties
rock (material)

Canada

INTERNAL REPORT

RESULTS OF SHEAR TESTING ON JOINTED PARADISE RIVER SPECIMENS

R. Jackson

MRL 88-128(TR)

RESULTS OF SHEAR TESTING ON
JOINTED PARADISE RIVER SPECIMENS

by

Rand Jackson*

ABSTRACT

Direct shear tests were conducted on seven jointed banded tuff specimens obtained from the Paradise River hydro-electric project by ShawMont Newfoundland Limited. The specimens constituted two sets of joint types, namely; planar and kink banded. Shearing was performed under normal loads of 500, 1000 and 1500 kPa for each joint type.

---

*Reasearch Officer, Canadian Mine Technology Laboratory, Mining Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa (Ontario).

Keywords

Shear Tests, Banded Tuff, Newfoundland, ShawMont Newfoundland Ltd., Shear Strength, Residual Shear Strength, Friction Angle

RÉSULTATS D'ESSAI DE CISAILLEMENT SUR DES ÉCHANTILLONS DIACLASÉS PROVENANT DE LA RIVIÉRE PARADISE

par

Rand Jackson*

RÉSUMÉ

Des essais de cisaillement directs ont été réalisés par la ShawMont Newfoundland Limited sur sept échantillons de tuf à bande diaclasée provenant du projet hydroélectrique de la riviére Paradise. Les échantillons comportaient deux séries de types de diaclases, soit à bande plane et à bande kinkée. Les essais de cisaillement ont été réalisé sur ces deux types de diaclase aux charges normales de 500, 1000 et 1500 kPa.

*Chercheur scientifique, Laboratoire canadien de technologie minière, Laboratoires de recherche minière, CANMET, Énergie, Mines et Ressources Canada, Ottawa (Ontario).

Termes-clés

Essais de cisaillement, tuf rubanné, Newfoundland, ShawMont Newfoundland Ltd., résistance au cisaillement, résistance au cisaillement résiduelle, angle de frottement

CONTENTS

TABLES

FIGURES

INTRODUCTION

Direct shear tests were performed on seven jointed specimens obtained from the Paradise River hydro-electric project by ShawMont Newfoundland Limited. The specimens constituted two sample sets, one representing planar joints and the other kink banded joints found on site. Specimens of each joint type were tested at normal loads of 500, 1000 and 1500 kPa. It is the purpose of this report to summarize the results of the testing and analyses.

SPECIMEN IDENTIFICATION AND PREPARATION

Seven specimens were received from the Paradise River dam site, six of which were obtained by coring and one which was presumably a surface block 'grab' sample. The six 200mm diameter cores provided for testing were kink banded tuffs with schistosity running parallel to the core axis and previously designated as samples P.R. #12, 13, 14, 15A, 15B and 16 by investigators on site. Sample P.R. 16 was found to be damaged during shipping and unsuitable for testing.

The joint surface of interest ran perpendicular to the schistosity and appeared to have considerable clay infilling although no petrographic study was conducted. The 'grab' sample joint surfaces were somewhat cleaner and less weathered than those of the cored specimens.

Samples were cut using a water-cooled cut off saw in such a way that the maximum shearing surface was maintained and ran centrally through the specimen. The 'grab' sample had sufficient surface area to allow two specimens to be prepared which were subsequently designated as P.R. GRAB1 and P.R. GRAB2.

Detailed test specifications supplied by ShawMont Newfoundland Ltd. including specimen orientation and direction of shearing are contained in Appendix A of this report.

DESCRIPTION OF TEST MEASUREMENTS

Direct shear tests were conducted on the seven Paradise River specimens using a constant displacement shear box designed and fabricated by CANMET. The bottom half of the box provides the shearing motion while the top box is constrained to move vertically only. Normal load is applied by a hydraulic jack attached to a yoke spanning the center of gravity of the upper box. The hydraulic jack is connected to a pressure compensator which enables the piston to retract or extend to accommodate normal displacements during testing without varying the normal load. Shear force is provided by a 50 kN screw type actuator. The actuator reaction arm is instrumented with a full strain gauge bridge and calibrated against a Wykeham Farrance Model 14240 proving ring to provide an analogue signal of the shear load. Normal displacement is measured using two linear variable differential transducers (lvdt's) attached via magnetic stands to the hydraulic jack yoke on either side of the box. Shear displacement is also measured using an lvdt mounted on the end of the shear box. Analogue signals from the three lvdt's, the full bridge load cell and the pressure compensator are fed to a Fluke 2280A data logger with simultaneous readings being taken every four seconds.

Samples were initially positioned in the upper box in such a way that the center of the anticipated shear surface coincided with the center of gravity of the box and line of action of the normal loading system. A quick setting, high strength cement (Hydrostone) was then poured to the top of the box and allowed to cure for 24 hours. After the cement had set sufficiently, the box/sample assembly was inverted and placed in position over the lower box with 12mm spacers between the two boxes. Cement was then poured into the bottom box and allowed to cure for an additional 48 hours. Spacers were then removed and the instrumentation installed. Normal load sufficient to affect the desired normal stress was subsequently applied and the test commenced. Samples were sheared at a rate of 3.3 mm/min. in the direction previously designated by the site investigators.

Residual strength for most specimens was estimated as the mean shear stress associated with the displacement range where no dilation occurred (ie. the horizontal portion of the normal versus shear displacement curve). Samples 13 and 15B, however, dilated continuously throughout the test. Their residual strength, therefore, was estimated by taking the lowest friction angle obtained during testing and subtracting off the angle of dilation associated with it. All other data reduction conformed with procedures outlined in CANMET's Pit Slope Manual.†

Testing began on October 18, 1988 and finished by November 1, 1988.

DATA SUMMARY

Table 1 contains a summary of the joint shear properties including sample name, joint contact area, normal stress and peak shear strength, residual shear strength, peak friction angle, residual friction angle and basic friction angle.

† Gyenge, M. and Herget, G. Pit Slope Manual Supplement 3-2 - Laboratory Tests for Design Parameters; CANMET (Canada Centre for Mineral and Energy Technology, CANMET Report 77-26; 74 p; May 1977.

Table 1: Mechanical Properties of Jointed Paradise River Specimens

Sample Number	Normal Stress (kPa)	Joint Contact Area (cm^2)	Peak Shear Strength (kPa)	Residual Shear Strength (kPa)	Effective Dilatancy i	Peak Friction Angle ϕ_p	Residual Friction Angle ϕ_r	Basic Friction Angle ϕ_b
PR 12	500	77.18	299	222	0°	31°	24°	31°
PR GRAB2	1000	86.98	815	N/A	4°	35°	N/A	31°
PR 13	1500	118.27	1052	921	4°	35°	32°	31°
PR 14	1500	141.50	1180	890	6°	38°	31°	32°
PR 15A	500	280.74	830	400	11°	59°	39°	48°
PR 15B	1000	224.12	1252	768	7°	51°	38°	44°
PR GRAB1	1500	193.30	1362	987	4°	42°	33°	38°

Figures 1 through 7 represent the shear force versus shear displacement curves for P.R. 12, GRAB2, 13, 14, 15A, 15B and GRAB1, respectively. Corresponding normal displacement versus shear displacement curves are contained in Figures 8 to 14. Figure 15 represents a plot of peak shear stress versus normal stress for the planar joint sample set. For comparison, Figure 16 contains the same data including results of testing on sample number P.R. GRAB1. Figures 17 and 18 also include and exclude, respectively, the P.R. GRAB1 results for the kink banded joint sample set. Figures 19 through 22 summarize similar data treatments for the residual shear stress versus normal stress curves. Figures 23 through 29 are the after shearing pictures of samples PR 12, 13, 14, 15A, 15B, GRAB1 and GRAB2 respectively.

OBSERVATIONS AND CONCLUSIONS

As mentioned earlier, sample number P.R. 16 was damaged during shipping. According to the documentation received from site investigators, the 'grab' sample was to be used if any of the kink banded specimens (of which P.R. 16 was one) proved unsuitable. Subsequent testing on P.R. GRAB1, however, indicated that its strength and dilation characteristics more closely resembled those of the planar joint set than the kink banded joint set. As Table 2 indicates, including P.R. 16 data with data obtained from the planar joint set results in a minor 1° change in the peak friction angle. If the P.R. 16 data are included with the kink banded sample set results, however, a much more substantial reduction of 6° is observed. Similar results were obtained for the residual strength analyses.

Table 2: Summary of Friction Angle Analyses

	Excluding P.R. GRAB1 Results		Including P.R. GRAB1 Results	
	Peak Friction Angle ϕ_p	Residual Friction Angle ϕ_r	Peak Friction Angle ϕ_p	Residual Friction Angle ϕ_r
Planar Joint Set	37°	31°	38°	32°
Kinked Joint Set	53°	38°	47°	35°

The shear stress vs. normal displacement plot for P.R. GRAB2 shows a second maximum shear stress occuring after approximately 2.25 cm of shear displacement. This was caused by a localized failure along the schistosity into the specimen which resulted in some buckling and crushing of the intact material. It was not, therefore, considered the maximum shear strength of the joint surface and was discounted.

Sample number P.R. 13 was inadvertantly tested at a normal stress of 1500 kPa rather than 1000 kPa as planned. However, as mentioned earlier, P.R. GRAB1 appeared to behave more as a planar jointed sample than a kink jointed one. Consequently, P.R GRAB2 was prepared and sheared at a normal stress of 1000 kPa to supply the missing data point.

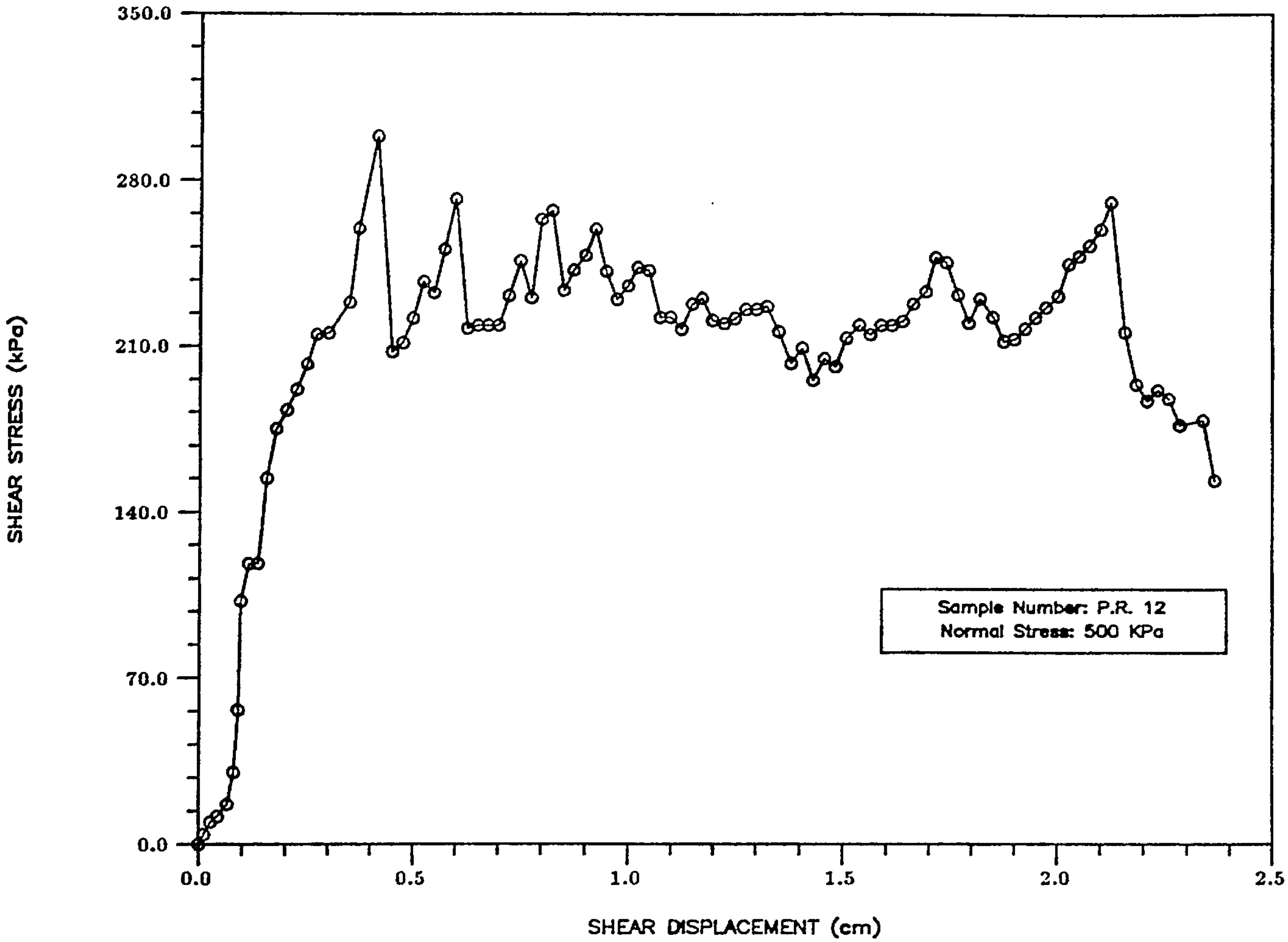


Fig. 1: Shear stress vs. shear displacement: Paradise River Specimen No. 12

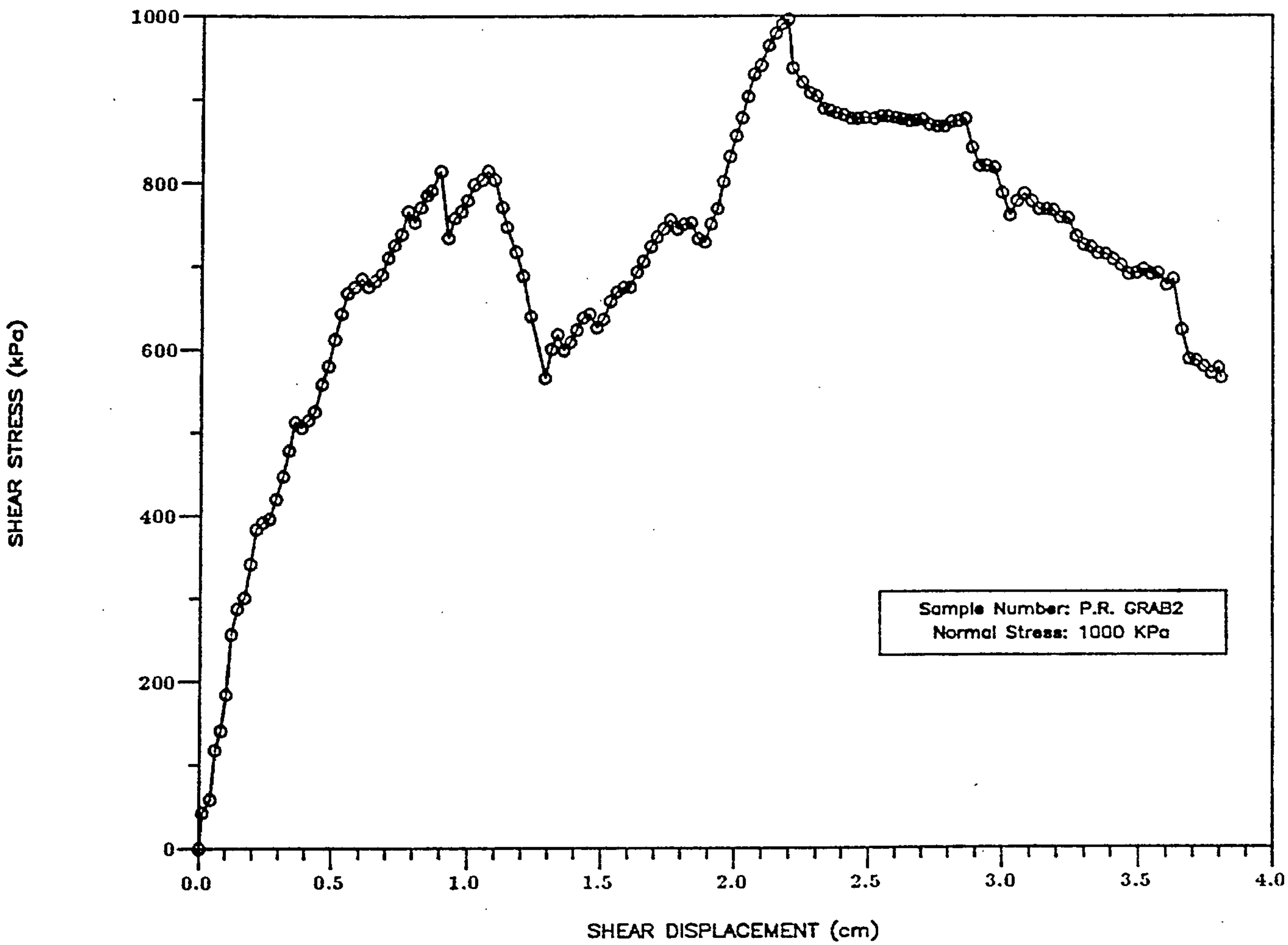


Fig. 2: Shear stress vs. shear displacement: Paradise River Specimen No. GRAB2

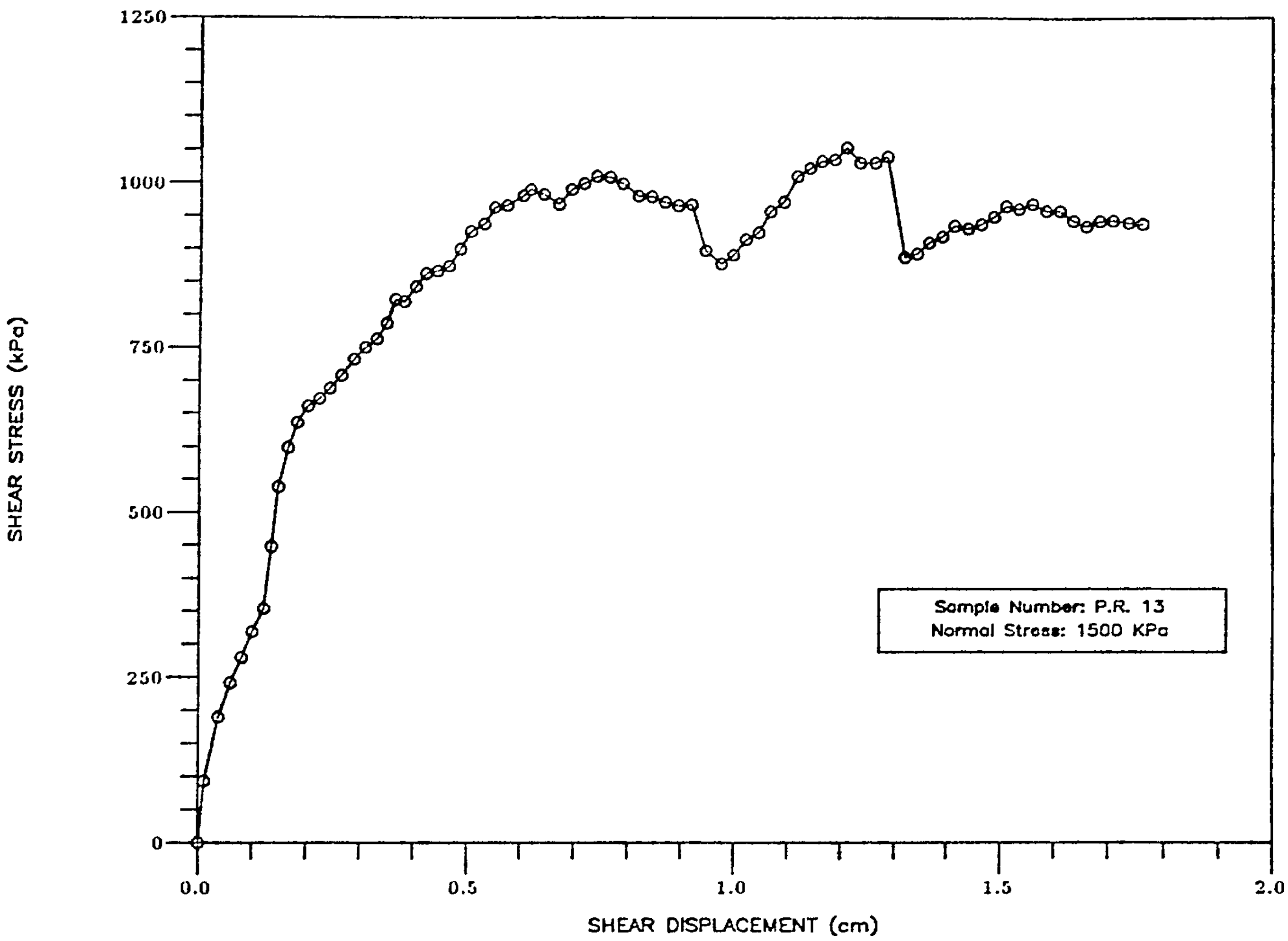


Fig. 3: Shear stress vs. shear displacement: Paradise River Specimen No. 13

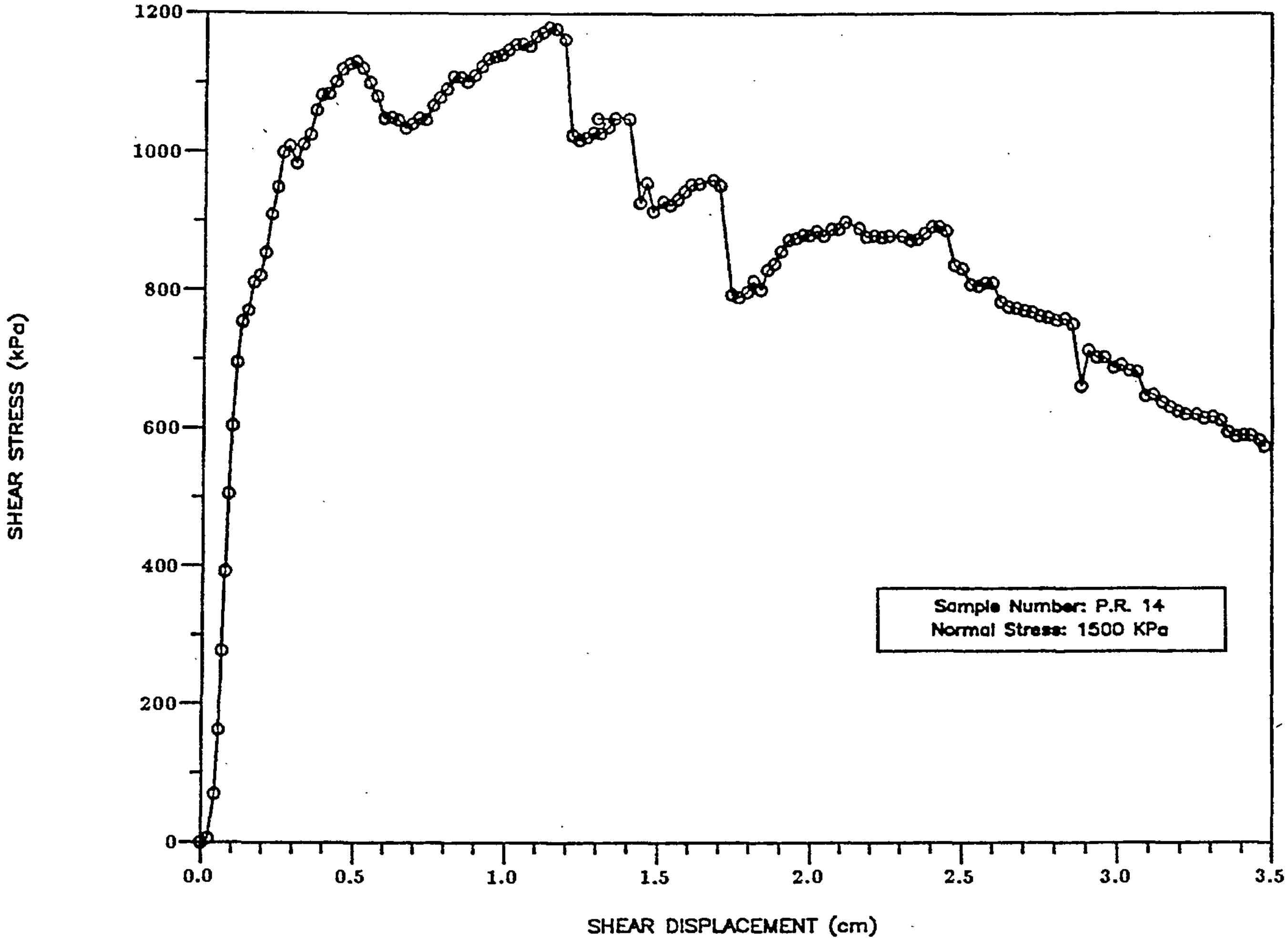


Fig. 4: Shear stress vs. shear displacement: Paradise River Specimen No. 14

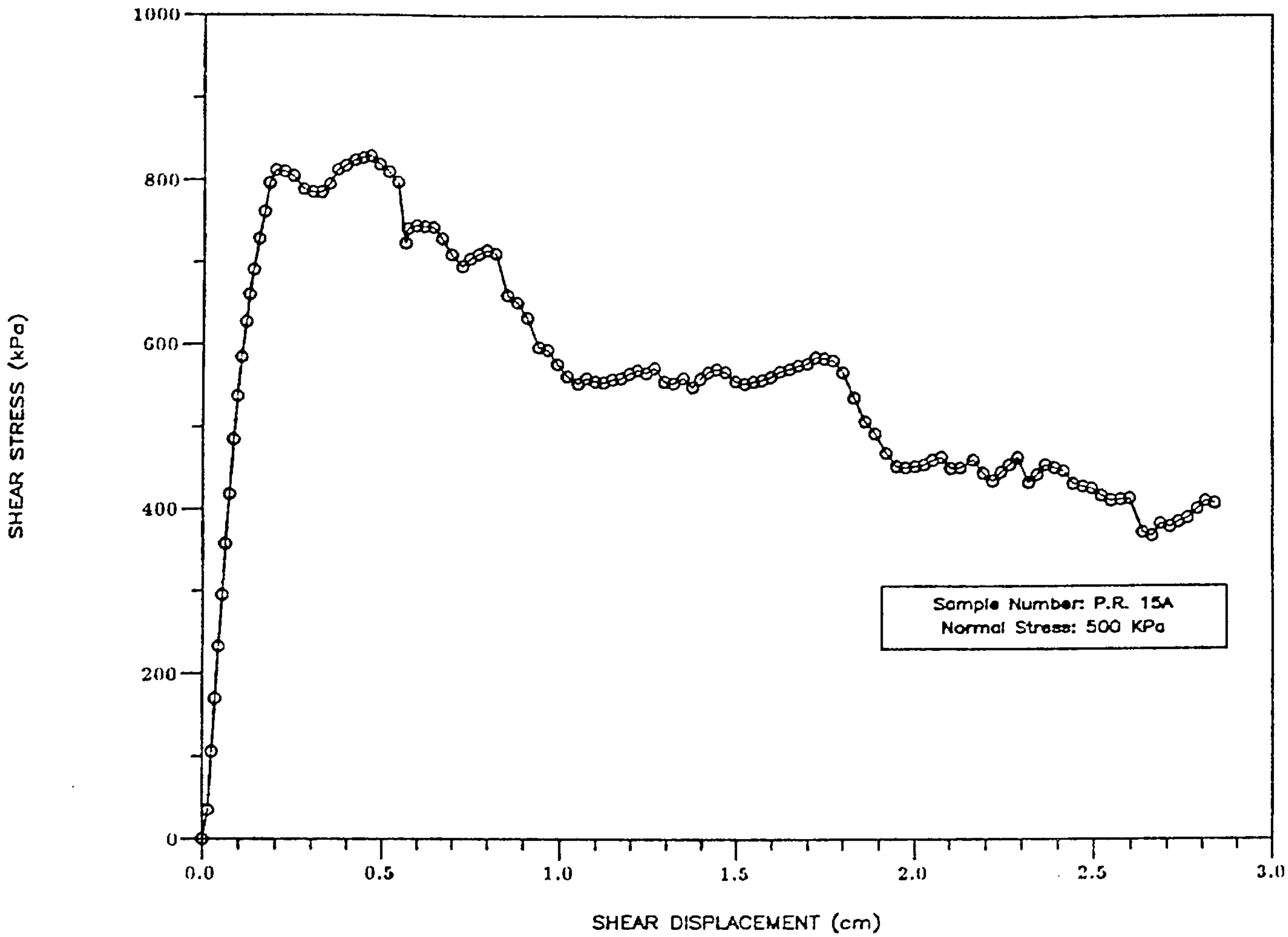


Fig. 5: Shear stress vs. shear displacement: Paradise River Specimen No. 15A

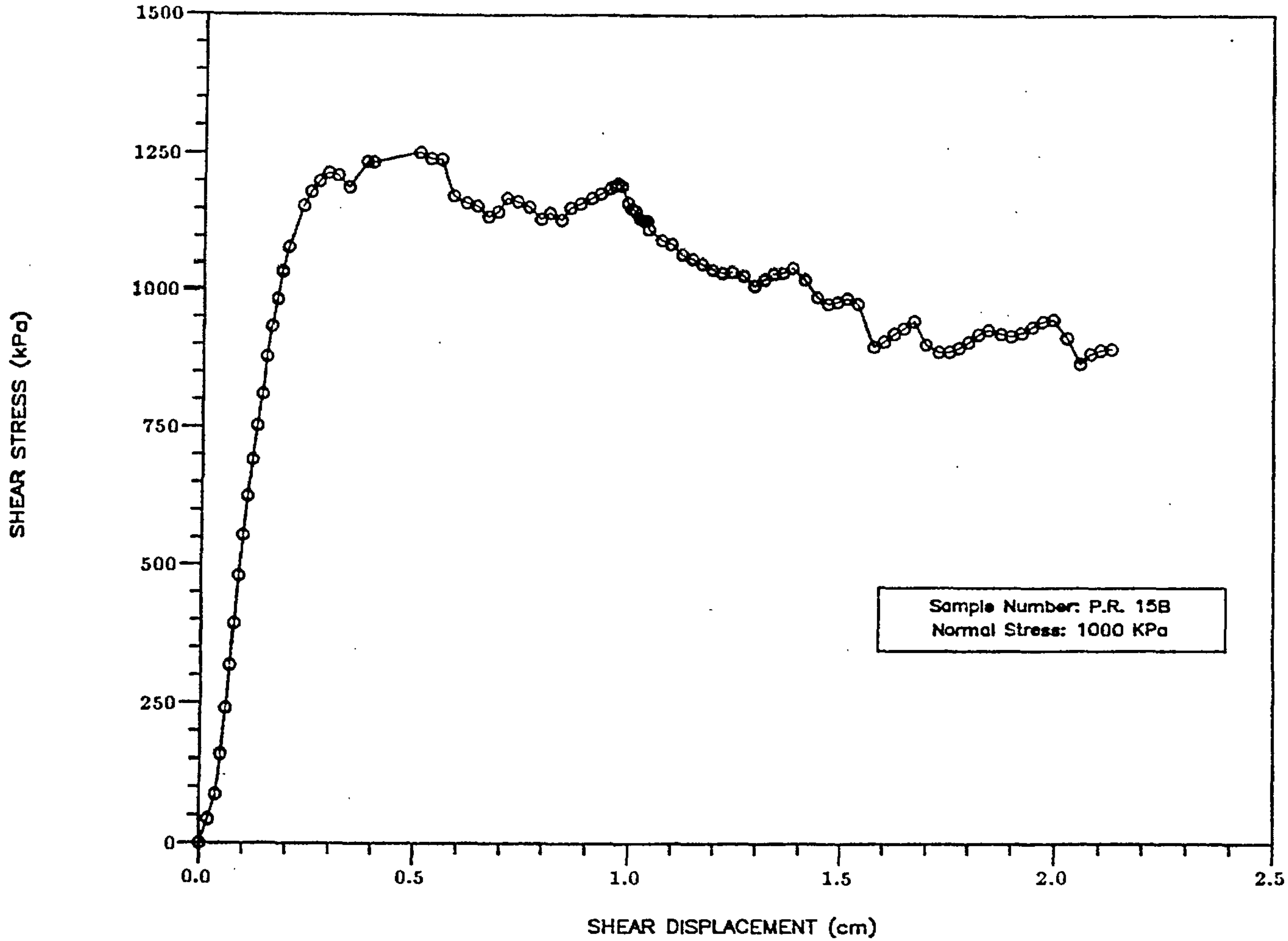


Fig. 6: Shear stress vs. shear displacement: Paradise River Specimen No. 15B

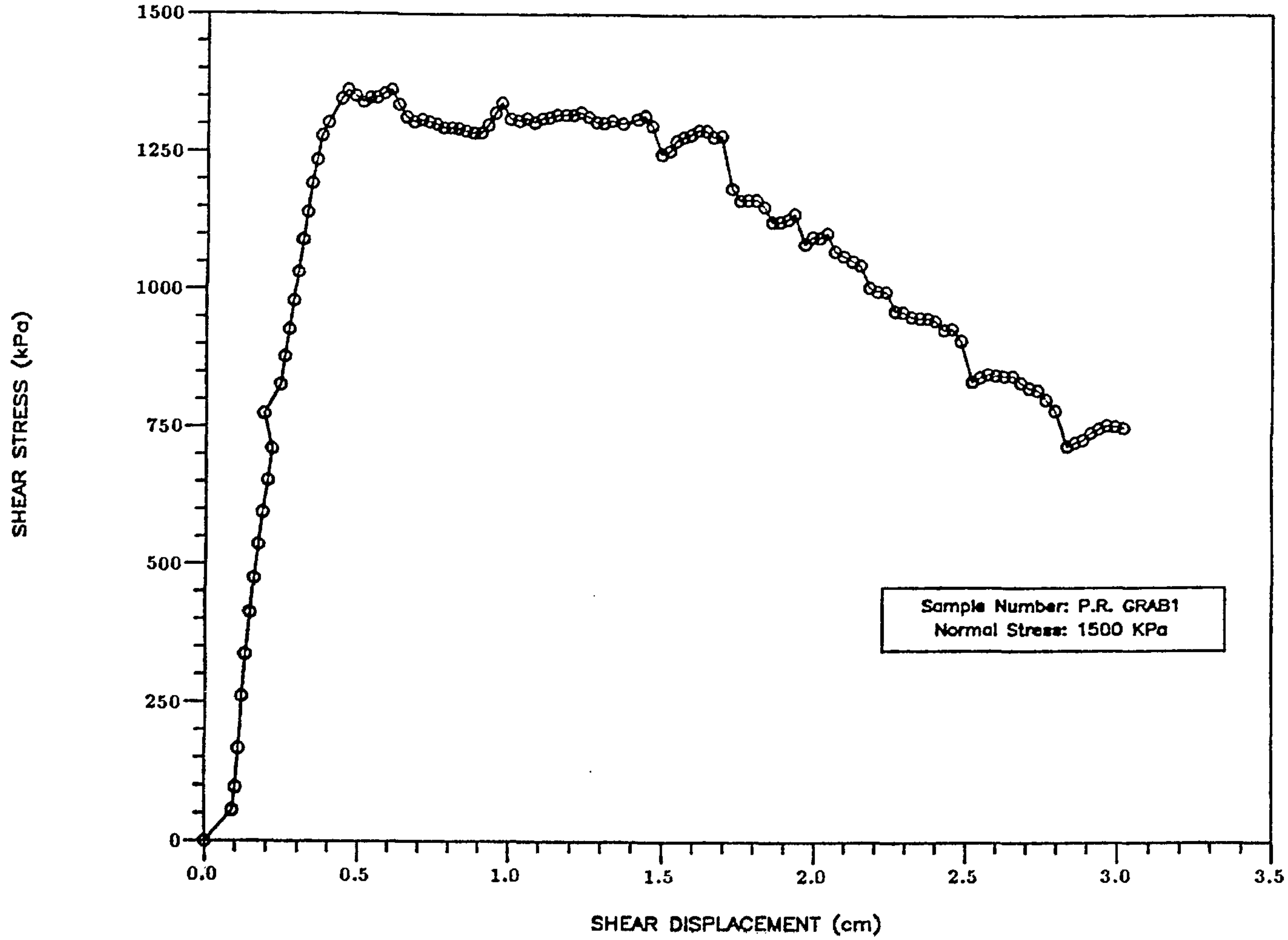


Fig. 7: Shear stress vs. shear displacement: Paradise River Specimen No. GRAB1

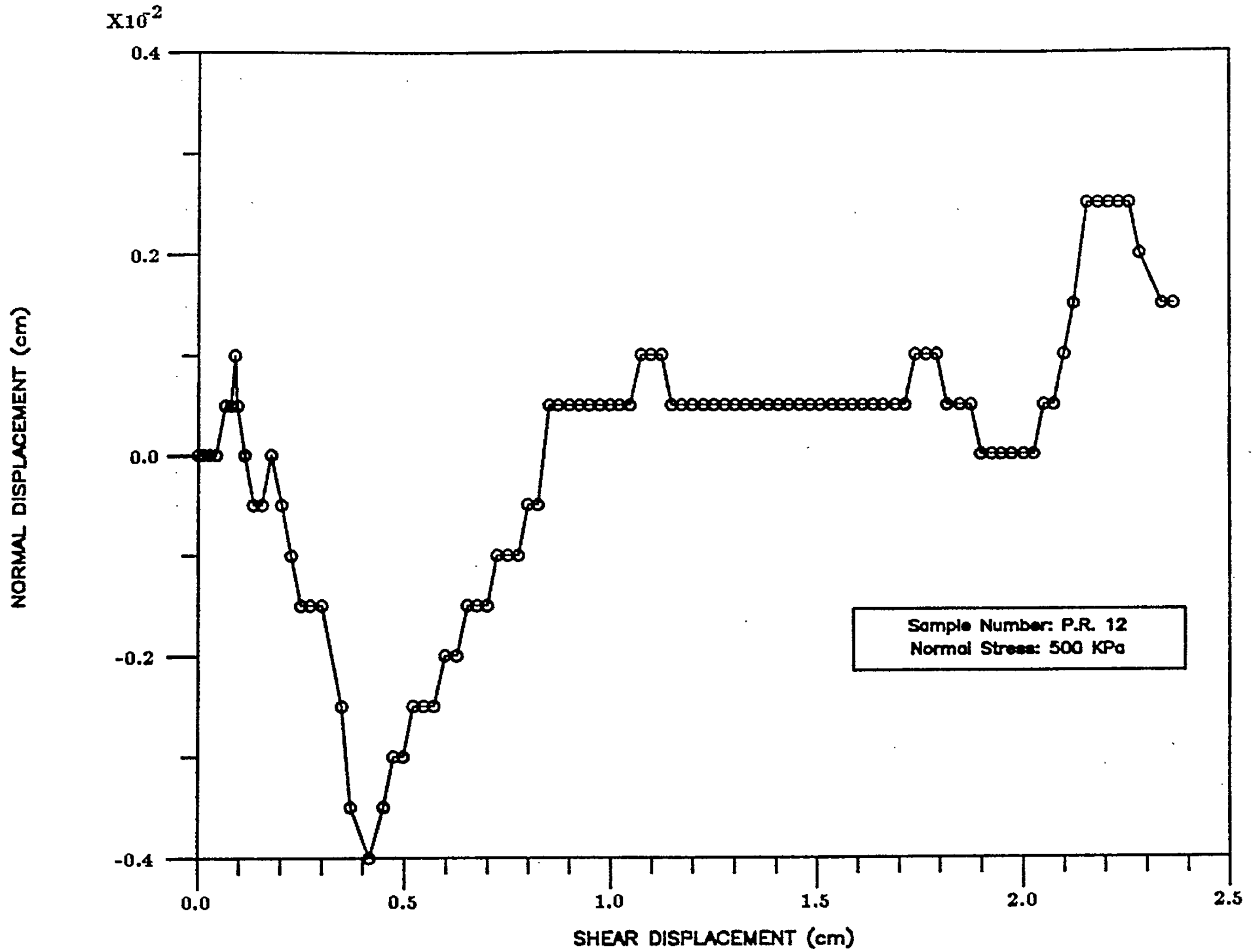


Fig. 8: Normal vs. shear displacement: Paradise River Specimen No. 12

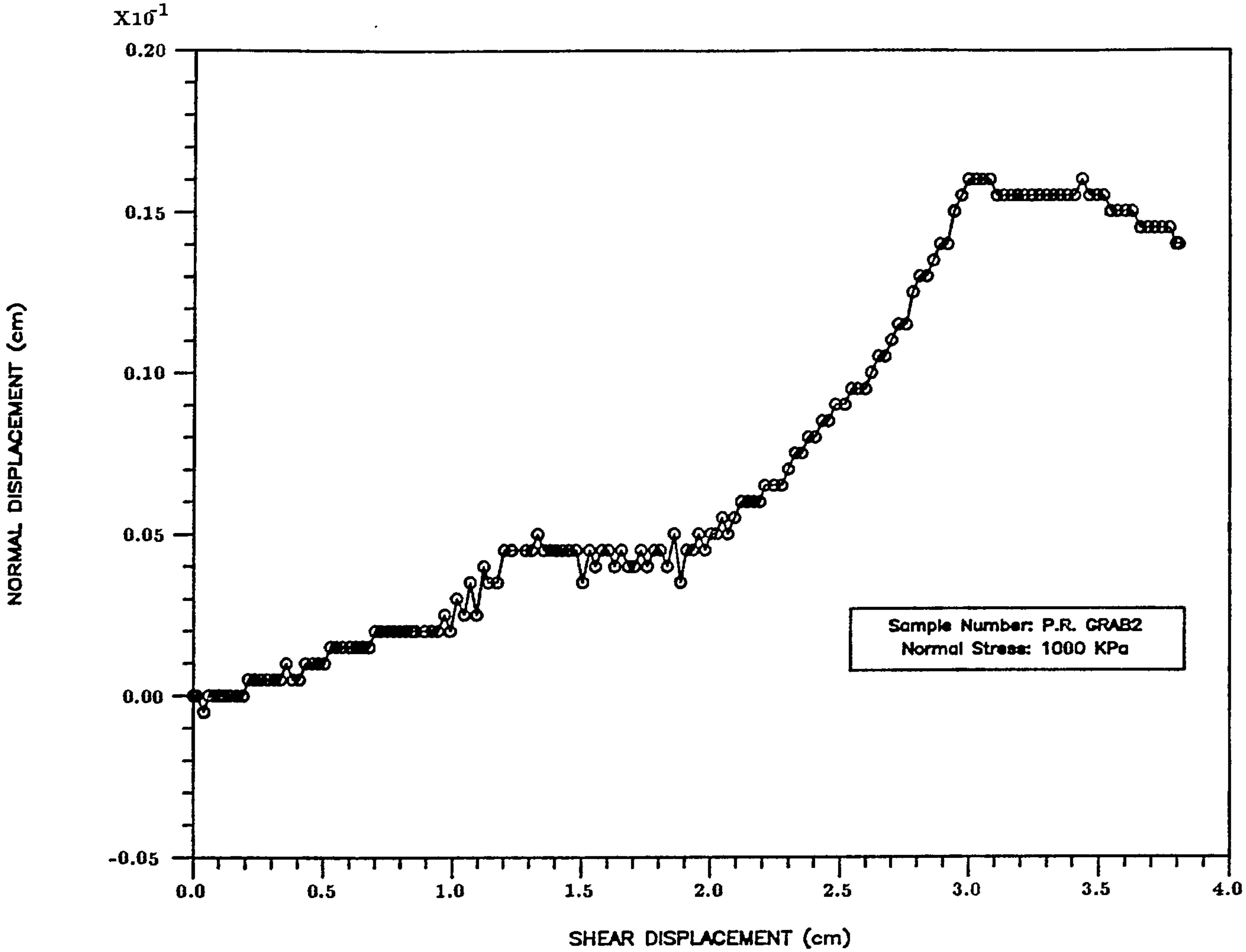


Fig. 9: Normal vs. shear displacement: Paradise River Specimen No. grab2

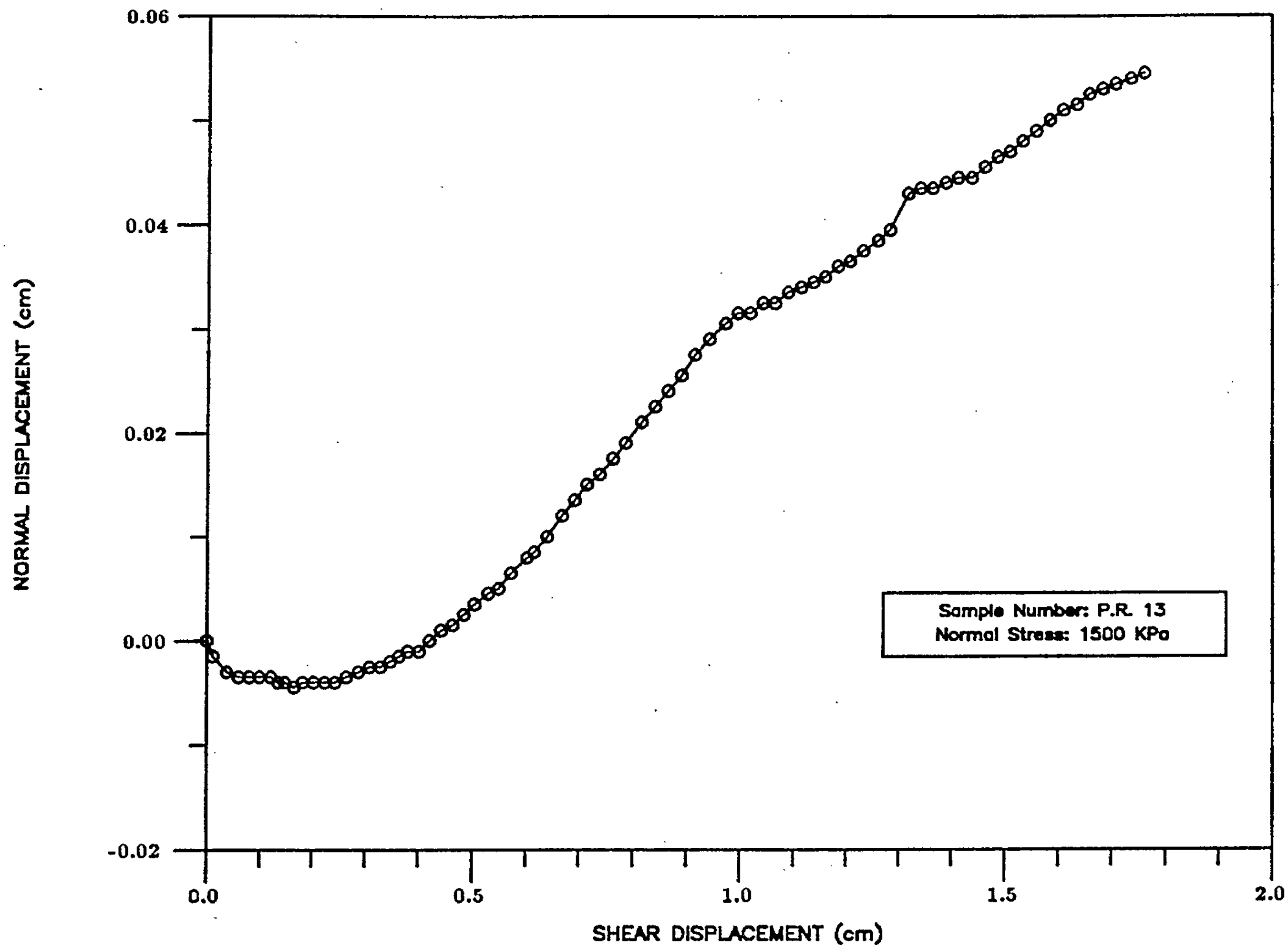


Fig. 10: Normal vs. shear displacement: Paradise River Specimen No. 13

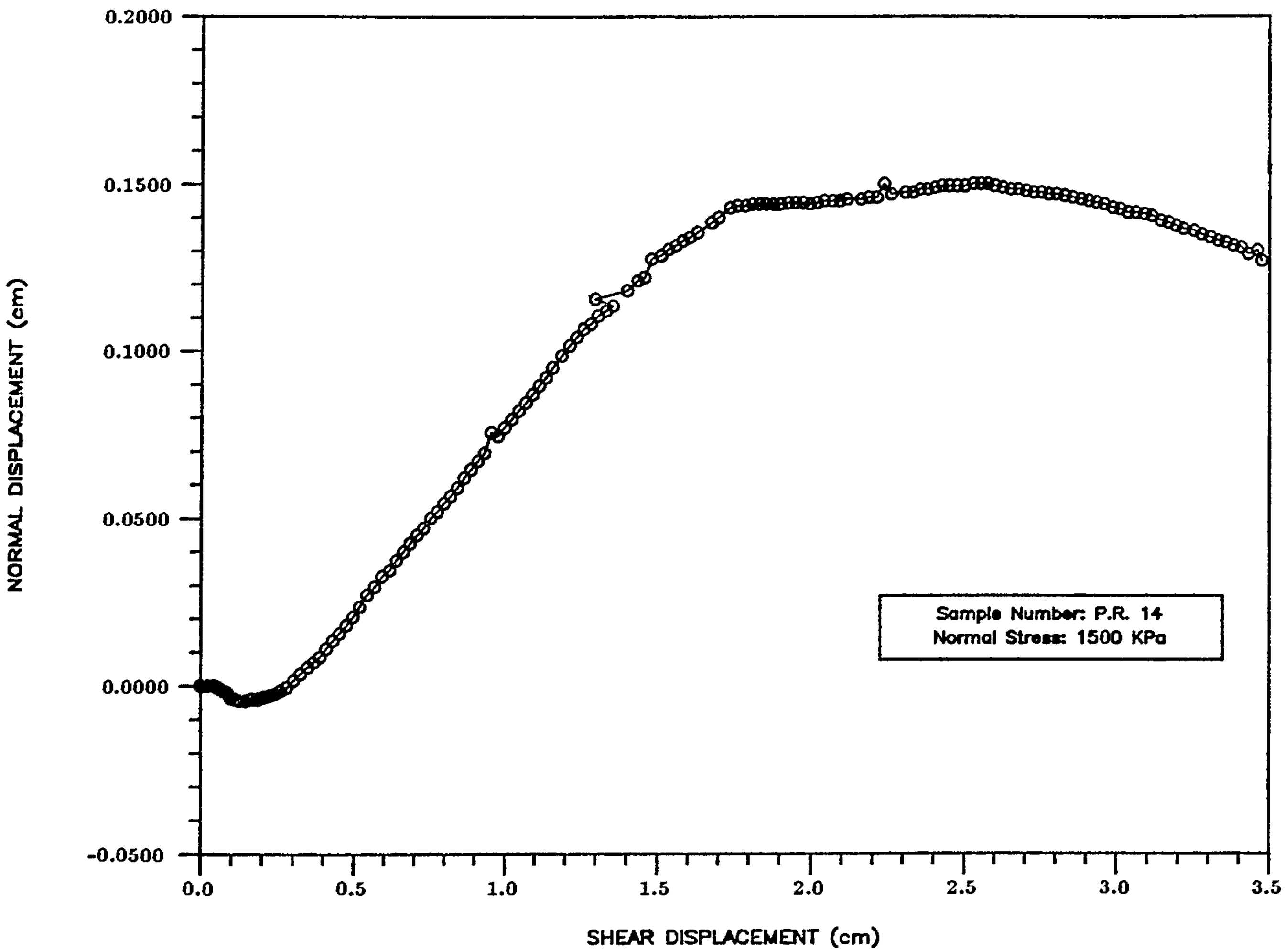


Fig. 11: Normal vs. shear displacement: Paradise River Specimen No. 14

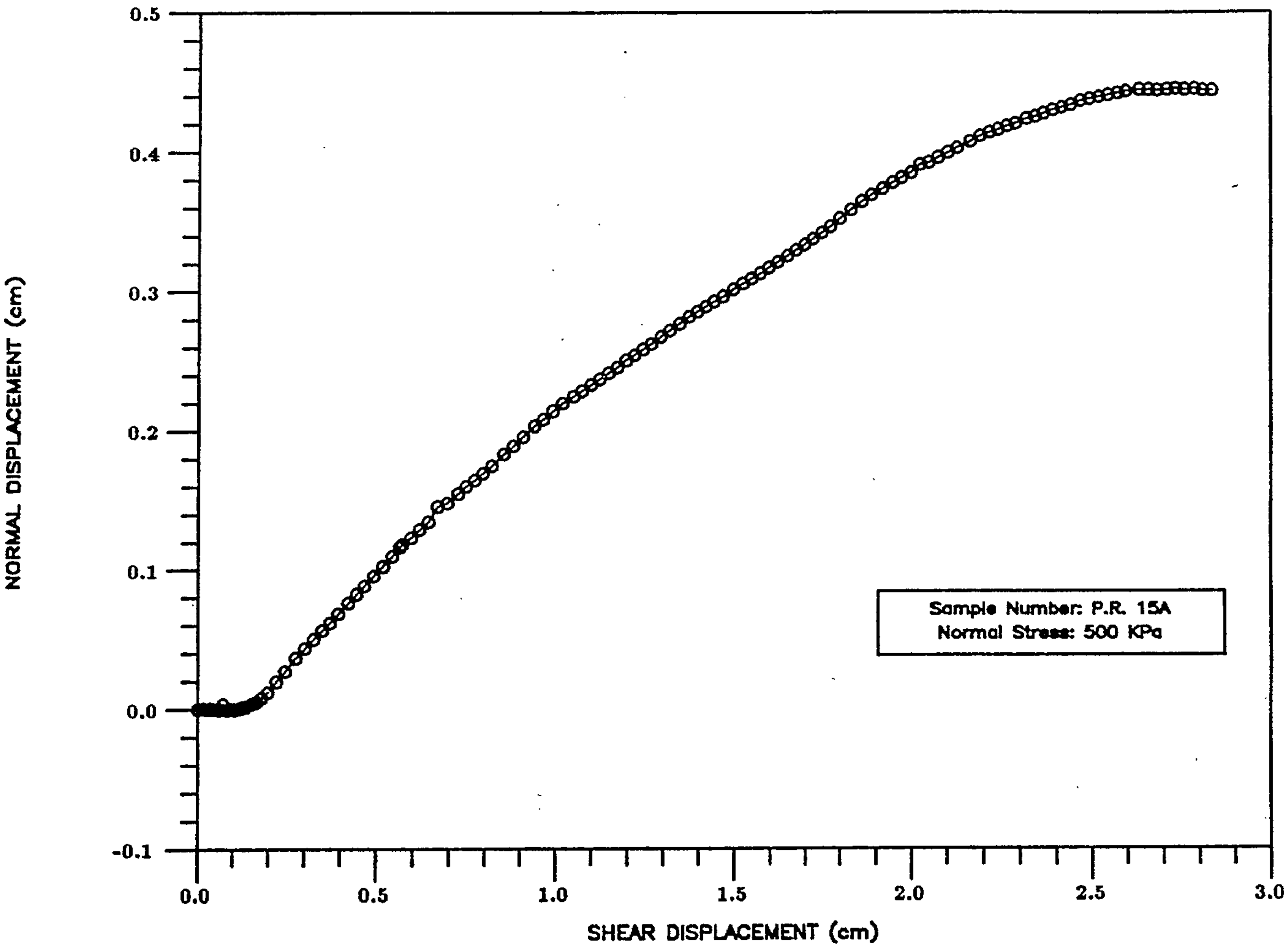


Fig. 12: Normal vs. shear displacement: Paradise River Specimen No. 15A

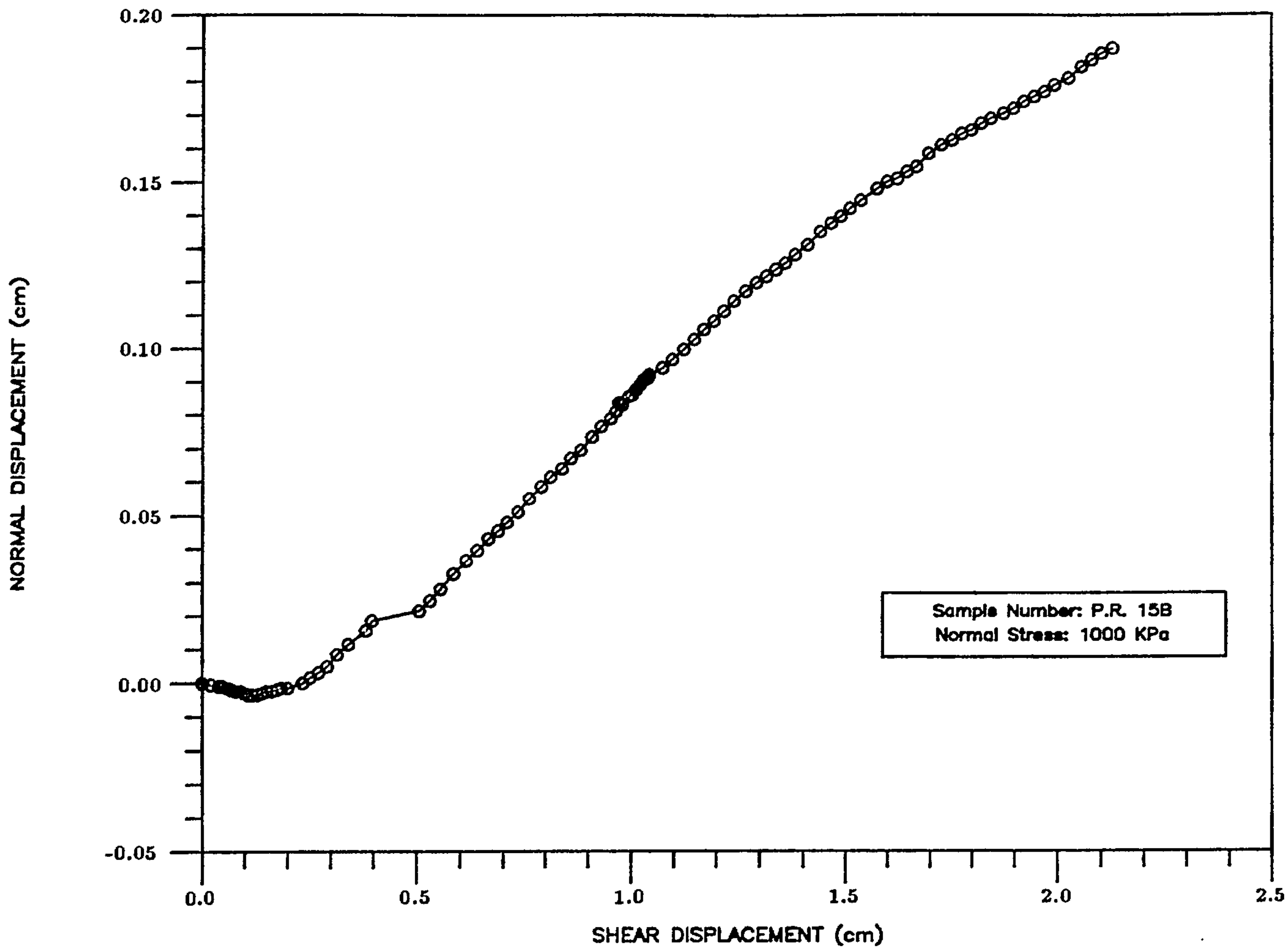


Fig. 13: Normal vs. shear displacement: Paradise River Specimen No. 15B

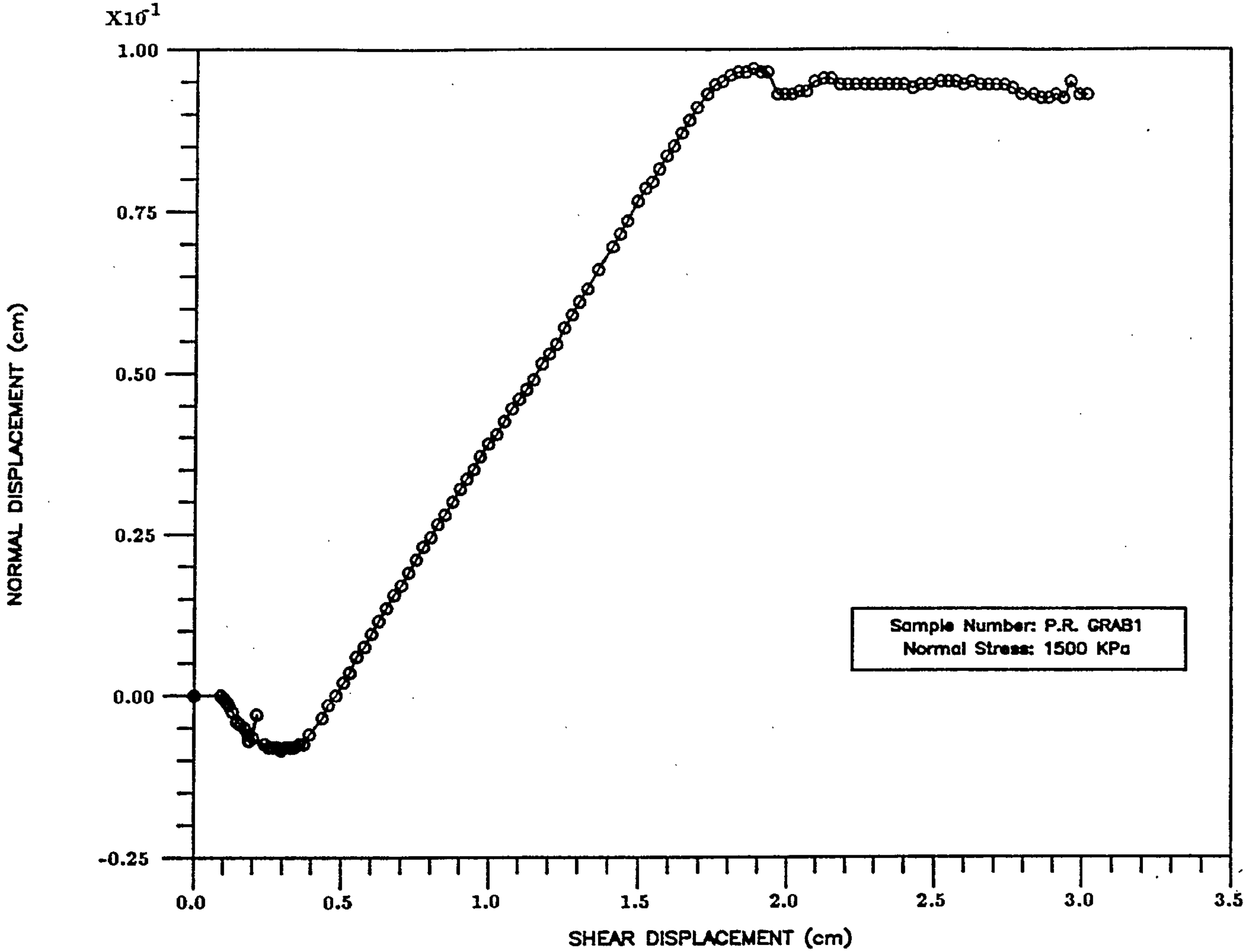


Fig. 14: Normal vs. shear displacement: Paradise River Specimen No. GRAB1

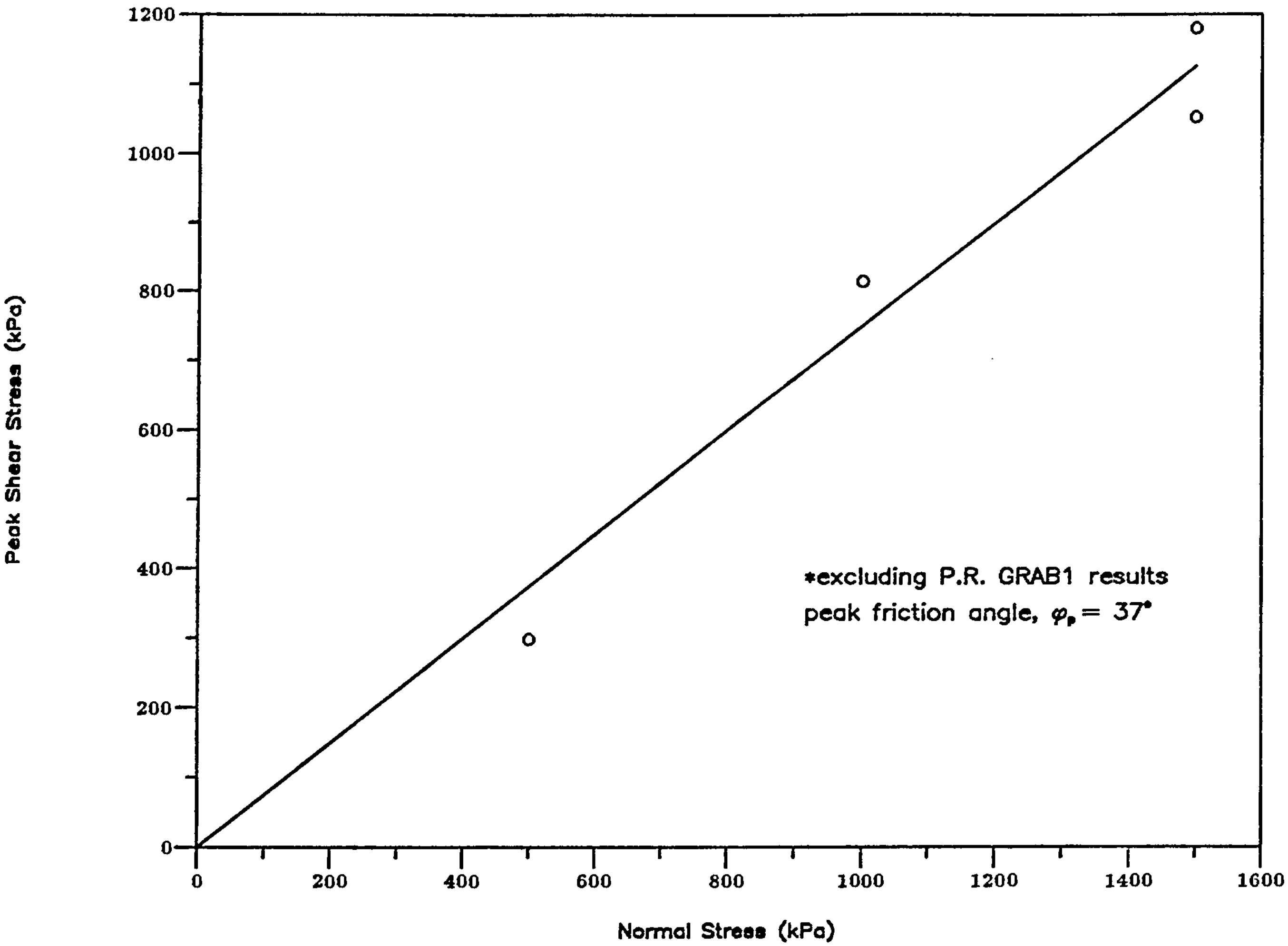


Fig. 15: Peak shear stress vs normal stress for planar jointed Paradise River specimens

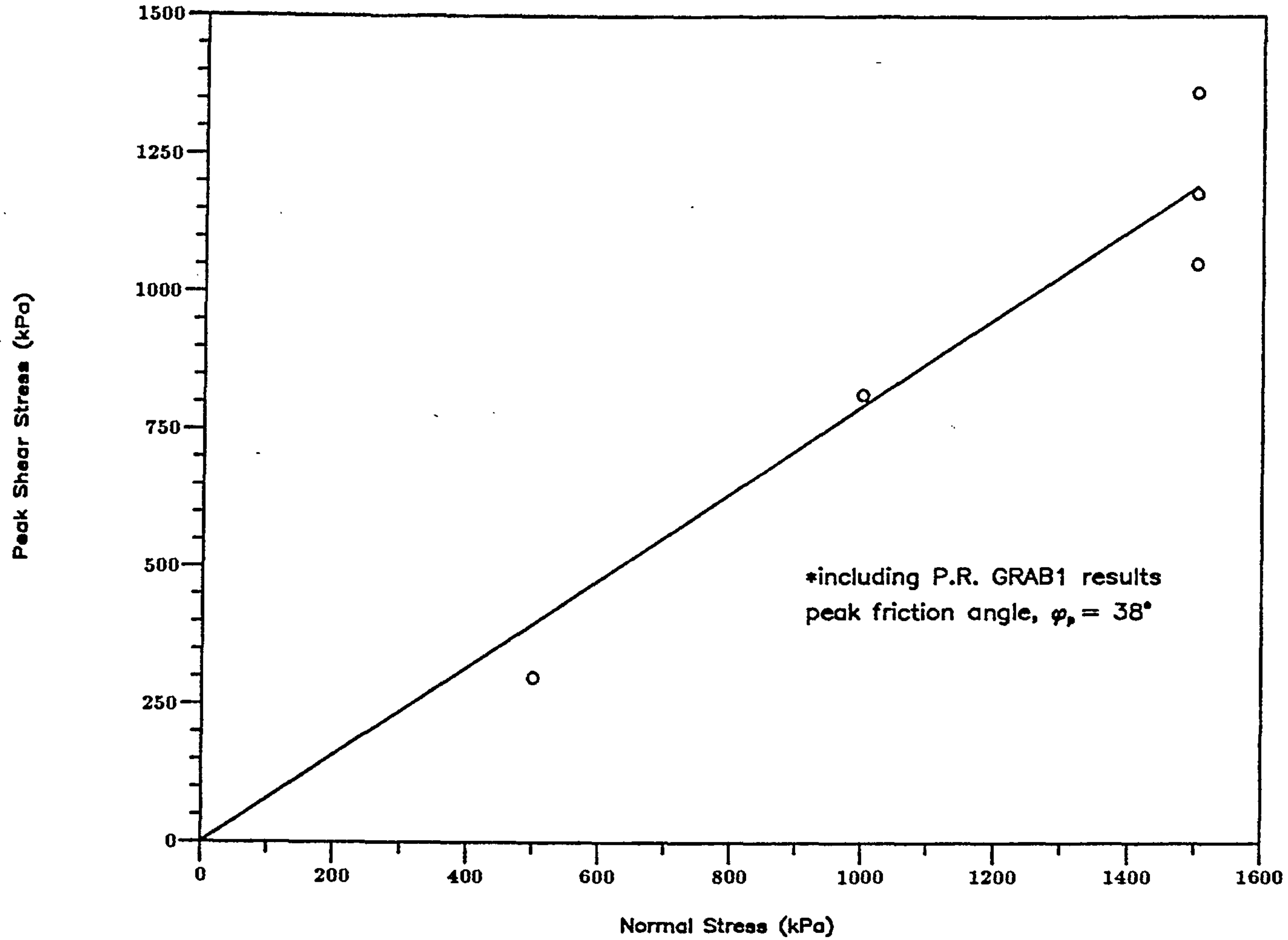


Fig. 16: Peak shear stress vs normal stress for planar jointed Paradise River specimens

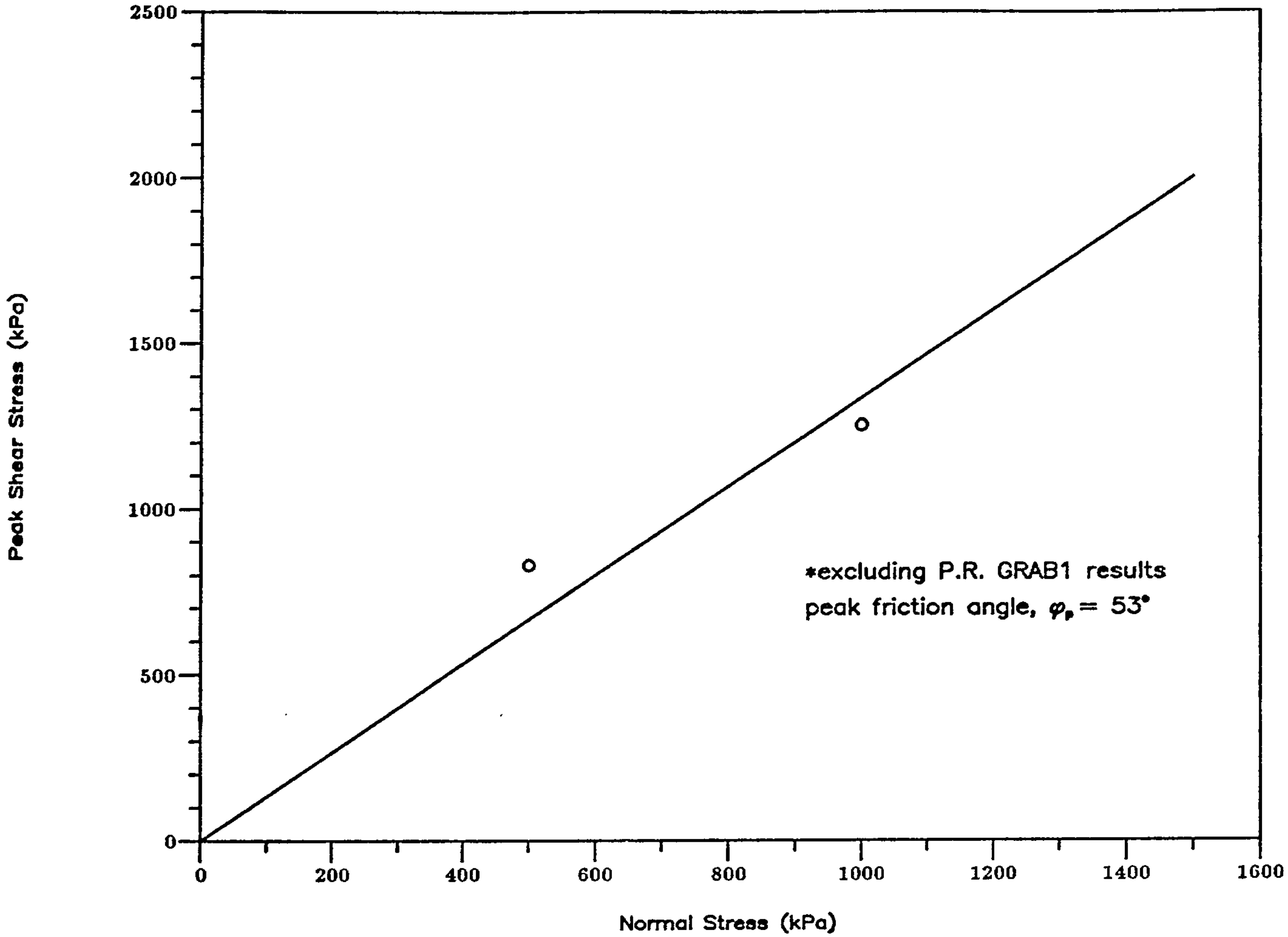


Fig. 17: Peak shear stress vs normal stress for kink jointed Paradise River specimens

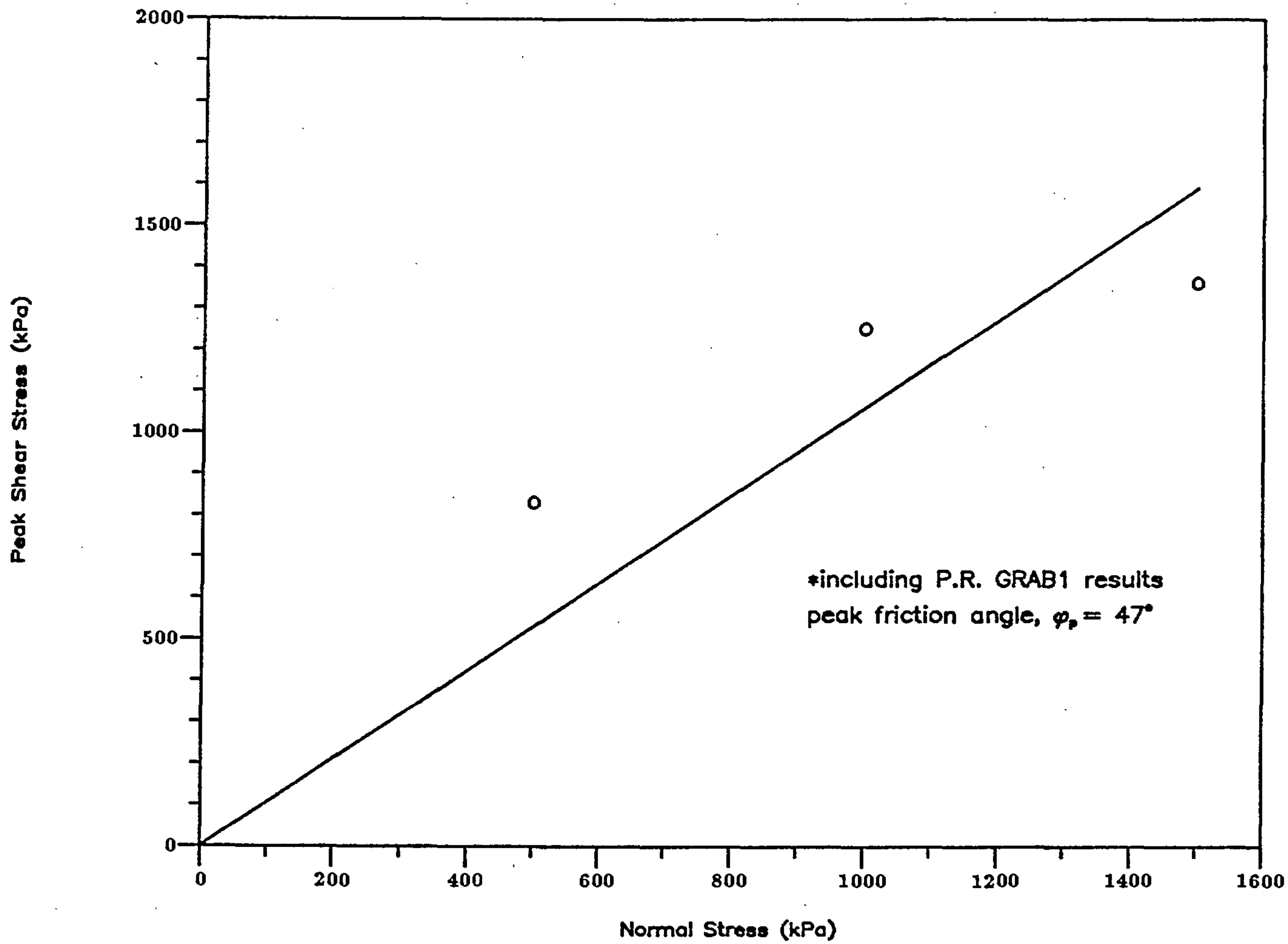


Fig. 18: Peak shear stress vs normal stress for kink jointed Paradise River specimens

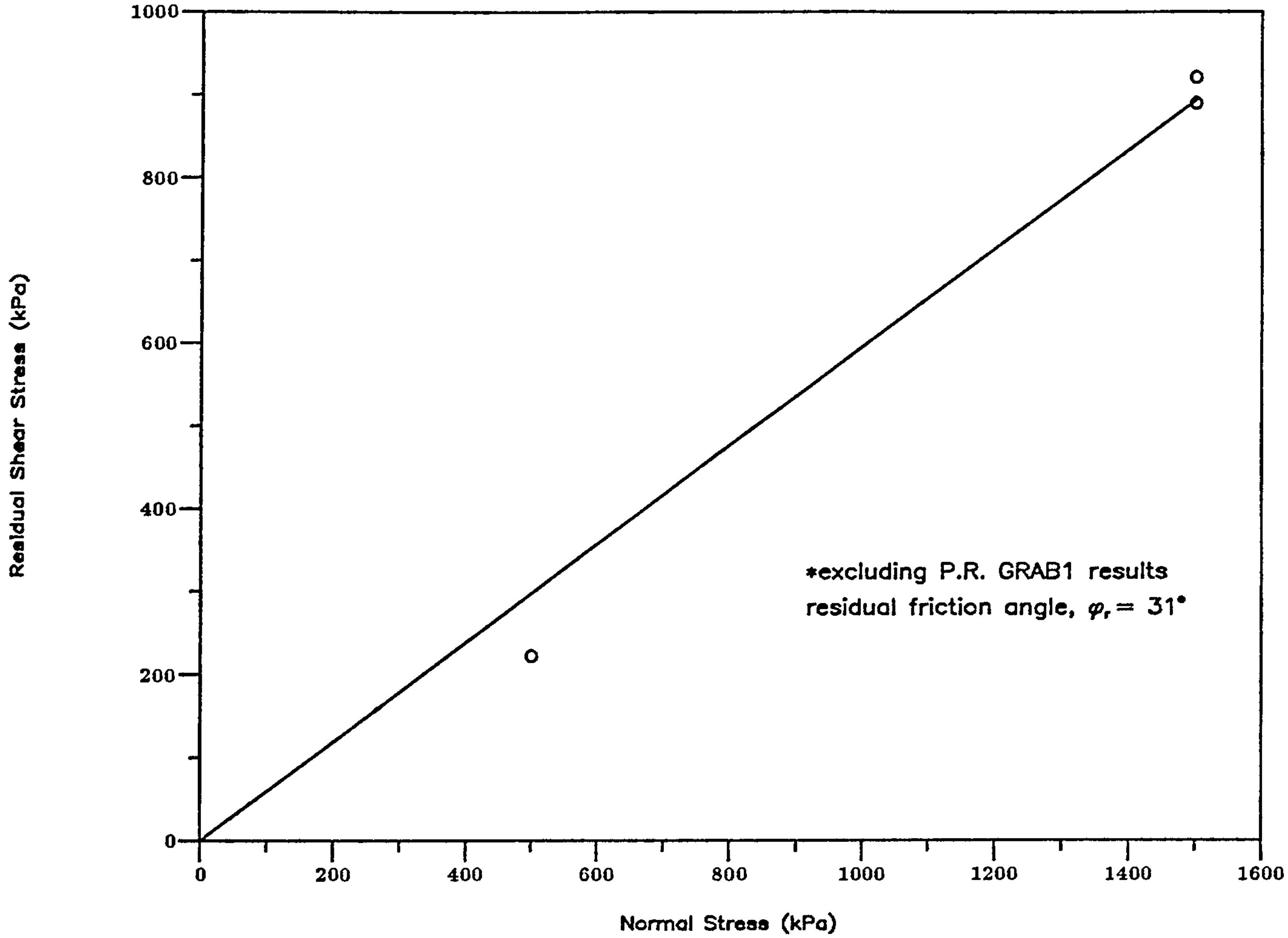


Fig. 19: Residual shear stress vs normal stress for planar jointed Paradise River specimens

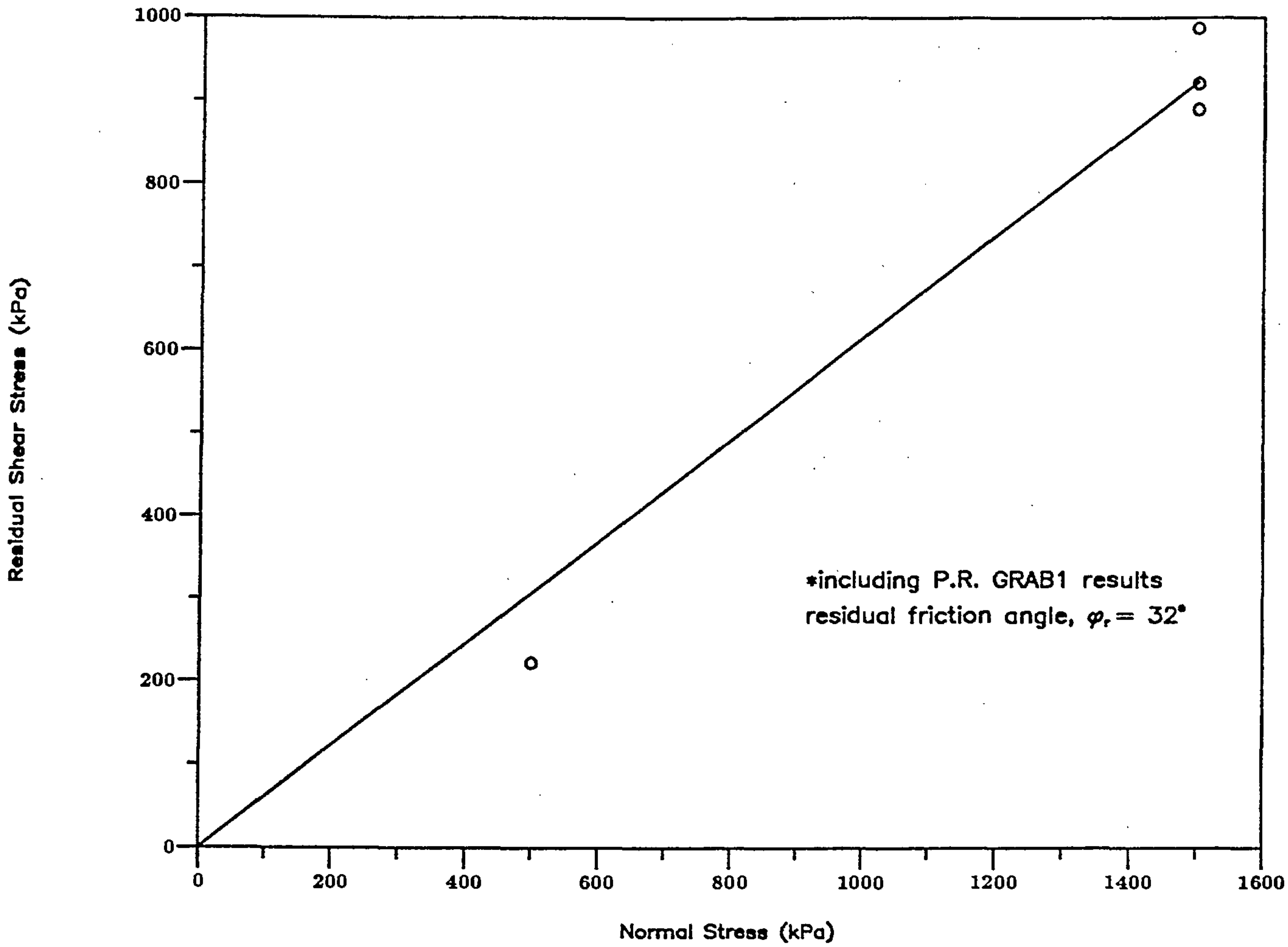


Fig. 20: Residual shear stress vs normal stress for planar jointed Paradise River specimens

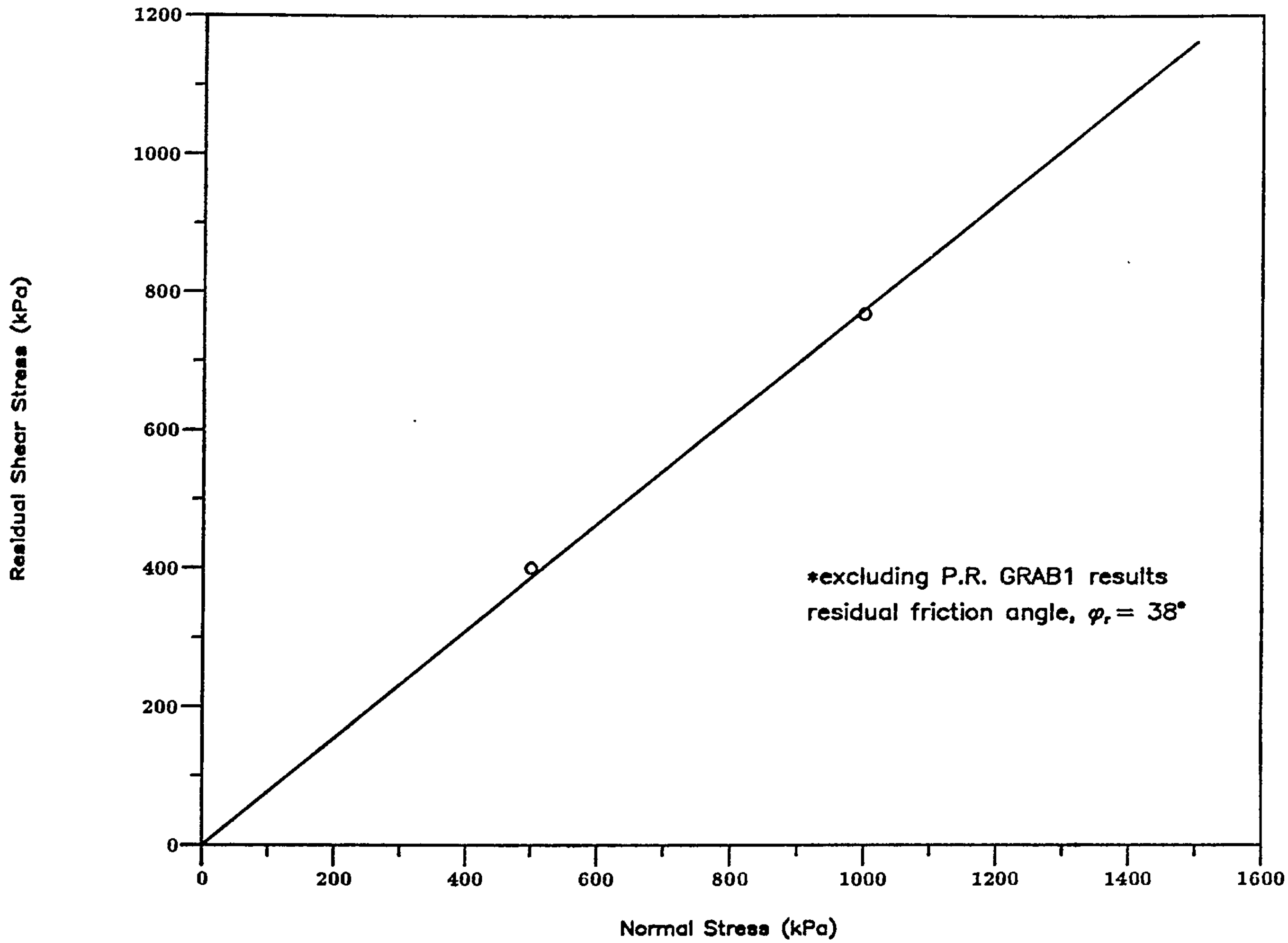


Fig. 21: Residual shear stress vs normal stress for kink jointed Paradise River specimens

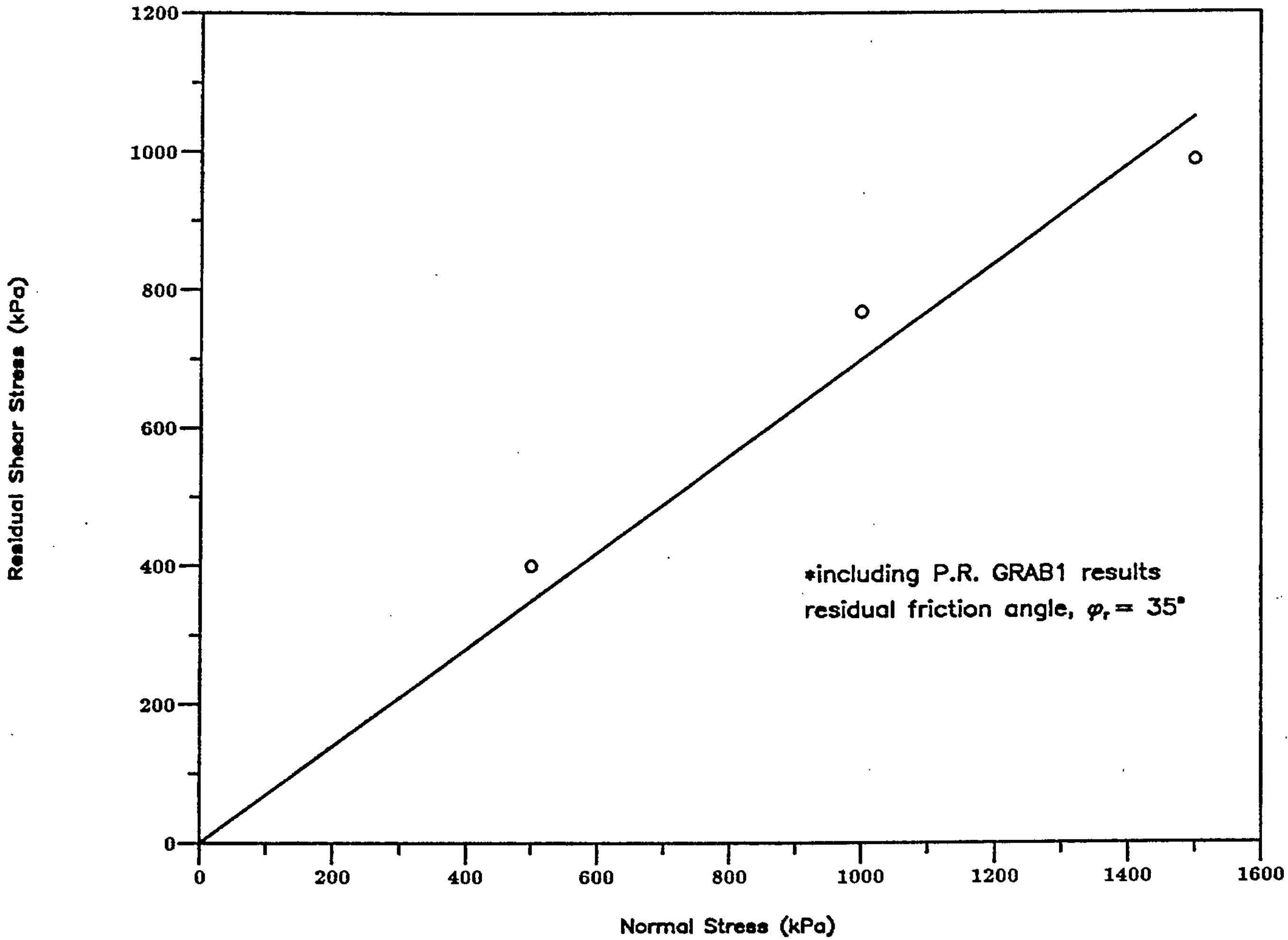


Fig. 22: Residual shear stress vs normal stress for kink jointed Paradise River specimens

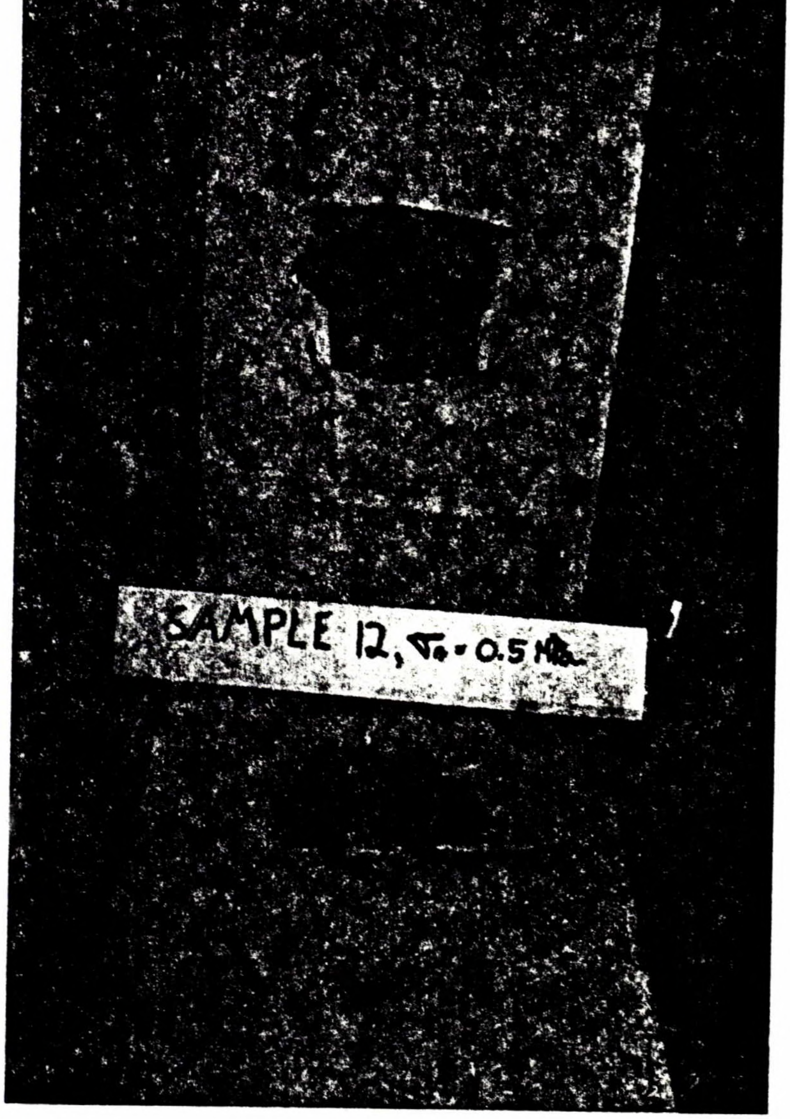


Fig. 23: Sample No. PR 12 after shearing

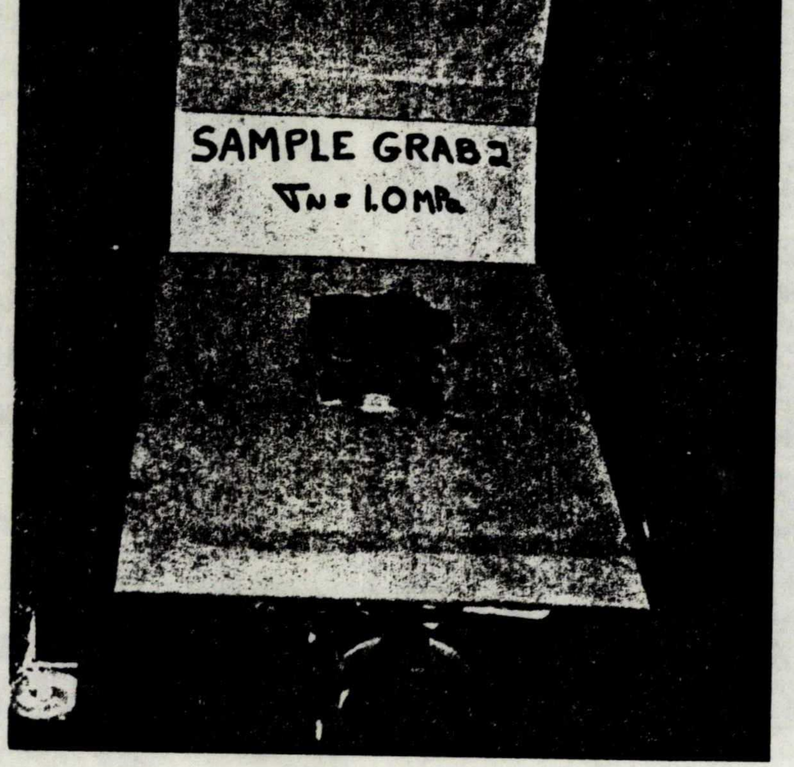


Fig. 24: Sample No. PR GRAB2 after shearing

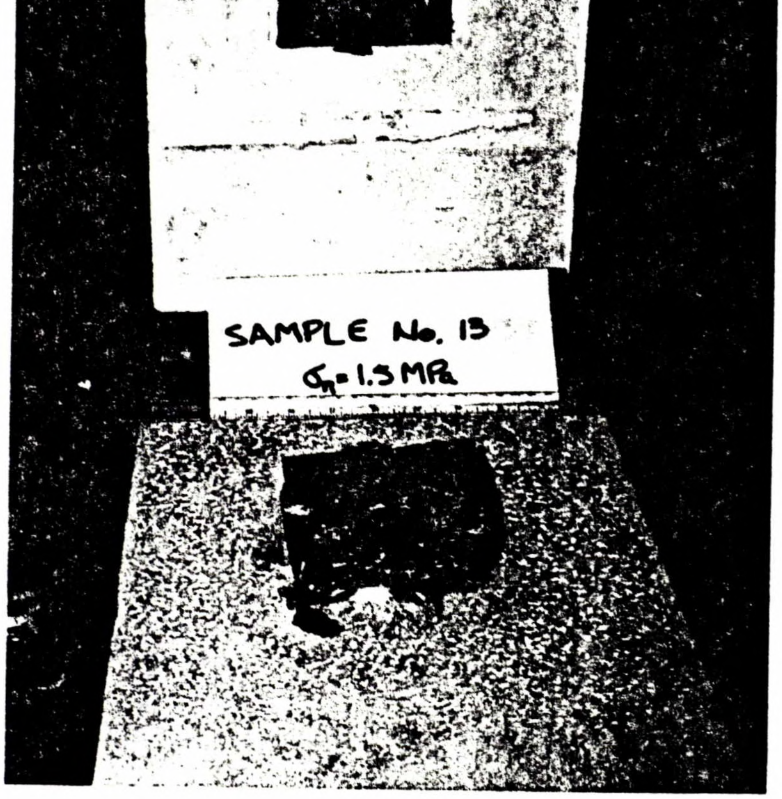


Fig. 25: Sample No. PR 13 after shearing

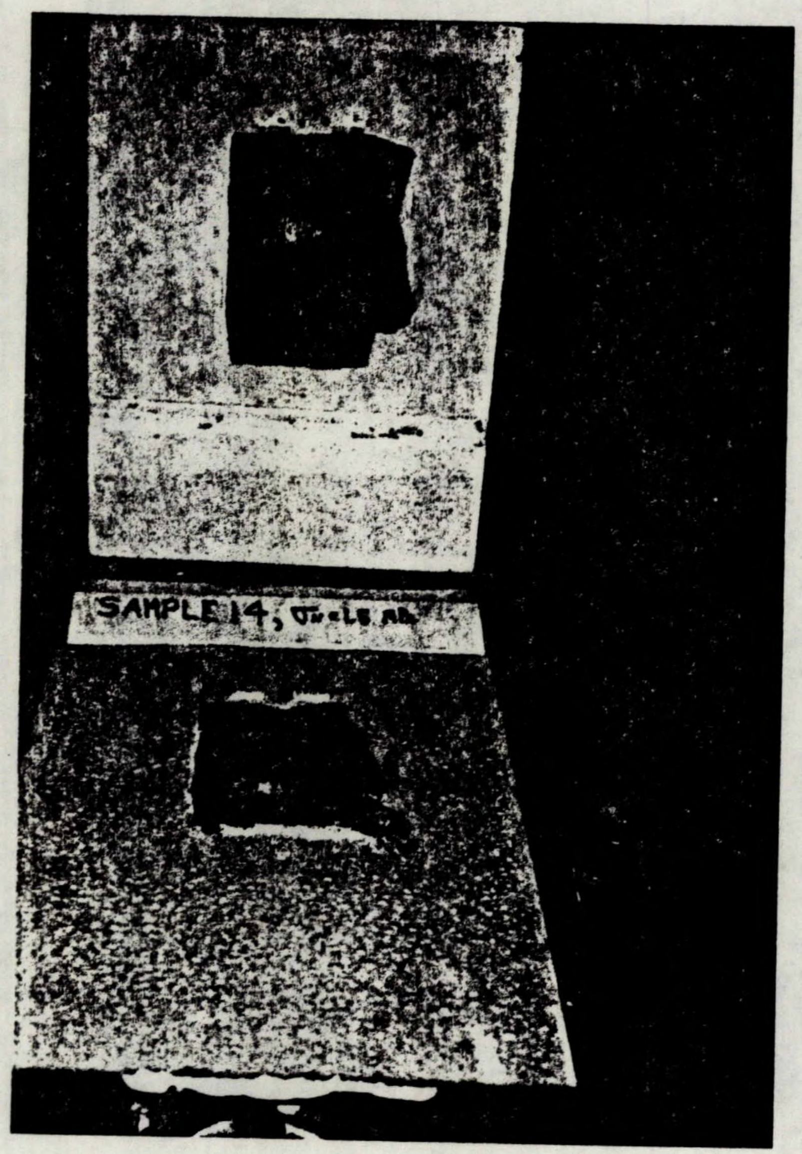


Fig. 26: Sample No. PR 14 after shearing

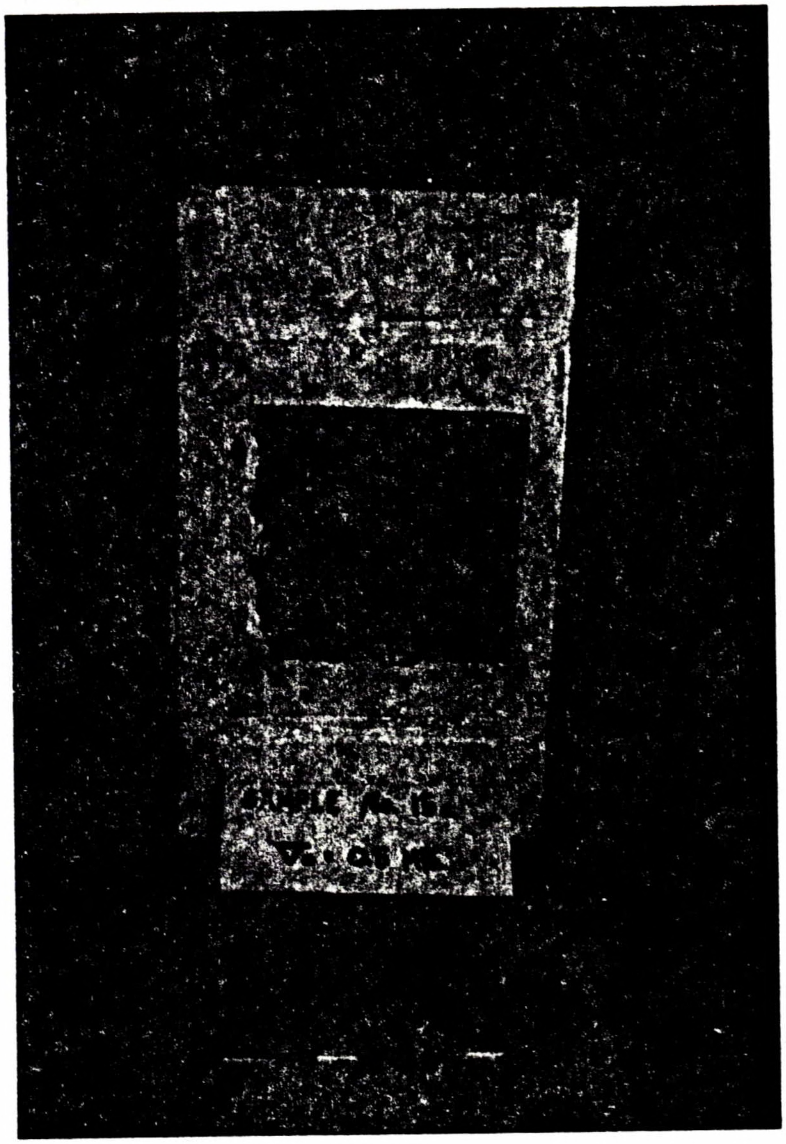


Fig. 27: Sample No. PR 15A after shearing

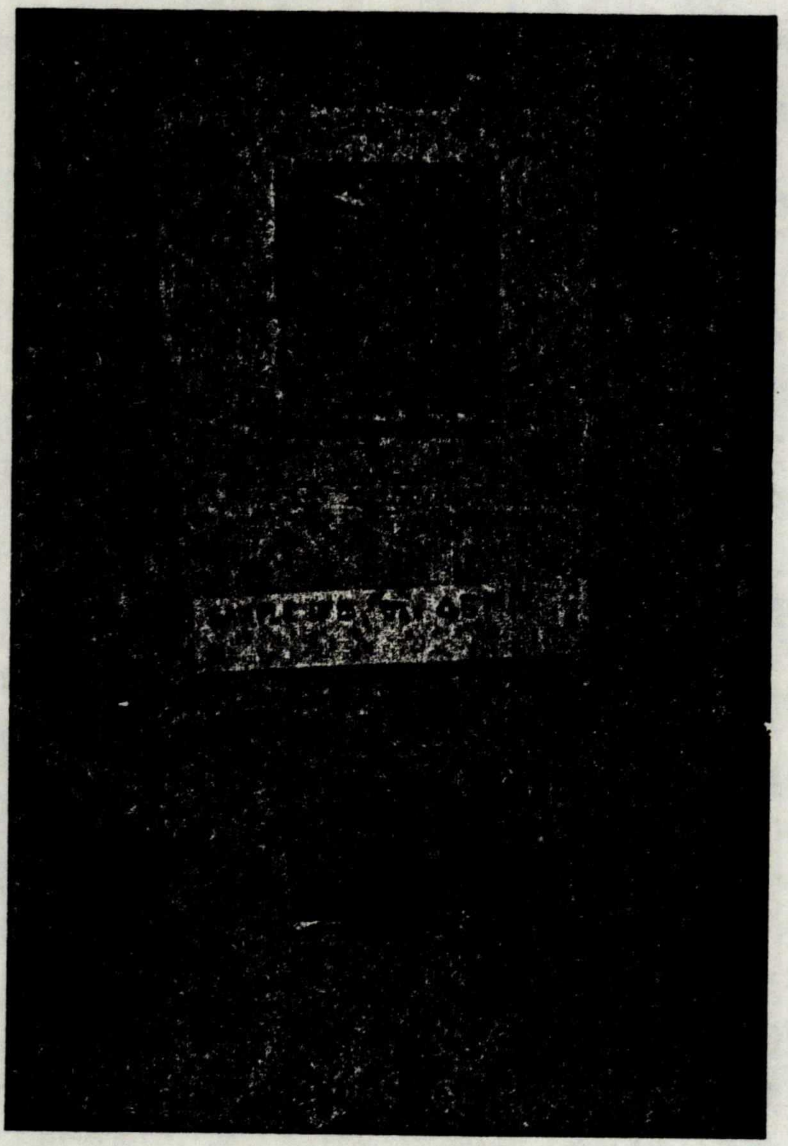


Fig. 28: Sample No. PR 15B after shearing

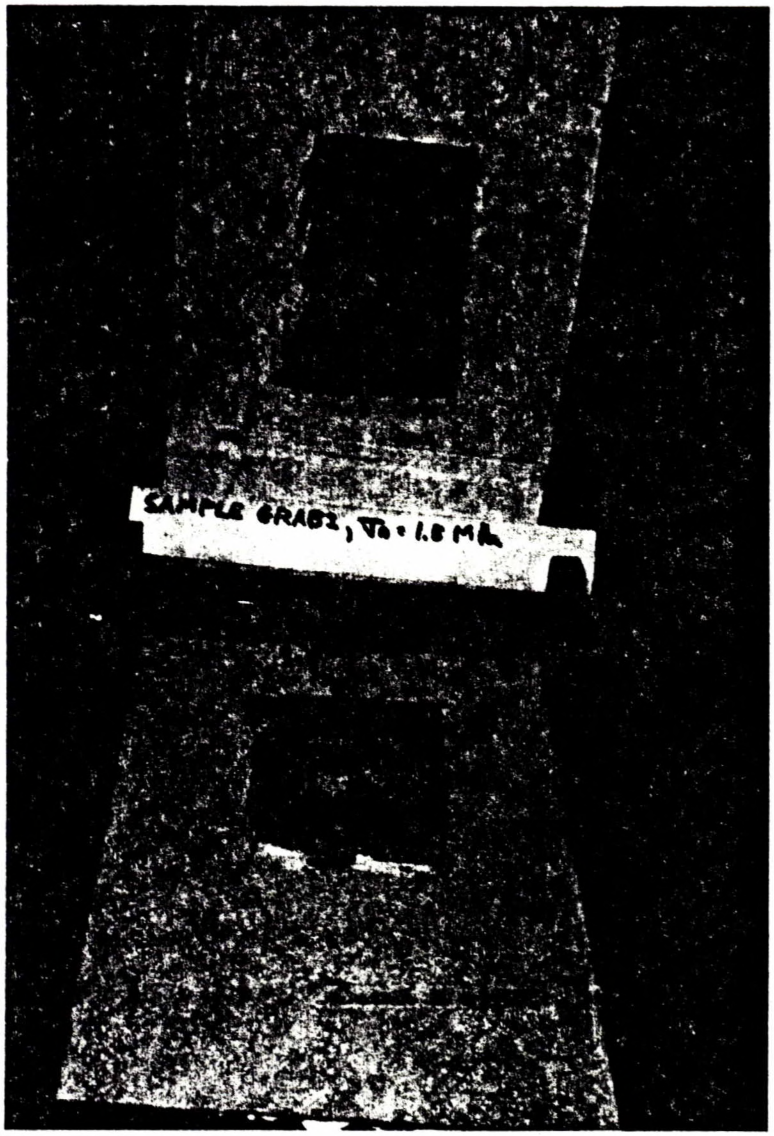


Fig. 29: Sample No. PR GRAB1 after shearing

APPENDIX A

ShawMont Newfoundland Limited

BALLY ROU PLACE
280 TORBAY ROAD, ST. JOHN'S

Postal Address
P. O. Box 9600
St. John's
Newfoundland
A1A 3C1
Ph: (709) 754-0250
Telex: 016-4122
Telefax: 739-6823

1988 10 24
File: 8352-8-301/306

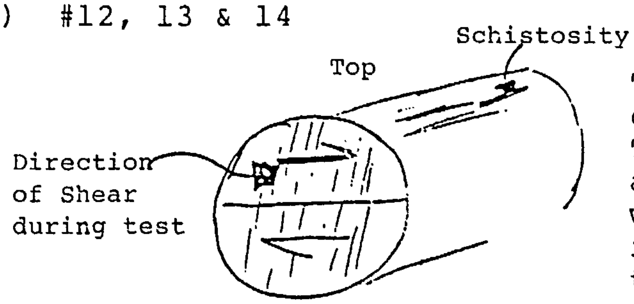
Energy Mines and Resources Canada
Mining Research Laboratory
Canmet

Dear Rand,

Attached are two boxes of rock samples for shear (direct) tests.

<u>Sample Description</u>

1) #12, 13 & 14



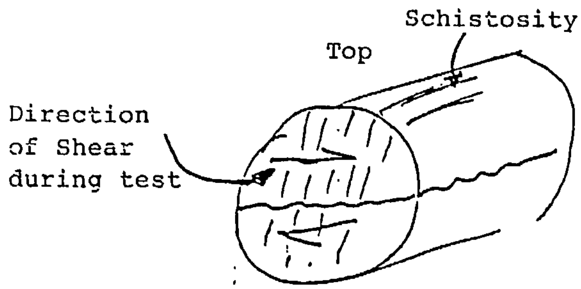
These three samples have been cored parallel to the schistasity. The top of each sample is marked and the shear direction is marked with shear arrows. The samples is <u>not</u> to be sheared parallel to the schistosity but normal to it.

Samples 12, 13 & 14 belong to one joint plane. This joint is planar.

The wet rags are intended to keep sample moist.

#11 location EC 25-8 N 10072.500
E 9842.738

2) #15A, 15B & 16



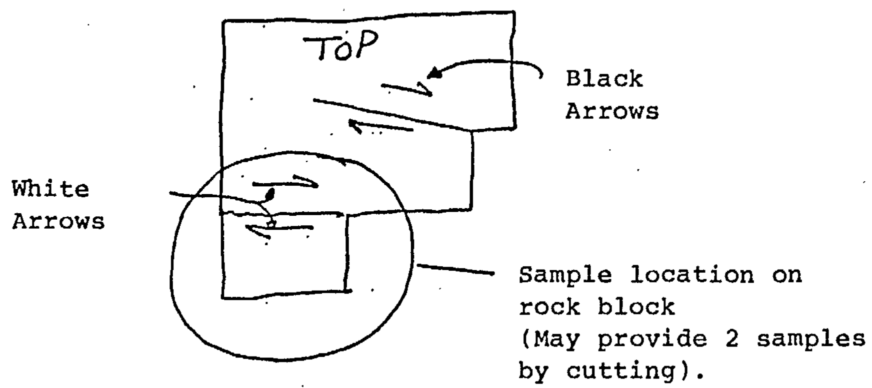
As in the first set, these three samples have been cored parallel to the schistosity. The top of sample is marked on metal casing and direction of shear during test is shown with shear arrows on face of samples. The samples are <u>not</u> to be sheared parallel to schistasity but normal to it.

Samples 15A, 15B & 16 belong to one kink joint plane. This joint is rough.

<u>IMPORTANT NOTE:</u> <u>Shear samples 15A, 15B & 16 first</u>.
<u>Sample 15A is a disturbed sample.</u>

...../2

3) Grab Sample



This sample is to be kept in reserve and used only if samples 15A, 15B & 16 present problems.

TESTING & REPORTING

1. Take every precaution to keep samples structurally intact using adhesive reinforcing strapping or binding during encasement removal and cutting.

2. Sample must be failed in direction, as shown by arrows i.e normal to schistasity, never parallel to schistosity.

3. Shear sets of samples 12, 13, 14 and Samples 15A, 15B & 16 with the following normal loads - 500 kpa, 1000 kpa, 1500 kpa. Shear each sample beyond peak shear for given load.

4. Provide preliminary data as data becomes available but all before November 10 as discussed.

5. Final report to be written in accordance with specification of work completed in April, 1988. See attached specifications.

Regards,

For: D. Besaw

DB/kn
Enclos.

PARADISE RIVER DEVELOPMENT

REPORT SPECIFICATIONS FOR SHEAR TESTS

(To be attached to Requisition)

METHOD OF SHEAR TESTING

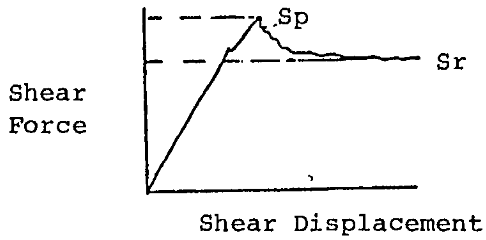
The rock specimens are divided into 2 sets by numbers. Each set represents a single joint plane. The sets are:

Planar Joint set 1: 12, 13, 14
Kink Joint set 2 : 15A, 15B, 16

Each sample set is to be sheared in a direct shear box beyond the peak shear stress with the following respective loads. The loads are 500 kPa, 1000 kPa and 1500 kPa.

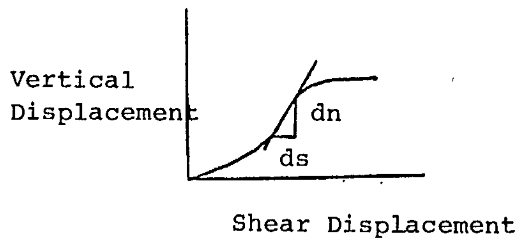
The following are required:

a) Plot of shear force vs. shear displacement plot of totally sheared sample. Its plot is expected to be as:



Sp - Peak Shear Force
Sr - Residual Shear Force

b) Plot of normal displacement vs. shear displacement.



Effective Dilatency, d
$d = \text{Arc Tan} \left(\frac{dn}{ds}\right)$

From the above data the following will be calculated:

a) peak shear stress τ_p = SP/Area

b) residual shear stress τ_r = Sr/Area

c) normal stress $\tau_n = \frac{Pn}{Area}$ where Pn = applied normal force

d) effective dilatency d = Arc tan (dn/ds)

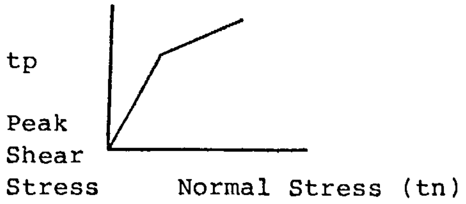
e) peak friction angle 0p = Arc tan (τ_p/τ_n)

f) basic friction $\phi b = \phi p - d$

g) residual angle of friction
0r = Arc tan (τ_r/τ_n)

METHOD OF SHEAR TESTING (Cont'd)

c) Plot of peak shear stress vs. normal stress



CONTENT OF SHEAR TEST REPORT

The report should include apart from the above graphs the following information on each sample tested:

a) sample identification (rock type and description),

b) the angles of friction (i.e. peak, residual and basic in tabulated form,

c) method of sample preparation,

d) information on testing such as: date, type and description of testing apparatus, rate of displacement,

e) In addition, the report should include in convenient tabulated form, the following information for each specimen sheared beyond peak stress:

  a. specimen identification (specimen's number)
  b. dimensions of the shear surface (length, width), shape and area of the shear surface
  c. type of discontinuity, description of the infilling material, any signs of previous displacement, weathering condition of the contact surfaces and/or infilling material and notes on their hardness, dimension and characteristic records of the roughness features, direction of shearing with respect to the roughness features, direction of shearing with respect to any orientation identifiable in relation to the insitu position of the sample and qualitative remarks with respect to the shear surface
  d. test conditions
  e. test duration
  f. notes on the after-shear conditions of the shear surface
  g. applied normal stress
  h. peak shearing stress
  i. effective dilatancy
  j. any recorded graphs during tests
  k. photographs of failed specimens.