SWEDISH GEOTECHNICAL INSTITUTE
PROCEEDINGS
No. 19

STANDARD PISTON SAMPLING

A Report by the Swedish Committee
on Piston Sampling

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Preface

In Sweden, with its very sensitive clays, the procedure of taking undisturbed samples is of great importance and a great number of types of piston samplers have come into use. It has, however, been found difficult to evaluate test results from specimens taken with the various samplers. This disadvantage has been indicated especially by the authorities.

In order to investigate the possibilities to standardize piston sampling, the Swedish Geotechnical Society appointed a Committee, consisting of the following members:

J. Osterman (Chairman), Swedish Geotechnical Institute
A. Hellgren, Public Works Department of Stockholm
B. Jakobson, Swedish Roads Board
R. Lundström, Messrs. Orrje & Co., Stockholm
E. Sandegren, Swedish Railways Board
T. Kallstenius (Secretary), Swedish Geotechnical Institute
The members were sitting as individuals.

Several institutions have contributed to the work. Thus, the main part of the research, including the design of the prototype of the standard sampler, has been performed at the Geotechnical Institute (Mechanical Department). The Roads Board has, for the purpose of rationalization, supported the work of the Institute, and the Railways Board has, in connection with investigations of a slide, done sampling in collaboration with the Committee. At the laboratories of the Public Works Department of Stockholm and Messrs. Orrje & Co., testings have been performed for special pertinent problems. Also, some field equipment has been put to the Committee's disposal.

On the Committee's proposal, in February 1961, the Society settled regulations for standard piston samplers and the sampling procedure.

This report briefly describes the main considerations and part of the research work which were the basis of the specifications. After a general description, for which the Committee is responsible, additional paragraphs by individual authors follow.

Stockholm, May 1961

SWEDISH GEOTECHNICAL INSTITUTE

1. General Report

By the *Swedish Committee on Piston Sampling*

10. Synopsis

A special committee of the Swedish Geotechnical Society has had the task of studying the possibility of standardizing piston sampling in Sweden for routine purposes. Based upon earlier experiences and after about three years of activity including research work also, the Committee suggested such a standard.

The standard comprises a composite piston sampler type with 50 mm diameter of the cutting edge, 700 mm punching stroke and 0.4 % inside clearance. The sampling tubes are of plastic due to its low friction against soil and its resistance to corrosion. The sampler type can be provided with shutter. Only those dimensions and procedures which were deemed to affect sample quality were standardized.

A sampler prototype, in three specimens, was tested out in the field with regard to sample quality, ruggedness and handling. It has proved to have qualities superior to most routine samplers existing in Sweden and is easy to handle.

At the time of the final standardization proposal as presented in this report, full agreement was reached by the Committee. The standard was also accepted by the Society in February 1961.

11. Introduction

The first piston sampler for clay (OLSSON, 1925) was developed at the *Swedish State Railways (SJ).* It had an inside diameter of 44 mm, an outside diameter of 51 mm, a sampling length of 640 mm and a 45-degree edge angle. This sampler has been used mainly by the railway administrations in Scandinavia but also by others.

Samplers with about the same diameter as the first piston sampler but which were composite and contained sample tubes made of brass were developed at the *Gothenburg Harbour* (PETTERSON, 1933), and also used at some Swedish firms and, from 1951, at the *Public Works Department of Stockholm.* The sampler of the last mentioned authority (called sampler Gk) was designed with an edge angle of 10.5 degrees.

In 1936, *W. Kjellman* developed a sampler with an inside diameter of 60.5 mm, an outside diameter of 83.5 mm, a sampling length of 224 mm and an edge angle of 30 degrees (later 26.5 degrees). This sampler has been used by the *Swedish Geotechnical Institute (SGI),* several official institutions and engineering firms. The sampler was also composite.

After the appearance of *M. J. Hvorslev's* report on soil sampling (HVORSLEV, 1949), the piston sampler design in many respects was influenced by his recommendations. Hvorslev's area-ratio rule was, however, not accepted in practice in Sweden since one wanted to keep the ruggedness of the piston samplers.

Many engineering firms in Sweden developed their own samplers based to a varying degree on existing experience. The large number of sampler types with different characteristics gradually became annoying for engineers in charge of the evaluation of test results from different samplers. At the Geotechnical Institute comparisons for research purposes were made among different samplers (JAKOBSON, 1954, and KALLSTENIUS, 1958).

These investigations demonstrated great differences in test results on samples taken with the various types of samplers. They showed further that the scatter of results increased with increasing sample disturbance. Thus it was proved that a standardization of the sampling procedure was desirable for routine purposes.

It was desirable that the sampler to be standardized should be of high quality and permit inexpensive sampling. In detail it was noted that the sampler ought to be long to permit selection of test specimens free from the zones of disturbance, caused at the upper end of the sample by the pushing of the sampler into the soil, as well as at the lower end by the withdrawal of the sampler. The sampler edge should be sharp and thin.

At its meeting in December 1956, the *Swedish Geotechnical Society (SGF)* decided that a committee on standardization of piston sampling in Sweden should be appointed. Such a committee was nominated by the Society board and consisted of the following members: *A. Hellgren, B. Jakobson, T. Kallstenius, R. Lundström, J. Osterman* and *E. Sandegren.* Mr. Osterman acted as chairman and Mr. Kallstenius as secretary.

The Swedish Committee on Piston Sampling has had more than twenty meetings. At three meetings of the Society, its members have been informed about the progress of the Committee work.

12. First Steps of the Work

At first the Committee distributed a questionnaire to the members of the Geotechnical Society to get the actual standing of sampling and the members' attitudes toward standardization and their opinions on the required qualities of a possible standard sampler.

Answers were obtained from most of the branch organizations of importance in Sweden and all of them but one were positive in principle to the standardization of piston sampling. A compromise between existing sample diameters of 50 mm was advocated by the majority, whilst a few wanted to keep to the original 60.5 mm or 43–44 mm diameters. The latter dimensions were especially desired when using a special type of thick-walled three inch casing.

The majority wanted a simple and rugged sampler with the possibility to apply a simple shutter when sampling cohesionless soil under the water table. It was presumed that a standard sampler should have properties equivalent to the best routine samplers existing.

The Committee also studied available literature on sampling. It is beyond the scope of this publication to give a complete bibliography of all such literature. Only that literature which has been used in the Committee's work (*cf.* Section 18) has been referred to.

13. Sampler Type

The Committee had to choose between a piston sampler of the simple thin-walled type and the composite type.

The earlier tests at SGI had shown that, the edge being sharp, the increased wall thickness of a composite sampler would not necessarily be harmful to the sample quality.

Composite samplers were deemed to have certain advantages over thin-walled simple types, *e.g.* for the following reasons:

a) Composite samplers tested earlier were more rapid in use.
b) They permitted the use of shutters.
c) Their cutting edges could easily be made exchangeable (possibility to change inside clearance by changing edge).
d) Their sample tubes, being positioned inside a protecting tube, did not have to take the forces required to penetrate the soil and could therefore be made of low-friction material with good corrosion resistance. Thus, reasonable inside clearance might be chosen. The sampler would therefore be more suited for varying depths.
e) By using short sample tubes, part of the sample could easily be inspected and tested at the boring site.
f) Short sample tubes could easily be protected against heat, freezing or damage during transport (possible storage under water in buckets in hot or cold weather, provided that rubber covers are used as seals instead of wax).
g) The composite sampler type could be made more rugged for the same weight of samples transported, since the cylinder which surrounds the sample tubes is not sent but only the light tubes.

The Committee was unanimous in its decision to choose the composite type.

14. Sample Dimensions

With regard to its economical and other consequences, the sample diameter has been one of the most important questions for the Committee to decide on. A small diameter would mean cheaper sampling (especially when casing is needed), less demand on storage space and less bulky laboratory equipment.

On the other hand, too small a diameter would involve risks of misjudgement due to poorer sample quality and less soil available (if comparing the same sample length).

Investigations (KALLSTENIUS, 1958) had hinted of a slight decrease of sample quality with decreasing diameter, if deemed from fall-cone tests, unconfined compression tests and laboratory vane tests. The decrease seemed to be tolerable in routine work for clay. From model-law considerations it might, however, be expected that a greater diameter would be required if testing coarser soils. In the tests just mentioned, it had not been studied how sample diameter influences consolidation and shear-box tests.

The Committee has studied available literature dealing with consolidation tests. It had been shown (MUHS and KANY, 1954, and VAN ZELST, 1948) that a certain minimum height of specimen was required due to difficulties in sample trimming.

The experience from consolidation tests with diameters smaller than 50 mm was very limited outside Scandinavia, also. In Spain (SALAS and SERRATOSA, 1953) a 45 mm diameter had been used. By letter, Mr. *J. Escario* submitted the information that practically equal results had been obtained with 100 mm and 70 mm diameter consolidometers, whilst 45 mm consolidometer tests had indicated disturbances caused by trimming, appearing through a more marked rounding of the stress-strain curves in the zone of pre-consolidation pressure.

Mr. *M. J. Hvorslev* told the Committee that, in his opinion, the error caused by wall friction may partially compensate for that caused by sample disturbance. One must thus be careful in drawing definite conclusions.

In order to get a better background for using small diameters on consolidation test specimens, the Committee decided to make consolidation tests on clay and silt with untrimmed and trimmed samples of the most actual diameters, *viz.* 43, 50 and 60.5 mm. The tests, which were planned by the Committee, are described by Mr *R. Lundström* in *Section 2*.

The results seem to favour the larger diameters. However, the differences were not great enough to give a striking demonstration. The small sampler diameter and trimming to small sample diameter thus seem to cause increased disturbance (*cf.* Figs. 10–12). In coarser soil, such as coarse clay or silt, the diameter influence seems to be greater than in fine-grained clay (*cf.* the results from the 10-metre depth at Kramfors, Fig. 14).

The common procedure in making the fall-cone test three times axially to the end surface of a sample resulted in greater scatter of results when testing 43–44 mm diameter samples than in the case of 60.5 mm diameter samples. This induced a discussion on whether it was permissible in small diameter samplers to increase the area available for cone testing by testing in radial direction. Mr. *A. Hellgren* describes in *Section 3* tests indicating that radial testing is permissible and in some respects even desirable.

Transportation of samples and avoiding damage during transport were also discussed by the Committee. (As it is desirable to carry all samples with great care, one would want a small sample diameter to reduce weight.) Mr. *E. Sandegren* describes in *Section 4* tests made by the Swedish State Railways on suitable packing for transport.

The 50 mm sample diameter was finally decided on by the Committee when tests with a 50 mm sampler had given test results comparable with the 60.5 mm samplers, and the same sampler had proved to be nearly as easy to handle as those of the 43 mm size. The amount of soil obtained in one 50 mm diameter sample was considered sufficient for most routine purposes. For special tests, the possibility still remains to use samplers adapted hereto.

The Committee further settled on the following recommendations:

— A piston sampler type should be chosen as it normally gives total recovery of the sample. Due to the required sampling length the principle of a piston rod running inside extension tubes ought to be utilized for the sampler.

— The sample tubes ought preferrably to be made of plastic due to its light weight, non-corrosive qualities and low friction to soils.

— The length of the sample tubes ought to be chosen so that one tube would contain a sufficient quantity of soil for the performance of fall-cone tests, one unconfined compression test, one consolidation test, and tests for the consistency limits. All this requires a length of about three times the untrimmed sample diameter. Together with the 50 mm diameter, a length of 170 mm was chosen, because it would permit two specimens of 80 mm length after trimming of the ends (*e.g.* triaxial test specimens) to be cut out.

— Total sampling length ought to be 700 mm. (A sample length of at least three sample diameters at each end were regarded as disturbed and two samples were desired to be undisturbed.)

— It would be convenient to transport the sampler head in a standard steel case. Therefore, the length of the sampler head (when disassembled) ought not to exceed one metre.

— The cutting edge angle should be 5° (*cf.* KALLSTENIUS, 1958).

— The inside clearance should be decided after practical tests (later on decided to be 0.4 %).

— The sampler should have possibilities to be provided with a shutter of very simple type.

15. Tests with Sampler Prototypes

At SGI, a sampler was designed with the above-mentioned points of view taken into consideration. The sampler (SGI XI—later called St I) was gradually developed. It is described by Mr. *T. Kallstenius* in *Section 5*. The standard sampling procedure is based on experience gathered with three specimens of that sampler.

Tests performed with this standard sampler prototype will only briefly be mentioned here. A more detailed description and analysis will be published later on.

In the beginning, the sampler was subjected to hard mechanical tests, *e.g.* hammering against a block of wood, hammering through the dry crust or in hard

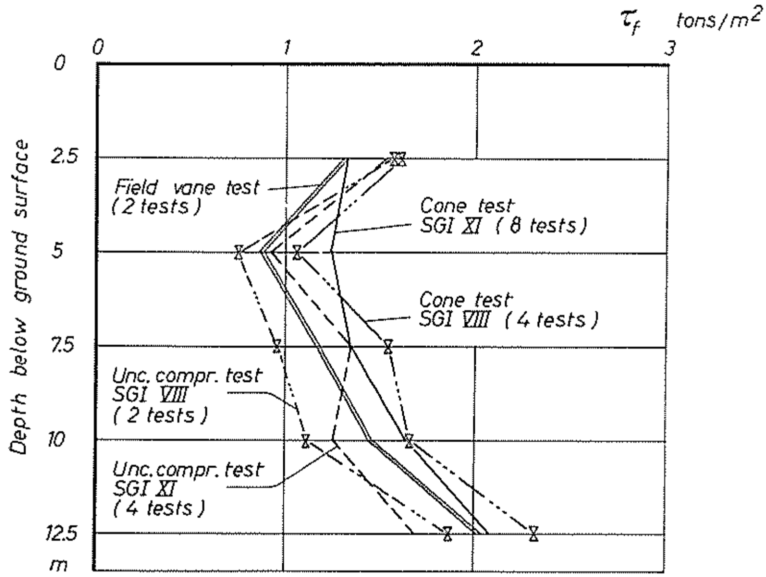


Fig. 1. Comparison between samplers SGI VIII and SGI XI (standard sampler St I) as indicated from different strength tests, Skå Edeby 1960. (Averages from number of tests indicated for each depth).

clay. Details which then proved too weak were strengthened until they worked satisfactorily.

Sampling was done with three prototypes in ordinary routine work and also under research conditions. During a period of more than two years, several hundred samples were taken. The sampler prototypes proved to be easy to handle and to give good test results.

In April 1960, the Swedish Geotechnical Society, on the proposal of the Committee, had a meeting for representatives of organizations interested in a standard sampler, and informed them of the experiences gained.

At that time, a considerable amount of samples had successfully been taken in clay, silt and sand with the test samplers. The clay samples showed higher unconfined compression test values than those taken with most of the samplers used in the parallel testings. The fall-cone test values[1] were of the same order as those of the best 60.5 mm samplers. Consolidation tests performed had also indicated good sample quality (*cf.* Figs. 10—11).

The representatives of the meeting were positive to the 50 mm diameter and type of sampler. Therefore, final calibrations and tests with revised prototypes could be started.

Now all three samplers were adjusted to the design later on standardized. The first two samplers then were used in ordinary routines, whilst the newest sampler was calibrated under careful observation of influencing factors.

[1] Interpretation of the fall-cone tests in the General Report is made according to the former SGI-method (Swed. Geot. Inst. Medd. No. 5, Sthlm 1959).

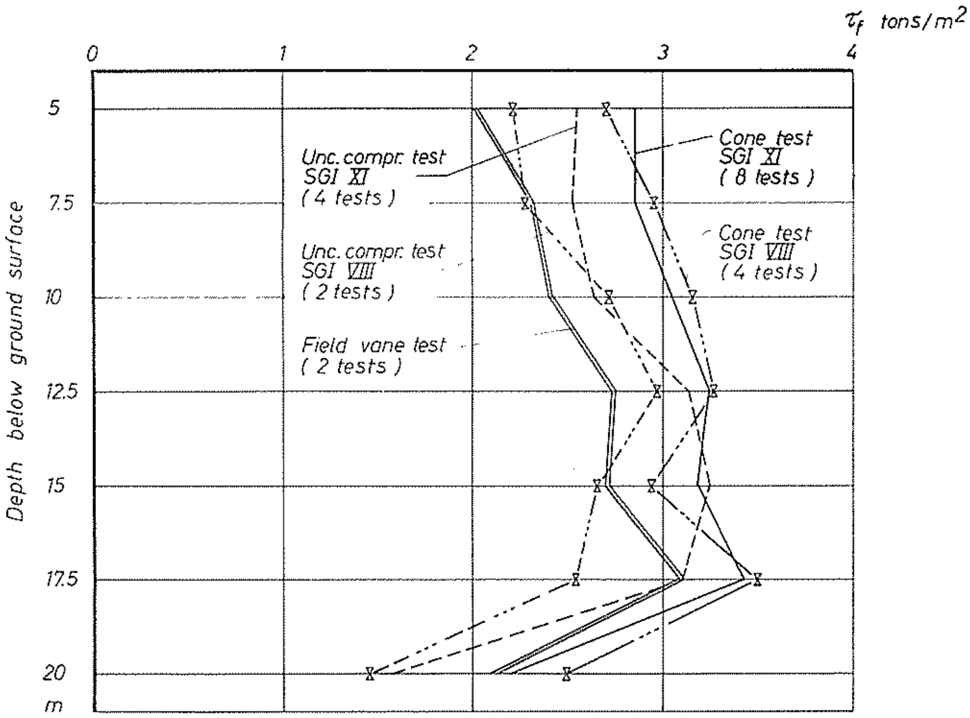


Fig. 2. Comparison between samplers SGI VIII and SGI XI (standard sampler St I) as indicated from different strength tests, Ultuna 1960. (Averages from number of tests indicated for each depth).

In September–December 1960, calibration tests were performed at *Skå Edeby* (near Stockholm) in glacial and post-glacial clay. The clay was post-glacial down to about 5 metres depth and below that glacial. At 2.5 m depth a weathering effect was still apparent. At 12 metres depth the clay became silty.

At Skå Edeby the sampler was provided with cutting edges of different inside diameters giving inside clearances of 0.2, 0.4, 0.8 and 1.4 %. The influence of the different clearances proved to be small. A clearance of 1.4 % was, however, too large.

Results from laboratory tests were then compared with field-vane tests and tests on samples taken with the 60.5 mm piston sampler SGI VIII. The comparison of the strength tests can be seen in Fig. 1. (At Skå Edeby the piston was not kept strictly at constant level, which affected unconfined compression test at little unfavourably.)

At *Ultuna* (near Uppsala) similar tests were performed in slightly organic clay. Inside clearances of 0.2, 0.8 and 1.4 % were compared. The 1.4 % clearance gave slightly smaller strength values. Fig. 2 shows a comparison between the two samplers as indicated from different strength tests.

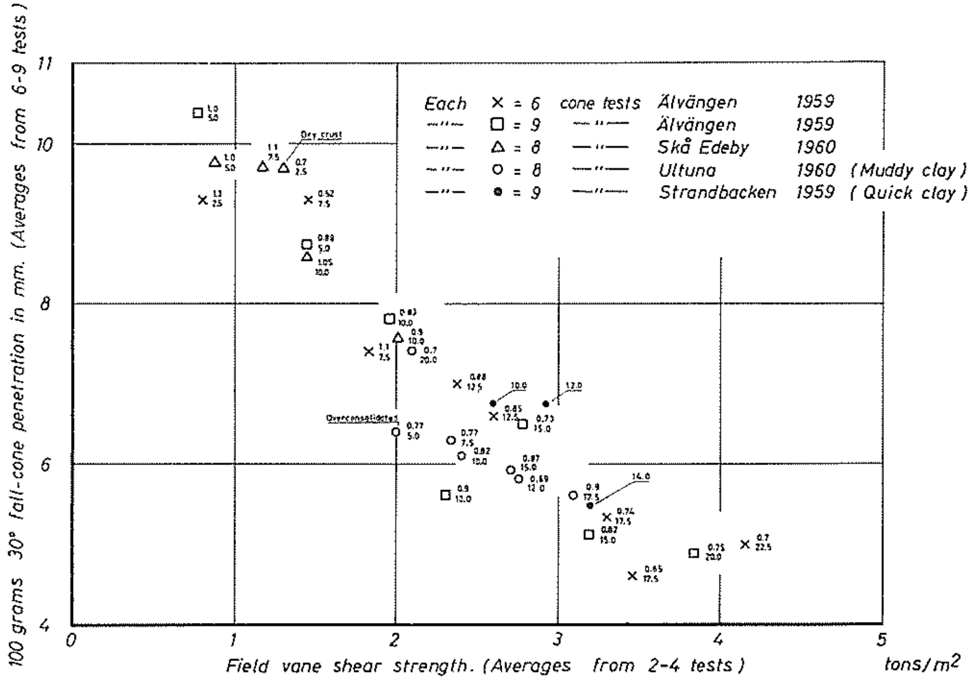


Fig. 3. Relation between shear strength according to field-vane tests and penetration of the 100 gm—30° cone in samples taken with sampler St I. When two figures are given at a certain point, the upper figure indicates the liquidity index (difference between natural water content and plastic limit divided by plasticity index), and the lower one indicates the sampling depth. Single figures give the sampling depth.

The above results comprise about 150 soil samples. Each sample consisted of two specimens and was tested with, on an average, six fall-cone tests and two unconfined compression tests. The values confirmed the results obtained earlier that the sampler (St I) gave fall-cone results as high as the best 60.5 mm samplers and better unconfined compression tests, seemingly due to increased length of the sampler proper (*cf.* KALLSTENIUS, 1958). For the St I, both fall-cone tests (with interpretation used) and unconfined compression tests gave strength values a little higher than the field-vane values.

In Fig. 3 is given a comparison between shear strength values obtained with the field-vane and the penetration of the 100 grams-30° cone of clay samples taken with the sampler St I at various sites. The scatter of results seems to depend on the soil type and sampling depth. It may be mentioned that each point represents the average of several tests, which showed rather small scatter mutually.

In the above, sampler St I has been compared with the field-vane borer and piston sampler SGI VIII. Earlier investigations have indicated the relative

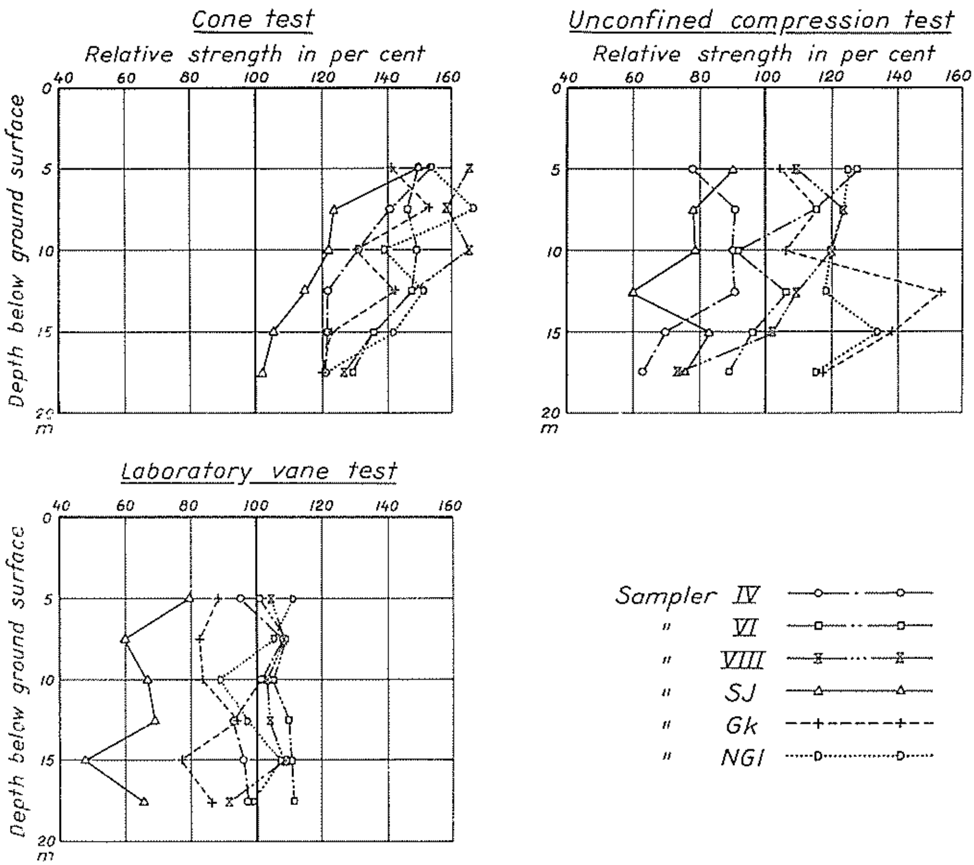


Fig. 4. Relative strengths of clay samples taken with different piston samplers (from SGI Proc. No. 16; results not corrected for consistency).

quality of samples taken with other samplers frequently used in Sweden. Fig. 4 is reproduced from such investigations (KALLSTENIUS, 1958). (The fall-cone test interpretations in Figs. 1–3 and in Fig. 4 were not identical.)

16. SGF Standard Piston Sampling Regulations

After a compilation of available experience and study of calibration-test results, the Committee was prepared to suggest a standardization and regulation of piston sampling, based mainly on the experiences with the sampler prototypes. Only dimensions and handling procedures which were deemed necessary to ensure good sample quality were suggested for standardization. The Society agreed on the proposal on February 10, 1961.

The main points of the regulations follow below.

"SGF Piston Sampling Regulations 1961"

A. General

A:1 The regulations were compiled by the Swedish Committee on Piston Sampling (1957–1960) of the Swedish Geotechnical Society, and were agreed on at a meeting of the Society on February 10, 1961.

A:2 The sampler and its handling influence the results of the investigations. Required uniformity is achieved through regulated piston sampling.
Regulated piston sampling requires:
a) Standardized piston sampling equipment (referring only to the sampler head).
b) Observance of certain regulations.

A:3 Sampling in full agreement with these regulations is called *Standard piston sampling*. Such sampling should normally be used and should be noted in the boring records.

B. Standard Piston Sampling Equipment and Special Measures

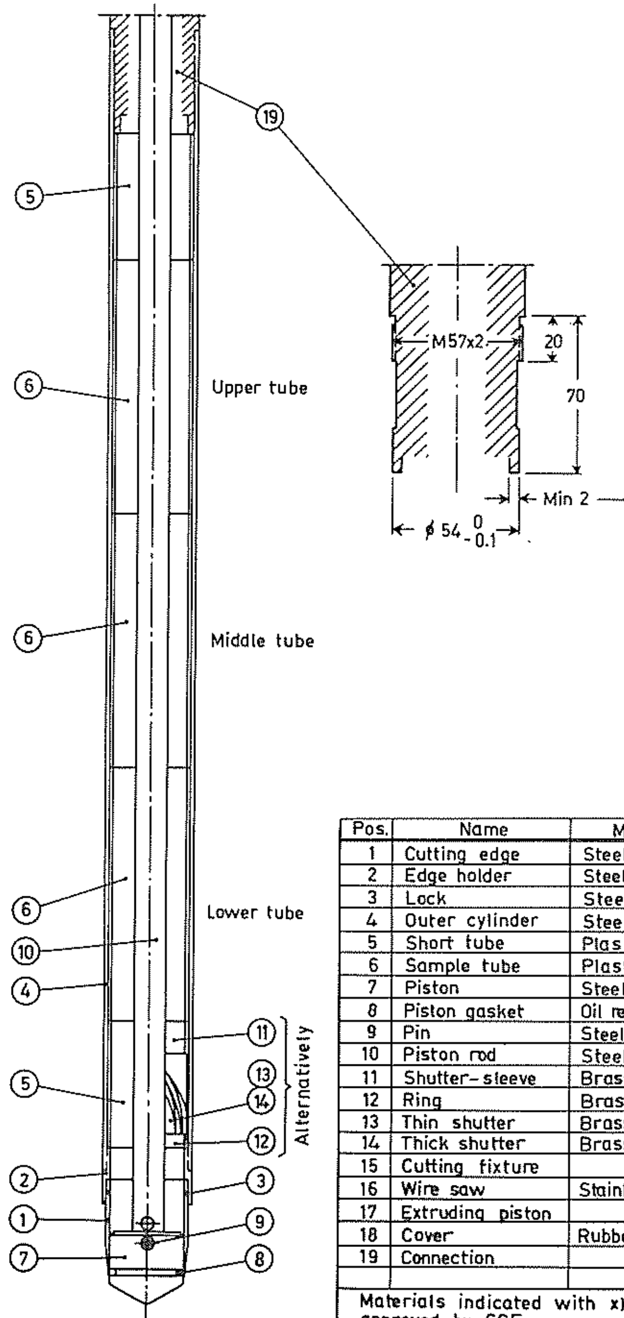
(*cf.* Figs. 5–7)

B:1 Sample diameter 50 mm (= inner diameter of normal cutting edge).
Punching stroke 700 mm.
Inside clearance 0.4 % (= difference in diameter between cutting edge and sample tube).

B:2 The *Sampler head* consists of *cutting edge* (1), *edge holder* (2) with *lock* (3) and *outer cylinder* (4).
Inserted in the outer cylinder are (counted from the edge) a *short tube* (5), three *sample tubes* (6) and another *short tube*. To the standardized sampler head also belong a *piston* (7) with *piston gasket* (8), *pin* (9) and a *piston rod* (10). The standard head is joined to a *connection* (19) which shall agree with the dimensions given in Fig. 6.

B:3 *Additional parts* to the standard head are *shutter-sleeve* (11) with *ring* (12) and *thin shutter* (13). A *thick shutter* (14) may be used only when the thin shutter is not sufficient. Further, there shall be a *cutting fixture* (15) with *wire saw* (16) and *extruding piston* (17) and a sufficient supply of sample tubes (6) with tightly fitting *covers* (18).

B:4 The three sample tubes are termed *upper tube, middle tube* and *lower tube,* in order from above. The recorded sampling depth is measured to the joint between the lower tube and the middle tube (340 mm above the cutting edge) after the sample is punched. As a rule, the middle and lower tubes give samples in clay that can be accepted as standard samples with regulated sampling. The upper ends of the sample tubes shall be numbered.



Pos.	Name	Material
1	Cutting edge	Steel
2	Edge holder	Steel
3	Lock	Steel ø 1.5
4	Outer cylinder	Steel
5	Short tube	Plastic x)
6	Sample tube	Plastic x)
7	Piston	Steel
8	Piston gasket	Oil resist. rubber
9	Pin	Steel
10	Piston rod	Steel
11	Shutter-sleeve	Brass
12	Ring	Brass
13	Thin shutter	Brass
14	Thick shutter	Brass
15	Cutting fixture	
16	Wire saw	Stainl. steel wire
17	Extruding piston	
18	Cover	Rubber or plastic
19	Connection	

Materials indicated with x) to be approved by SGF

Fig. 5. Standard piston sampler. Assembly.

B:5 The piston rod shall be extended upwards to the ground surface and be fixed during the punching of the sample to keep the piston constantly in position. The principles of the arrangement for this shall be approved by SGF. Where earth anchors are used, the fixing of the piston shall be independent of travel of the anchors.

B:6 The extension upwards of the sampler shall be provided with clearly distinguishable marks for each metre. Before punching a sample at an even number of metres below the ground surface, a mark shall be placed 20 centimetres above ground (at sampling depth 1.0 m, the upper end of the outer cylinder may substitute for this mark).

B:7 Manufacture of equipment for standard piston sampling shall be supervised and approved by SGF.

B:8 Equipment for standard sampling shall not be used for this purpose when, through wear or damage, it no longer meets the standard requirements.

C. Boring Regulations

C:1 A printed set of handling instructions approved by SGF should be available for all items of equipment for standard piston sampling.

C:2 A record on important data and observations shall be made in the boring log for every sampling carried out.

C:3 The sampler shall be pushed whenever possible. Punching ought to be done continuously. The punching time shall be at least 5 seconds and should not exceed 3 minutes. If hammering proves necessary within one metre from the sampling depth, or when punching out a sample, hammering should be done as an aid to pushing respectively to punching and with such gentle blows as to eliminate "rebound". The hammering shall be noted in the boring log. During withdrawal of the sampler, no hammering is permitted.

C:4 Sampling in the same bore-hole closer than one sample per metre gives sample disturbance and should generally be avoided.

C:5 Sampling in the bottom of a pre-bored hole affects the samples and influences the laboratory results. When doing such sampling, one must make a note in the boring log.

C:6 If the full stroke at the punching operation cannot be performed (because of some obstacle) this is to be noted in the log.

C:7 When sampling in clay, a shutter should, in general, not be used. (It is considered that the shutters disturb the samples.) If a shutter is necessary, the use of it shall be noted in the log. In the first hand the thin shutter (13) is used, and this case is normal for sand below the water table. The thick shutter may be necessary in special cases (mainly in organic clay).

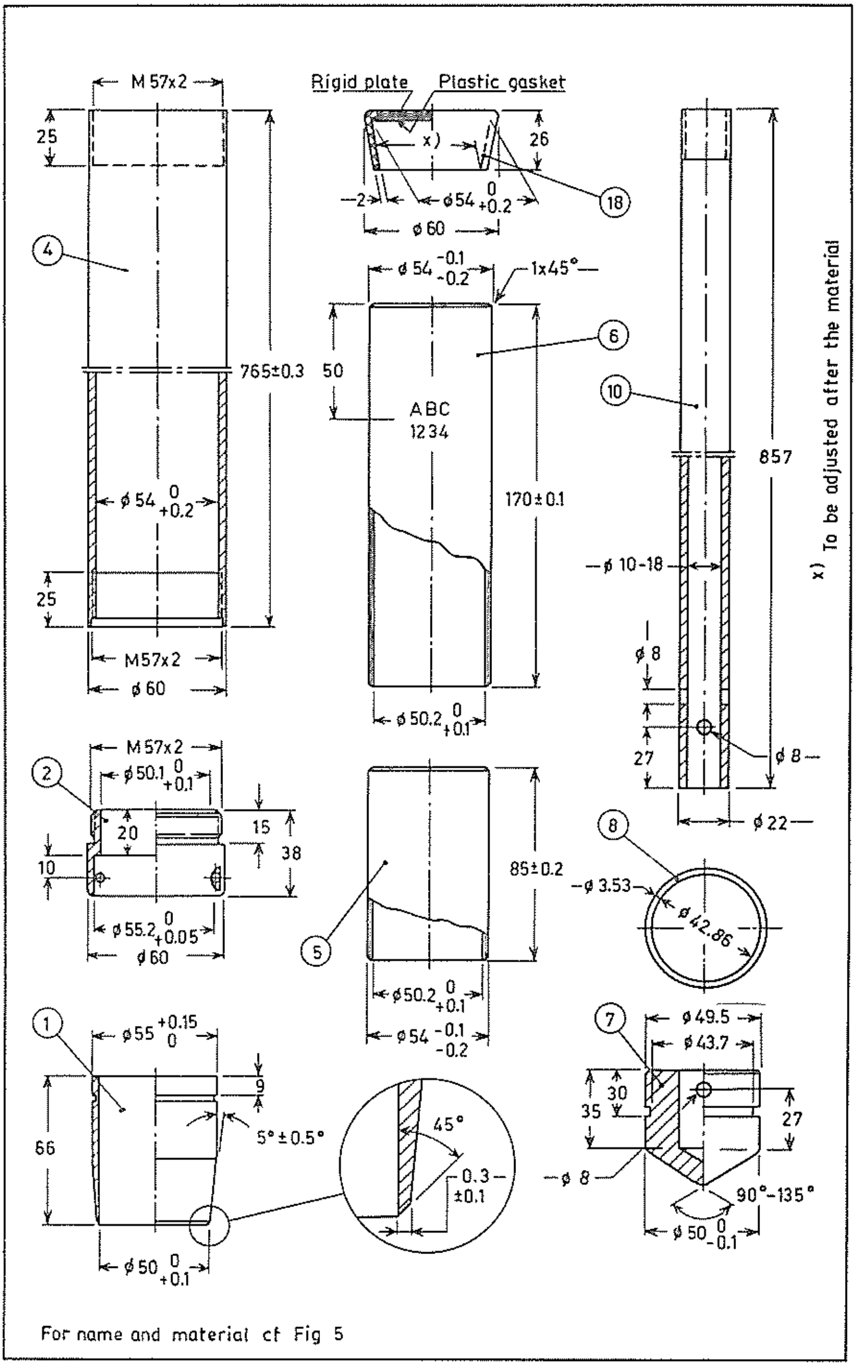


Fig. 6. Standard piston sampler. Parts.

C:8 Cutting off the samples after extracting shall be done with the aid of cutting fixture (15), wire saw (16) and extruding piston (17). In the log shall be noted, a) Co-ordinates of the position etc. of bore-hole, b) Bore-hole number, c) Sampling depth, d) Number and position of sample tube and e) Date of sampling.

C:9 If a sample does not fill the sample tube, a plastic gasket shall be inserted and the rest of the tube be filled with soil, which may be taken from the cutting edge or the lower short liner. Such filling should be marked at the tube end by means of a label indicating the filling and be noted in the log. If the sample, after being cut off, does not fill the cross-section of the tube, this shall also be noted in the log.

C:10 The samples should not be subjected to shocks, vibrations, freezing or heat, etc. To prevent defects before transportation, the samples can be stored in water (provided, of course, that the tight fitting covers have been applied at both ends). During transportation, a proper type of packing must be used. If disturbance (*e.g.* by misadventure) is supposed from shock, vibration, freezing or heat, this shall be noted in the log.

Comments on the regulations

B:1

The inside clearance chosen was 0.4 %. Experience had shown that the desirable and permissible clearance was dependent on the coefficient of friction between the soil and the inside of the sampler tube. As already mentioned, a clearance of 1.4 % has some disadvantages. It was also difficult to retain the samples in the tubes with so great a clearance. Experience with a clearance of 0.6 % had been rather favourable, but on some occasions samples had been lost nevertheless.

B:5

In practice it is impossible to keep the piston at constant level. A piston travel of, say, ten millimetres at the very beginning of a punch does no harm as the uppermost part of the sample is not adopted for use. Later on in the punching operation, even small travel causes local or extended disturbance. The arrangements for fixing the piston must suit the conditions required.

C:3

If hammering is necessary and produces a "rebound" for each blow, the sample may be seriously damaged. The punching time (lower limit) should ensure escaping of fluid or air (entrapped above the piston) without high overpressure (which might cause leakage past the piston) as well as avoiding dynamical

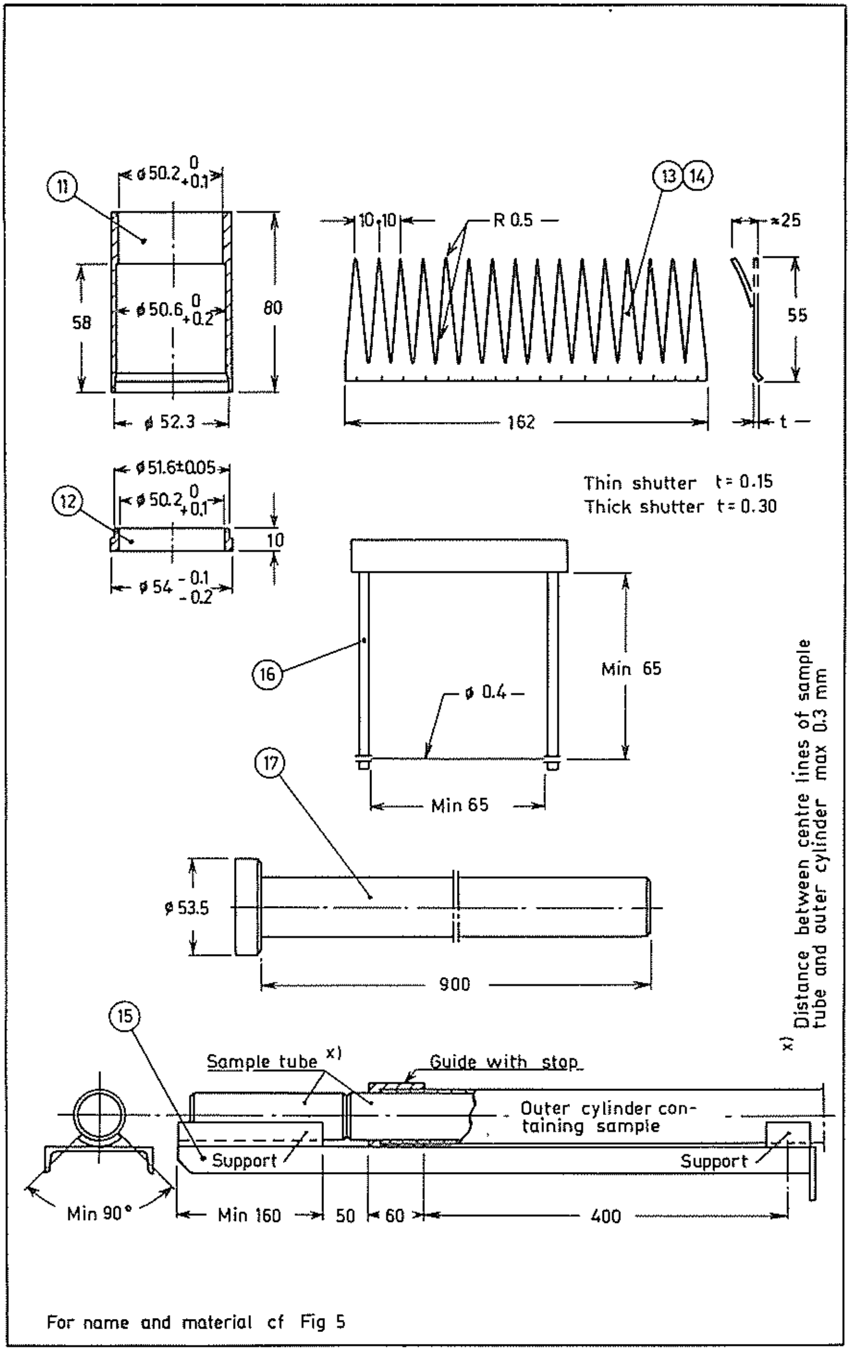


Fig. 7. Standard piston sampler. Additional equipment.

forces. The punching time (higher limit) should not be so long as to make possible consolidation in situ and high inside frictions. Discontinuous punching may increase inside friction and should be avoided. However, tests have indicated that punching, if done carefully, in steps (within the time limits) may not disturb the samples.

Concerning the conditions of punching continuously, see comments on p. 44.

C:7

There is little evidence of sample disturbance caused by thin shutters, but it was thought advisable to be careful in the use of shutters. Thick shutters would seemingly disturb the samples more.

C:9

The marking of filled material in a sample tube shall prevent, among other things, that cone testing will not be performed on the filled part of the sample.

Fig. 6

Plastic gaskets are placed at the ends of the samples to prevent adhesion between the covers and the sample.

17. Conclusions and Final Remarks

The settlement of the piston sampling regulations will provide a uniformity of the samples taken. It will facilitate gathering of information on the properties of different soil types and proper evaluation of the tests made.

Standard sampling means a mutual agreement on certain common dimensions and procedures in order to ensure the necessary uniformity of routine sampling. The standard comprises the minimum requirements for that purpose, *e.g.* of the parts which may affect sample quality. In the future some Swedish authorities will most probably claim the use of standard samplers or, in special cases, samplers tested out with the necessary thoroughness.

After that the piston sampling regulations were settled, about fifty standard samplers of the type St I were, in March 1961, ordered by Swedish institutions and geotechnical firms.

The standardization will not hinder a development of most parts of the sampling equipment. For the laboratory equipment the most decisive part of the standard is the selected diameter 50 mm. In certain coarse grained soils, however, the 50 mm diameter may prove too small, and in such special cases larger diameter may be necessary. There is, however, no economy in using heavy samplers where not needed.

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2. Influence of Sample Diameter in Consolidation Tests

By *Rune Lundström*

21. Performance of Laboratory Tests

The investigations to find a suitable standard piston sampler have also comprised consolidation tests in oedometer. The latter tests have had the purpose of elucidating the disturbance effect which might depend on the sample diameter and the trimming procedure.

The oedometer equipment, shown in Fig. 8, is made of stainless steel with a fixed ring container (LAMBE, 1951). Test diameters have been 42.9, 49.8 and 60.5 mm. The piston samplers used to take the soil samples for the oedometer tests have had the diameters 43.0, 50.0 and 60.5 mm. The dimension of the oedometer has been adapted to the inside clearance of the piston sampler. The

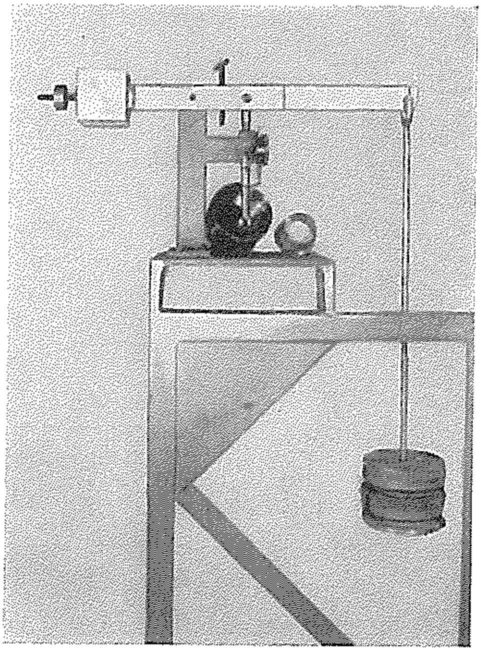

Fig. 8. Oedometer equipment (oedometer is shown in tilted position).

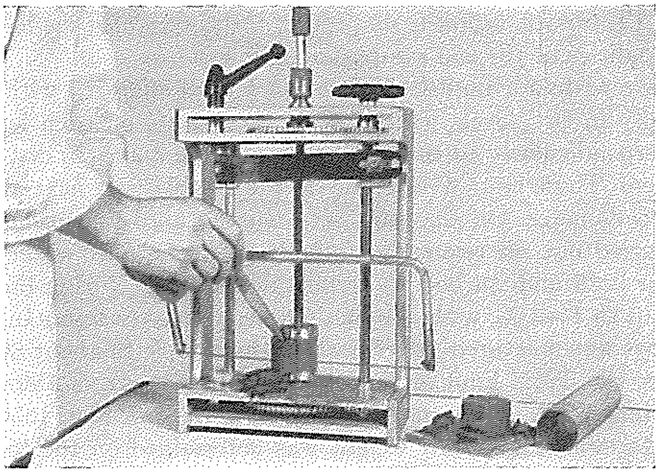

Fig. 9. Trimming apparatuses. Left: Wire saw trimmer (TWS). Right: Punching edge trimmer (TPE).

soil samples have been sent to the laboratory in brass or plastic tubes with a length of 12.5 cm for the 43 mm piston sampler, 15 cm for the 50 mm sampler, and 17 cm for the 60.5 mm sampler. For the 50 mm samples, plastic tubes reinforced with glass fibre were used and, for the other samplers, brass tubes.

For the oedometer tests, 20 mm of the lower end of the sample was primarily cut away and rejected because of possible disturbance. Then 20 mm of the sample was inserted in the oedometer ring.

The sample has usually been inserted directly from the sampling tube into the oedometer ring with a special fixture. In certain cases, however, a trimming down of samples from a larger to a smaller diameter has been performed. For the trimming procedure two trimming apparatuses, shown in Fig. 9, were used. When using one apparatus, thin slices were successively cut off with a wire saw at the periphery of the sample, thus reducing the sample diameter to the desired size (this method is here called TWS). When using the other apparatus, the sample was cut down to a somewhat larger diameter than the desired one, and then the final sample was punched out with a ring having a sharp cutting edge of 7 degrees (this method is here called TPE).

The load was applied the day after the insertion. Up to the moment of loading, the sample was kept under water in the oedometer. At this time the sample was exposed to a load of a filter stone, on which the stamp rested. The load due to this amounted to 0.02–0.033 kg/cm^2, depending on the diameter. This load was constant during all the load-steps and, being very small, was negligable when plotting and judging the test results. The load steps of the oedometer tests corresponded to 0.1, 0.2, 0.4, 0.8, 1.6 and 3.2 kg/cm^2, whereby each loading step was kept on the sample for one day.

Aside from the consolidation tests proper, tests were also made to determine the general qualities of the soil samples as follows.

The shear strengths for undisturbed samples were analyzed with the fall-cone method, usually in two levels with at least three tests on each level. The cuts were made perpendicularly to the axis of the sample and at a distance apart of about 3 or 4 cm. These tests were made on the sample part next above the part used for the oedometer. On the part between the above-mentioned cuts, cone tests were carried out on remoulded samples. The natural water content was determined for both undisturbed and remoulded states. (During the remoulding, some water, up to 1—3 %, with the method used, may escape.) In certain cases the ignition loss was measured (after heating the sample to about 800°C). Beside these analyses, the liquid limit or fineness number[1] (STATENS JÄRNVÄGAR: Geotekniska Kommissionen, 1922, and CALDENIUS & LUNDSTRÖM, 1956) and plastic limit were determined. The unit weight was determined on the total sample in its tube before the insertion in the oedometer.

The tests comprised clay and silt.

22. Tests on Clay

The tests on clay were performed on samples taken at *Lilla Mellösa*, situated about 30 kilometres north of Stockholm. All samples were taken from a depth of 6 metres in bore holes placed in a hexagon with sides of two metres' length. At three points, samples were taken with the 60.5 mm diameter piston sampler SGI VIII, and at three points with the 43 mm sampler designed by the Public Works Department of Stockholm (Gk).

The clay is post-glacial of a black-spotted dark-grey colour. It is homogeneous without any visible stratification. The average values of undisturbed shear strength (fall-cone test) = 1.55 t/m^2, sensitivity = 19, unit weight = 1.47 t/m^3, natural water content (undisturbed sample) = 91.5 %, fineness number (from the cone method) = 71 %, liquid limit = 76 % and plastic limit = 27 %.

The oedometer tests were carried out on a total of 12 test series. Three tests were performed with diameter 60.5 mm (SGI VIII) and three with diameter 42.8 mm (Gk). Three samples were trimmed from 60.5 to 42.9 mm with the TWS method and two with TPE. Furthermore, tests were made on remoulded clay in 60.5 mm oedometer.

The results of the oedometer tests are shown in diagrams, Figs. 10, 11 and 12. The diagrams in Figs. 10 and 11 show the relationship between stress, in kg/cm^2, and strain, in per cent, while the diagram in Fig. 12 shows the relationship between stress, in kg/cm^2, and the consolidation coefficient c_v, in cm^2/sec. The evaluation of c_v has been made according to the Casagrande method. In the stress-strain diagrams one can find the typical straight line of the remoulded sample. The more disturbed the sample is, the more the curve approaches the

[1] Water content in per cent of dry weight at 10 mm impression when using 60 gm-60° fall-cone.

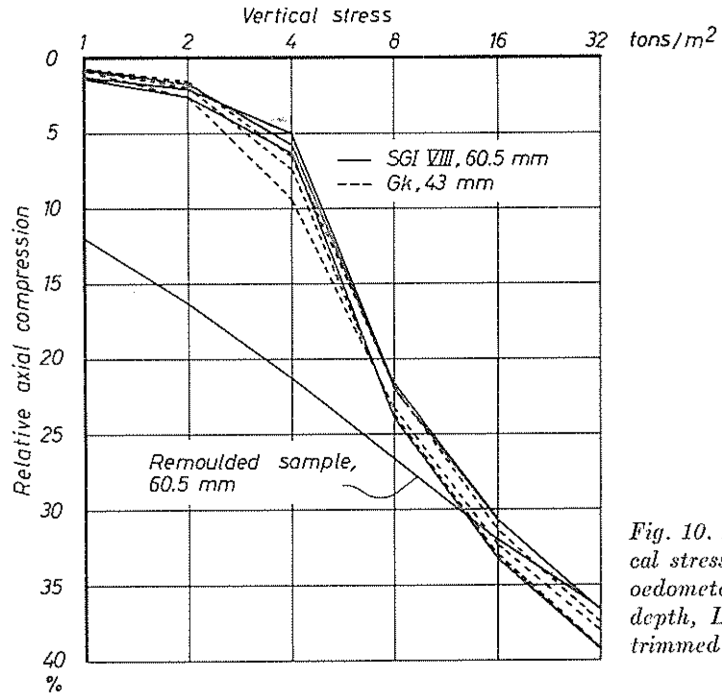

Fig. 10. Relation between vertical stress and compression from oedometer tests on clay at 6 m depth, Lilla Mellösa 1959 (untrimmed specimens).

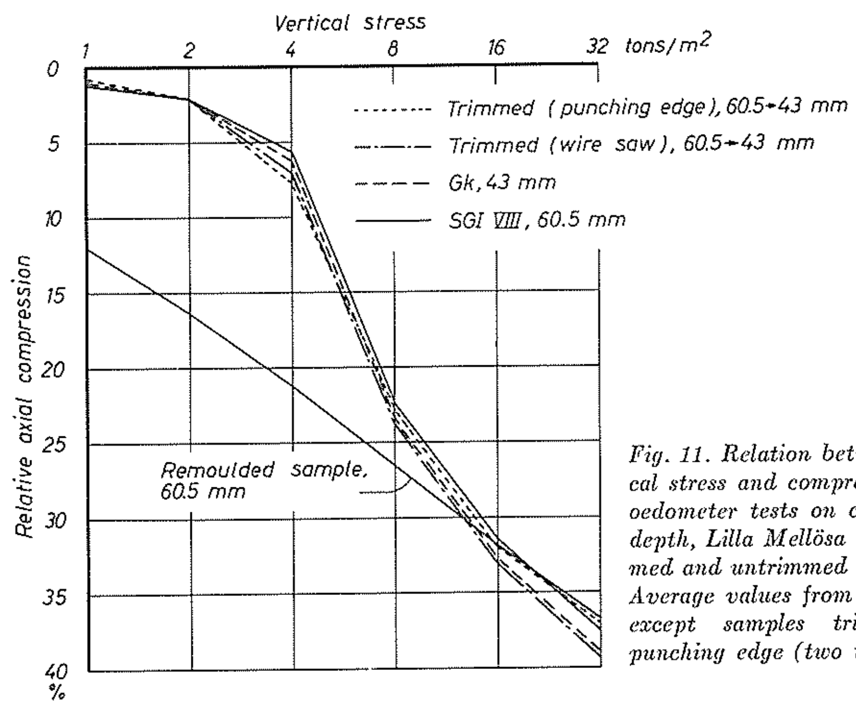

Fig. 11. Relation between vertical stress and compression from oedometer tests on clay at 6 m depth, Lilla Mellösa 1959 (trimmed and untrimmed specimens). Average values from three tests except samples trimmed by punching edge (two tests).

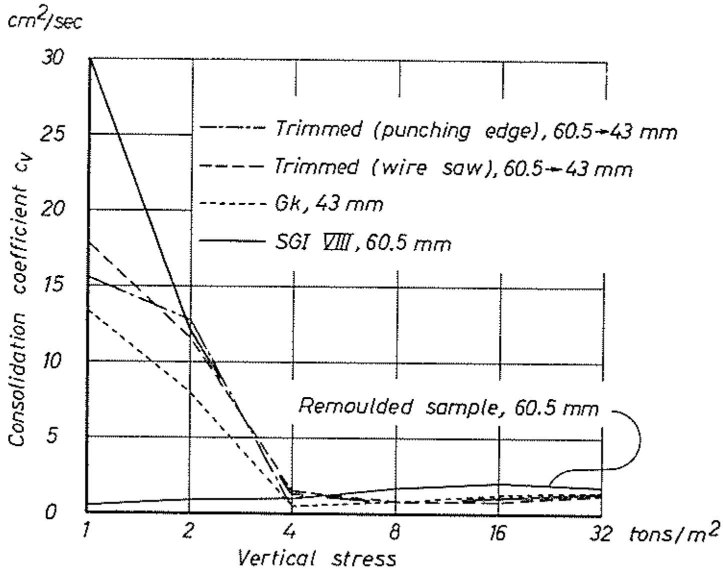

Fig. 12. Relation between vertical stress and consolidation coefficient (average values) from oedometer tests on clay at 6 m depth, Lilla Mellösa 1959.

remoulded sample curve (RUTHLEDGE, 1944). A tendency to disturbance is found at the diameter 42.9 mm, in comparison with the curve for the diameter 60.5 mm.

All tests with clay samples were performed during 1958. The tendency to disturbances at diameter 43 mm contributed to a concentration of the Committee's work on a 50 mm diameter piston sampler.

23. Tests on Silt and Coarse Clay

The tests on silt were carried out on samples taken at *Kramfors*, about 500 kilometres north of Stockholm. Samples were taken at depths of 3, 6 and 10 metres in bore holes placed in two concentric circles with radii of 4 and 6 metres. The bore holes were normally situated at a distance apart greater than some two metres. The tests were carried out in 1959. At that time the first prototype of the subsequent Standard piston sampler (here called St I), with a diameter of 50 mm, had been developed by the Committee. The samples at Kramfors were thus taken with this new sampler and the above-mentioned samplers SGI VIII and Gk.

From each of the depths 3, 6 and 10 metres, oedometer tests were carried out as follows.

2	tests,	diameter	60.5,	of	samples	taken	with	SGI VIII
2	,,	,,	49.8,	,,	,,	,,	,,	St I
4	,,	,,	42.9,	,,	,,	,,	,,	Gk
2	,,	,,	42.9,	,,	,,	,,	,,	SGI VIII
2	,,	,,	42.9,	,,	,,	,,	,,	St I

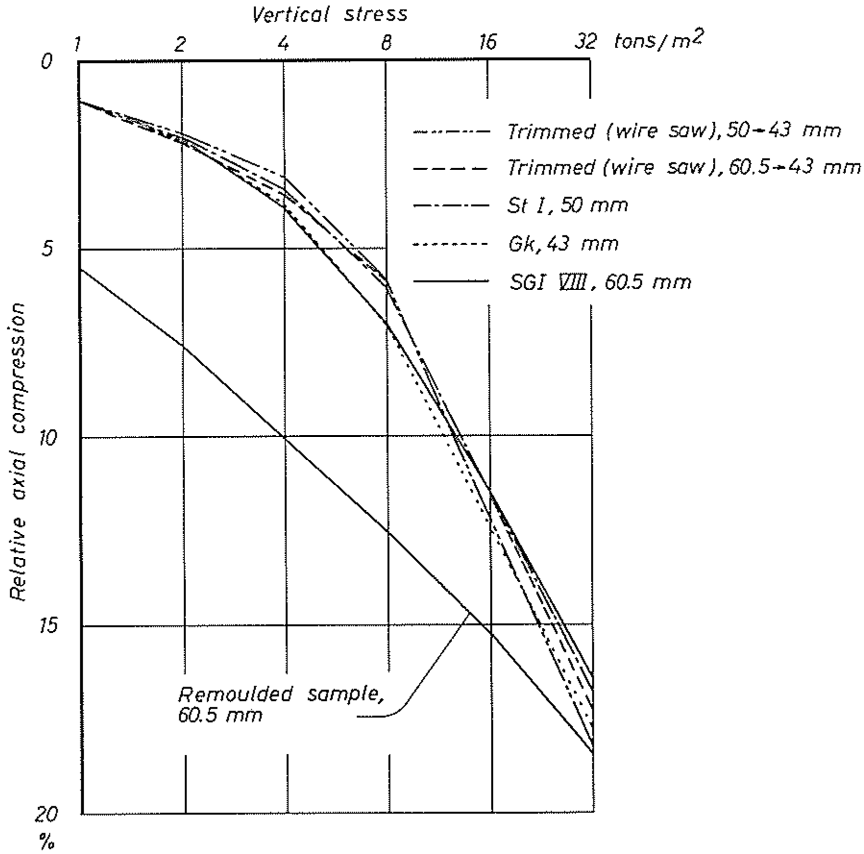

Fig. 13. Relation between vertical stress and compression from oedometer tests on silt at 3 m depth, Kramfors 1959 (trimmed and untrimmed specimens, average values).

The four last-mentioned samples were trimmed from the diameter 60.5 and 50, respectively, to 42.9 mm, according to the TWS method for samples from the depth of 3 and 6 metres and by the TPE method for samples from the depth of 10 metres.

The soil is very heterogeneous, and its character varies considerably from one depth to another and also within the same depth.

From the *depth of 3 metres,* fine grey clayey silt was found, usually with black-spotted layers. The soil is somewhat organic, the ignition loss being 3.5 to 4.0 %. The natural water content is 59 % (± 2.5 %), the average value of the liquid limit 46 % (± 7 %) and the plastic limit 28 % (± 5 %) (figures in parentheses refer to maximum deviation). The unit weight varies little, and is about 1.65 t/m^3. The shear strength, according to the fall-cone method, amounts on an average to 2.2 t/m^2. The sensitivity is very high, varying between 50 and 240.

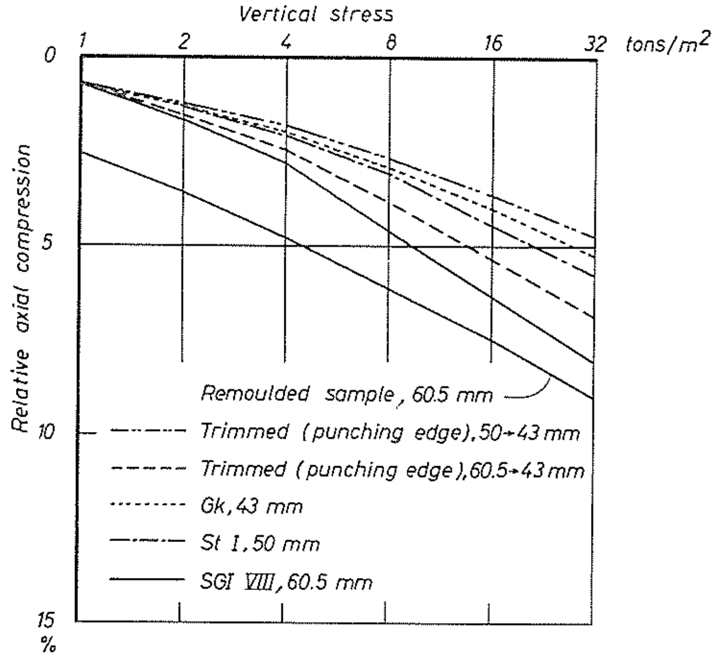

Fig. 14. Relation between vertical stress and compression from oedometer tests on silt at 10 m depth, Kramfors 1959 (trimmed and untrimmed specimens).

In spite of the high sensitivity, the oedometer stress and strain curves are rather well grouped, also for the trimmed specimen (Fig. 13). The diagrams for the tests from the piston samplers (SGI VIII, Gk and St I) show that the St I sampler seems to be good.

The samples from the *depth of 6 metres* might principally be characterized as grey silty clay with, in many cases, black-spotted layers. The clay seems to be organic, and the sensitivity is in general very high. The oedometer tests with samples from the 6 metres depth were difficult to interpret, probably due to the high sensitivity and some variations in the soil properties.

It seems, however, that the samples from *10 metres depth* give a clearer picture. These samples are more homegeneous in their characteristics than the others, in spite of distinct varved stratification. The soil at this depth consists of varved silt with clayey layers. Organic admixture does not occur. The natural water content is 30 % (± 3 %), plastic limit 23 % (± 3 %), fineness number 31 % (± 1 %) and unit weight 1.93 t/m³. The shear strength has not been investigated.

In Fig. 14 each curve represents an average for each of the oedometer tests from the 10 m depth. To obtain a good comparison between the curves, they have been moved along the strain-axis to some extent, so that a common basis has been established. The curve for the remoulded sample has been given in the figure, also.

The progress in the stress-strain curves can be described as follows. The smallest disturbance has been obtained in the samples taken with piston sampler SGI VIII and tested in the 60.5 mm oedometer, and the greatest disturbance in the samples taken with the St I sampler and trimmed to 42.9 mm. Samples taken with the St I sampler and tested in the 49.8 mm oedometer give here somewhat better results than the samples taken with the Gk sampler and tested in the 42.9 mm oedometer.

This should indicate, firstly, that the diameter of the sampler is of influence on the disturbance on the soil samples and, secondly, that the trimming of the sample also may be of influence. The two trimmed samples show poorer results than the original samples.

24. Conclusions

As a conclusion of making the oedometer tests, it might be said that a small tendency of disturbance was observed in the oedometer diagrams for the 42.9 mm diameter in comparison with the 60.5 mm diameter. The trimming with wire saw gave only slight disturbance in the tests here reported.

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3. Strength Dispersion in Fall-Cone Tests on Varved Clay

By *Arne Hellgren*

In order to investigate the dispersion of results which can be expected at the shear strength determination by means of the fall-cone test, 22 samples have been taken of varved clay from certain points at *Råcksta träsk* near Stockholm. Each sample consisted of two specimens with a diameter of 43 mm and a height of 10 cm situated close above each other.

The samples have been taken by means of sampler Gk (see Section 1) at depths of 2–8 metres in a varved glacial clay. The annual varves had a thickness of ½—1 cm and were brown and grey.

Average values for the clay data were:

Unit weight	1.67 t/m^3
Shear strength (cone test[1])	1.66 t/m^2
Sensitivity	14
Natural water content	59.4 %
Fineness number (= water content in per cent of dry weight at 10 mm impression when using 60 gm—60° fall-cone)	53.1 %

An aluminium fixture shown in Fig. 15 was used, the diameter of the hole being 43 mm. Every specimen was brought over to this fixture and the overtopping part (above the chord) was cut away by means of a thin wire. After that, lids were placed at the ends of the fixture, and cone tests were performed in sections A, B and C in about radial direction. Then a lid was put on the chord-surface and the end-lids were taken away. The specimen was then placed with its axis in a vertical position and cone tests were performed on the surfaces A, B and C in the axial direction. Also determined for the parts *a*, *b* and c were unit weight, natural water content, fineness number, remoulded shear strength and sensitivity. The appropriate results have been arranged as frequency diagrams. In Fig. 16 the percentage of total numbers of tests are plotted as a function of the percentage deviation from average strength (radial and vertical cone test results, and quotient of these) as well as fineness number. The mean deviations in the samples were as follows:

[1] Interpretation according to the former SGI-method (Swed. Geot. Inst. Medd. No. 5. Sthlm 1959).

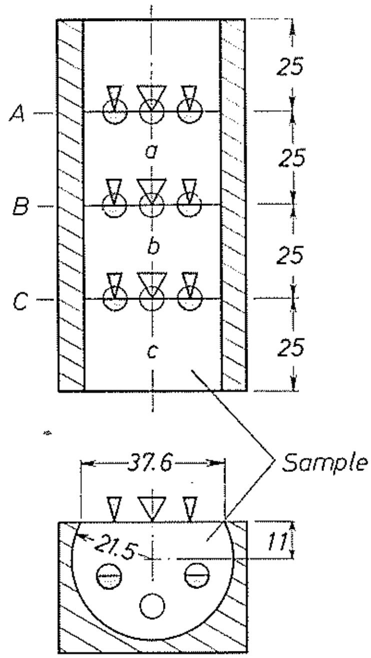

Fig. 15. Fixture with sample arranged for fall-cone testing. Triangles and circles indicate test points and cone angles, 30° and 60°, respectively.

Shear strength, axial (common vertical) cone test	± 13.6 %
Shear strength, radial cone test	± 10.6 %
Sensitivity	± 23.4 %
Natural water content	± 13.1 %
Fineness number	± 12.2 %
Quotient of radial and vertical cone test results (with an average value of 1.01)	± 5.8 %

The investigation shows that rather large mean deviations in, among other things, shear strength, can occur in test sections chosen at random in a specimen.

Another investigation of the same kind has also been made of about 50 specimens of varved clay from *Nälsta* near Stockholm. The dispersion of the cone test results were about the same.

The same main tendency of strength dispersion has also been found by Mr. *T. Kallstenius* (not published) in investigations made of other clays where the soil was more homogeneous but disturbances had caused great scattering.

With reference to the above, it seems more important to make many tests distributed in a vertical direction (radial tests) than in a horizontal one (axial tests). Furthermore, it is more suitable to test in the radial direction, so that various layers can accordingly be recognized. As far as these results are valid for other clays also, the author recommends, especially for varved clays, that the tests be performed in a radial direction.

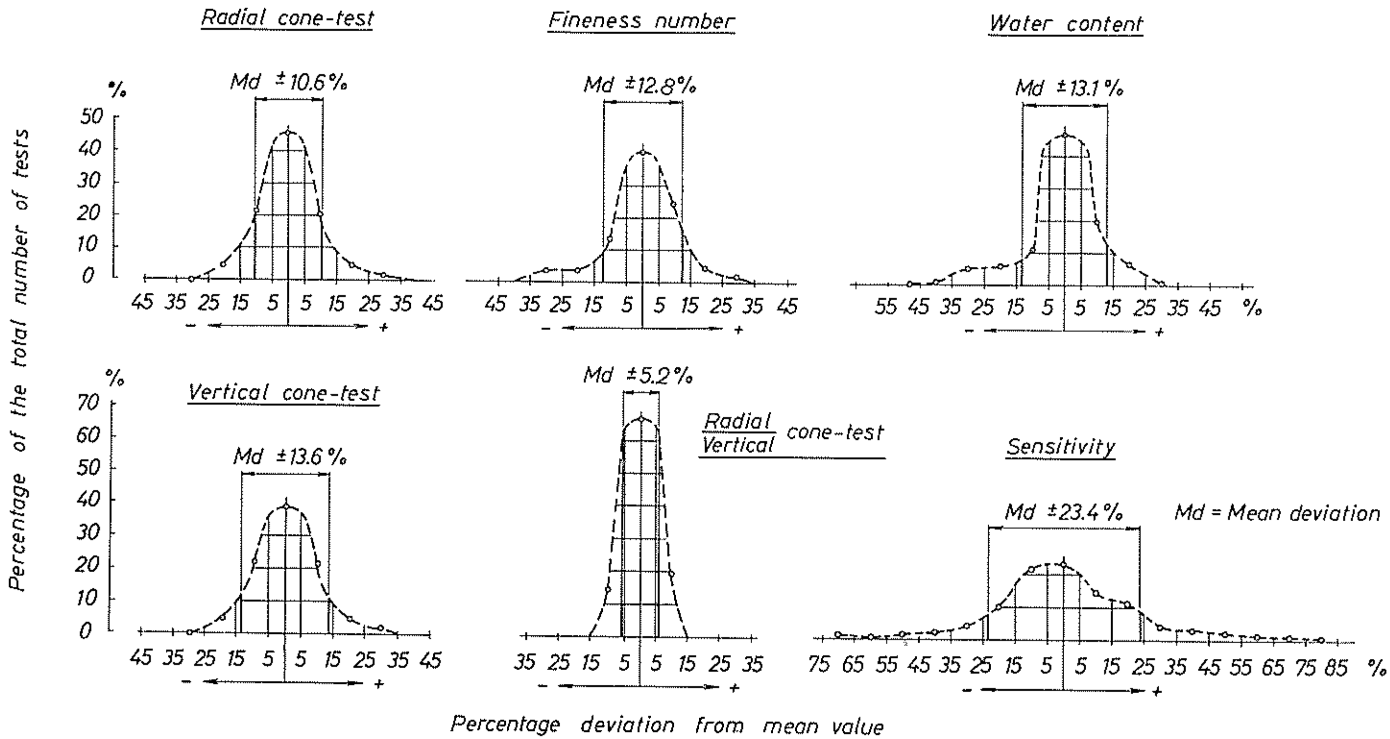

Fig. 16. Results from fall-cone tests in axial and radial direction. Frequency diagrams for deviation from mean values.

4. Sample Transportation Problems

By *E. Sandegren*

In 1954, the Geotechnical Department of the Swedish Railways Board investigated the effect of transport on the strength of so-called "undisturbed" clay samples (*Alte*, 1955[1]).[2] A number of different clay types were tested, some on the site, and some in the laboratory after railway transport. A decrease in strength was then observed for the transported samples. To begin with, this decrease was presumed to be caused by shaking and bumping during the transportation of the samples.

Later investigations (*T. Kallstenius,* 1958, *G. Sökjer-Petersen,* 1959, not published) show that the observed strength decrease of a sample is a question not only of transport but also of time. Experiments were therefore carried out by the Geotechnical Department on samples taken with a piston sampler, type SJ, in the *Kramfors* area. A series was tested on the site up to 10 minutes after the sample reached the ground surface, and another on the site 13 days later, and finally one in the laboratory in Stockholm 13 days after the sampling and another 18 days later after railway transport of about 530 kilometres. The series consist of samples from nine different levels represented by four samples each. The shear strength was determined by three cone tests on each sample. The average strength of the sample series decreased 8 %, 20 % and 18 %, respectively, compared to the series tested immediately on the site. Although no definite conclusions can be drawn from an experiment on such a small scale, the results seem to confirm that the time factor may play as important a rôle as the handling and the transportation of the samples in the reduction obtained of the strength of the clay.

The standard sampler prototype, developed by the Committee, disturbs the samples less than most older types. It is therefore important to pack the samples in such a way that as little as possible of the relative gain in strength, as compared to the results obtained from samples taken by the other samplers, will be lost during handling and transportation. Moreover, the samples should be protected against heat and cold.

[1] Alte, B., 1955. Redogörelse för jämförande försök med olika lerprovtagare. Stockholm (not published).

[2] Cf. also Hvorslev, M. J. 1949, Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes. New York. *U.S. Waterw. Exper. Station.*

In this connection the question of a suitable package for samples was discussed with the Railways Board. In the Board's design of the package it was considered that, for good results, it should withstand certain exertions and be satisfactory with respect to the following factors:

1) Impact from normal falls
2) Vibration during transport
3) Exposure to normal climate conditions
4) Endurance in being used many times
5) Simplicity in handling
6) Costs

Considering these factors, a package was developed in the form of a wooden case, the outer dimensions being 56 × 40 × 27.5 cm.

A shock absorbing medium of polyuretan is moulded into the box and its lid. The sample tubes, 24 in number, are put in furrows in the absorbent material and are kept in position. When filled with 24 samples, its weight is about 31–34 kg, depending on the unit weight of the soil.

Polyuretan has been chosen from several possible materials because of its elasticity at low temperatures and resistance to atmosphere. It also has a good shock absorbing effect on impact, which has been shown by laboratory tests. For this purpose an accelerometer was installed in a tube. The tube was then filled with soil and fall-tests were performed against different materials from varying heights. Some results are shown in Fig. 17.

Objections to this type of package are that it is rather expensive and also that the conventional wooden case should be replaced by another type of case, for instance of corrugated hard plastic, which is strong and light.

In order to facilitate the rapid and convenient transport of samples, for example with portable packages in which the field engineer can bring back the samples on his return, a package of moulded plastic foam has also been designed. The lid and the bottom are shaped alike one another, with furrows for tubes lying two abreast and ten lengthwise. A unit for 20 samples with total dimensions 71 × 38 × 8 cm has a weight of about 16-18 kg.

Several units can be packed together to form a packing measuring 71 × 38 × × 8 n cm, where n is the number of units packed above each other. For transport, a suitable number of units can be packed in a transport container.

The transport tests are being continued.

Investigations performed up to now have lead to the opinion that merely an improvement in the package cannot retain the above-mentioned gain in strength which is obtainable with the new sampler, since the strength decrease with time is also of influence.

The conclusion will be that the conditions of the samples and the time of storing should be observed. The author recommends that testing of the samples should, when possible, be performed in a field laboratory on the site as soon as possible after the samples have reached the ground surface.

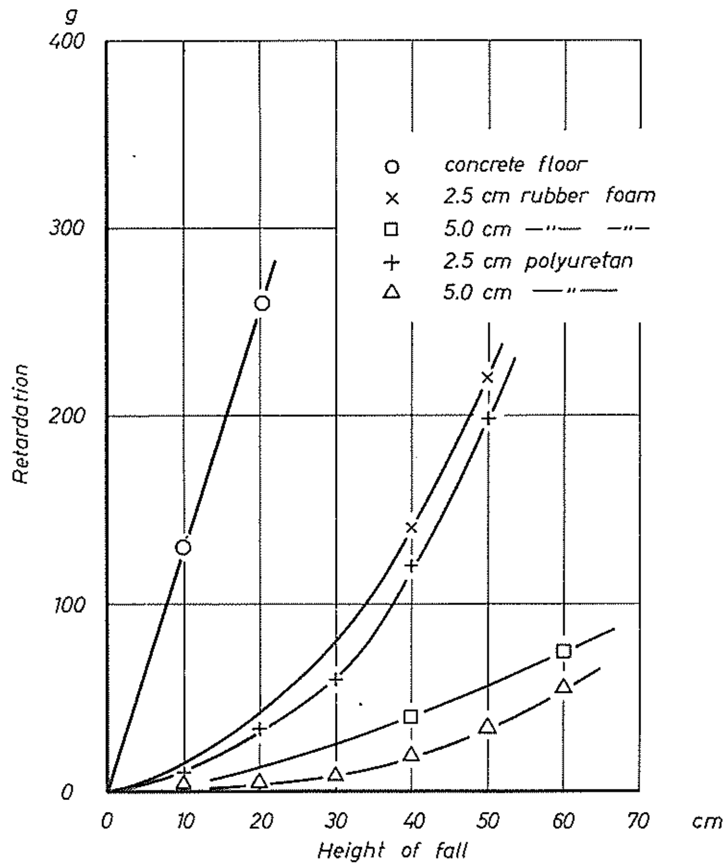

Fig. 17. Retardation, in g, as a function of height of free fall of sample tubes (filled with sand) on various materials.

It can be added that since 1954 the Geotechnical Department has had a laboratory railway car in service, in which samples from places where the disturbances were supposed to be of importance have been tested on the site. In 1960 another laboratory car with modern equipment was also taken in use. Between 1954 and 1960 several tests have been performed which in the main show the same decrease in strength for transported samples compared with samples tested on the site.

5. A Standard Piston Sampler Prototype

By *T. Kallstenius*

51. Principles

A piston sampler generally consists, as is well known, of two separate systems, the piston system and the sample cylinder system.

When sampling, both systems together are firstly pushed into the soil. At the desired level the piston system is to be fixed in relation to the ground, and the sample cylinder is then forced further downward, thus punching out a sample of soil.

Both systems together are then withdrawn with a soil specimen remaining in the sample cylinder.

The piston serves to keep the recovery ratio constant during the punch and to prevent the sample from falling out of the sample cylinder. For the latter purpose, the piston is tight-fitting and may create underpressure above the sample.

Normally the sampler cylinder is extended upwards to the soil surface by means of extension tubes and the piston is extended upwards to the soil surface by means of extension rods or tubes, which normally are to be fixed to a scaffold on the ground surface.

During the beginning of a punching stroke, excess soil pressure against the piston normally gives the piston a lifting tendency whilst after a certain stroke soil pressure has decreased and inside friction in the sample tube has increased sufficiently to cause a sinking tendency of the piston. The piston rod must therefore normally be able to resist forces in both directions in order to keep the piston fixed.

At the Swedish Geotechnical Institute a sampler was designed in co-operation with the Committee, as mentioned in the General Report. This sampler prototype was first called SGI XI and later on, when accepted as a standard, it was called St I. The sampler is shown in Fig. 18.

Here the sample cylinder system can be fixed to the piston during the pushing by means of a special lock capable of withstanding even hammering (*cf.* Fig. 18 a). This greatly facilitates the work of pushing the sampler into the ground as no inner parts are required above the lock.

Instead of an internal piston rod, a wire-rope of low extension properties and ample dimension is used to fix the piston to a scaffold on the ground surface when punching out of a sample is performed (Fig. 19). The wire-rope, provided

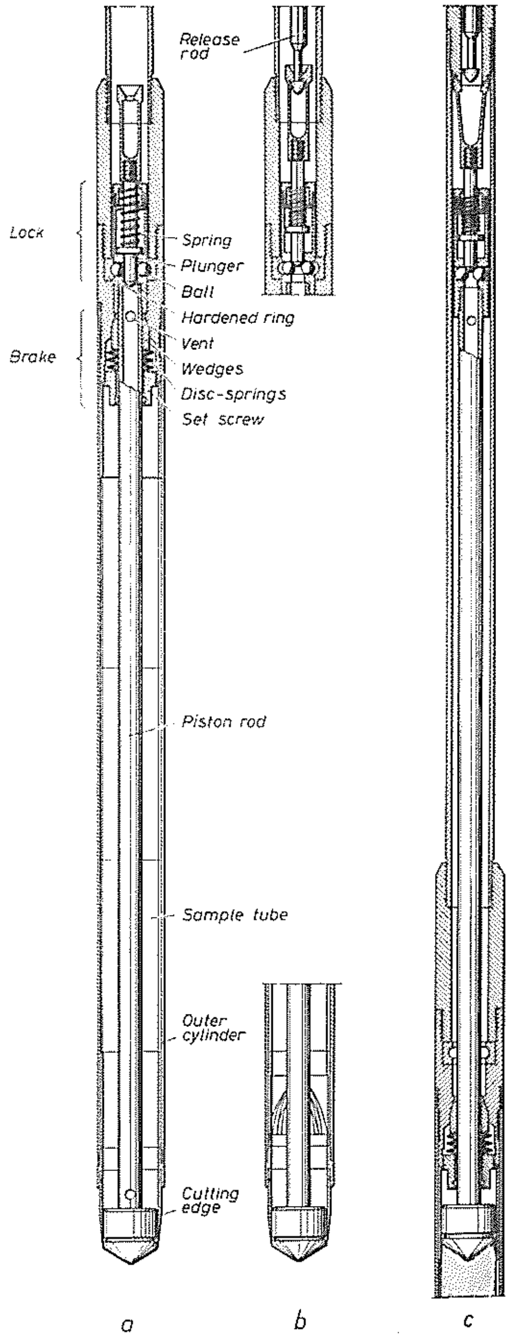

Fig. 18. Standard sampler prototype, St I (for dimensions, cf. Figs. 5—7)
a) Sampler before punching
b) After releasing the lock, alternative with shutter
c) When punching is finished and rod is released.

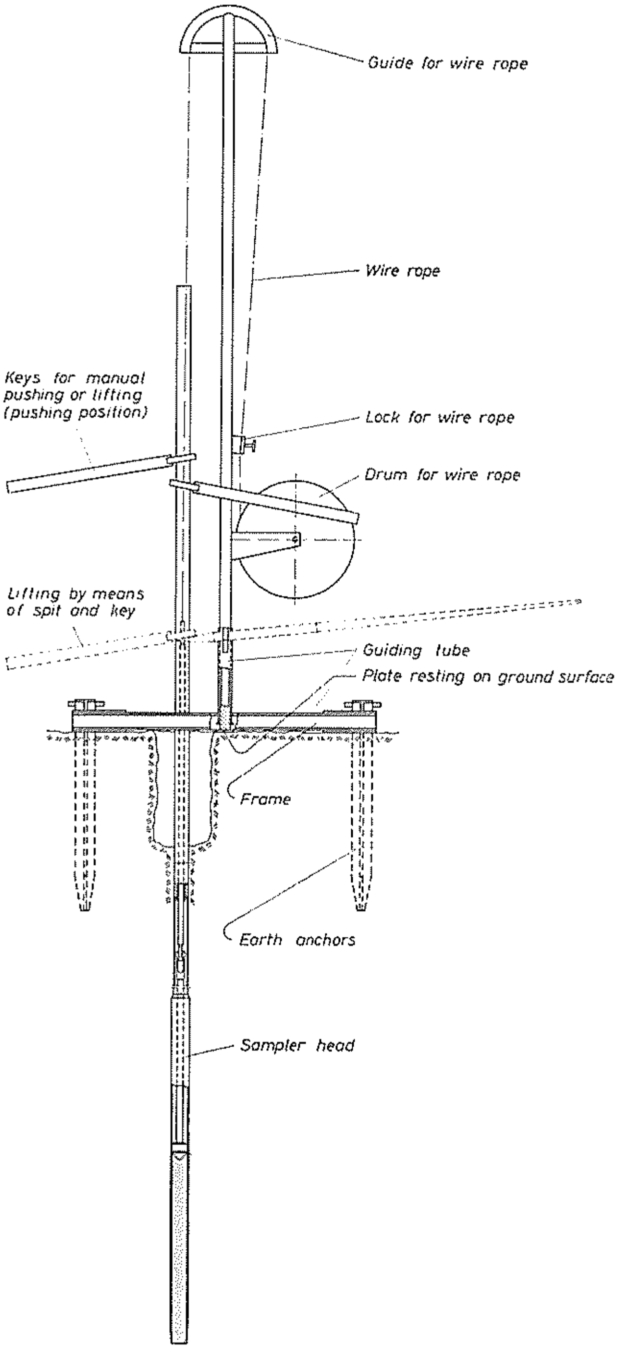

Fig. 19. Simple boring scaffold for standard sampler prototype.

with a release rod at its lower end, is sunk down in the extension tubes, gets hold of a release plug of the special lock mentioned above (*cf.* Fig. 18 b), and is stretched until the lock is opened.

The wire-rope can take no compression forces, and the piston would travel upwards after release if this were not prevented by a friction brake between the piston system and the sample cylinder system.

When 0.5 cm of the punching stroke remains, the connection between the release-rod of the wire-rope and the piston is separated by means of a conical ring situated in the extension rod near the sampler head (*cf.* Fig. 18 c). One can then remove the wire-rope before withdrawing the sampler. During the withdrawal, the piston is kept in position by the friction brake.

In this way one has secured simple and rapid handling of the sampler.

52. Design

Most of the dimensions of the sampler St I are given in the sampling regulations (*cf.* Section 16). Some parts may, however, need further explanation.

521. Cutting Edge

In order to secure good samples, the cutting edge is very sharp. As long as the edge is carefully treated and works in normal ground it can withstand great forces. When stones of some size appear in the ground the edge will, however, be damaged. To prevent this, the edge should be made so blunt that sample quality would be seriously affected. In order to enable cheap cutting edges, which can quickly and easily be exchanged, they are usually manufactured of precision-drawn mild steel tubes which need no shaping except to form the taper, a groove for the lock and cutting off. For special purposes the edges can, of course, be manufactured of high quality steel and hardened.

When sampling with a sharp edge, which gives less disturbance, also slight cohesion present in many natural soils may remain unbroken.

Experiences with frequent sampling in clay has shown that edge exchange may be necessary, say, once every hundred samplings. The cost of replacing edges is negligible compared to other sampling costs.

522. Outer Cylinder

For the same reasons as for the edges, the outer cylinder has been manufactured from precision—drawn mild steel tubes of proper diameter. Here also, special material may be chosen for extremely hard handling.

523. Sample Tubes

Brass tubes as hitherto used in Sweden react chemically with samples of clay; the sample tubes are therefore made of plastic (other reasons for this are stated in Section 1). Glass fibre reinforced polyester plastic was temporarily chosen and gives tubes of great strength and correct dimensions. The plastic tubes were inferior to brass ones only with respect to ovality but not to average outer and inner dimensions. A small ovality (less than twice the acceptable variation in the average diameter) may be acceptable as it, in fact, helps to centre the tube in the outer cylinder. There is no significant difference in the dimensions between brass tubes and the above plastic ones when situated in the sampler. The ovality must, of course, not be so great that the sample is disturbed by excess deformation of the tube when extruded from the outer cylinder. Furthermore, excess ovality is, of course, an inconvenience in the laboratory. It can, however, be disregarded when the difference between smallest and greatest diameter is less than 0.2—0.3 mm.

The sample tubes are tight and light. They have numbers engraved 5 cm from one end. This end should be placed upwards when sampling.

Tests with pressed sample tubes of plastic without reinforcement are started but not yet finished, but such tubes could be manufactured much more cheaply.

524. Sealing of Sample Tubes

The samples are cut off flush with the tube ends. Two circular plastic plates are laid against the cut surfaces and two tight-fitting reinforced rubber caps are applied in such a way that no air is trapped. This is a quick and reliable way of sealing the tubes. If one should desire waxing for long-term storage, this is more easily done in the laboratory.

525. Piston Rod

The piston rod is hollow to permit air or fluid situated above the piston to escape via connection holes. This part also can be manufactured at minimum cost from standard size tubing.

526. Lock

The lock consists of four hardened steel balls pressed against a hardened ring by a plunger. To prevent the plunger from releasing the balls during hammering, it is pressed downwards by a spring. When the plunger is raised, the bearings are free to travel inwards, and the lock becomes released. (The release rod mentioned above is coupled by means of two spring hooks, and one can then raise the plunger (*cf.* Fig. 16 b).

527. Brake

The brake consists of wedges which are pressed against the piston rod by disc-shaped springs and a set-screw. By tightening the screw, the braking force can be increased from a few kilograms to about 200 kilograms. Normally, the brake need be set only slightly (half a turn of the screw after it has begun to give resistance). With increasing depth the screw is set more when experience during the running sampling shows that the wire-rope (see below) has a tendency to begin slackening.

The disc-springs ensure less dependence on the exact position of the set-screw.

528. Wire-Rope

A wire-rope is usually lighter and easier to handle than the rods which have hitherto been common in Sweden for extension of the piston upwards or for releasing. On the other hand, one must be especially careful not to damage the wire-rope. If it becomes too much buckled, it should no longer be used.

The wire-rope must, as mentioned above, have low extension but must be sufficiently flexible. A rope of 6 mm diameter with a total of 49 wires without hemp core has been found suitable. (The tension forces in the wire-rope are normally less than 100 kg.) It must necessarily be wound up on a drum, and this drum must be situated in a fixed frame to avoid twisting of the wire. Arrangements for handling it are shown in Fig. 19.

In order to release the lock of the sampler, a certain tension must be created in the wire-rope. After the lock has been released, the uplift pressure against the piston and also the effect of other factors tend to decrease the tension. If then the brake is too loosely set, the piston may be lifted a little and the wire-rope slackened. This need not disturb sampling if only the rope is stretched before punching. During the main punching out of the sample, the force in the rope varies very little, and if a change occurs, it will be gradual.

Measurements of the piston travel were taken by means of a thin wire under constant tension. It was fastened directly to the piston. No travel could be measured. Theoretical considerations indicate, however, that the travel of the piston normally might be about 1 mm.

There is, of course, always the possibility to use rods also for sampler St I, but it has been proved that, if properly handled, a wire-rope gives equal sample quality and facilitates sampling at depths below, say, 5 metres, where rods must be connected and disconnected.

529. Extension Tubes

These tubes are standard European diamond drill tubes of 42 mm external diameter with flush joints and of one metre effective lengths. Of course, the use of drill tubes is optional. Flush joints facilitate handling and cleaning of the sampler.

53. Sampling Operation and Equipment Used

In the regulations it is stated that the fixing of the piston should be independent of earth anchor travel. Of course several types of boring rigs are possible for that purpose.

A very light and simple rig has been constructed to fulfill the minimum requirements (Fig. 19) and works as follows.

The wire-rope is guided over a bent and slit up tube welded on a vertical pipe to which a lock and the pivot for the wire drum are fastened. The pipe passes a guiding tube and rests against a horizontal plate placed directly on the ground. This is so, even if the guiding tube—being a part of the frame, which is secured to the ground by means of earth anchors—should be lifted (if the earth anchors give way because of the driving force).

In the frame, pushing or pulling can be performed by means of simple spits when necessary. This driving scaffold is perhaps more primitive than desired in many cases but is suitable in soft soil to shallow depths, especially where pushing by hand is possible. As mentioned above, the punching ought to be performed continuously. (In tests performed, in clay, the sample quality was, however, not reduced by using discontinuous punching by means of spits instead of punching continuously.) More advanced scaffolds are provided with transmissions for the required continuous stroke.

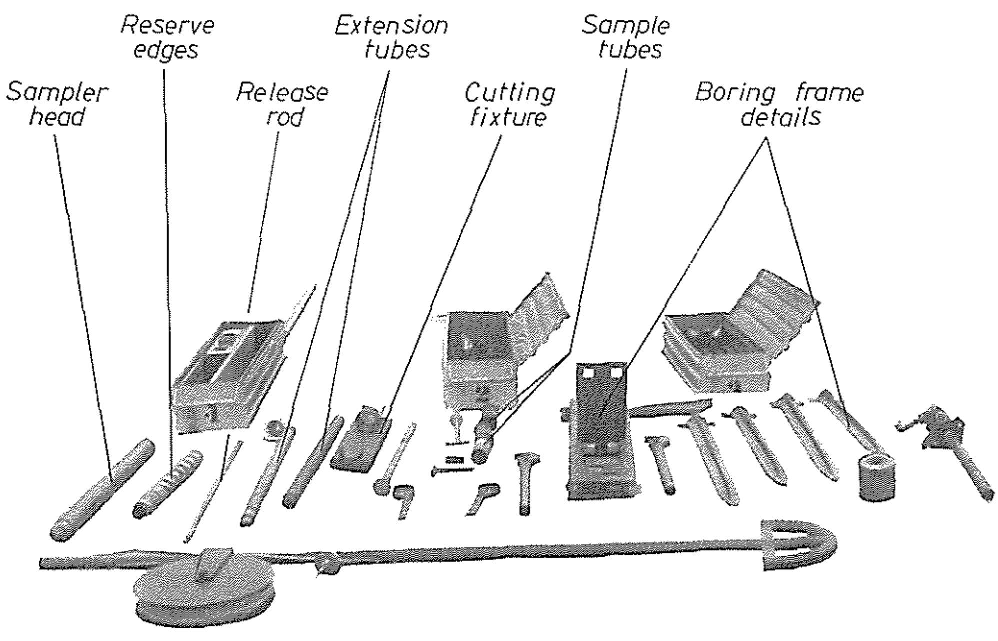

Fig. 20. Set of standard sampler equipment.

In hard ground the scaffolds must resist higher forces and hammering will be necessary on many occasions in practice.

In Fig. 20, a complete set of standard sampler equipment is shown, and Fig. 21 shows the sampler equipment when a punching operation is performed.

Fig. 21. Standard sampler during punching.

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		Year	Sw. Crs. Price
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2.	The Vane Borer. An Apparatus for Determining the Shear Strength of Clay Soils Directly in the Ground. *Lyman Cadling* and *Sten Odenstad*	1950	4:—
3.	Device and Procedure for Loading Tests on Piles. *W. Kjellman* and *Y. Liljedahl*	1951	3:—
4.	The Landslide at Sköttorp on the Lidan River, February 2, 1946. *Sten Odenstad*	1951	4:—
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6.	A New Geotechnical Classification System. *W. Kjellman, L. Cadling* and *N. Flodin*	1953	4:—
7.	Some Side-Intake Soil Samplers for Sand and Gravel. *Torsten Kallstenius*	1953	4:—
8.	Influence of Sampler Type and Testing Method on Shear Strength of Clay Samples. *Bernt Jakobson*	1954	4:—
9.	Some Relations between Stress and Strain in Coarse-Grained Cohesionless Materials. *W. Kjellman* and *B. Jakobson*	1955	4:—
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11.	Influence of Organic Matter on Differential Thermal Analysis of Clays. *Lennart Silfverberg*	1955	4:—
12.	Investigations of Soil Pressure Measuring by Means of Cells. *Torsten Kallstenius* and *Werner Bergau*	1956	4:—
13.	Pore Water Pressure Measurement in Field Investigations. *Torsten Kallstenius* and *Alf Wallgren*	1956	4:—
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	D:o med plastpärmar för fältbruk ...	1961	10:—
5.	Kompendium i geoteknik 1959 ...	1959	12:—