RAPID CONSOLIDATION TESTS

- ON SILT CLAY MIXTURES

THESIS

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R A P I D   C O N S O L I D A T I O N   T E S T S

- ON   SILT   CLAY   MIXTURES

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A C K N O W L E D G E M E N T

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A B S T R A C T

The aim of this project " Rapid Consolidation Tests", was to see whether the soil consolidation parameters found by Rapid Consolidation Tests are comparable with the ones obtained by the Standard Consolidation Test, for the purposes of estimating soil settlements. Laboratory prepared mixtures of silt-clay soil with Bentonite were tested, and thus a wide range of soil plasticity was covered .

It was found that these soil parameteres are in reasonable agreement in most cases. The differences are certainly below the level of engineering significance. Also it was found that the applicability of the Rapid tests (i.e.whether it can be completed in a working day) was limited by the Activity of the clay of the soil .

TERMS AND DEFINITIONS

The definition of the terms which will be adopted in this project, as well as their respective symbols and dimensions, are in close agreement with those recommended by the " American Society of Civil Engineers ", Soil Mechanics Journal vol. 84, proc. paper I826 (I958).

If no dimension is added, the symbol indicates a dimensionless term. They are as follows:-

a_v ($cm^2/kg.$) Coefficient of compressibility.- Is the secant slope, for a given pressure increment, of the " Pressure-void ratio curve".

Cc Compression index.- Is the slope of the linear portion of the " Pressure-void ratio curve," on a semilog. paper.

Cv (cm^2/min) Coefficient of consolidation.- Is a coefficient containing the physical constants of a " Soil " affecting its rate of volume change.

m_v	($cm^2/gr.$)	Modulus of volume compressibility.- Is the compression of a " Soil " layer per unit of original thickness due to a given unit increase in pressure.
u	($kg./cm^2$)	Excess hydrostatic pressure.- Is the pressure that exists in pore water in excess of the hydrostatic pressure.
H	(cm)	Drainage path.- Is the half-thickness of soil layer in double drainage.
K	(cm/seg)	Coefficient of permeability.
P	(kg/cm^2)	Applied pressure.
t	(min)	Time.
T		Time factor.- Is the factor containing the physical constants of a " Soil " stratum influencing its time-rate " Consolidation ".
e		Void ratio.
L.L.		Liquid limit.

P.L. Plastic limit.

P.I. Plasticity index.- Is the numerical difference between the liquid limit and the plastic limit.

m.c. Moisture content.- Is the ratio expressed as a percentage of the weight of water in a given " Soil " mass to the weight of solid particles.

Gs Specific gravity of solids.

γ_w (gr/cm^3) Unit weight of water.

Thixotropy The property of a material that enables it to stiffen in a relatively short time on standing, but upon agitation or manipulation to change to a very soft consistency or to a fluid of high viscosity, the process being completely reversible.

C.F. Clay fraction.- Percentage by weight of particles finer than 2 microns.

Act. Activity: (1)- Is the ratio of the plasticity index to the clay fraction.

For inactive clays- activity < 0.75

Normal clays - activity 0.75 to 1.25

Active clay - activity > 1.25

(1).- Concept introduced by Skempton to describe the colloidal " Activity " of clays. 3rd International conference, Soil Mechanics. vol. 1. 1953.

CHAPTER I

INTRODUCTION

The study of soil settlement under various structures is of a primary importance for the foundation engineer.

The problem of most concern is when differential settlement occurs among the various parts of the structure, which together with the problem of the uniform settlement, may cause total or partial damage to buildings, dams, embankments or to the services of the structure.

The magnitude of the total settlement that a soil will undergo under the load of a structure, and the settlement that may occur at any time during the life of the structure, could be estimated by obtaining the soil parameters from a consolidation test .

The consolidation test is the laboratory application of Terzaghi's Theory Of Consolidation, where a soil sample is allowed to come into equilibrium under a series of loads, so that a relationship between void ratio- applied pressure and time - consolidation relationships can be obtained .

In the standard consolidation test, the load is applied in daily increments, with the standard increment ratio of

$\Delta P/P = 1$, where the total load is doubled each 24 hours.

In this project " Rapid Consolidation Tests", the duration of the load is reduced to the duration of the primary consolidation only.i.e. the next increment is applied as soon as the primary compression in the preceding increment is over. This is reasonable for soils that exhibit little or no secondary consolidation; hence, the consolidation test will be completed in few hours in comparison with several days for the standard test. This means a considerable saving in machine time, hence, reducing the unit cost of testing.

CHAPTER II

PURPOSE AND SCOPE

The purpose of the present work is to investigate the effect of the following factors :-

I - Duration of loading.

2 - Load increment ratios.

3 - Increased drainage at sample boundaries.

4 - A higher initial load.

With a view to determine whether the soil parameters found by such rapid consolidation tests, are comparable with the ones obtained by the standard test.

The tests were conducted using slurried samples of silt-clay mixtures, obtained by combining a natural silt-clay soil from Rachaya(Lebanon), with different amounts of Bentonite (Montmorillonitic Clay). These mixtures were tested by both standard and rapid consolidation tests.

The data obtained from the various tests are presented in this work, and an attempt is made to interpret the significance of the results.

CHAPTER III

THEORY OF CONSOLIDATION

The first theoretical treatment of consolidation, was made by Terzaghi in 1923, and, for lack of a better working model, this theory is still used today, by foundation engineers. Terzaghi considered that the consolidation process was a gradual transfer of load, from the pore water to the soil skeleton, the speed of this transfer being controlled by the rate at which pore water drains from the soil.

The consolidation process was considered complete when all applied load was taken by the soil skeleton, i.e. the excess hydrostatic pressure caused by the applied load, was zero. The amount of volume change, or consolidation would be controlled by the excess hydrostalic pressure, and in the Terzaghi theory this was considered equal to the applied load.

It is well known that this concept ignores the phenomenon of secondary consolidation, (which is a gradual process of volume change, due it is thought to a slow readjustment of clay particles within the soil). In highly plastic and organic clays, secondary consolidation can contribute largely to the total consolidation process. The theory also implies that primary consolidation - the drainage of pore water, as above and secondary consolidation, are two separate processes, secondary consolidation starting when the primary is completed. Despite these shortcomings, the parameters used for settlement analysis are obtained from fitting the results of a consolidation test, to the theoretical curves obtained from the Terzaghi's Theory.

In order to develop theoretical equations, Terzaghi made certain simplifying assumptions.

Assumptions are as follows :-

The soil is homogeneous.

The compression is one dimensional, i.e.no lateral expansion is allowed .

The soil is fully saturated .

The pore water and soil skeleton are incompressible.

The drainage of pore water is governed by Darcy's Law.

There is one dimensional flow of pore water.

There is a straight line relationship between pressure and void ratio .

Incorporating these assumptions, and equating change in volume to rate of drainage of pore water, the result is a partial differential equation :

$$\frac{\partial u}{\partial t} = c_v \frac{\partial^2 u}{\partial z^2}$$

With z and t being independent variables in direction of flow and time and U the dependent variable of excess hydrostatic pressure. The quantity C_v is a soil parameter named coefficient of consolidation, which can be expressed as : -

$$C_v = \frac{K(1+e)}{a_v . \gamma_w}$$

With the appropiate boundary conditions, this equation is solved in terms of average consolidation of a layer of soil, and a dimensionless parameter T - the time factor. The solution is expressed conveniently in the form of a curve relating U & T so that it is general, and once the curve is available, no further use is made of the equations.

In order to relate the results of a consolidation test to the consolidation theory, it is necessary to fit the experimental data to the theoretical curve U versus T and in this way the time- compression data from the experiment, is converted to a time- consolidation curve, the link between theoretical and actual curve being C_v, i.e.

$$T = \frac{C_v . t}{H^2}$$

Therefore, time - consolidation estimates can be based upon the above equation and amount of settlement can be obtained from experimental changes in volume during specific load increments, usually by means of a_v or C_c

It is clear from the above considerations that only the consolidation due to the primary process is accounted for .

However, with soil in which the secondary consolidation process is significant, it is reasonable to assume that some of the secondary consolidation is incorporated in the primary part and is thus not completely ignored in settlement estimates.

In order to fit the experimental data to the theoretical U - T relationship, two methods can be used. These methods which relate laboratory data of compression dial versus time are as follow : -
The square root of time fitting method, devised by Taylor(1948) and the logarithm of time fitting method devised by : -
A. Casagrande .

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CONSOLIDATION TEST (STANDARD AND RAPID)

As defined in " glossary of terms and definitions in soil mechanics ", A.S.C.E. proc. paper I826(I958) , a consolidation test is a test in which the specimen is laterally confined in a ring and is compressed between porous stones.

The standard procedure generally adopted for the consolidation requires that each increment of load is applied to the test sample for a time sufficient to ensure the completion of primary consolidation, so that the point of I00% primary consolidation can be found, according to theory. This time is usually taken as 24 hours, and in many types of soil, such a load increment time allows a substantial amount of secondary consolidation to take place; therefore, in the standard test, where the load increment ratio is I (the load of next increment is twice the load of the preceding one), depending on the range of loads used, and the amount of unloading and reloading required, the test may take more or less days to complete.

For soils that exhibit little or no secondary consolidation, and for routine investigations for settlement calculations, there would seem to be no reason why the " increment time " in the consolidation test cannot be reduced to the duration of the primary consolidation only.

This time may be very short,- a matter of minutes rather than 24 hours- and consequently a complete "rapid " consolidation test can be completed in a few hours. This would mean that con solidation machines would not be tied up with one sample for long periods, and also settlement estimates can be obtained in a much shorter time than presently possible. To reduce further the loading time, higher load increment ratios may be used to speed up the primary consolidation process.

This concept of a rapid consolidation test is not new; Karol (1951) compared 20 minutes and 24 hours increments on samples 1/2" high. Northey (1956) compared 20 minutes and 24 hours increments on samples 3/4" high, and Leonards and Ramiah (1959) compared 4 hours and 24 hours increments on samples 1 1/2" high. The results from the above mentioned work shows good agreement with the standard test. However, all this work was done on specific soils from specific areas, and at present, no work has been attempted to investigate fully the potential of the rapid consolidation test over a wide range of soil types.

CHAPTER IV

EXPERIMENTAL WORK

The experimental work done on the different soils of this project are presented below.

1- SOIL DESCRIPTION

The samples on which the tests were carried out consisted of silt-clay mixtures that ranged from 12% to 68.1% of clay fraction. These mixtures were obtained by combining a natural silt-clay soil from Rachaya (Lebanon) with different amounts of Bentonite (a montmorillonitic clay).

The consideration governing the choice of Laboratory made rather than undisturbed samples, were as follows:-

a- With the present sampling equipment available, it could be difficult to obtain good undisturbed samples in the field.

b- From the point of view of time available, more soil types could be tested, and more tests performed by using laboratory made samples.

c- A wider range of plasticity could be obtained by artificial mixes, than could be obtained by undistrubed samples.

These combinations of Rachaya and Bentonite were made on the basis of dry weight. e.g. per 100% of weight of B10R90, 10% and 90% per weight corresponds to Bentonite and Rachaya respectively.

The only deviation from this procedure was the sample called " Silt-Rachaya ". This soil was obtained by mixing in water for 10 minutes, 75 gr. of Rachaya with 2 C.C. of deflocculating agent (10% solution of Daxad 23); Water was added to bring the level to the 1000 C.C. mark. This solution was then allowed to sediment in a graduated cylinder (1000 C.C. capacity) for a period of 10 hours approximately. At the end of this period, the soil which had accumulated at the bottom was taken and dried. This period of 10 hours for the time of sedimentation, was found by a trial and error method based on the hydrometer analysis of Rachaya.

Thus eight mixtures were obtained, with percentages of Bentonite varying from 5% (B5R95) to 75% (B75R25).

II.- SOIL PROPERTIES:

The following tests were performed on the soils used in this project, the results of which are presented in table 1.

a- Grain Size Analysis: A combined grain-size analysis (sieve and hydrometer) was performed on the " Rachaya " and " Bentonite " samples, in order to find their respective granulometric curves.

These results were used to find the granulometric curves of the different mixtures, based on the method of proportioning mixtures of aggregate by Rothfhchs (I935). In order to check this method, hydrometer analysis were carried out on the mixtures B10R90 and B50R50. It was found that the results agreed within 2 or 3 %, hence Rothfuchs method was adopted for the rest of the granulometric curves.

The granulometric curves of the 10 soils are given in fig. 1 & 2.

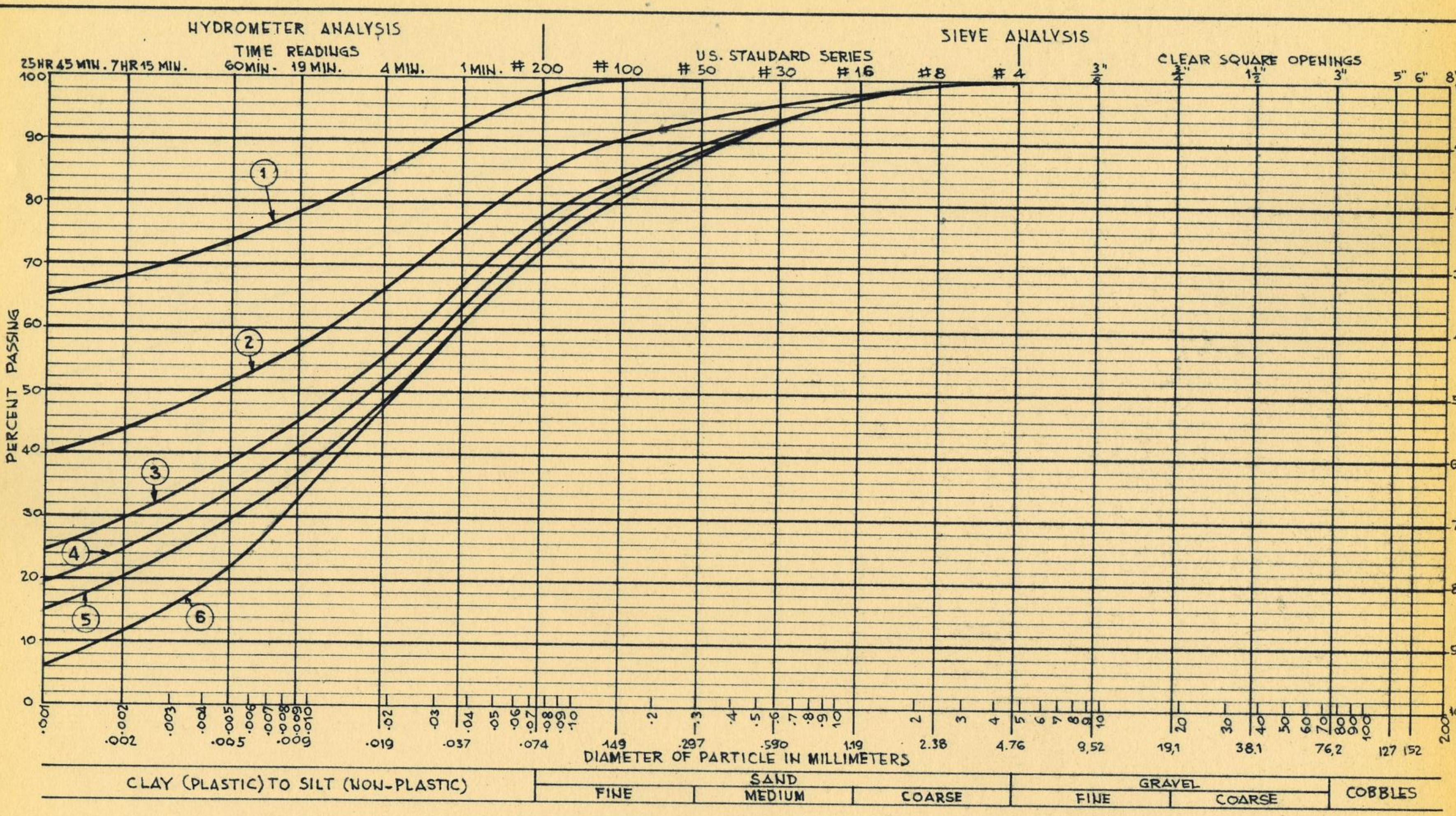
The clay fraction content of each soil was thus obtained from its granulometric curve, and are listed in table 1.

b- <u>Atterberg Limts</u>: Liquid limit and plastic limit tests were performed on each type of soil according to standard procedures. The above determinations are presented in table I.

c- <u>Specific Gravity</u>: The specific gravity of solids Gs was determined for each soil by the density bottle method, using a 50 m.l. density bottle. Because of the swelling properties of the Bentonite in water due to its high liquid limit, kerosene was used as the displacing liquid in these determinations.

SOIL DESCRIPTION	L.L. %	P.L. %	P.I. %	C.F. %	ACTIVITY
SILT-RACHAYA	36	19	17	I2	1.41
RACHAYA	38	20	I8	20.2	0.89
B5R95	42	21	21	22.4	0.94
B10R90	52	22	30	24.8	1.21
B15R85	68	24	44	27.2	1.62
B20R80	86	26	60	29.6	2.03
B25R75	104	28	76	32.0	2.37
B50R50	191	30	161	44.0	3.66
B75R25	320	43	277	56.1	4.94
BENTONITE	4I8	52	366	68.1	5.37

Table No. 1.



GRANULOMETRIC CURVES

(1) BENTONITE
(2) B 50
(3) B 20
(4) B 10
(5) RACHAYA
(6) SILT-RACHAYA

Fig. Nº 1

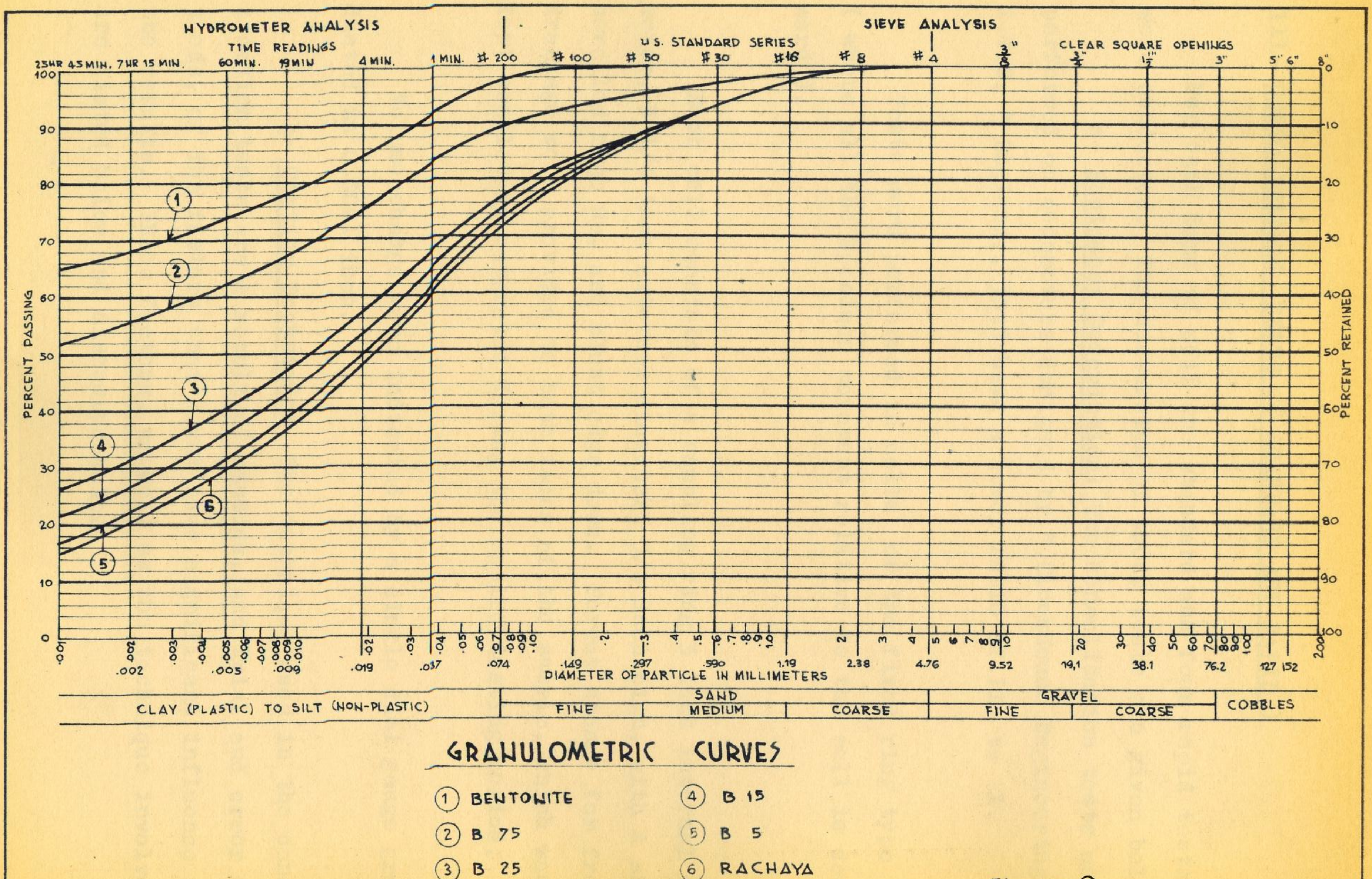

HYDROMETER ANALYSIS
TIME READINGS
25HR 45MIN. 7HR 15 MIN. 60MIN. 19MIN 4MIN. 1MIN.
SIEVE ANALYSIS
U.S. STANDARD SERIES
200 # 100 # 50 # 30 #16 # 8 # 4
CLEAR SQUARE OPENINGS
3/8" 3/4" 1 1/2" 3" 5" 6" 8"
PERCENT PASSING
PERCENT RETAINED
DIAMETER OF PARTICLE IN MILLIMETERS
.002 .005 .009 .019 .037 .074 .149 .297 .590 1.19 2.38 4.76 9.52 19,1 38.1 76.2 127 152
CLAY (PLASTIC) TO SILT (NON-PLASTIC)
SAND
FINE
MEDIUM
COARSE
GRAVEL
FINE
COARSE
COBBLES
GRANULOMETRIC CURVES
1 BENTONITE
2 B 75
3 B 25
4 B 15
5 B 5
6 RACHAYA

Fig. No 2

111- CONSOLIDATION TESTS (STANDARD AND RAPID)

For each type of soil one standard and four rapid tests were conducted. The discussion of these tests are given below.

a- Equipment Description: The consolidation tests were performed on oedometers designed by " ClockHouse Engineering L.T.D. " England., that have a lever ratio of 11 to 1.

Tests were performed in cells of the fixed ring type (where all the specimen movement relative to the cell is downward).

Each cell consists of a sampling ring 3 inch internal diameter, 3 1/4 inch external diameter, 3/4 inch high, with a sharp bevelled edge up, and blunt edge down. Porous stones for free drainage were provided to both faces of the sample, which was kept completely saturated during the entire testing period.

Volume change were indicated by a single dial gauge graduated in 0.0001 inch.

b- Testing Technique: The technique used in the consolidation tests are a result of studies, and trial and error methods, of the factors that might have significant influence in the results. These factors, as well as the technique involved are listed below and discussed later.

1- Soil sampling.

2- Duration of loading.

3- Load increment ratio.

4- Increased drainage at sample boundaries.

5- A higher initial value of load increment.

6- Side friction effect.

1- <u>Soil Sampling:</u> The work has been done with slurried samples of the different laboratory made mixtures of Rachaya and Bentonite as described before. Slurried samples were mixed to a water content corresponding to only a few blows of the liquid limit, in order to ease the manipulation and preparation of the sample. Thus, an initial starting point of water content for standard and rapid consolidation tests was achieved, facilitating the comparison of the results. After preparation, slurried samples were tested as soon as possible, in order to avoid an increase of the strength of the material by thixotropy.

It was found, that for the mixtures of high percentage of Bentonite, namely B20R80, B25R75, B50R50, B75R25 and Bentonite, the initial starting point of water content corresponding to a few blows below the liquid limit resulted in excessive compression,- due to high compressibility of the montmorillonite together with high void ratio of the soil,- and the oedometer machine got stuck early in the loading sequence.

Two alternative procedures were tried for these soils:-

1- To start with a water content very much below the liquid limit.

2- Keep the original water content but use smaller loads e.g.- an initial load of 1/32 kg. / cm^2. Both alternative resulted in a high loading duration, and it was apparent that it was impossible to complete a rapid consolidation test in a working day. Thus, for the purpose of this present project, the above mentioned soils were discarded. The high loading duration may be explained in the first case by the pore water being held by capillary action, at low moisture content. In the second case, by a slow volume change at low load increments.

2- <u>Duration Of Loading:</u> As mentioned before, one standard and four rapid tests were conducted for each soil. In the standard test, the duration of the loading was 24 hours, and in all the rapid tests described in this project, the duration of loading was taken as the duration of the primary consolidation only. This time of primary consolidation completion was obtained by applying the square root of time fitting method to the laboratory data of compression dial versus time. These results were plotted whilst the test was being carried out, so that loads could be changed without delay.

3- Load Increment Ratio: In the standard test, the load increment ratio is 1,- the load of the next increment is twice the load of the preceding one.
In the rapid tests, a load increment ratio of 1 was also used, together with a load increment ratio of 2 and 3, - where the load of the next increment is three and four times the load of the preceding one respectively. The reason of having higher load increment ratio is to reduce the time of the consolidation test, by means of reducing the number of load increments.

4- Increased Drainage At Sample Boundaries: The effect of the application of filter paper between the soil sample and the porous stones in the rapid tests, was also studied. Thus, rapid tests having filter paper were conducted for the following soils namely:- Silt-Rachaya, Rachaya, B5R95, and B10R90.

5- A higher Initial Load: In order to reduce further the duration of the rapid tests, an initial load of 0.5 kg / cm^2 instead of the standard initial value of 0.25 kg / cm^2 were conducted in 2 soils, namely B10R90 and B15R85. These soils were chosen in view of the high load duration of the first increment.

6- Side Friction Effect: The effect of side friction was not considered in this project due to a lack of time. A thin coating of grease was applied to the interior face of the ring in order to reduce this effect.

CHAPTER V

PRESENTATION AND DISCUSSION OF RESULTS

Only the results of the consolidation tests carried on the soils Silt-Rachaya, Rachaya, B5R95, B10R90 and B15R85 are presented in this chapter, since results of the consolidation tests on the remaining mixtures namely B20R80, B25R75, B50R50, B75R25 and Bentonite, were impossible to achieve, due to reasons mentioned before. They are presented in appendix "A" directly in graphical form. A tabulation of the results can be found in appendix "B".

Of primary interest, in comparing the standard and rapid tests, is the comparison of parameters used in settlement analysis, namely a_v and c_v. The log. pressure-void ratio curves are thus plotted, together with curves of log.p - a_v and log.p - c_v, for both standard and rapid tests.

COMPARISON OF RESULTS

a- Void Ratio - log. Pressure Curves: Fig. 4 shows the e - log. p curves of the five consolidation tests (one standard and 4 rapid) carried out on Silt-Rachaya. Similar presentation is made for the other soils and are shown in fig. 6, 8, 10 and 12.

It will be seen from these graphs, that-for each type of soil- an agreement of slopes is obtained for the various rapid tests compared with the standard one. There is however a tendency for the e - log.p curve of the standard test to remain below the others. This may be explained, because in the standard test, lower void ratios can be achieved due to the fact that we are allowing the sample to compress for more time (specifically 24 hours) hence, some secondary consolidation can take place. This cannot be considered as a general rule from the results, and exceptions may be considered as variations in the samples. The main interest in these curves for the purpose of this project, is the slope, as both compression index Cc and coefficient of compressibility a_v are a function of the slope. The close agreement of the slopes of the e - log.p curves for the Standard and Rapid tests, is illustrated more clearly in the comparison of the a_v - log.p curves.

b- <u>Coefficient of Compressibility a_v - log.Pressure:</u> Fig. 5 shows the a_v - log.p curve of the standard test of Silt-Rachaya, together with the corresponding 4 rapid tests. Similar presentation is made for each one of the other soils, and are shown in fig. 7, 9, 11 and I3.

It will be seen that apart from the first few increments, the agreement between the rapid and standard tests is quite close. The scatter of results in the first increments, may be explained by the initial conditions varying for each sample. It is suggested that the major reason here is the thixotropic regain in strength due to the Bentonite, which will vary with the Bentonite content - the effect being greater, the higher the bentonite content - and with the time between preparation of sample and starting the test.

The a_v - log.p curves of the standard tests of the different types of soils are shown in fig. 3. It can be seen that a_v is smaller the lower the clay fraction present in the soil; Although these curves are separated in the first few increments, the tendency is to converge to a common value of a_v as the sequence of loading is progressing. This behaviour may be explained by the fact that for higher % of Bentonite, higher void ratios are obtained. As the pore water drains, the rate of change of the void ratio with respect to pressure is larger at these high Bentonite contents, compared with the same void ratio changes at lower Bentonite content.

c- <u>Coefficient of Consolidation c_v - log. Pressure</u> : Simmons (1965) found that for undisturbed norwegian clays, Casagrande's logarithm of time fitting method usually gives more reliable results than Taylor's square root method for the determination of 100 % consolidation. Also for standard tests, the usual curve fitting method used is the Casagrande log. method, as the asymptote of the time - compression curve is usually well defined. Moreover, from the mathematical solution for the consolidation expression, it can be said that T = 0.197 at

$U = 50\ \%$ gives more accurate results than $T = 0.848$ at $U = 90\%$ and hence c_v is usually calculated, using the time for 50 % consolidation.

In order to compare the coefficient of consolidation c_v for the standard and rapid tests, a base of comparison of c_v for the standard test based on $U = 50\ \%$ from the log. fitting method is taken, due to reasons given above. The log. fitting method cannot be applied to the rapid tests, since the asymptote of the consolidation curve (compression dial - time) cannot be obtained because the sample is not allowed to consolidate more than the 100 % of primary consolidation. For these reasons exposed above, a value of c_v for all the rapid tests is taken based on $U = 50\ \%$ from the square root of time fitting method (Taylor I948).

Sample construction of c_v for both square root of time and log. fitting methods are given in appendix " C ".

Fig. 15 shows the c_v - log. p curves of the five consolidation tests (one standard and 4 rapid) carried out on Silt-Rachaya. Similar presentation is made for the other soils and are shown in fig. I6, I7, I8 and I9.

It will be seen from these graphs, that - for each type of soil - there is a good agreement between the rapid and standard tests. More this agreement being closer the higher the Bentonite content. This closer correlation for the values of c_v in soils with high percentage of Bentonite could probably be explained by the fact that the relative error of fitting the time - compression curve to the theoretical consolidation curve, is less the larger the consolidation time.

The c_v - log. p curves of the standard tests of the different types of soils are given in fig. 14. From these curves it may be seen that :-

1- The coefficient of consolidation c_v, decreases as the percentage of Bentonite increase. This may be explained by the permeability - being less in soils with a higher clay content (c_v is proportional to k). It requires more time in soils with high percentage of Bentonite to achieve the same drainage path than in soils with low percentage of Bentonite (high permeability).

2- The variation of the values of c_v (between any two limits of pressure) is less when more percentage of Bentonite is present. This may be explained by considering c_v is proportional to H^2/ t . In soils with a low Bentonite content, (e.g. Rachaya) it was found that H^2/t increases as applied pressure increases. i.e. t is decreasing more rapidly than H^2. On the other hand, with higher Bentonite content changes in H^2/t are smaller, as changes in H^2 are comparable to changes in t.

EFFECT OF CLAY CONTENT AND ACTIVITY

It is expected that the time and amount of consolidation would increase as the amount of clay in the soil increases. Another factor influencing the consolidation characteristics would be the plasticity of the clay. Generally high plastic clays show a greater amount of secondary consolidation and high consolidation time. As plasticity is a function of the type as well as of the amount of clay, a useful parameter to express the relationship of these two factors, is Skempton's " Activity", defined as P.I./ % clay. Using this parameter, it can be shown that some types of clay, e.g. montmorillonite have a large effect on the Plasticity, althogh the amount of montmorillonite is quite small. Such clays are called active clays. Conversely, inactive clays such as kaolinite, althogh present in large quantities, do not have a marked effect on the Plasticity.

An important consideration for the application of the Rapid test to a particular soil, is the time taken for the primary consolidation to be completed for each increment of loads and whether the whole loading sequence can be completed within a working day. Using the clay content and Activity as quantitative parameters, an attempt has been made to correlate these quantities with time of consolidation in order to both the amount and type of clay present in a soil will restrict the application of a rapid test. These correlations are shown in Fig. 20, 2I and 22.

Fig.20 shows the relation between clay content and activity. Also shown in the same graph are the activities of the three major clay minerals: kaolinite, illite, and montmorillonite (Na. and Ca.)- after Skempton(I953). It is seen that with the samples used in this project, as the quantity of Bentonite is increasing, there is a rapid increase in Activity until a limiting Activity is reached with Bentonite (bentonite IOO %). From the indicated values of Activity for the other clay minerals, it is clear that with increasing contents of such clays in a soil, the activity reached would be limited by the Activity of the clay mineral itself, and corresponding curves would be less steep. The actual curve shown therefore may be considered as upper limit of normal clay soil activities.

Fig. 2I shows the relationship of total time for 90 % consolidation in the rapid test, and clay fraction content for pressures between 0 and 8 kg./cm^2 . As expected, as the clay content increases, the time for 90% consolidation increases.

Fig. 22 shows the relation of Activity and total time for 90% consolidation in the rapid test for pressures between 0 and 8 Kg./cm^2, and it is shown that as Activity increases, time of consolidation increases.

From these curves, it can be seen that considering a normal 8 hours working day (500 min. approx.) the limiting clay content for the mixtures used was 25.5 %, and Activity was I.3I. However if a soil contains an inactive or normal clay such as kaolinite and illite for example, it would have a lower Activity for a higher percentage of clay fraction. Thus on the basis of Clay Fraction a rapid test could not be applied, but on the basis of Activity it could.

It would appear that the more meaningful factor giving whether or not a Rapid test can be applied to a particular soil is the Activity, as this parameter indicates the property of the clay in terms of both Plasticity and Clay Fraction. Based upon this, the limiting Activity for an 8 hours working day is I.3I. Unfortunately there was not enough time available to check this conclusion by carrying out rapid tests on actual soils.

EFFECT OF DURATION OF LOADING

It was found from the results obtained, that the duration of loading does not have marked influence in the determination of the soil consolidation parameters, and any difference obtained-between the standard and rapid consolidation tests- are quite small and certainly below the level of engineering significance when one considers the other sources of uncertainty in settlement computations .

EFFECT OF LOAD INCREMENT RATIO

It was found that higher load increment ratio, does not result in marked difference in the determination of the soil consolidatiðn parameteres, yet the total time is reduced. The higher the load increment ratio, the lower time is required to complete a rapid consolidation test. This can be illustrated in table N° 2, which relates the total time required to achieve 90% of primary consolidation in rapid tests, for $\Delta P/P = I$ and $\Delta P / P = 3$, and for pressures between 0,0 Kg/Cm^2 and 4 $kg./ cm^2$. The results of rapid tests carried out with $\Delta P / P = 2$, could not be directly compared with the above results, since the time taken to consolidate to a pressure of 4 $Kg. / cm^2$, could not be exactly determined .

SOIL DESCRIPTION	TIME in Minutes for	
	$\Delta P / P = I$	$\Delta P / P = 3$
RACHAYA	99	77
B5R95	240	I4I
BIOR90	309	273
BI5R85	744	560

Table N°. 2

EFFECT OF INCREASED DRAINAGE AT SAMPLE BOUNDARIES

It can be seen from the results of the rapid consolidation tests performed with the placing of filter paper between the sample and the porous stones, that altheughthe soil consolidation parameters found by these tests are comparable with the ones found by the standard test, yet the total time of completion of 90 % primary consolidation was not lower than of a similar rapid test performed without filter paper. This can be illustrated in table N°.3, which relates total time required to achieve 90 % of primary consolidation in rapid tests for $\Delta P / P = I$, one done with filter paper and the other without it, for limits of pressure between 0.0 Kg/cm^2 and 8 Kg/cm^2 .

SOIL DESCRIPTION	TIME in Minutes for	
	$\Delta P / P = I$	$\Delta P / P = I$ F.P.
RACHAYA	I07.5	I04
B5R95	258	255
BIOR90	336	376

Table N°. 3

EFFECT OF A HIGHER INITIAL LOAD

It can be seen from the results shown below for the Rapid Tests on the soil BI5R85, that the effect of a higher initial load of 0.5 Kg. / cm^2 instead of 0.25 Kg. / cm^2 was to decrease the total time of 90% of primary consolidation .

Although this is the result of only one sample which has a high clay content, it is expected that similar results would be obtained for lower clay content.

Time for $\Delta P / P = I$, for initial value of 0.25 kg / cm^2= 744min.

Time for $\Delta P / P = I$, for initial value of 0,50 kg / cm^2= 5I9min.

EFFECT OF SIDE FRICTION

This effect was not studied due to a lack of time. An attempt was made to reduce this effect by applying a thin layer of silicon grease on the inner face of the consolidation ring.

CHAPTER VI

CONCLUSIONS

Data from the rapid consolidation tests described in this project, are in reasonable agreement with those obtained from the standard test. Considering other sources of error in settlement computations, the differences obtained are below the level of engineering significance.

The following conclusions may be drawn:-

1- Reducing the duration of loading to that of primary consolidation only, does not affect the coefficient of compressibility a_v nor the coefficient of consolidation c_v.

2- Increasing the load increment ratio, to $\Delta P/P = 2$ and $\Delta P / P = 3$, decreases the time of primary consolidation, and does not significantly affect the values of a_v and c_v.

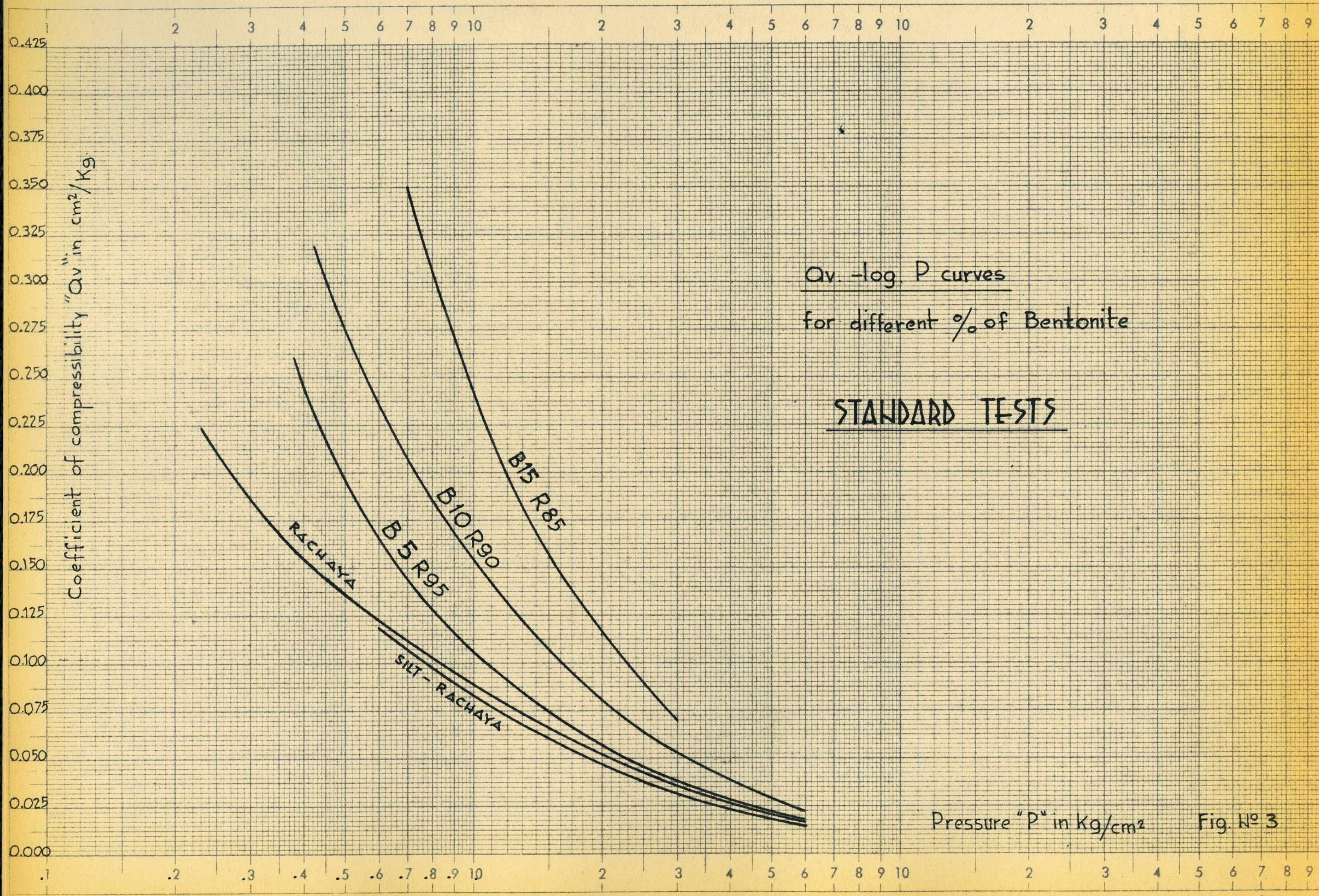
3- Increasing drainage facilities at sample boundaries by the inclusion of filter paper between the sample and the porous stones, does not seem to have significant effect in decreasing the duration of primary consolidation, at least for the samples tested in this project.

4- A higher initial value of load increment, is effective in decreasing the time of primary consolidation. Practical application of this conclusion, would be governed by the range of loading required in the settlement analysis.

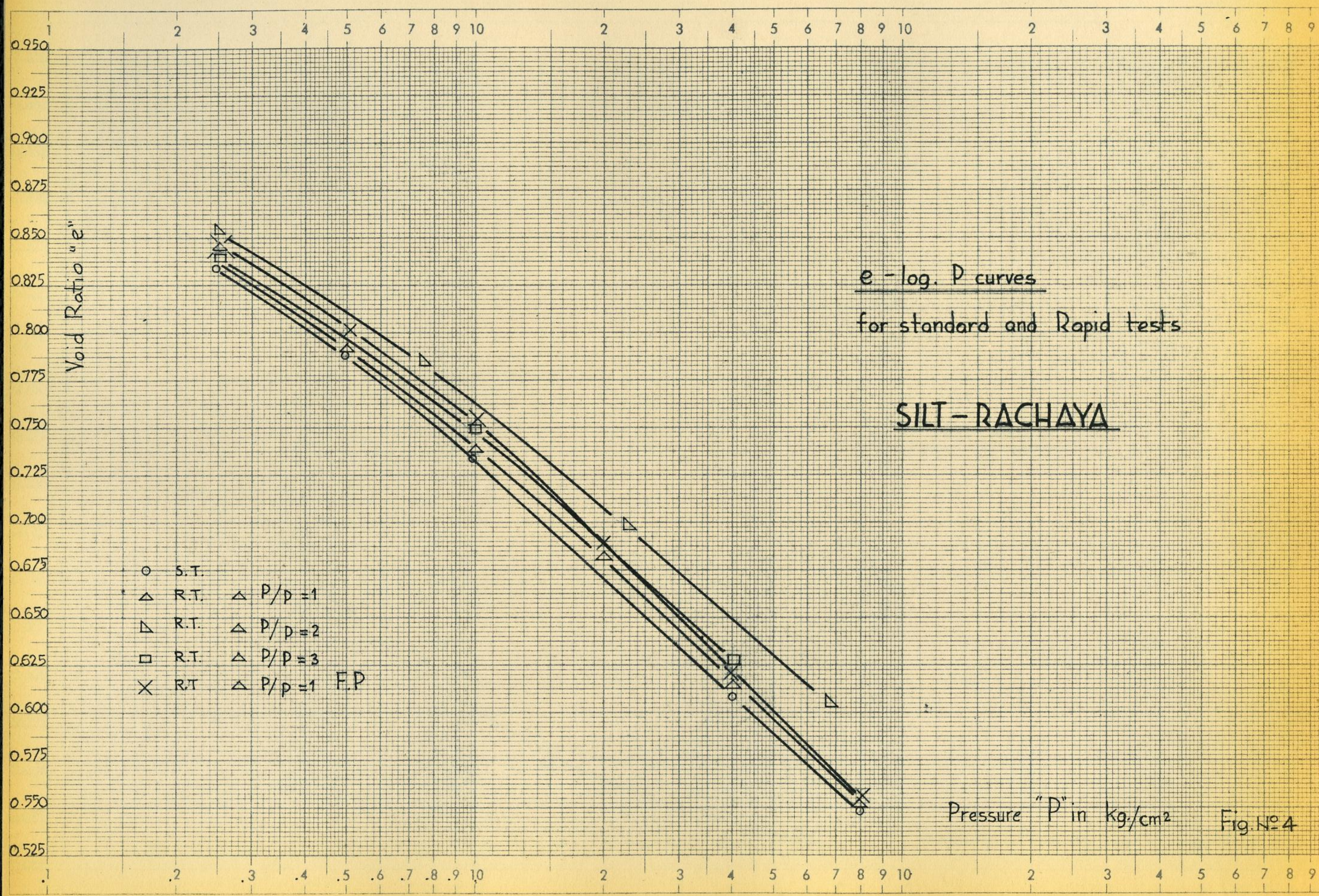
5- Soils with high plasticity have large consolidation time which will restrict the applicability of the Rapid tests. Describing the soil in terms of its activity rather than of clay fraction alone, the upper limit of activity for Rapid tests to be carried out within 8 hours is 1.31.

Conclusions 3 and 5 must be considered as tentative, and could be modified in the light of further work.

APPENDIX "A"


Qv. -log. P curves
for different % of Bentonite
STANDARD TESTS
B15 R85
B10 R90
B 5 R95
RACHAYA
SILT - RACHAYA
Coefficient of compressibility "Qv" in cm²/Kg
Pressure "P" in Kg/cm²
Fig. Nº 3

A- 1



e - log. P curves
for standard and Rapid tests
SILT - RACHAYA
Void Ratio "e"
0.950
0.925
0.900
0.875
0.850
0.825
0.800
0.775
0.750
0.725
0.700
0.675
0.650
0.625
0.600
0.575
0.550
0.525
S.T.
R.T. P/p =1
R.T. P/p =2
R.T. P/p =3
R.T P/p =1 F.P
Pressure "P" in kg./cm²

Fig. No 4

A- 2

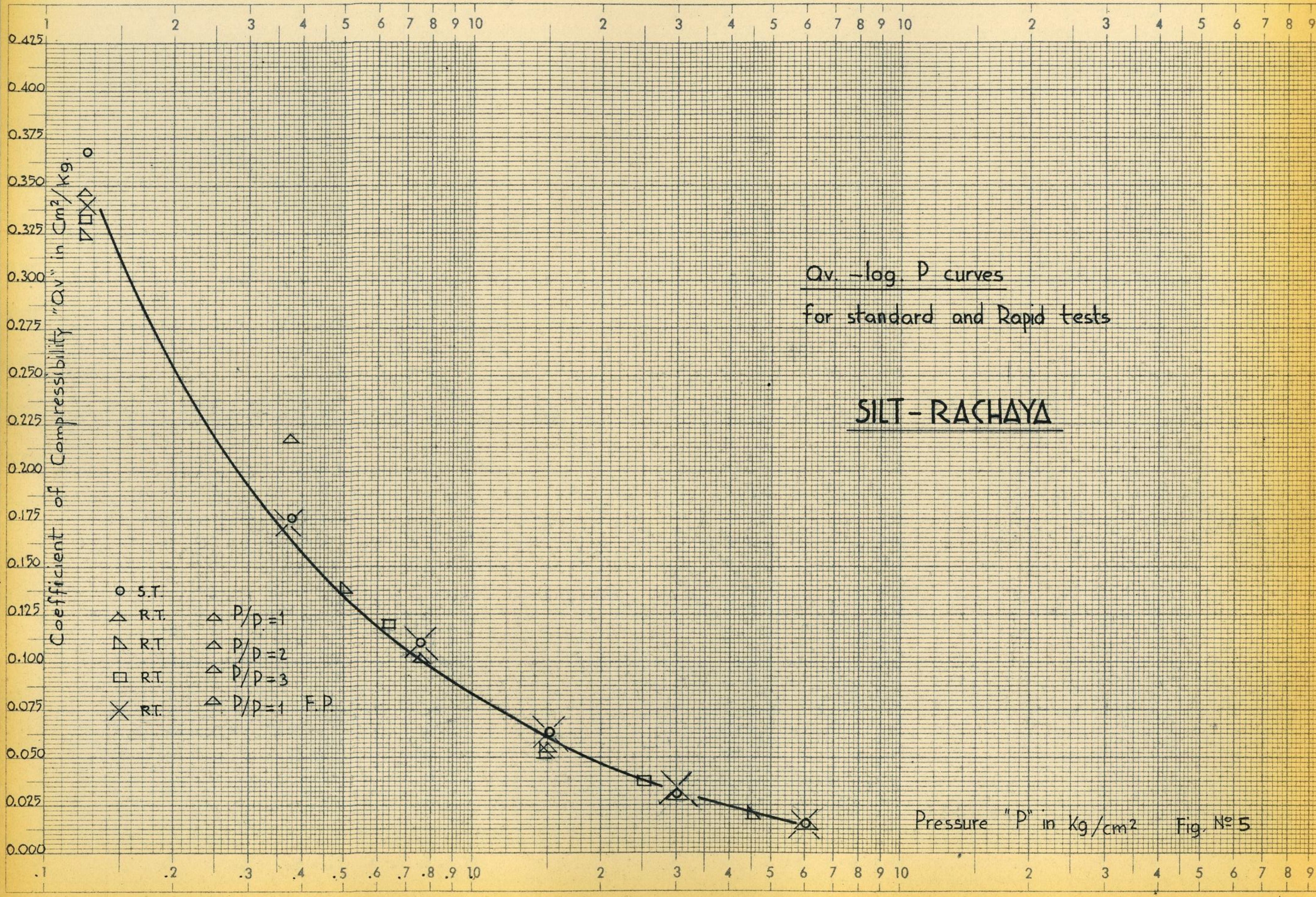
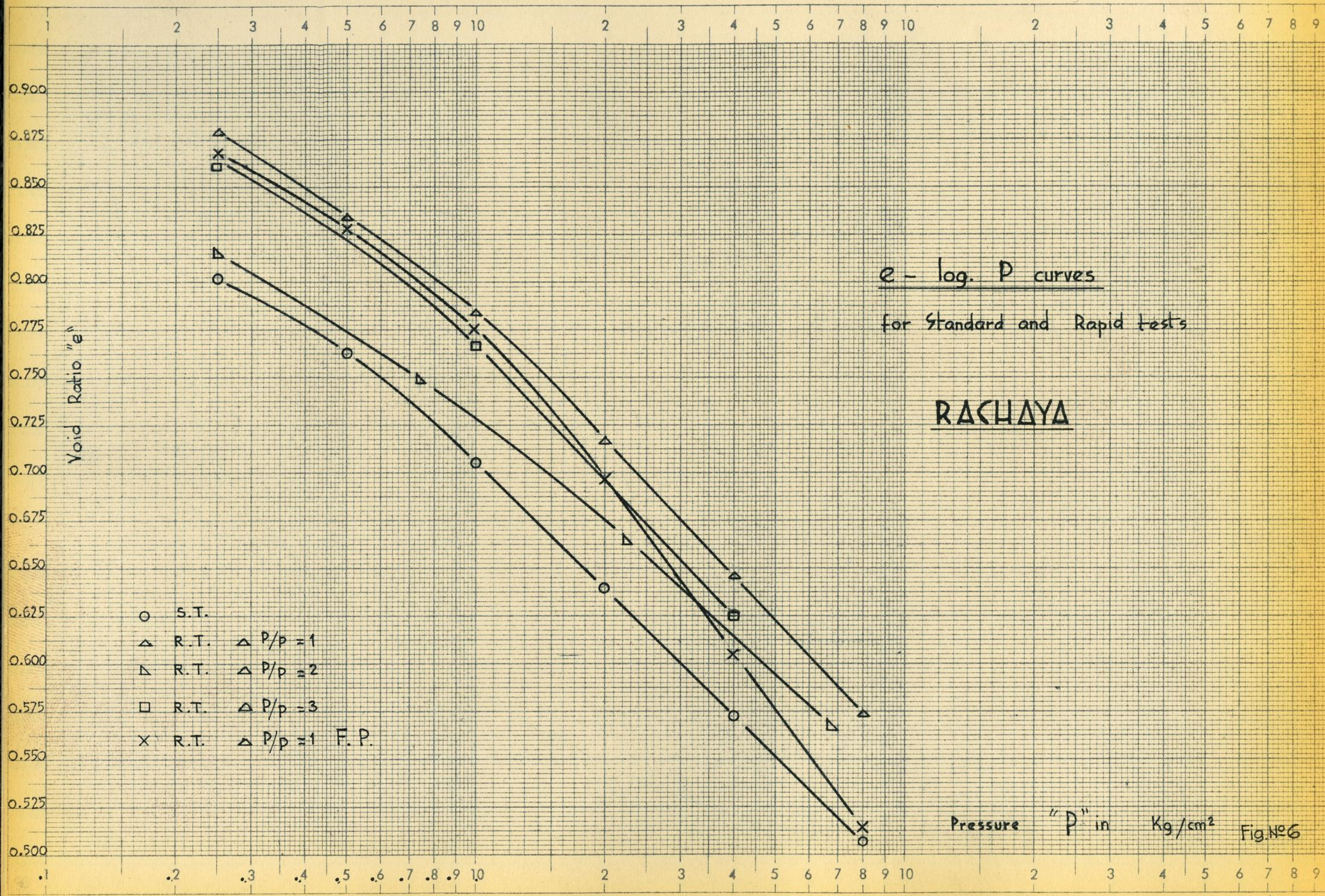

Qv. -log. P curves
for standard and Rapid tests
SILT-RACHAYA
Coefficient of Compressibility "Qv" in Cm²/Kg.
Pressure "P" in Kg/cm²
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 2 3 4 5 6 7 8 9 10 2 3 4 5 6 7 8 9
o S.T.
R.T. P/p = 1
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 F.P.

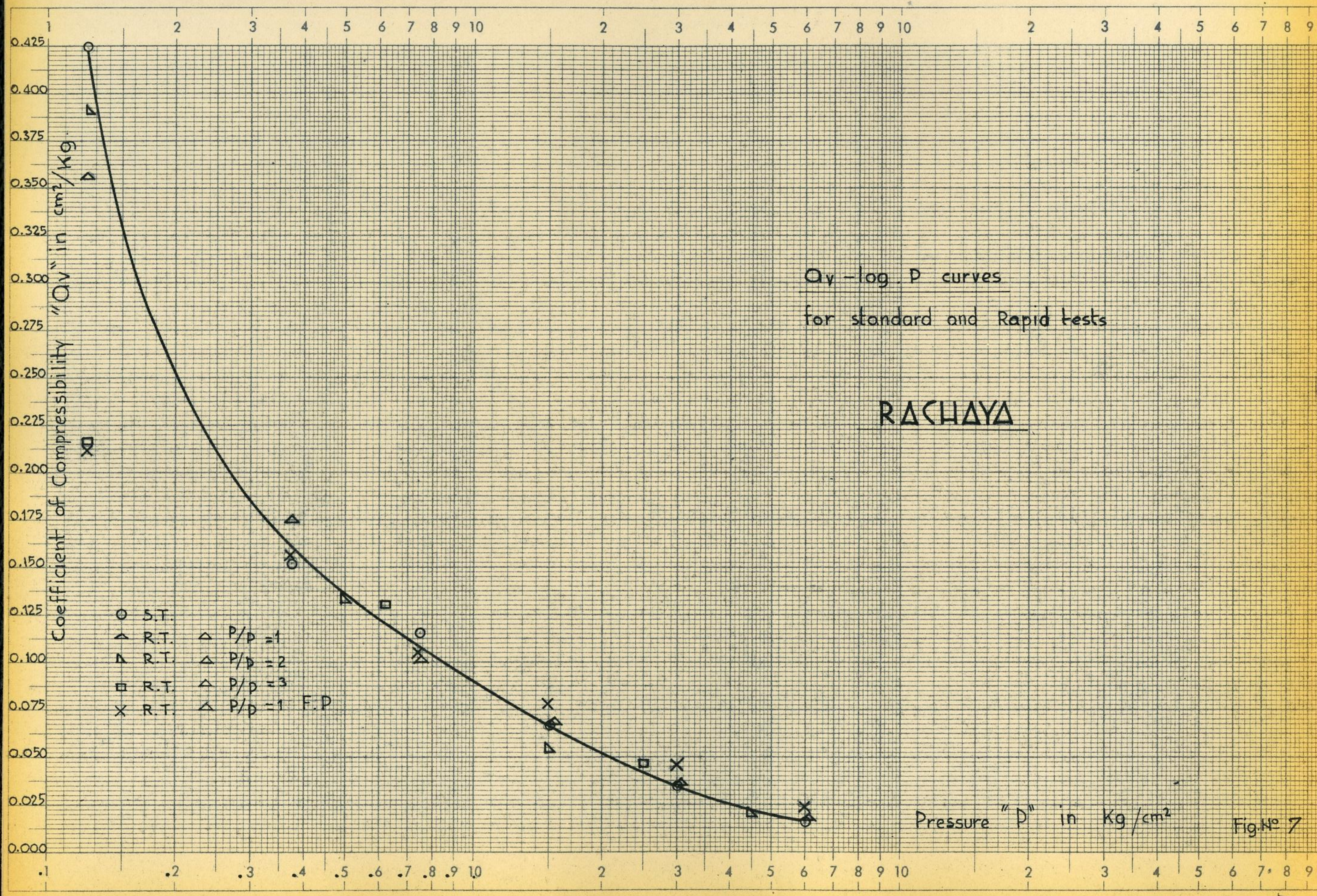
Fig. Nº 5

A- 4



e - log. P curves
for Standard and Rapid tests
RACHAYA
Void Ratio "e"
0.900
0.875
0.850
0.825
0.800
0.775
0.750
0.725
0.700
0.675
0.650
0.625
0.600
0.575
0.550
0.525
0.500
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10
○ S.T.
△ R.T. △ P/p = 1
△ R.T. △ P/p = 2
□ R.T. △ P/p = 3
× R.T. △ P/p = 1 F.P.
Pressure "P" in Kg/cm²

Fig. No 6



Av - log. P curves
for standard and Rapid tests
RACHAYA
Coefficient of Compressibility "Av" in cm²/Kg
Pressure "P" in Kg/cm²
S.T.
R.T. P/p = 1
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 F.P
Fig.Nº 7

A- 5

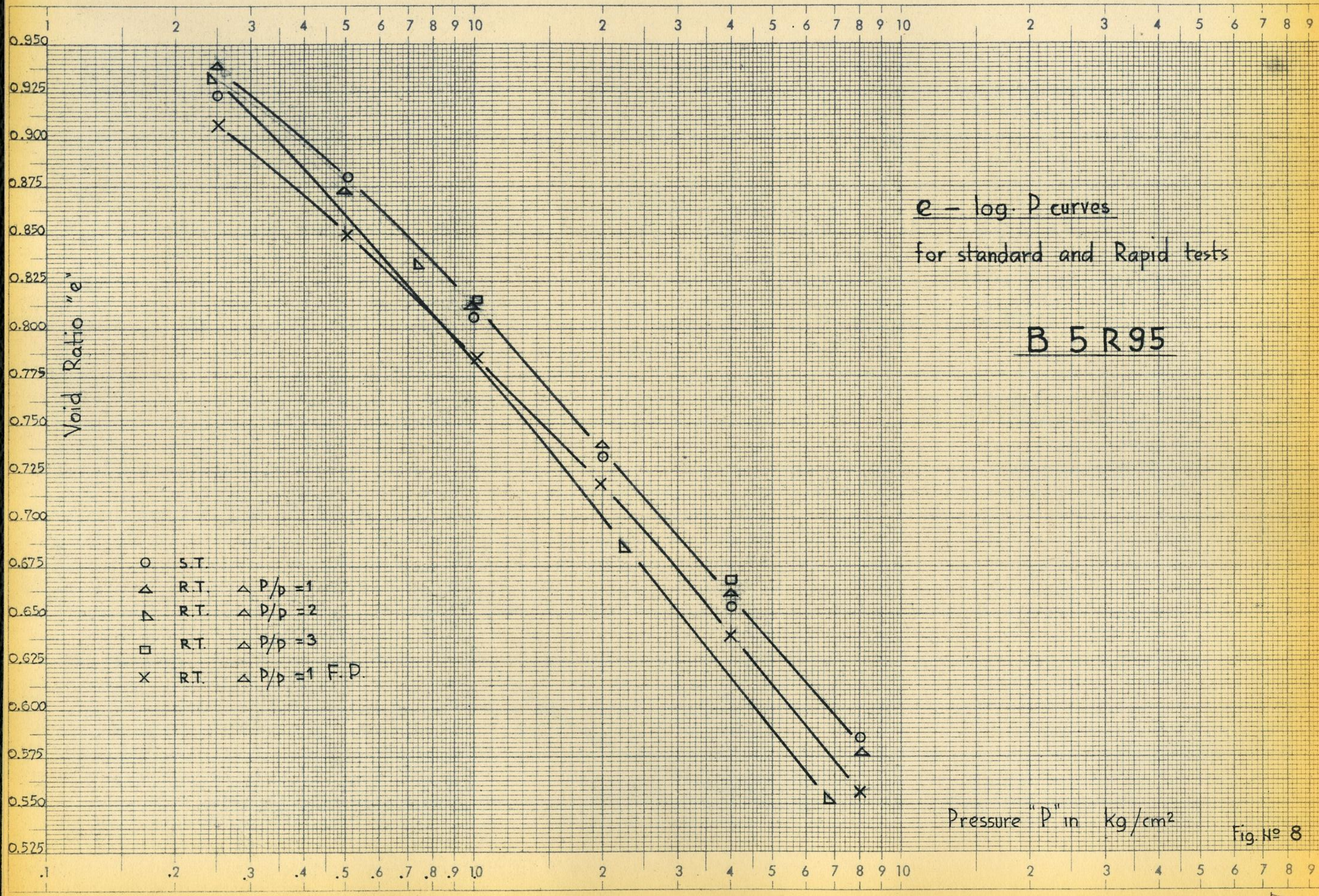
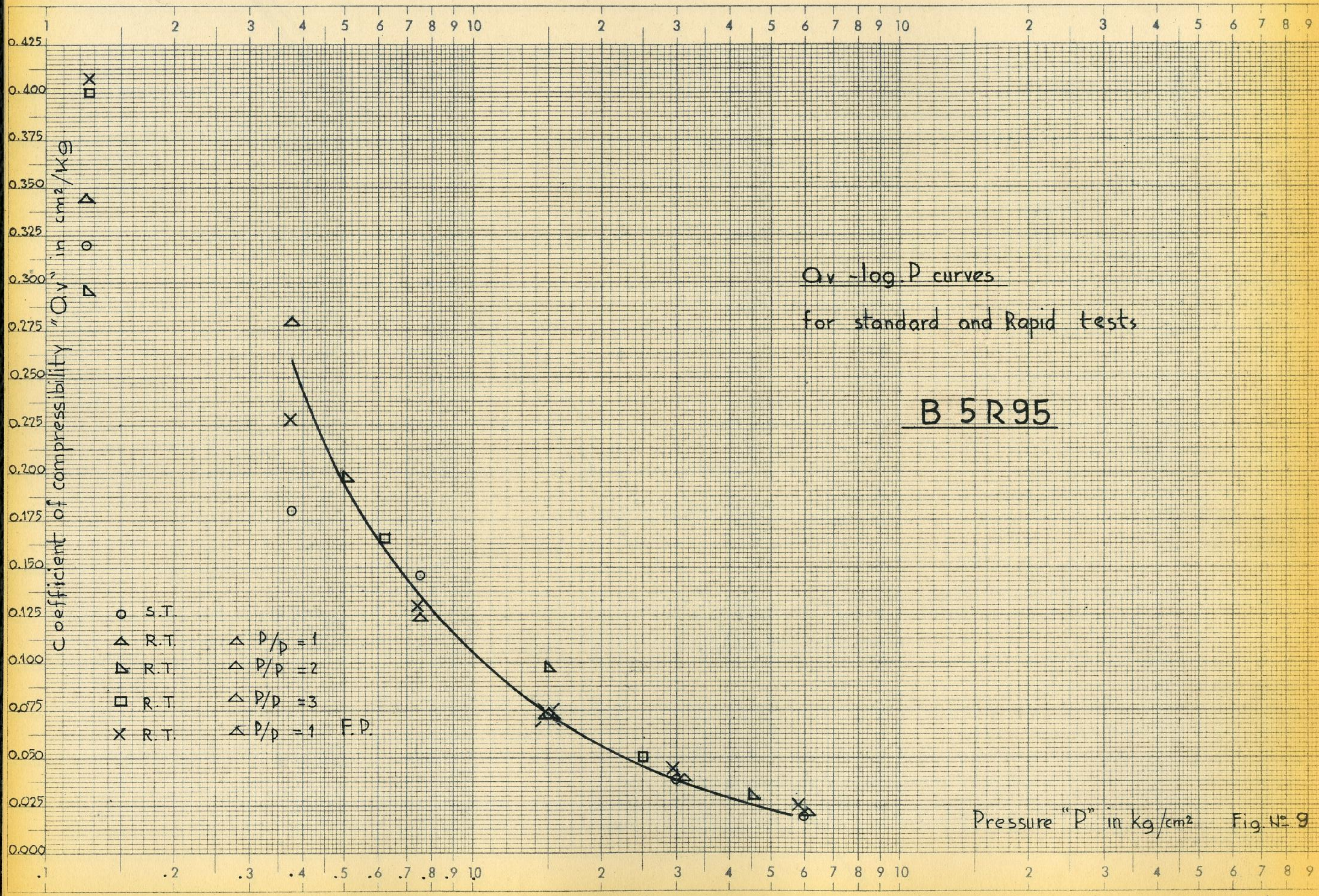

e – log. P curves
for standard and Rapid tests
B 5 R95
Void Ratio "e"
Pressure "P" in kg/cm²
S.T.
R.T. △ P/p =1
R.T. △ P/p =2
R.T. △ P/p =3
R.T. △ P/p =1 F.D.

Fig. № 8


Qv -log. P curves
for standard and Rapid tests
B 5R95
Coefficient of compressibility "Qv" in cm²/kg
Pressure "P" in kg/cm²
Fig. N° 9
o S.T.
R.T. P/p = 1
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 F.P.
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10

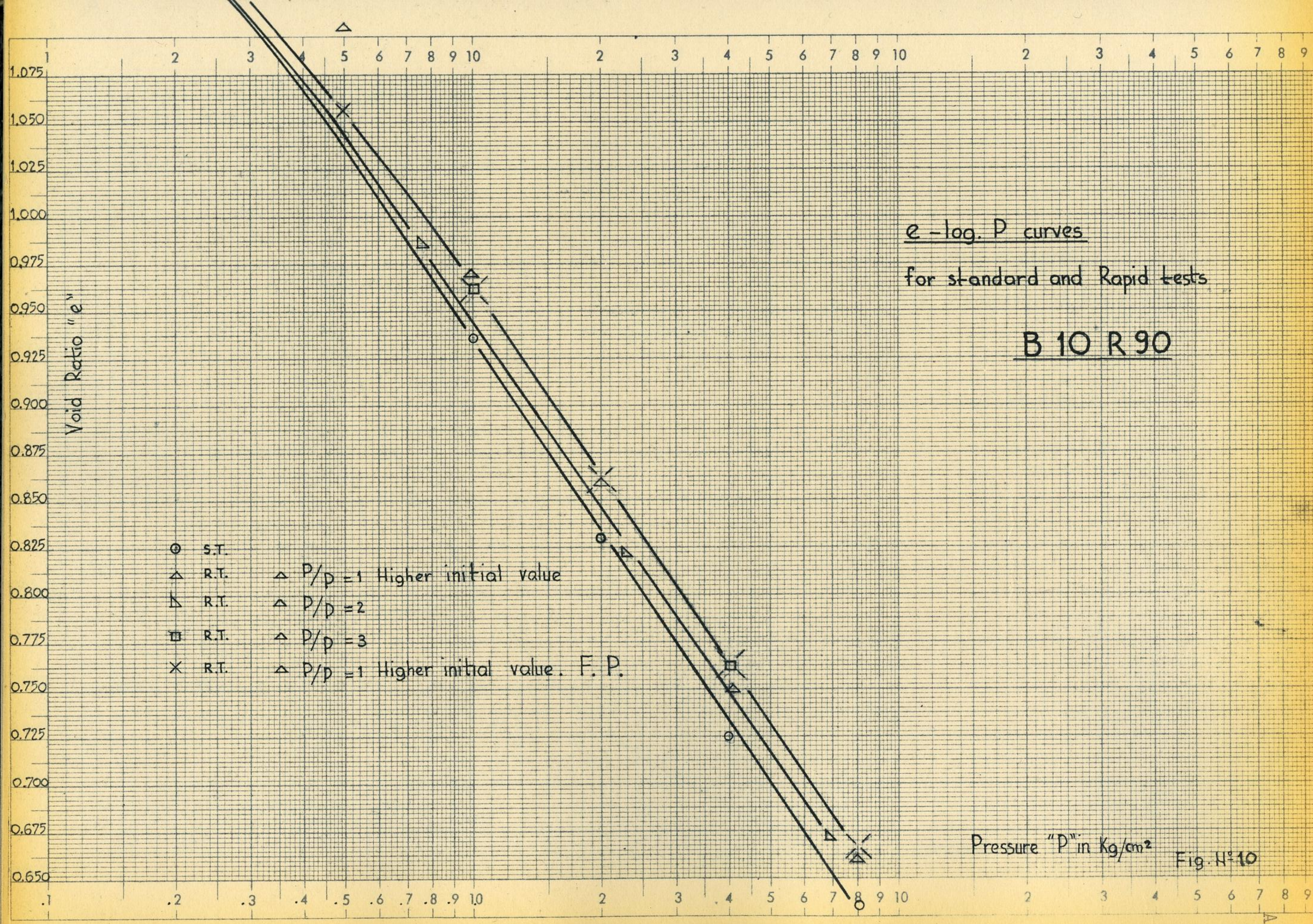
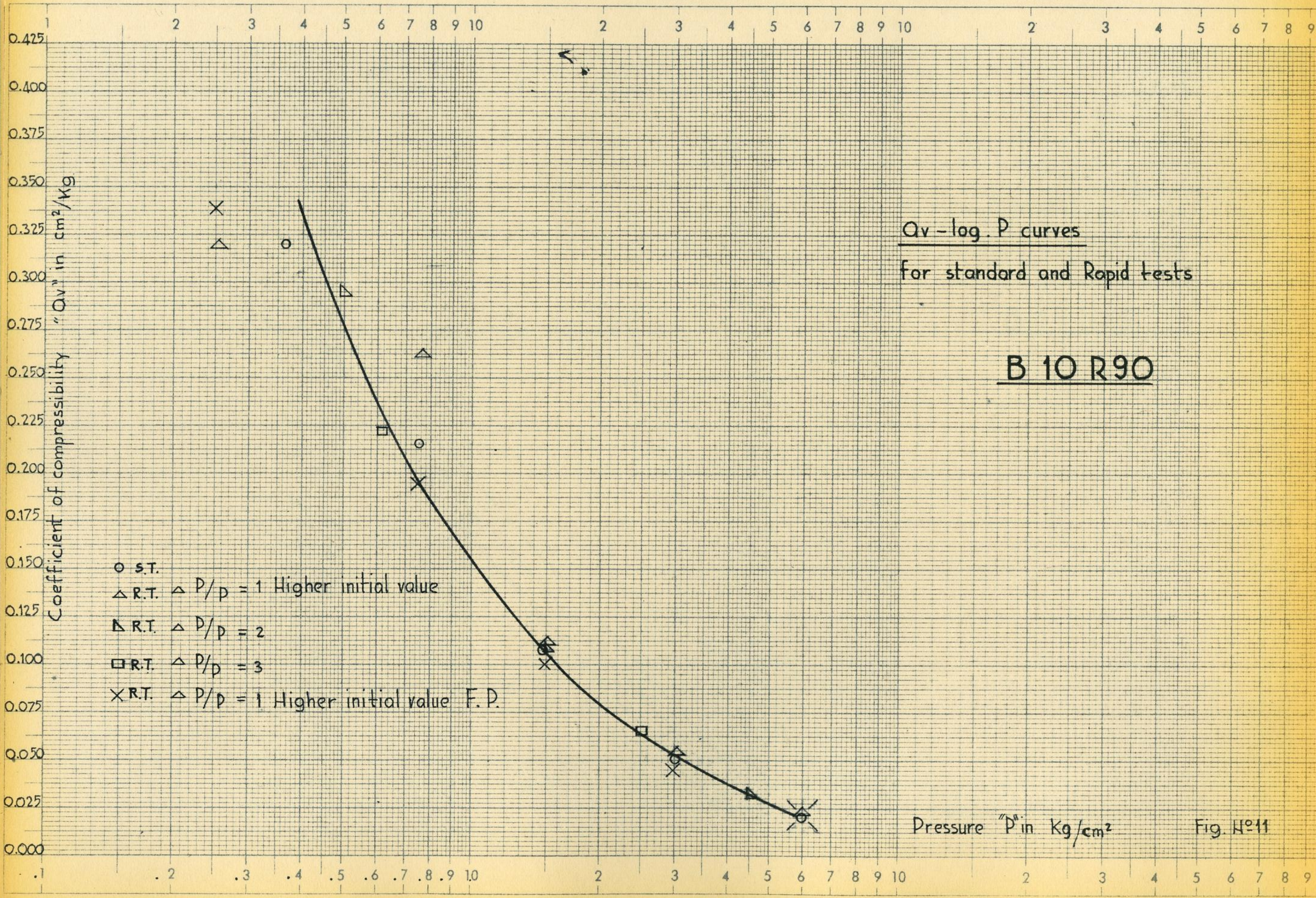
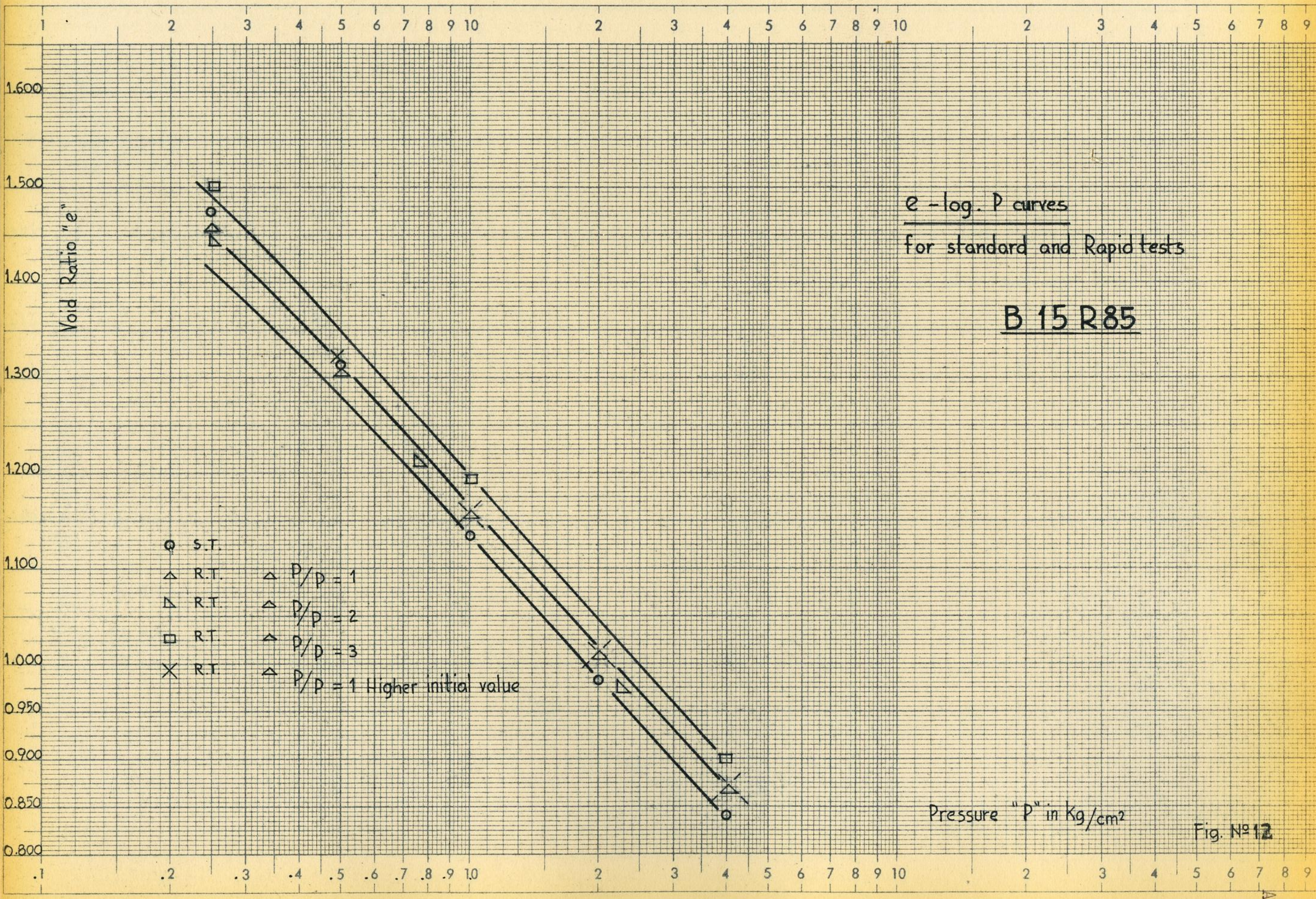

e - log. P curves
for standard and Rapid tests
B 10 R 90
Void Ratio "e"
Pressure "P" in Kg/cm²
S.T.
R.T. P/p = 1 Higher initial value
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 Higher initial value. F. P.

Fig. N°10



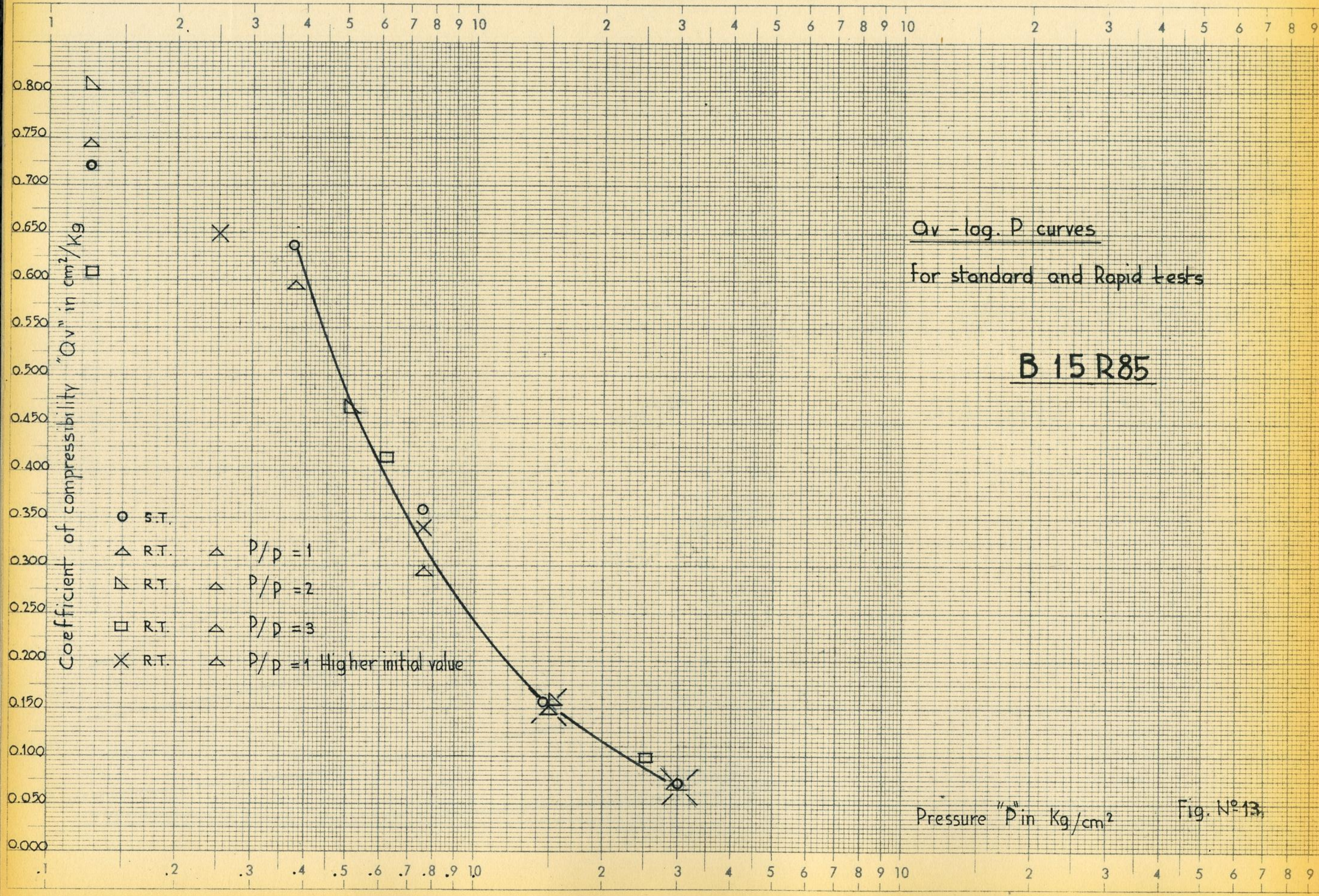
Qv - log. P curves
for standard and Rapid tests
B 10 R90
Coefficient of compressibility "Qv" in cm²/Kg
Pressure "P" in Kg/cm²
o S.T.
R.T. P/p = 1 Higher initial value
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 Higher initial value F. P.
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2
3
4
5
6
7
8
9
10

Fig. Nº 11



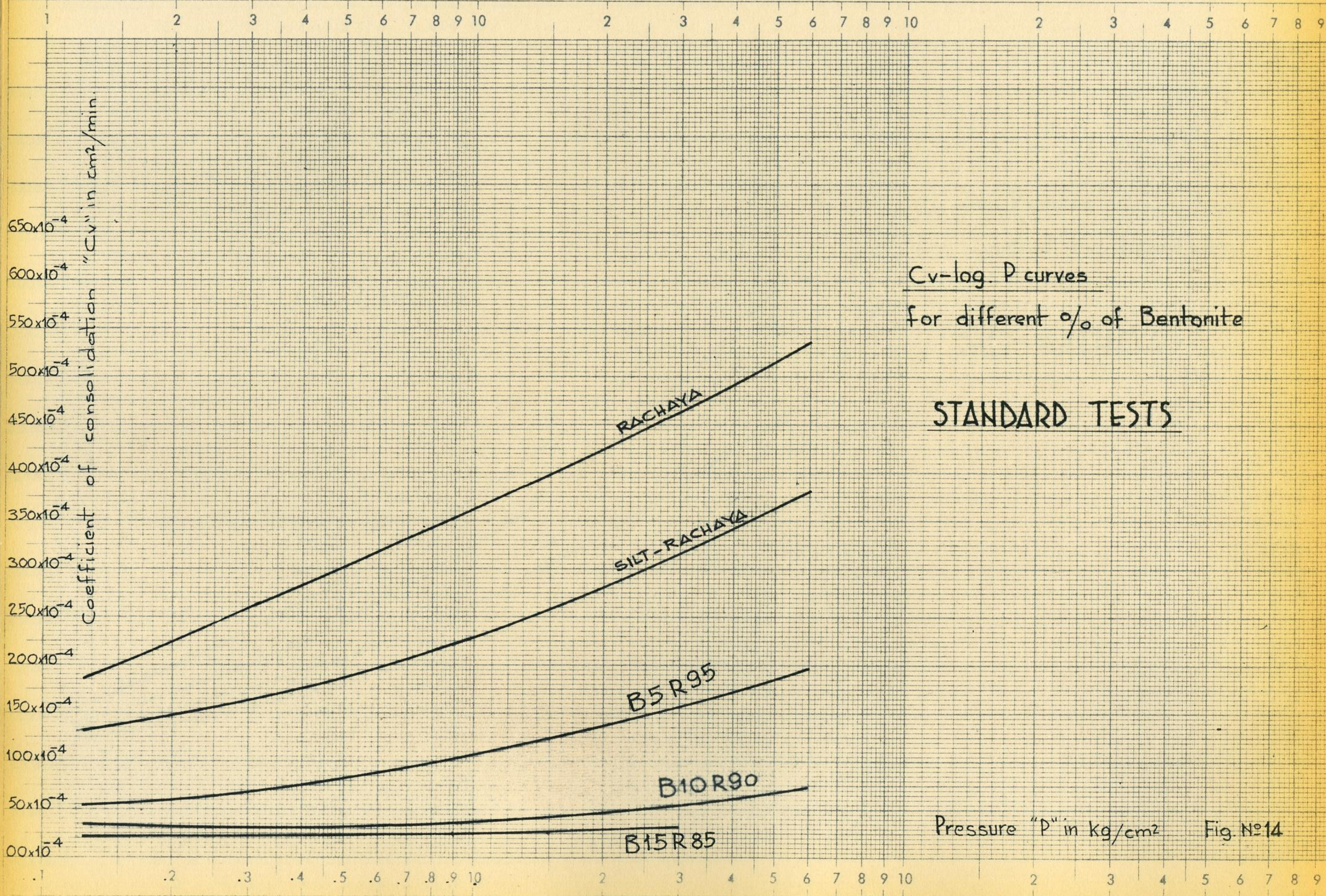
e - log. P curves
for standard and Rapid tests
B 15 R85
Void Ratio "e"
Pressure "P" in Kg/cm²
S.T.
R.T. P/p = 1
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 Higher initial value
1.600
1.500
1.400
1.300
1.200
1.100
1.000
0.950
0.900
0.850
0.800

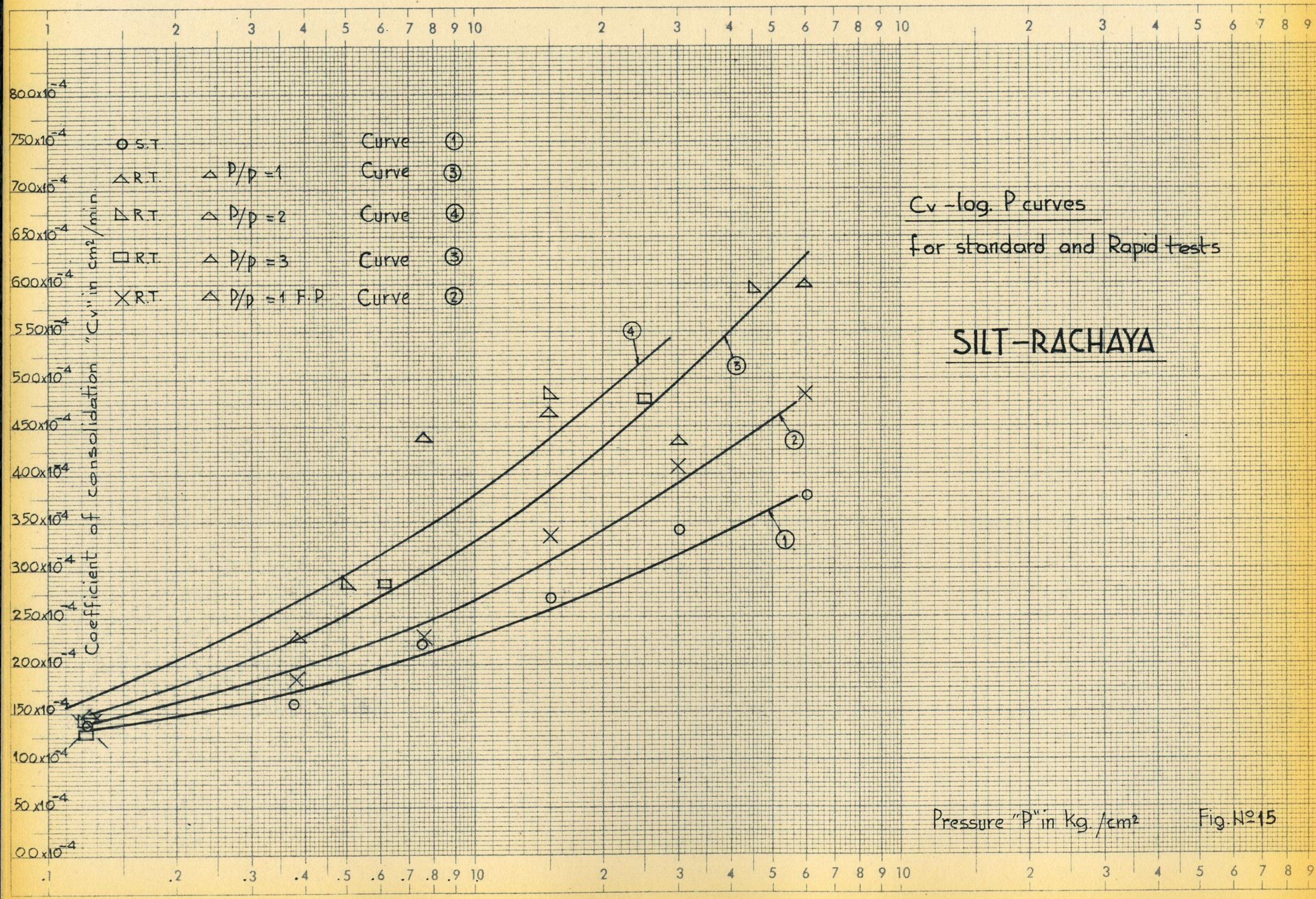
Fig. Nº 12

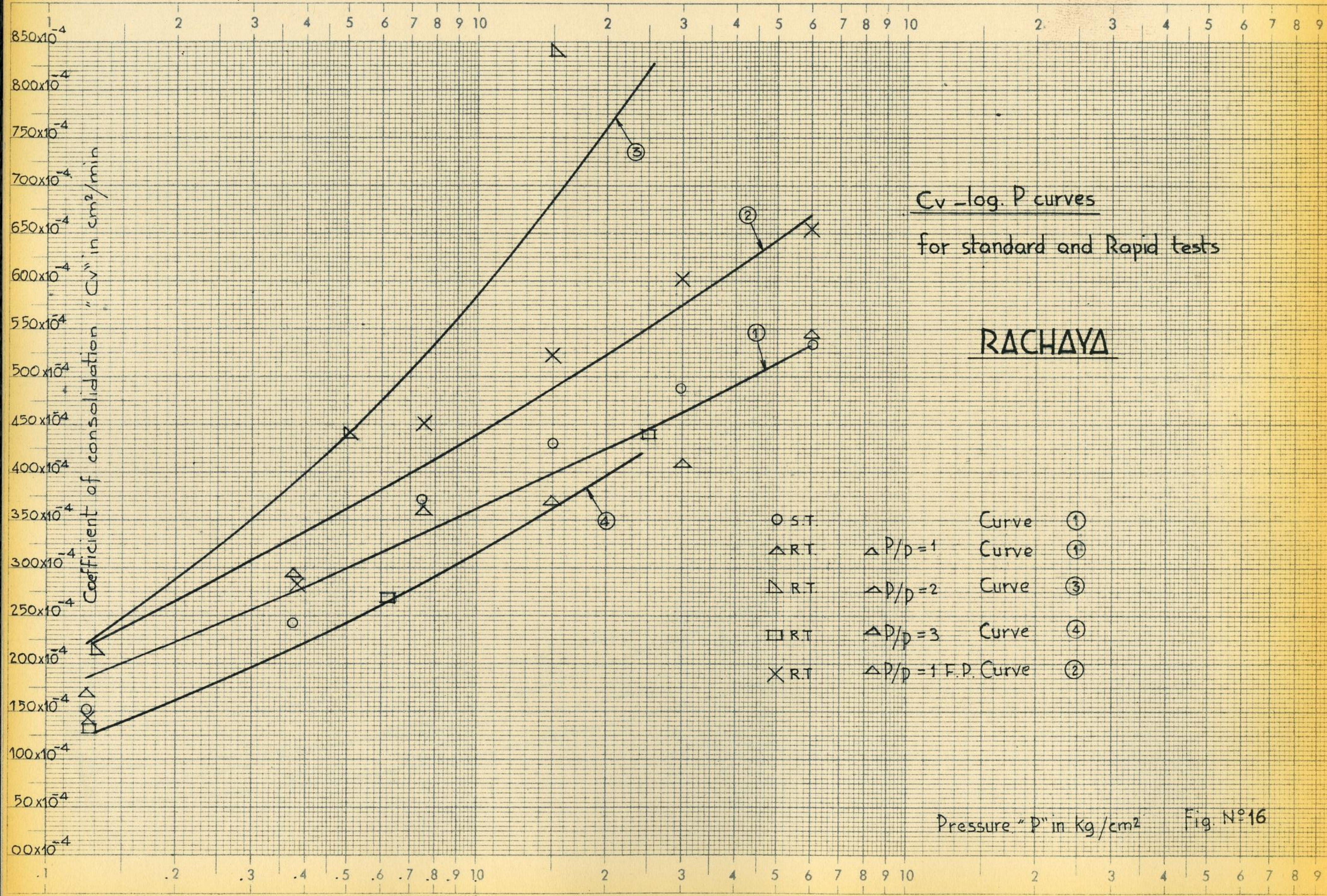


Qv - log. P curves
for standard and Rapid tests
B 15 R85
Coefficient of compressibility "Qv" in cm²/Kg
Pressure "P" in Kg/cm²
S.T.
R.T. P/p = 1
R.T. P/p = 2
R.T. P/p = 3
R.T. P/p = 1 Higher initial value

Fig. Nº 13

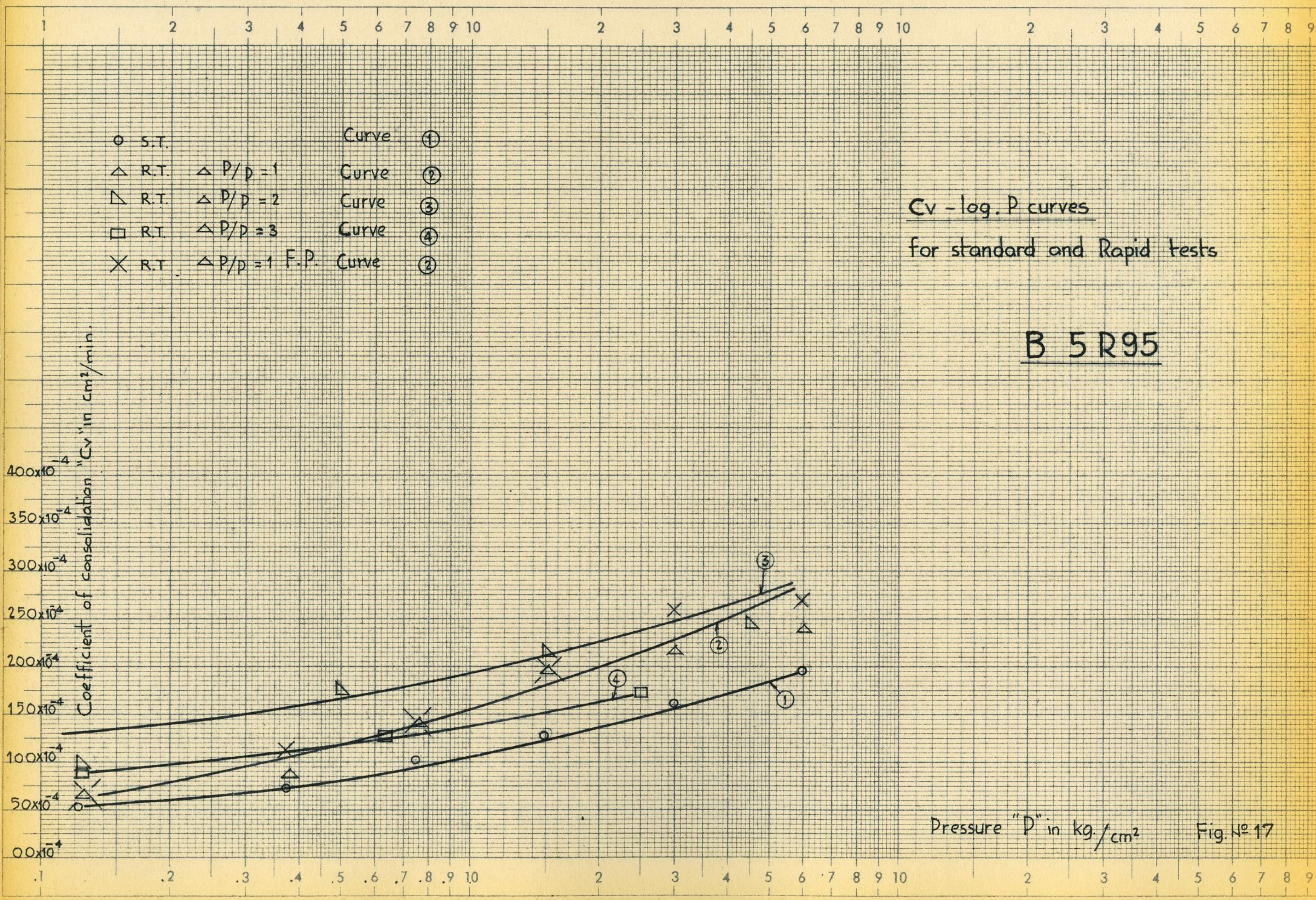

Cv-log. P curves
for different % of Bentonite
STANDARD TESTS
Coefficient of consolidation "Cv" in cm²/min.
650x10⁻⁴
600x10⁻⁴
550x10⁻⁴
500x10⁻⁴
450x10⁻⁴
400x10⁻⁴
350x10⁻⁴
300x10⁻⁴
250x10⁻⁴
200x10⁻⁴
150x10⁻⁴
100x10⁻⁴
50x10⁻⁴
00x10⁻⁴
RACHAYA
SILT-RACHAYA
B5 R95
B10R90
B15R85
Pressure "P" in kg/cm²
Fig. №14

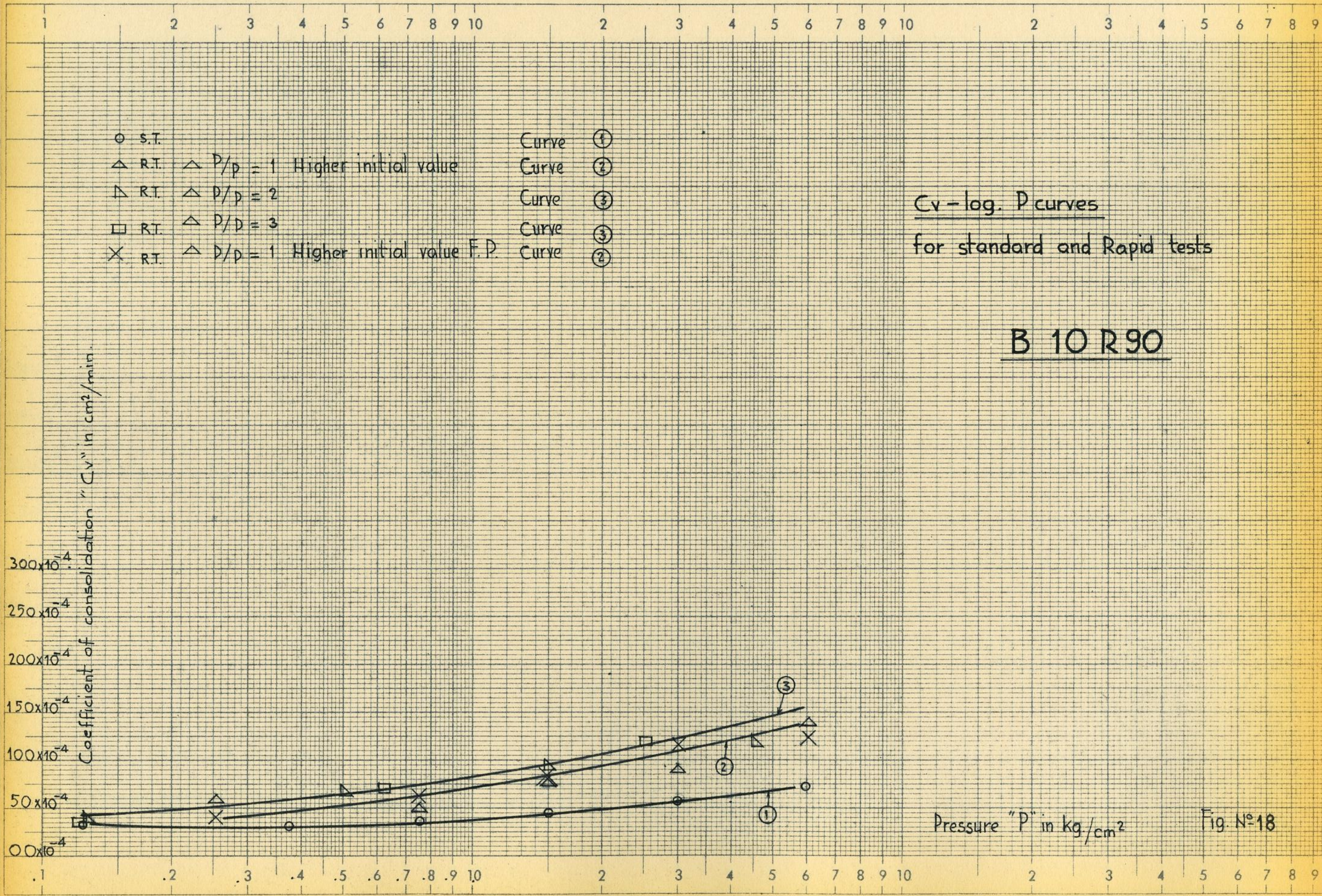

Cv -log. P curves
for standard and Rapid tests
SILT-RACHAYA
o S.T. Curve ①
△ R.T. △ P/p = 1 Curve ③
△ R.T. △ P/p = 2 Curve ④
□ R.T. △ P/p = 3 Curve ③
× R.T. △ P/p = 1 F.P. Curve ②
Coefficient of consolidation "Cv" in cm²/min.
800x10⁻⁴
750x10⁻⁴
700x10⁻⁴
650x10⁻⁴
600x10⁻⁴
550x10⁻⁴
500x10⁻⁴
450x10⁻⁴
400x10⁻⁴
350x10⁻⁴
300x10⁻⁴
250x10⁻⁴
200x10⁻⁴
150x10⁻⁴
100x10⁻⁴
50 x10⁻⁴
0.0 x10⁻⁴
.1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 2 3 4 5 6 7 8 9 10 2 3 4 5 6 7 8 9
Pressure "P" in kg./cm²
Fig. Nº 15

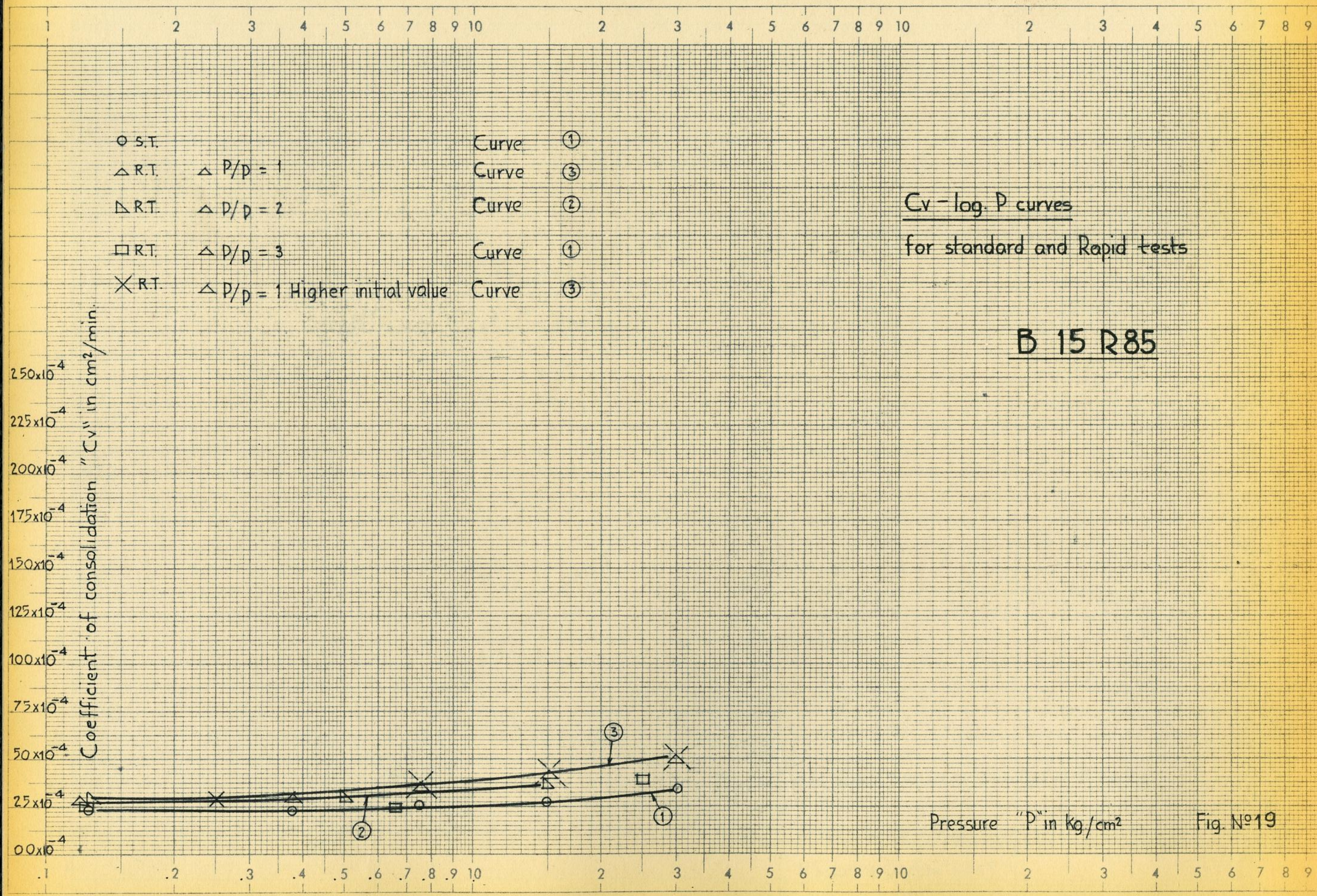


Cv _log. P curves
for standard and Rapid tests
RACHAYA
Coefficient of consolidation "Cv" in cm²/min
850x10⁻⁴
800x10⁻⁴
750x10⁻⁴
700x10⁻⁴
650x10⁻⁴
600x10⁻⁴
550x10⁻⁴
500x10⁻⁴
450x10⁻⁴
400x10⁻⁴
350x10⁻⁴
300x10⁻⁴
250x10⁻⁴
200x10⁻⁴
150x10⁻⁴
100x10⁻⁴
50x10⁻⁴
00x10⁻⁴
○ S.T. Curve ①
△ R.T. △P/p = 1 Curve ①
◺ R.T. △P/p = 2 Curve ③
□ R.T. △P/p = 3 Curve ④
✕ R.T. △P/p = 1 F.P. Curve ②
Pressure "P" in Kg/cm²

Fig. N° 16


Cv - log. P curves
for standard and Rapid tests
B 5R95
o S.T. Curve ①
△ R.T. △ P/p = 1 Curve ②
◺ R.T. △ P/p = 2 Curve ③
□ R.T. △ P/p = 3 Curve ④
✕ R.T. △ P/p = 1 F.P. Curve ②
Coefficient of consolidation "Cv" in cm²/min.
400x10⁻⁴
350x10⁻⁴
300x10⁻⁴
250x10⁻⁴
200x10⁻⁴
150x10⁻⁴
100x10⁻⁴
50x10⁻⁴
0.0x10⁻⁴
Pressure "P" in kg/cm²
Fig. № 17


Cv - log. P curves
for standard and Rapid tests
B 10 R 90
○ S.T. Curve ①
△ R.T. △ P/p = 1 Higher initial value Curve ②
◁ R.T. △ P/p = 2 Curve ③
□ R.T. △ P/p = 3 Curve ③
× R.T. △ P/p = 1 Higher initial value F.P. Curve ②
Coefficient of consolidation "Cv" in cm²/min.
300x10⁻⁴
250x10⁻⁴
200x10⁻⁴
150x10⁻⁴
100x10⁻⁴
50x10⁻⁴
0.0x10⁻⁴
Pressure "P" in kg/cm²
Fig. No 18



Cv – log. P curves
for standard and Rapid tests
B 15 R85
○ S.T. Curve ①
△ R.T. △ P/p = 1 Curve ③
◺ R.T. △ P/p = 2 Curve ②
□ R.T. △ P/p = 3 Curve ①
╳ R.T. △ P/p = 1 Higher initial value Curve ③
Coefficient of consolidation "Cv" in cm²/min.
250x10⁻⁴
225x10⁻⁴
200x10⁻⁴
175x10⁻⁴
150x10⁻⁴
125x10⁻⁴
100x10⁻⁴
75x10⁻⁴
50x10⁻⁴
25x10⁻⁴
0.0x10⁻⁴
.1 .2 .3 .4 .5 .6 .7 .8 .9 10 2 3 4 5 6 7 8 9 10 2 3 4 5 6 7 8 9
Pressure "P" in kg/cm²

Fig. N°19

A-17

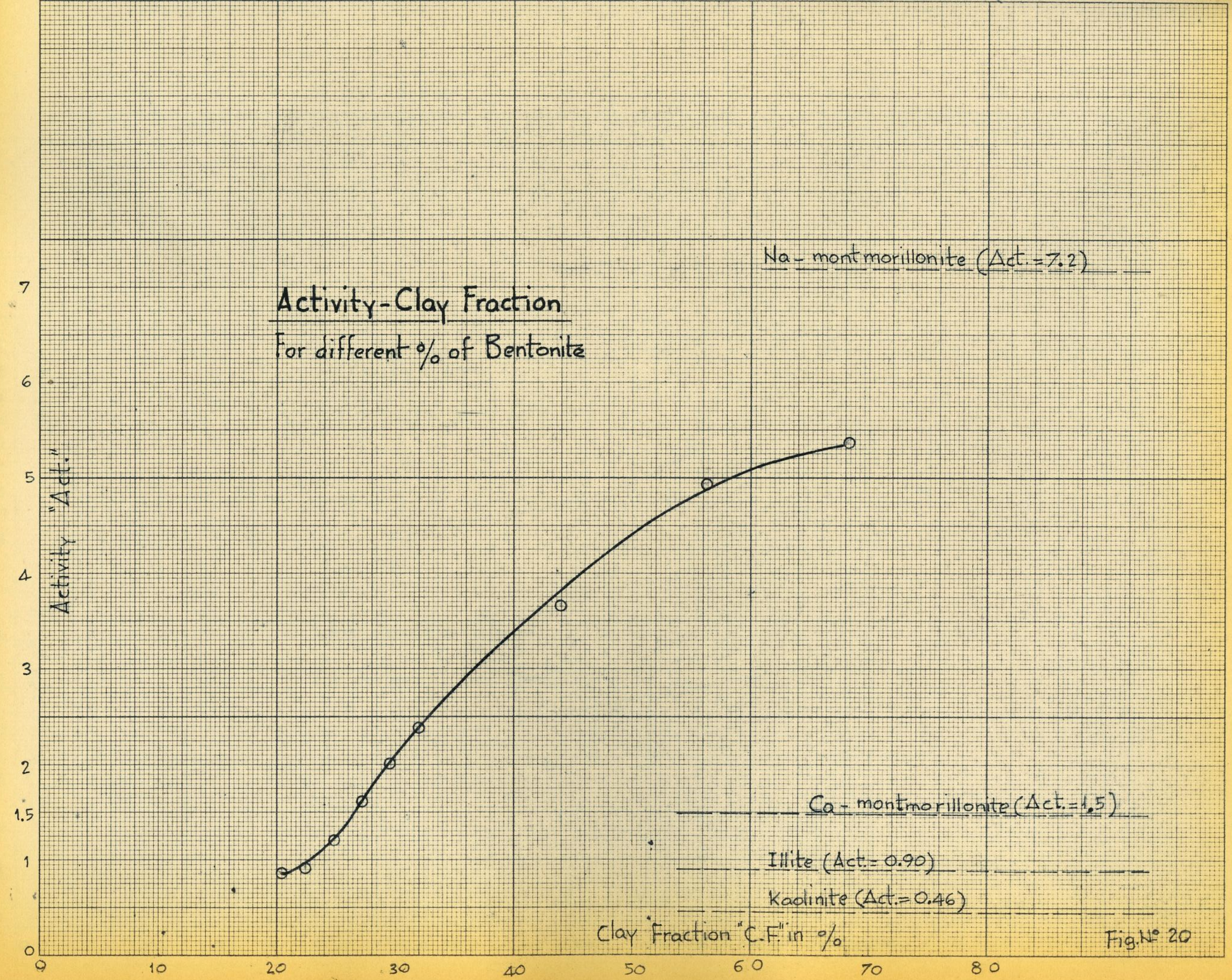

Activity-Clay Fraction
For different % of Bentonite
Na - montmorillonite (Act.=7.2)
Ca - montmorillonite (Act.=1,5)
Illite (Act.= 0.90)
Kaolinite (Act.=0.46)
Activity "Act."
Clay Fraction "C.F" in %
0
1
1.5
2
3
4
5
6
7
10
20
30
40
50
60
70
80

Fig.Nº 20

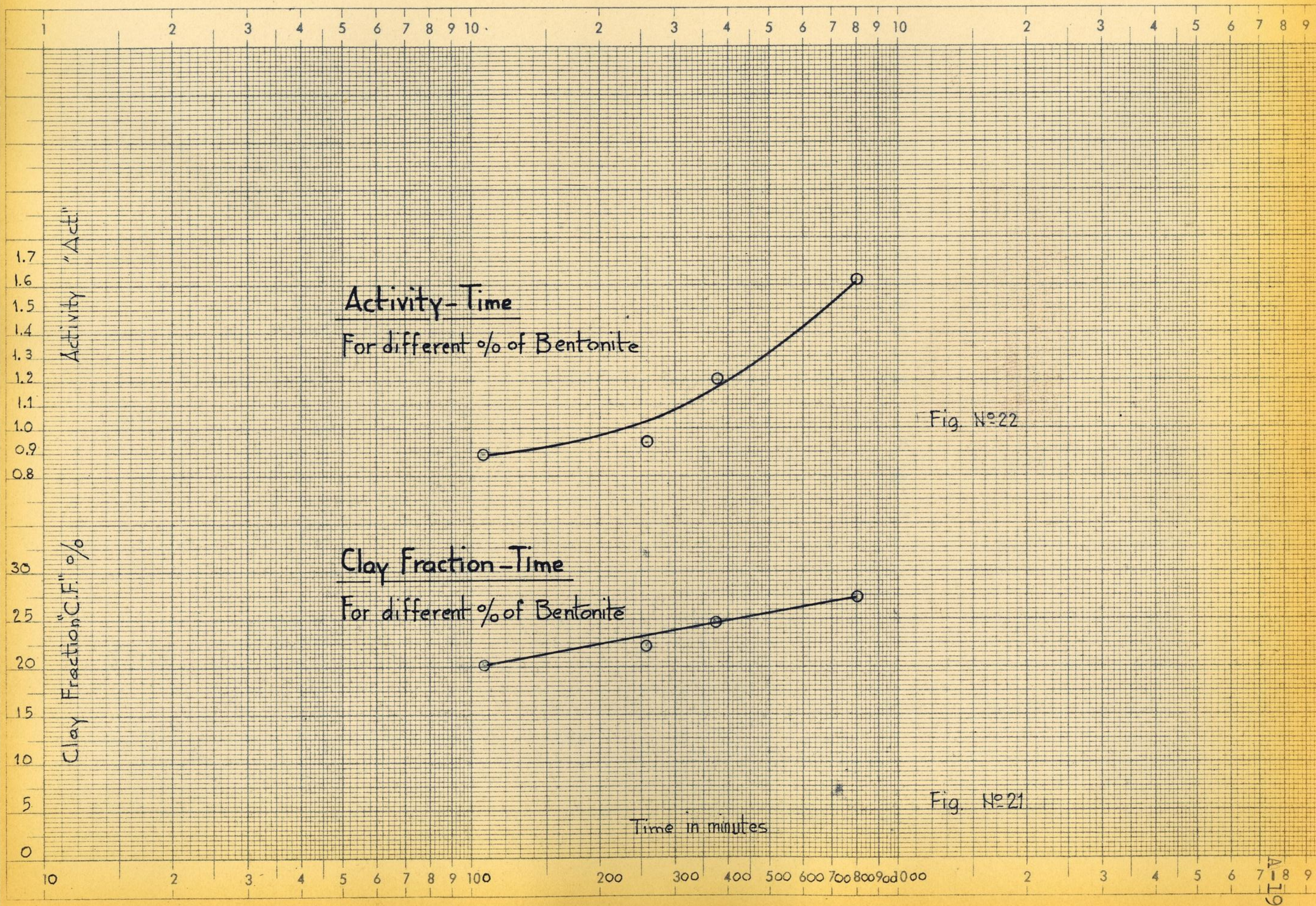


Fig. Nº22

Fig. Nº21

A P P E N D I X " B "

SILT-RACHAYA S.T.

Pressure (Kg/cm^2)	dial (cm)	2H (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 log. (min)	t 50 (min)	t 90 (min)	$\frac{0.197\ H^2}{t\ 50\ log}$ (cm^2/min)	$\frac{0.197\ H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848\ H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	0.925							
	0.0909			0.368	I2.5	I2.0	47.0	0.0I37	0.0I42	0.0I56
0.25		I.8I9	0.833							
	0.0437			0.I76	I0.0	8.0	30.0	0.0I59	0.0I98	0.0228
0.50		I.775	0.789							
	0.0556			0.II0	6.8	5.4	20.0	0.022I	0.0279	0.0324
1.00		I.720	0.734							
	0.06I4			0.063	5.2	3.2	I4.2	0.0270	0.0438	0.0425
2.00		I.658	0.671							
	0.0632			0.03I	3.8	2.7	10.0	0.0342	0.0482	0.0560
4.00		I.595	0.608							
	0.0604			0.0I5	3.2	2.4	9.0	0.0376	0.0501	0.0575
8.00		I.535	0.547							

Initial m.c.= 33.9% Final m.c.= 2I.8% $2Ho = \frac{I22.3}{45.58 \times 2.71 \times 1} = 0.992$ cm

SILT - RACHAYA R.T. $\Delta P/P = 1$

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	0.922	0.933					
	0.0863				0.348	11.2	43.0	0.0I53	0.0I7I
0.25		I.824	0.836	0.846					
	0.0536				0.220	6.9	26.0	0.0230	0.0263
0.50		I.770	0.782	0.791					
	0.05I5				0.I04	3.4	I3.0	0.0440	0.0496
1.00		I.7I8	0.730	0.739					
	0.054I				0.055	3.0	I2.0	0.0469	0.0504
2.00		I.664	0.676	0.684					
	0.0683				0.034	3.0	10.0	0.0436	0.0563
4.00		I.596	0.608	0.6I5					
	0.0630				0.0I6	2.0	7.5	0.0602	0.0691
8.00		I.533	0.545	0.551					

Initial m.c.= 33.6% Final m.c.= 2I.5% $2Ho = \frac{I22.I5}{45.60x2.71x1} = 0.988$ cm.

SILT - RACHAYA R.T. $\Delta P/P = 2$

Pressure	Δ dial	2H	2H-2Ho	$\frac{2H-2Ho}{2Ho}$	a_v	t 50	t 90	$\frac{0.197\,H^2}{t\,50}$	$\frac{0.848\,H^2}{t\,90}$
(Kg/cm^2)	(cm)	(cm)	(cm)	e	(cm^2/Kg)	(min)	(min)	(cm^2/min)	(cm^2/min)
0.00		1.910	0.923	0.935					
	0.0802				0.324	12.5	50	0.0138	0.0148
0.25		1.830	0.843	0.854					
	0.0681				0.138	5.5	23	0.0288	0.0297
0.75		1.762	0.775	0.785					
	0.0838				0.056	3.0	12	0.0485	0.0522
2.25		1.678	0.691	0.700					
	0.0935				0.021	2.2	8	0.0594	0.0704
6.75		1.584	0.597	0.605					

Initial m.c.= 33.2 % Final m.c.= 21.9% $2Ho = \frac{122.0}{45.6 \times 2.71 \times 1} = 0.987$ cm.

SILT - RACHAYA   R.T. $\Delta P/P = 3$

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	0.9I7	0.923					
	0.0825				0.332	I3.0	5I.0	0.0I32	0.0I45
0.25		I.827	0.834	0.840					
	0.0904				0.I2I	5.5	20.0	0.0284	0.0336
1.00		I.737	0.744	0.749					
	0.I20I				0.040	2.9	11.2	0.0477	0.053I
4.00		I.6I7	0.624	0.628					

Initial m.c.= 33.5%   Final m.c.= 23.4% $2Ho = \frac{122.75}{45.60 \times 2.71 \times 1} = 0.993$ cm.

SILT-RACHAYA R.T. $\Delta P/P = 1$ F.P.

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.I97\ H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848\ H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	0.933					
	0.0820			0.340	I2.5	44.5	0.0I37	0.0I5I
0.25		I.828	0.848					
	0.0420			0.I72	7.4	26.5	0.0I85	0.0202
0.50		I.786	0.805					
	0.0560			0.110	3.5	I3.1	0.0230	0.0251
1.00		I.730	0.750					
	0.0700			0.063	3.0	I2.0	0.0335	0.0349
2.00		I.660	0.687					
	0.0720			0.033	2.6	9.6	0.0408	0.04I9
4.00		I.588	0.621					
	0.07I0			0.0I6	1.8	6.8	0.0484	0.0511
8.00		I.5I7	0.556					

Initial m.c.= 33.5% Final m.c.= 2I.6% $2Ho = \frac{I22.I6}{45.58x2.71x\ 1} = 0.989$ cm

RACHAYA S.T.

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	$\frac{2H-2Ho}{2 Ho}$ e	a_v (cm^2/Kg)	t 50 log. (min)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50\ log.}$ (cm^2/min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/min)
0.00		1.9I0	0.908							
	0.I056			0.424	11.0	10.0	37	0.0I54	0.0I69	0.0I97
0.25		1.804	0.802							
	0.0383			0.I52	6.5	4.6	I8	0.024I	0.0340	0.0374
0.50		I.766	0.764							
	0.0582			0.II6	4.0	4.2	I6	0.037I	0.0353	0.0399
1.00		1.708	0.706							
	0.0655			0.066	3.2	3.3	I2	0.0430	0.04I8	0.0494
2.00		I.642	0.640							
	0.0678			0.034	2.6	2.3	8	0.0489	0.0553	0.0685
4.00		I.574	0.572							
	0.0665			0.0I6	2.2	1.9	7	0.053I	0.06I5	0.07I8
8.00		I.508	0.506							

Initial m.c.= 36 % Final m.c.= 23.2% $2Ho = \frac{123.6}{45.72 \times 2.7 \times 1} = 1.001$ cm.

RACHAYA R.T. $\Delta P/P = 2$

Pressure (Kg/cm^2)	Δ dial (cm)	2 H (cm)	2H-2Hc (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	0.9I2	0.9I4					
	0.0970				0.392	8.0	32.0	0.02I3	0.0229
0.25		I.8I3	0.8I5	0.8I6					
	0.0665				0.I34	3.5	II.0	0.0444	0.0609
0.75		I.746	0.748	0.749					
	0.0838				0.055	I.7	6.0	0.084I	0.I020
2.25		I.663	0.665	0.666					
	0.0977				0.022	I.2	4.2	0.I070	0.I3I0
6.75		I.565	0.567	0.568					

Initial m.c. = 34.8 % Final m.c. = 23.7 % $2Ho = \frac{I23.3}{45.72x2.7\ xI} = 0.998$ cm.

RACHAYA R.T. $\Delta P/P = 3$

Pressure	Δdial	2 H	2H-2Ho	$\frac{2H-2Ho}{2 Ho}$	a_v	t 50	t 90	$\frac{0.197 H^2}{t_{50}}$	$\frac{0.848 H^2}{t_{90}}$
(Kg/cm²)	(cm)	(cm)	(cm)	c	(cm²/Kg)	(min)	(min)	(cm²/min)	(cm²/min)
0.00		I.9I0	0.9I5	0.9I9					
	0.0536				0.2I6	I3.0	45.0	0.0I34	0.0I66
0.25		I.856	0.86I	0.865					
	0.0975				0.I29	6.0	20.0	0.0268	0.0346
I.00		I.759	0.764	0.768					
	0.I422				0.047	3.2	I2.0	0.0438	0.0503
4.00		I.6I7	0.622	0.625					

Initial m.c = 34.6 % Final m.c. = 25.6 % $2 Ho = \frac{122.9}{45.72 \times 2.7 \times 1} = 0.995$ cm.

RACHAYA R.T. $\Delta P/P$ = I F.P.

Pressure (Kg/cm²)	Δdial (cm)	2 H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm²/Kg)	t 50 (min)	t90 (min)	$\frac{0.197\ H^2}{t\ 50}$ (cm²/min)	$\frac{0.848\ H^2}{t\ 90}$ (cm²/min)
0.00		I.9I0	0.9I6	0.92I					
	0.0533				0.2I2	I2.5	45.0	0.0I40	0.0I67
0.25		I.857	0.863	0.868					
	0.0386				0.I56	5.8	22.0	0.0286	0.0325
0.50		I.8I8	0.824	0.829					
	0.052I				0.I06	3.5	I2.0	0.045I	0.0567
I.00		I.766	0.772	0.776					
	0.0775				0.078	2.8	II.0	0.0524	0.0574
2.00		I.688	0.694	0.698					
	0.09I4				0.046	2.2	7.5	0.0603	0.0762
4.00		I.597	0.603	0.606					
	0.09I9				0.023	I.8	6.5	0.0656	0.0783
8.00		I.505	0.5II	0.5I4					

Initial m.c. = 34.6 % Final m.c. = 23.7 % $2Ho = \frac{I22.7}{45.72 \times 2.7 \times 1} = 0.994$ cm.

B5R95 S.T.

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 log (min)	t 50 (min)	t 90 (min)	$\frac{0.197H^2}{t\ 50\ log.}$ (cm^2/min)	$\frac{0.197H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	I.006							
	0.0762			0.320	33	32.0	I20	0.0052	0.0054	0.0062
0.25		I.834	0.926							
	0.0426			0.I80	22	I5.0	55	0.0073	0.0I08	0.0I26
0.50		I.791	0.88[illegible]							
	0.0696			0.I46	I5	I3.0	50	0.0I01	0.0II7	0.0I3I
I.00		I.72I	0.808							
	0.0706			0.074	11	7.5	27	0.0I27	0.0I86	0.0223
2.00		I.651	0.734							
	0.0726			0.038	8	6.5	24	0.0I60	0.0I97	0.0230
4.00		I.578	0.657							
	0.0691			0.0I8	6	4.5	I7	0.0I95	0.0261	0.0297
8.00		I.509	0.585							

Initial m.c.= 37.5% Final m.c.= 24.1% $2Ho= \frac{116.35}{45.58x2.68x1} = 0.952$ cm.

B5R95 R.T. $\Delta P/P = 1$

Pressure (Kg/cm^2)	Δdial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197\,H^2}{t\,50}$ (cm^2/min)	$\frac{0.848\,H^2}{t\,90}$ (cm^2/min)
0.00		I.910	0.969	1.029					
	0.08I3				0.344	25.0	90	0.0068	0.0082
0.25		I.829	0.888	0.943					
	0.0660				0.280	I8.0	65	0.0088	0.0I05
0.50		I.763	0.822	0.873					
	0.0584				0.I24	I0.5	38	0.0I4I	0.0I67
1.00		I.704	0.763	0.811					
	0.0683				0.073	6.9	25	0.0I99	0.0236
2.00		I.636	0.695	0.738					
	0.0741				0.039	5.8	22	0.02I7	0.0246
4.00		I.562	0.621	0.660					
	0.0762				0.021	4.7	I8	0.0243	0.0273
8.00		I.485	0.544	0.578					

Initial m.c. = 38.1 % Final m.c. = 25.1% $2Ho = \frac{II4.95}{45.58 \times 2.68 \times 1} = 0.941$ cm.

B 5R95 R.T. $\Delta P/P = 2$

Pressure	Δdial	2H	2H-2Ho	$\frac{2H-2Ho}{2Ho}$	a_v	t 50	t 90	$\frac{0.197H^2}{t\ 50}$	$\frac{0.848\ H^2}{t\ 90}$
(Kg/cm^2)	(cm)	(cm)	(cm)	e	(cm^2/Kg)	(min)	(min)	(cm^2/min)	(cm^2/min)
0.00		I.9I0	0.958	1.006					
	0.0706				0.296	18.0	65	0.0096	0.0114
0.25		I.839	0.887	0.932					
	0.0939				0.I98	9.0	3	0.0I76	0.0200
0.75		I.745	0.793	0.833					
	0.I409				0.098	6.4	24	0.02I5	0.0247
2.25		I.604	0.652	0.685					
	0.I249				0.029	4.7	I8	0.0248	0.0279
6,75		I.479	0.527	0.553					

Initial m.c.= 38.2% Final m.c.= 26.3% 2Ho= $\frac{II6.35}{I22.I54}$ = 0.952 cm.

B 5R95 R.T. $\Delta P/P = 3$

Pressure (Kg/km^2)	Δ dial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2\,Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197\,H^2}{t\,50}$ (cm^2/min)	$\frac{0.848\,H^2}{t\,90}$ (cm^2/min)
0.00		I.9I0	0.973	I.038					
	0.0939				0.400	I9.0	68	0.0089	0.0I08
0.25		I.8I6	0.879	0.938					
	0.II68				0.I66	I2.0	45	0.0I27	0.0I45
1.00		I.699	0.762	0.8I3					
	0.I4I7				0.050	7.5	28	0.0I74	0.0200
4.00		I.557	0.620	0.662					

Initial m.c.= 37.8% Final m.c.= 27.2% $2Ho = \frac{II4.45}{I22.I54} = 0.937$ cm.

B 5R95 R.T. $\Delta P/P = 1$ F.P.

Pressure (Kg/cm^2)	Δdial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t_{50}}$ (cm^2/min)	$\frac{0.848 H^2}{t_{90}}$ (cm^2/min)
0.00		1.910	0.960	1.010					
	0.0965				0.408	26.0	105	0.0065	0.0069
0.25		1.813	0.863	0.908					
	0.0546				0.228	14.0	55	0.0112	0.0123
0.50		1.759	0.809	0.851					
	0.0609				0.128	10.5	38	0.0140	0.0166
1.00		1.698	0.748	0.787					
	0.0660				0.069	6.7	24	0.0203	0.0244
2.00		1.632	0.682	0.718					
	0.0736				0.039	4.8	18	0.0260	0.0299
4.00		1.558	0.608	0.640					
	0.0792				0.021	4.2	15	0.0270	0.0325
8.00		1.479	0.529	0.557					

Initial m.c. = 38.2 % Final m.c.= 25.2% $2Ho = \frac{116.05}{122.154} = 0.950$ cm.

BIOR90 S.T.

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 log (min)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50\ log.}$ (cm^2/min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	I.239							
	0.0983			0.460	55	53	205	0.003I	0.0032	0.0036
0.25		I.8I2	I.I24							
	0.0678			0.320	50	42	I60	0.0031	0.0037	0.0042
0.50		I.744	I.044							
	0.0922			0.2I6	38	27	97	0.0037	0.0052	0.0063
1.00		I.652	0.936							
	0.0902			0.I06	30	26	95	0.0042	0.0049	0.0057
2.00		I.56I	0.830							
	0.0891			0.052	I9	I6	58	0.0059	0.0071	0.0084
4.00		I.472	0.725							
	0.0759			0.022	I4	I2	45	0.0072	0.0084	0.0097
8.00		I.396	0.636							

Initial m.c.= 46.1 % Final m.c.= 26.2 % $2Ho = \frac{103.2}{45,48 \times 2.66 \times 1} = 0.853$ cm.

BIOR90 R.T. $\Delta P/P = 1$ Higher initial value

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848\ H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	I.066	1.263					
	0.I346				0.320	28.0	95	0.0060	0.0076
0.50		I.775	0.93I	I.I03					
	0.III7				0.264	29.0	I08	0.0050	0.0058
1.00		I.664	0 820	0.97I					
	0.0940				0.111	I6.5	60	0.0078	0.0092
2.00		I.570	0.726	0.860					
	0.09I4				0.054	I2.2	46	0.0093	0.0I07
4.00		I.478	0.634	0.75I					
	0.0762				0.022	7.1	27	0.0I44	0.0I63
8.00		I.402	0.558	0.661					

Initial m.c.= 46.9% Final m.c.= 27.8% $2Ho = \frac{102.1}{45.48 \times 2.66 \times 1} = 0.844$ cm.

BIOR90 R.T. $\Delta P/P = 2$

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\,50}$ (cm^2/min)	$\frac{0.848 H^2}{t\,90}$ (cm^2/min)
0.00		I.9I0	I.066	I.263					
	0.I092				0.5I6	46.0	I70	0.0037	0.0043
0.25		I.80I	0.957	1.I34					
	0.I244				0.296	22.0	80	0.0067	0.0080
0.75		I.676	0.832	0.986					
	0.I384				0.I09	I3.5	50	0.0094	0.0I09
2.25		I.538	0.694	0.822					
	0.I244				0.033	9.0	34	0.0119	0.0I36
6.75		I.4I3	0.569	0.674					

Initial m.c.= 48.0 % Final m.c.= 28.2% 2Ho= $\frac{102.1}{45.48 \times 2.66}$ = 0.844 cm.

BIOR90 R.T. $\Delta P/P = 3$

Pressure (Kg/cm^2)	Δdial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848\ H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	I.065	I.260					
	0.III2				0.524	45.0	I60	0.0037	0.0045
0.25		I.799	0.954	I.I29					
	0.I4I0				0.223	20.0	75	0.0073	0.0084
1.00		I.658	0.8I3	0.962					
	0.I676				0.066	I0.5	38	0.0II6	0.0I38
4.00		I.490	0.645	0.763					

Initial m.c.= 47,4%   Final m.c.= 30.4% $2Ho = \frac{I02.2}{I20.976} = 0.845$ cm.

BIOR90 R.T. $\Delta P/P = 1$ Higher initial value F.P.

Pressure	Δ dial	2H	2H-2Ho	$\frac{2H-2Ho}{2Ho}$	a_v	t 50	t 90	$\frac{0.197H^2}{t\ 50}$	$\frac{0.848H^2}{t\ 90}$
(Kg/cm^2)	(cm)	(cm)	(cm)	e	(cm^2/Kg)	(min)	(min)	(cm^2/min)	(cm^2/min)
0.00		I.9I0	I.052	1.226					
	0.I448				0.338	4I.0	I60	0.0040	0.0045
0.50		I.765	0.907	I.057					
	0.0833				0.I94	24.0	86	0.0061	0.0073
1.00		I.682	0.824	0.960					
	0.0863				0.I01	I6.0	58	0.0082	0.0098
2.00		I.595	0.737	0.859					
	0.0838				0.048	I0.2	40	0.0II6	0.0I28
4.00		I.5I2	0.654	0.762					
	0.08I3				0.024	8.5	32	0.0I25	0.0I43
8.00		I.430	0.572	0.666					

Initial m.c.= 45.9 % Final m.c.= 27.4% $2Ho = \frac{104.05}{45.60 \times 2.66 \times 1} = 0.858$ cm.

B I5R85 S.T.

Pressure (Kg/cm^2)	Δ dial (cm)	2H (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 log (min)	t 50 (min)	t 90 (min)	$\frac{0.197H^2}{t\ 50\ log}$ (cm^2/min)	$\frac{0.197H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	1.653							
	0.I293			0.720	72	63	240	0.0023	0.0026	0.0030
0.25		I.78I	I.473							
	0.II48			0.636	62	55	2I0	0.0024	0.0026	0.0030
0.50		I.666	I.3I4							
	0.I288			0.358	49	52	I90	0.0026	0.0024	0.0028
1.00		I.537	I.I35							
	0.II09			0.I55	40	36	I38	0.0027	0.0030	0.0034
2.00		I.426	0.980							
	0.I006			0.070	27	23	85	0.0034	0.0040	0.0047
4.00		I.325	0.840							

Initial m.c.= 60% Final m.c.= 32.2% $2Ho = \frac{86.65}{45.58 \times 2.64 \times 1} = 0.720$ cm.

B I5R85 R.T. $\Delta P/P = 1$

Pressure (Kg/cm^2)	Δdial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/Kg)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/Kg)
0.00		I.9I0	I.I88	I.645					
	0.I34I				0.744	64	240	0.0026	0.0030
0.25		I.776	I.054	I.459					
	0.I079				0.596	50	I90	0.0029	0.0033
0.50		I.668	0.946	I.3I0					
	0.I062				0.294	38	I42	0.0034	0.0039
1.00		I.562	0.840	I.I63					
	0.I087				0.I5I	27	100	0.0041	0.0048
2.00		I.453	0.73I	I.0I2					
	0.0995				0.069	I9	72	0.0051	0.0058
4.00		I.353	0.631	0.874					

Initial m.c.= 59.9%   Final m.c.= 34.0 % $2Ho = \frac{86.9}{45,58 \times 2.64 \times 1} = 0.722$ cm.

B I5R85 R.T. $\Delta P/P = 2$

Pressure (Kg/cm^2)	Δdial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197\,H^2}{t\,50}$ (cm^2/min)	$\frac{0.848\,H^2}{t\,90}$ (cm^2/min)
0.00		I.9I0	I.I89	I.649					
	0.I448				0.804	62	235	0.0027	0.0030
0.25		I.765	I.044	I.448					
	0.I676				0.466	45	I72	0.0031	0.0035
0.75		I.597	0.876	I.2I5					
	0.I752				0.I62	29	110	0.0039	0.0044
2.25		I.422	0.701	0.972					

Initial m.c. = 6I.I% Final m.c. = 37.2% $2Ho = \frac{86,65}{45,48 \times 2.64 \times 1} = 0.721$ cm.

B I5R85 R.T. $\Delta P/P = 3$

Pressure (Kg/cm^2)	Δdial (cm)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.197 H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848 H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	I.I9I	I.656					
	0.I092				0.604	68	250	0.0025	0.0029
0.25		I.80I	I.082	I.505					
	0.2222				0.4I3	56	2I0	0.0025	0.0029
1.00		I.578	0.859	I.I95					
	0.2I46				0.099	27	100	0.0039	0.0046
4.00		I.364	0.645	0.897					

Initial m.c.= 6I.7% Final m.c. = 35.8% $2Ho = \frac{86.55}{45.58 \times 2.64 x1} = 0.7I9$ cm.

B I5R85 R.T. $\Delta P/P = 1$ Higher initial value

Pressure (Kg/cm^2)	Δdial (cm.)	2H (cm)	2H-2Ho (cm)	$\frac{2H-2Ho}{2\ Ho}$ e	a_v (cm^2/Kg)	t 50 (min)	t 90 (min)	$\frac{0.I97.H^2}{t\ 50}$ (cm^2/min)	$\frac{0.848\ H^2}{t\ 90}$ (cm^2/min)
0.00		I.9I0	I.9I0	1.653					
	0.2337				0.650	52	I96	0.0030	0.0035
0.50		I.676	0.956	I.328					
	0.I2I9				0.340	39	I50	0.0033	0.0037
1.00		I.554	0.834	I.I58					
	0.III2				0.I54	27	100	0.0041	0.0047
2.00		I.443	0.723	I.004					
	0.0978				0.068	I9	73	0.0050	0.0056
4.00		I.345	0.625	0.868					

Initial m.c.= 6I.6 % Final m.c.= 37.2% $2Ho = \frac{86.70}{45.58 \times 2.64 \times 1} = 0.720$ cm.

A P P E N D I X " C "

"SQUARE ROOT" PLOTTING SHEET

Pressure before start of test ____ 5 Kg/cm² __________ t50 = 17.5 min.

Pressure at completion of test __ 10 Kg/cm² __________ t90 = 65 min.

Description of sample ________ B 5 RAPID TEST ____

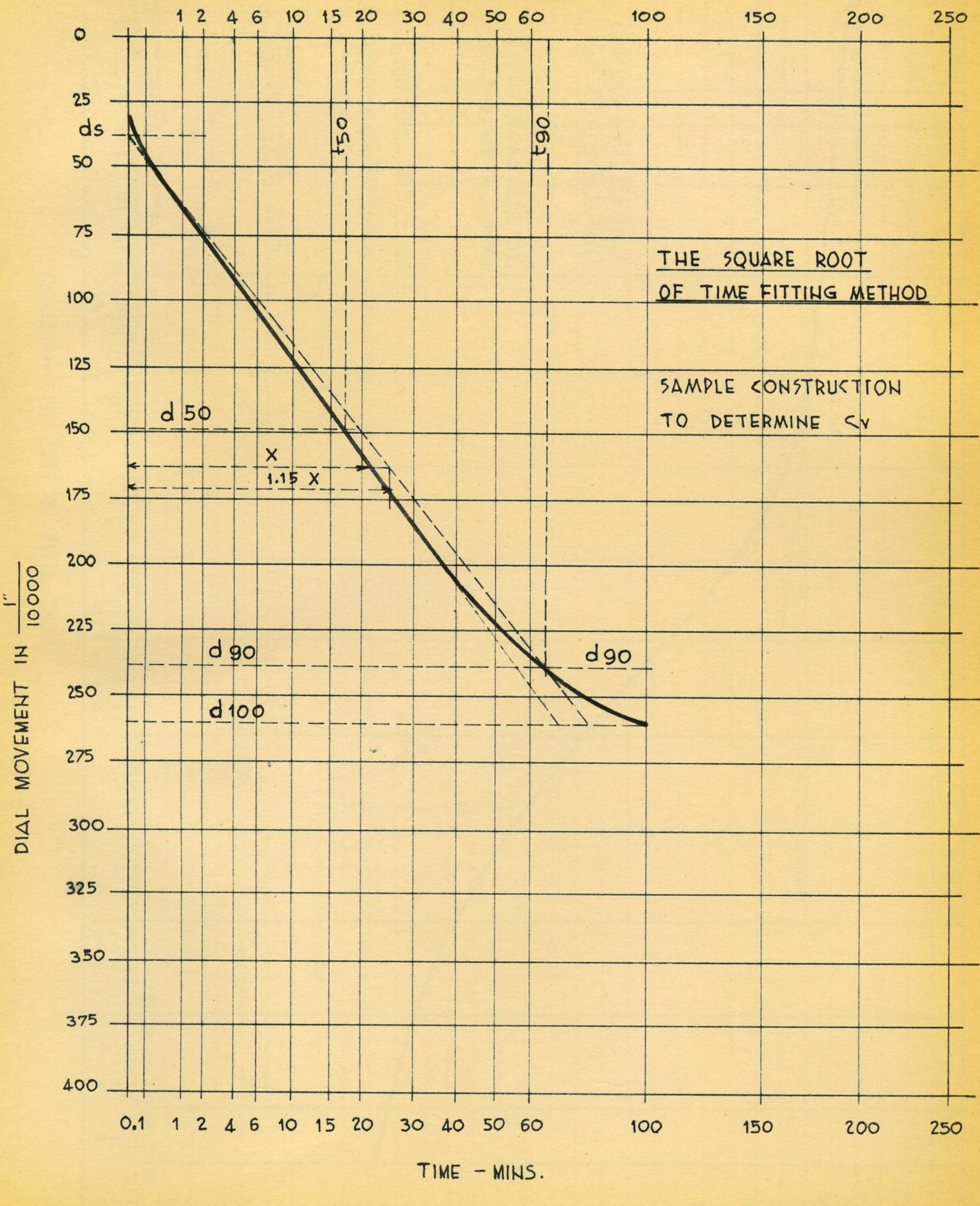


Fig. № 23

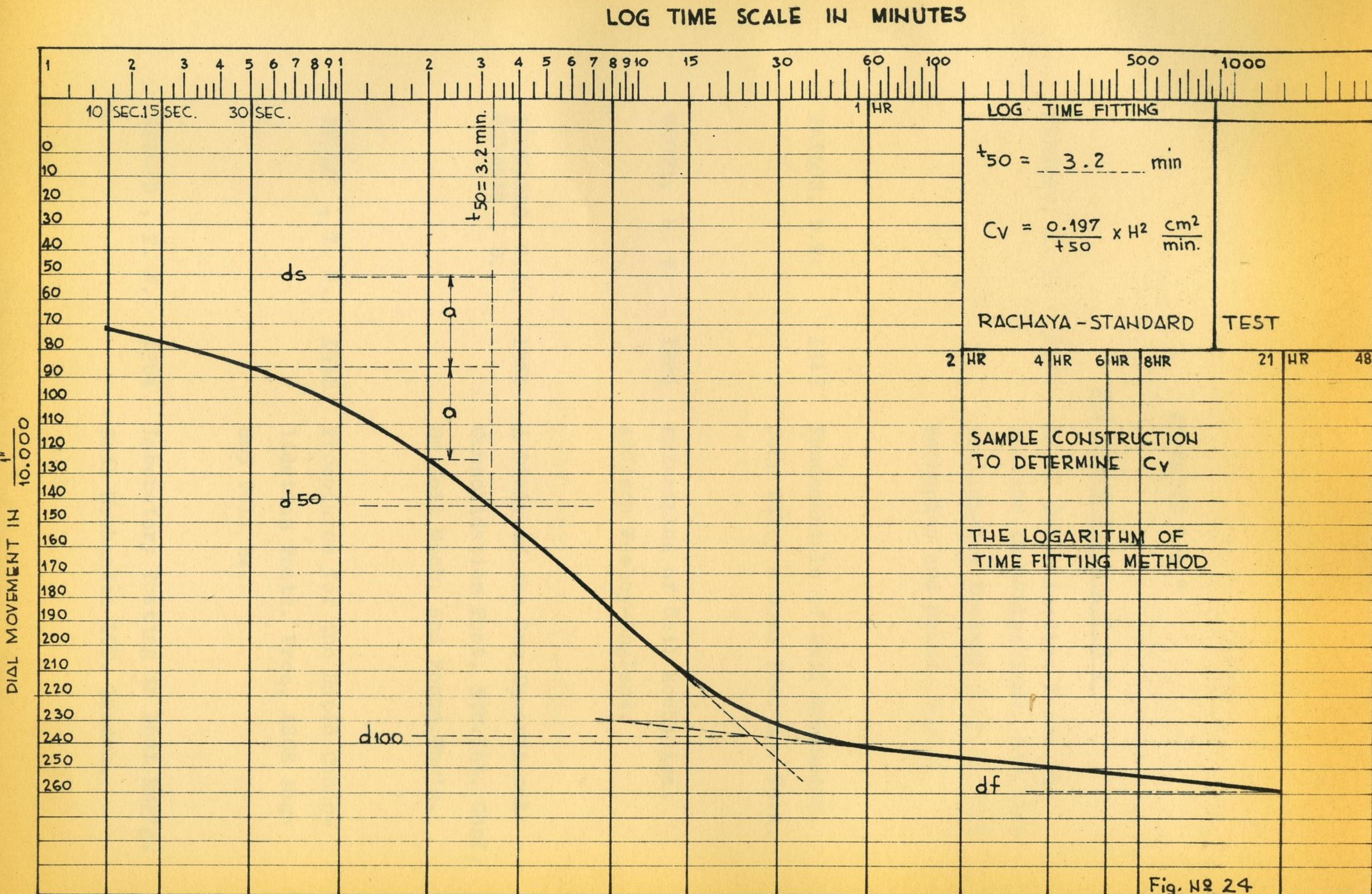

LOG TIME SCALE IN MINUTES
1 2 3 4 5 6 7 8 9 1 2 3 4 5 6 7 8 9 10 15 30 60 100 500 1000
10 SEC. 15 SEC. 30 SEC. 1 HR
2 HR 4 HR 6 HR 8HR 21 HR 48
DIAL MOVEMENT IN 1"/10.000
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260
t_{50} = 3.2 min.
ds
a
a
d50
d100
df
LOG TIME FITTING
t_{50} = 3.2 min
$Cv = \frac{0.197}{t_{50}} \times H^2 \ \frac{cm^2}{min.}$
RACHAYA - STANDARD TEST
SAMPLE CONSTRUCTION TO DETERMINE Cv
THE LOGARITHM OF TIME FITTING METHOD

Fig. Nº 24

APPENDIX " D "

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