Measurement of large scale roughnesses of rock planes by means of profilograph and geological compass

Mesure de la rugosité de grande extension des fissures à l'aide d'un profilographe et d'une boussole géologique

Messung grossräumiger Unebenheiten von Klüften mit Hilfe von Profilograph und Gefügekompass

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SUMMARY

The authors have developed a measuring instrument, the profilograph, which makes it possible to record roughness profiles of joint planes with a length of two metres.

By taking large number of measurements over such area using the geological compass after CLAR it is possible to receive very similar roughness diagrams out of the scatter of the measurements.

Because the size of the compass base plate greatly influences the results the investigation was carried out varying this parameter. This delivered a good impression of the unevenness of the joint in different orders of magnitude.

RESUME

Les auteurs ont développé un instrument de mesure - dit profilographe - servant à dessiner des profils de la rugosité des plans de séparation d'une longueur de deux mètres.

Si l'on exécute de nombreuses mesures sur ces surfaces à l'aide de la boussole géologique selon CLAR la dispersion des resultats donne presque la même image de la rugosité des surfaces que si l'on la couvrait avec beaucoup de profils de profilographe.

La dimension de la base de la boussole jouant un rôle important, on travaillait avec differentes dimensions. Par une exploitation séparée on gagnait une impression de la rugosité dans les différents ordres de grandeur.

KURZFASSUNG

Die Verfasser haben ein Meßgerät - einen sogenannten Profilographen - entwickelt, welcher es ermöglicht, zwei Meter lange Rauhigkeitsprofile von Gesteinstrennflächen aufzuzeichnen.

Belegt man dieselben Flächen mit zahlreichen Messungen mit dem CLAR-Gefügekompaß, so läßt sich aus der Streuung dieser Messungen ein nahezu gleiches Bild der Unebenheit der Fläche gewinnen, als wenn man sie mit vielen Rauhigkeitsprofilen überziehen würde. Da aber die Größe der Anlegefläche des Kompasses eine große Rolle spielt, wurde mit verschieden großen Anlegeflächen gearbeitet, und durch getrennte Auswertung ein Eindruck der Unebenheit in verschiedenen Größenbereichen gewonnen.

INFLUENCE OF SURFACE ROUGHNESS ON SHEAR BEHAVIOR

Recent investigations on friction along separation planes in rock (GOLDSTEIN et al., 1966, PATTON, 1966, RENGERS, 1971) show that the surface geometry of the rock surfaces is of extreme importance for the friction characteristics. RENGERS (197o, 1971) developed an method to determine from sections of the rock surfaces the amounts of "sliding up" and the "angle of sliding up" during shear displacement. This method is based on the fact that for a certain amount of shear displacement $n \cdot L$ (fig. 1) the amount of sliding up Δh can be calculated as follows:

$$\Delta h_n = n \cdot L \cdot \mathrm{tg}\, \alpha_n \tag{1}$$

α_n being the maximum angle between the reference plane "ref" and a secant to the profile with a base length $n \cdot L$. By measuring many secants to the sections, varying their base lengths $n \cdot L$ and collecting the maximum positive and negative angles of α_n for every base lengths used, a diagram like fig. 2 can be drawn. The curve connecting the maximum values of $+\alpha$ and $-\alpha$ for the different base lengths $n \cdot L$ is marked by the solid line. By multiplying the values for tg α of the points of this curve with the corresponding base length the amount of Δh can be calculated by equation (1). The dashed line connects the calculated amounts of sliding up for the increasing amounts of shear displacement.

The influence of amount of "sliding up" on the increase of normal stress acting on the separation plane and the influence of the "angle of sliding up" on the effective angle of friction are discussed by RENGERS (1971).

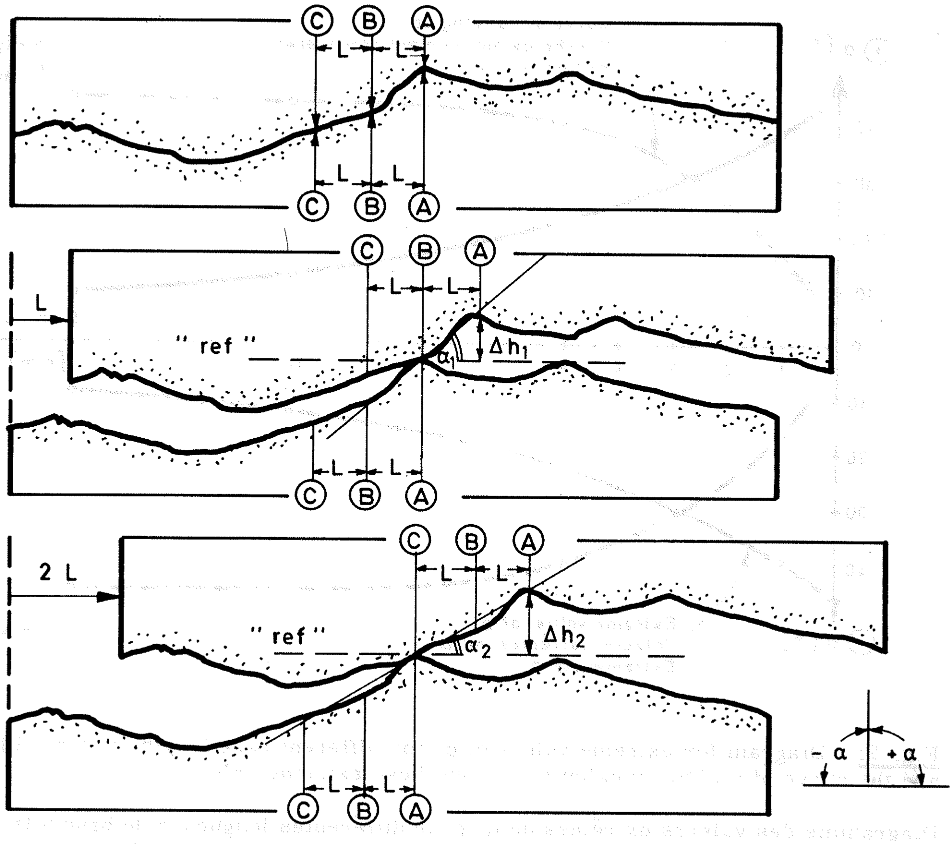

Fig. 1: Relationship between surface geometry and "sliding up" during shear displacement.

Relation entre la géométrie des surfaces et le mouvement transversal pendant le movement relatif longitudinal.

Zusammenhang zwischen Oberflächengeometrie und "Aufgleiten" bei Relativbewegung.

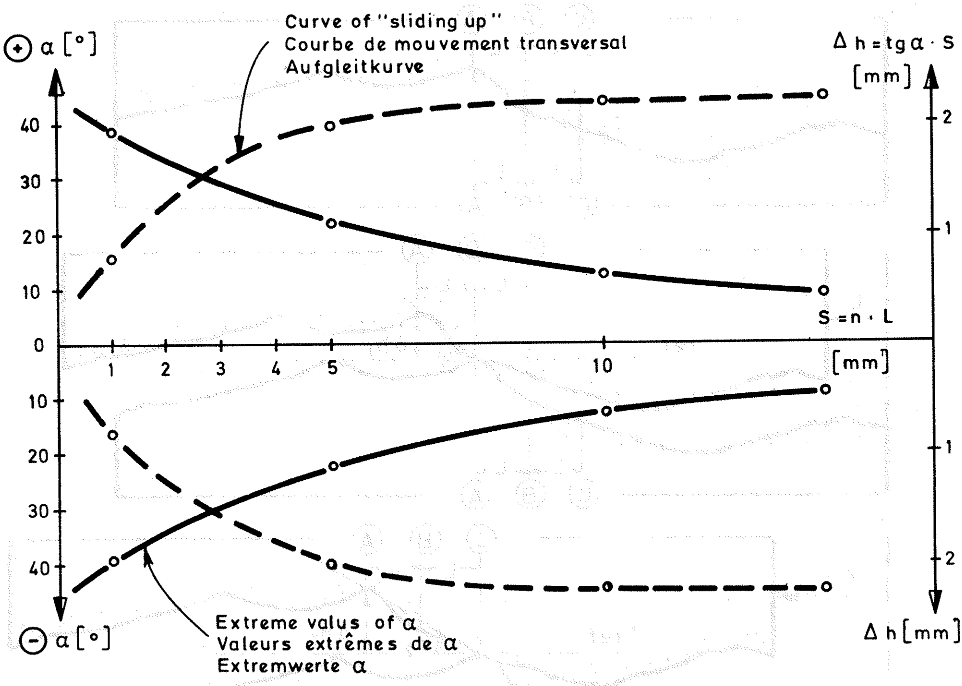

Fig. 2: Diagram for extreme values of α for different base lengths S (= n · L) and the curve of sliding up calculated from these extreme values.

Diagramme des valeurs extrêmes de α pour différentes longueurs de base S (= n · L) et la courbe de mouvement transversal calculé par ces valeurs extrêmes.

Diagramm der Extremwerte von α für verschiedene Basislängen S (= n · L) und die Aufgleitkurve, die aus diesen Extremwerten berechnet wurde.

MEASUREMENTS BY PROFILOGRAPH

FECKER (197o) and RENGERS (1971) describe two methods to obtain profiles across rock planes with lengths between 2. 5 cm and 2oo cm; optically for the smaller scales by using a stereomircroscope and mechanically for the larger scales by using a profilograph (fig. 3a, b). As both of these methods are time consuming and need special equipment, the authors developed a method which gives satsifactory data on the larger scaled roughness, often called waviness, of rock surfaces using a geological compass after CLAR.

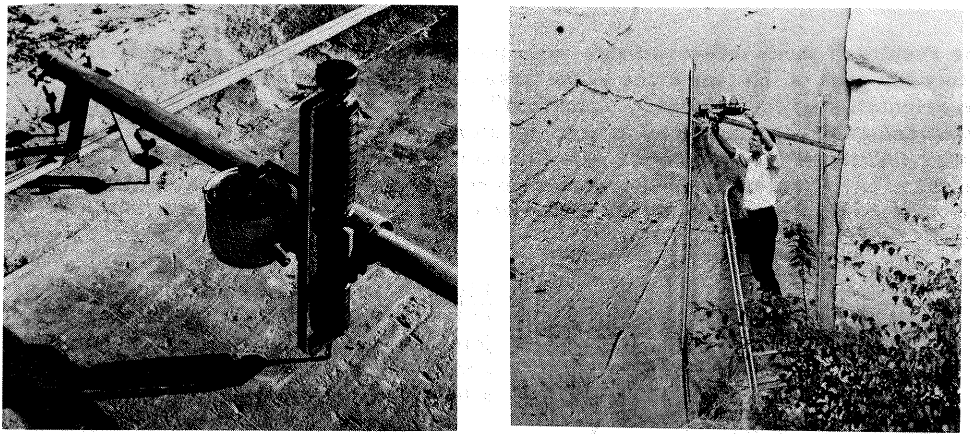

Fig. 3: Profilograph

COMPASS MEASURING METHOD

The scatter of compass measurements laid randomly over an rock surface is determined by the roughness of this surface as well as by the size of base plate of compass. By varying the size of the base plate it will be possible to assess the roughness in an area as large as or larger than the base plate. To investigate this approach to determine the roughness measurements were made with the profilograph as well as with a compass with different circular base plates with a diameter of 5,5 - 11 - 21 and 42 cm (figure 4).

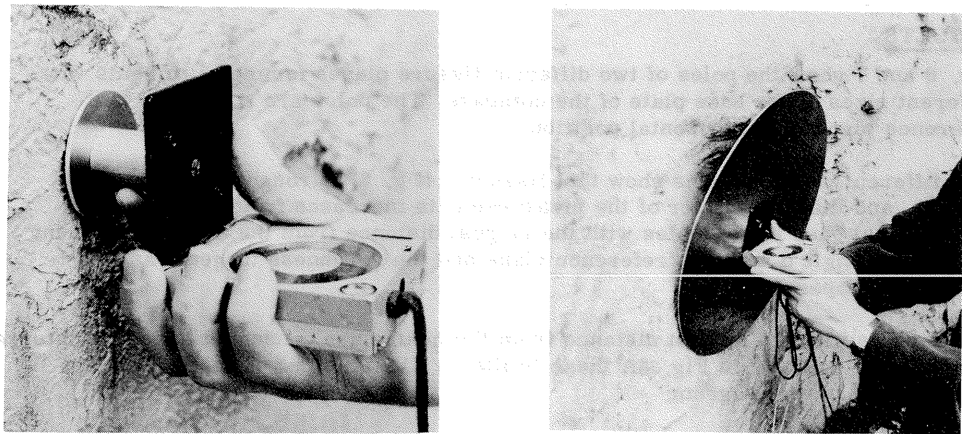

Fig. 4: Smallest and largest base plate of compass used in the roughness investigation.

La plus petite et la plus grande base employées pour les mesures de la rugosité.

Kleinste und größte Kompaßanlegefläche, die bei der Unebenheitsuntersuchung verwendet wurde.

The results of these measurements were plotted in a polar equal-area net, separately for each of the four sizes of the base plate of the compass. On this plot the orientation of the reference plane "ref" which was used in the profilograph measurements was marked by pole in the stereogram. It is rotated into the horizontal position around a rotation axis for easier evaluation. See figure 5. All of the poles of joint measurements were also rotated around the same axis. Plotting and rotations were quickly solved using the GELI-computing program (KRÜCKEBERG, 1968, KIRSCHKE, 197o).

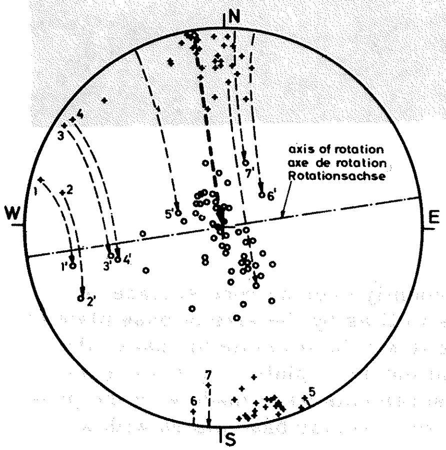

Fig. 5: Rotation of reference plane ◆ in horizontal position. The poles of joint measurements were also rotated around the same axis. Pole 1 will be after pole 1' etc.

Rotation due plan moyen ◆ dans la position horizontale. Les pôles des mesures des fissures sont également tournés autour du même axe. Pôle 1 devient pôle 1' etc.

Rotation der ausgleichenden Ebene ◆ in horizontale Lage. Die Durchstoßpunkte der Kluftmessungen sind um die gleiche Achse mitrotiert. Durchstoßpunkt des Flächenlotes 1 wird zu Durchstoßpunkt 1' etc.

RESULTS

Fig. 6 and 7 show the poles of two different fissure planes for measurements with different sizes of the base plate of the compass. The poles are rotated so that reference plane is in horizontal position.

The different pole diagrams show that fissure 1 (fig. 6) is rougher than fissure 2 (fig. 7), and that the scatter of the measurements increases from the largest to the smallest base plate. Poles with the largest distance from the centre represent the largest angle α between reference plane and the roughness tangents as determined by compass.

These poles with the largest distance from the centre are connected forming contours of maximum scatter. In Fig. 8A these limits of all four sizes of base plates are summarized in one diagram.

Additionally, the great circles of the horizontal and vertical planes of the profilograph sections are represented in these diagrams. The directions indicating the positive and negative values of α in the stereographical projection are represented, too.

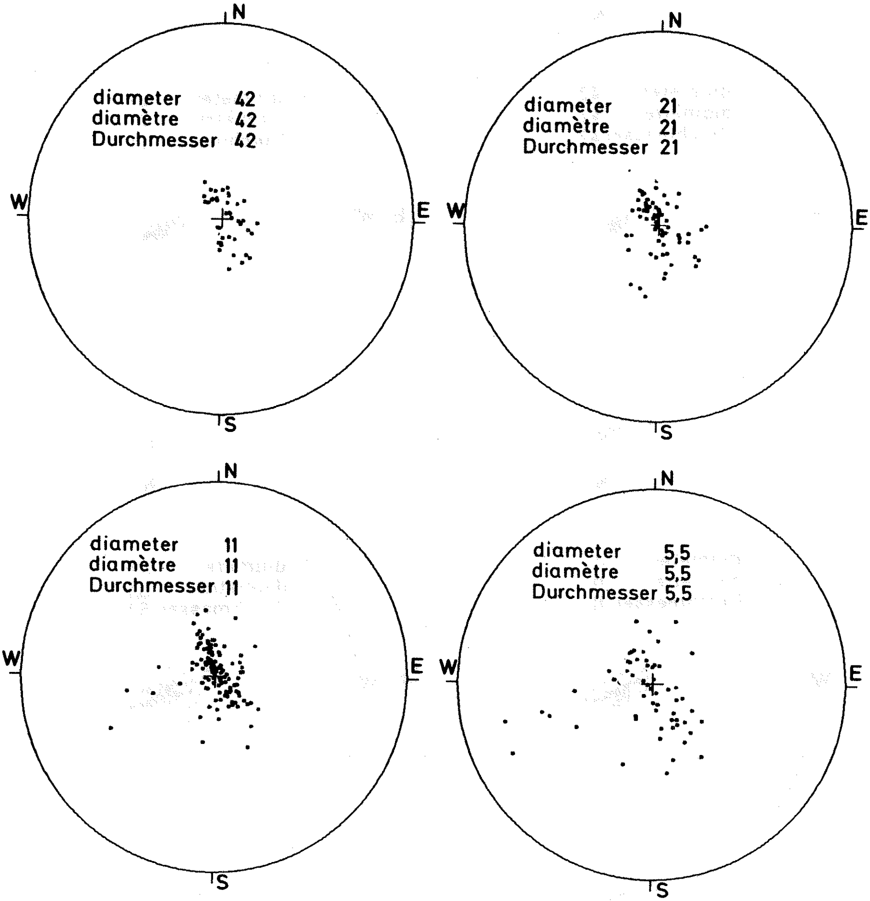

Fig. 6: Rotated pole diagram of fissure 1

Diagramme des pôles après rotation de la fissure 1

Rotierte Lotdurchstoßpunkte der Fläche 1.

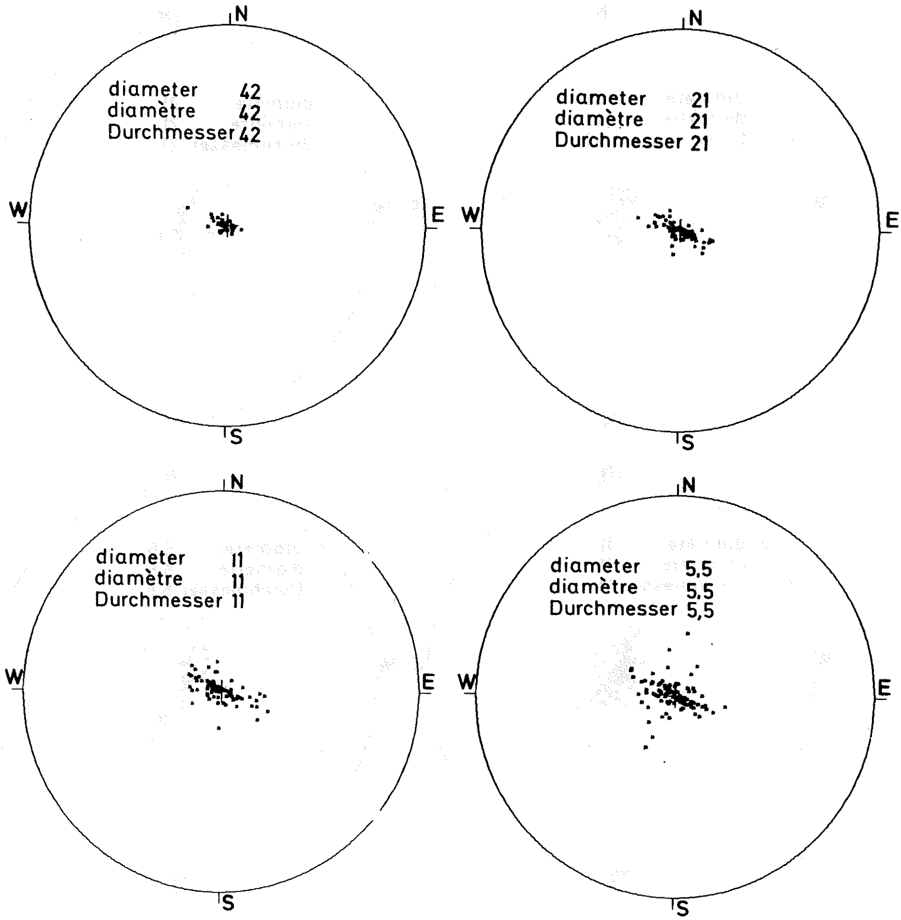

Fig. 7: Rotated pole diagram of fissure 2

Diagramme des pôles aprèsrotation de la fissure 2

Rotierte Lotdurchstoßpunkte der Fläche 2.

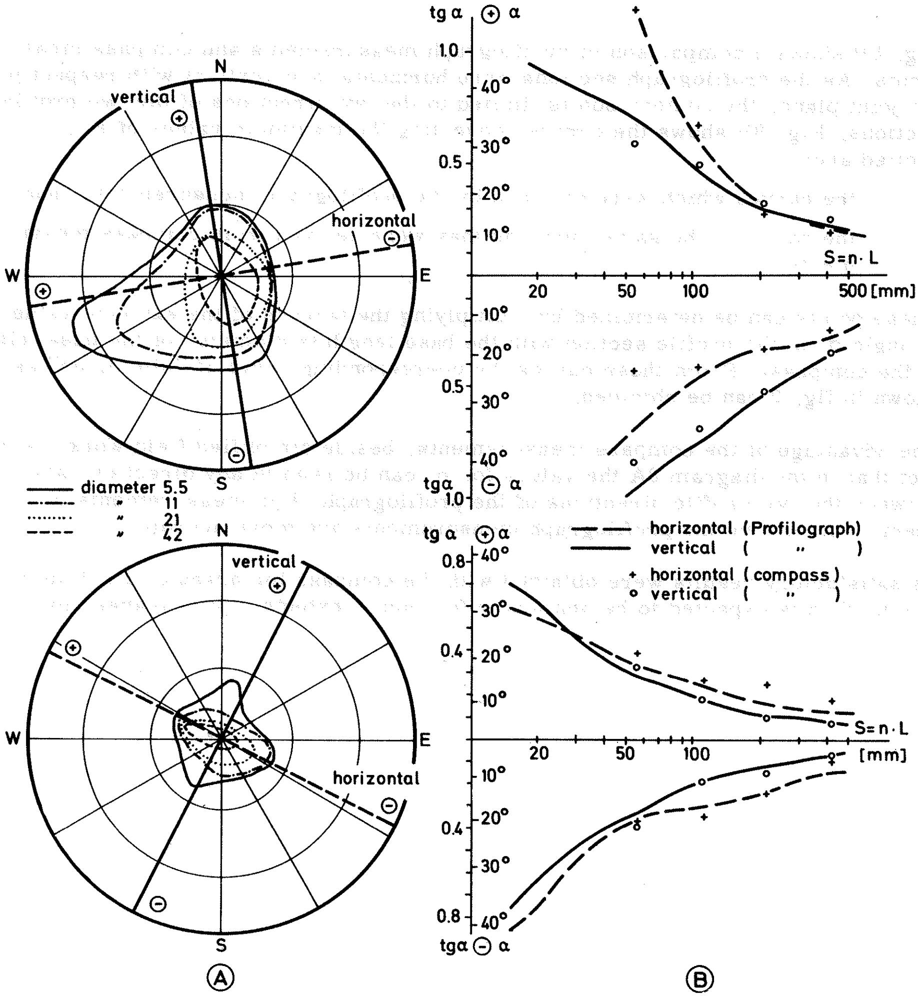

Fig. 8: (A) Curves of the maximal scattering from different base plates of the compass. (B) Comparison from compass measurements and profilograph measurements by the curve of the "extreme values of α ".

(A) Lignes de la déviation maximale des mesures pour différentes dimensions de la base. (B) Comparaison des mesures à boussole et profilograph par la courbe "des valeurs extrêmes de α".

(A) Linien der maximalen Streuung der Messungen mit verschiedenen Kompaß-Anlegeflächen. (B) Vergleich der Kompaß- und Profilographmessung an Hand der Kurve der "Extremwerte von α ".

Fig. 8B shows a comparison of profilograph measurements and compass measurements. As the profilograph sections were horizontal and vertical with respect to the joint plane, the comparison is limited to the two directions of the two profile sections. Fig. 8B shows the curves connecting the maximum values of α . Plotted are:

1) the curves which were obtained by the profilograph measurements, and

2) the points of the same curve as they were derived from compass measurements.

These points can be determined by multiplying the tangens of the extreme value of angle α in the profile section with the base length (= diameter of the base plate of the compass). From these curves the corresponding curve of "sliding up" as shown in fig. 2 can be obtained.

The advantage of the compass measurements, beside simplified field work, is the fact that in the diagram 8A the values for α can be read in any direction, also between the two profile directions of the profilograph. For measurements in specific directions the profilograph measurements are more acurate.

As satisfactory results were obtained with the compass for areas of 2 x 2 meters this method is expected to be applicable for larger extents of joint planes, too.

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