

Development of Artificial Porous Media

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ABSTRACT

This paper describes the various methods of developing artificial porous media and also presents some results from the preliminary tests already conducted. Firstly, a brief review of the techniques that have been tried before is given. Many types of materials and construction techniques have been tried but the products mostly had weaknesses. Thus the products were only useful for limited application. The objective of this research is to develop a method which can produce artificial cores with tailor-made characteristics like porosity, permeability and wettability. By producing this artificial porous media we can solve the problem of not having a field core or having to import berea cores.

INTRODUCTION

Oil is present underground in porous and permeable sandstones or carbonates rocks. Beside oil, water and gas may also be present. During well drilling, samples of reservoir rocks may be taken. The task of taking reservoir rocks sample is called coring. In the course of well drilling only limited rocks sample are taken as this job is expensive and delay the well completion. Cores are not always available when required. For experiments conducted in the laboratories normally surface sandstone like berea sandstones and clashach sandstone are used. These surface sandstones are obtained from USA and United Kingdom respectively. There is no surface sandstone available in Malaysia.

Sometimes artificial cores are used in experiments. The most basic artificial cores are sandpack and glass beads pack. Other examples of artificial cores are compacted and cemented sands, compacted and heated glass beads and compacted and heated teflon powder. The use of artificial cores over the field and surface cores have certain advantages and disadvantages. Artificial cores is good because the pore system and the wettability characteristics are more uniform and can be controlled. Artificial cores is good for fundamental studies and studies carried out at ambient conditions. The main disadvantage of artificial cores is simply that it is not representative of reservoir rock.

Review of artificial core construction

The earliest method of preparing artificial core was simply by packing sand in a holder (Coley et al 1956, Wygal 1963, Heath 1965). This is called sandpack. Later other packing materials such as glass beads, teflon beads and crushed rocks were used (Ever 1967, Beard and Weyl 1973, McCaffery 1973, Klimentos 1988). The method of constructing artificial cores combine several techniques like compaction, cementation and heating. Normally the raw materials are made into small sizes of a few hundred microns or in powder-like form. The compaction pressure employed is normaaly several thousands psi. The cementing agents are like resin, araldite or portland cement. Heating is used either to fused the material like glass or to speed up the chemical reaction between the material and the

cementing agent. After the porous media is ready it is sometimes treated with a wetting agent or age in crude oil in order to alter the wettability. Table 1 gives a summary of the methods of constructing artificial core.

Table 1: Summary of work on constructing artificial cores

Author, year	Raw Materials	Methods	Porosity range	Perm. range.
Coley, 1956	fritted glass	heat 560 C	0.32-0.40	0.4-1.5
Wygai, 1963	sand, glass beads	packing, cementation	0.15-0.40	0.3-5.0
Heath, 1965	sand, cement, water	vary proportion	0.23-0.40	0.1-6.0
Ever, 1967	sand, portland cement	adjust water vol.	0.00-0.05	0.00-0.01
Beard, 1973	sand	vary size of sand	0.10-0.40	0.2-7.0
Mc Caffery, 1973	teflon (PTFE)	compressed, heated	0.20-0.35	0.15-0.75
Klimentos, 1988	sand, glass beads	epoxy resin	0.28-0.35	1.8-14.6

Porous media and wettability

The rock surface has a preference to be wetted either with water or oil. Some rocks have equal or nearly equal preference for water or oil. Rock of this type has intermediate wettability. The rock surface with greater tendency to be covered with water film is called water-wet and the rock surface which has greater tendency to be covered by oil film is called oil-wet. Material which has only one type of wettability all over its surface has uniform wettability. For example cleaned glass surface is water-wet while clean teflon surface is oil-wet. However reservoir rocks are made up of different materials and interaction with the fluids present in the reservoir may turn the rock surface into different kinds of wettability. This may create a situation in which the rock surface has a different degree of wetting or different wetting all-together. In the microscopic scale reservoir rocks have a nonuniform wettability. In nonuniform wetted rock some of the surface are water-wet and some are oil-wet. The distribution of the wettability types are either random or follow a certain kind of order. When the water-wet surface and oil-wet surface do not follow any certain order (random) the rock is having fractional wettability (Fatt, 1959). In mixed wettability rock the surfaces surrounding the relatively large voids are oil-wet while the surface in tight spots like pore throat and interconnecting channels are water-wet. This distribution was proposed by Salathiel (1973). A detail account of methods of adjusting the wettability of porous media has been described by Anderson (1986). It is an objective of this research to prepare artificial cores with uniform wettability and nonuniform wettability.

Effects of wettability on fluid distribution and fluid flow behaviour

This topic is included in the overall scope of the research but it is not included in the scope of this paper. Thus only a brief account giving the definition and the importance of investigating this topic is given here. It is now accepted that wettability has a very strong influence on fluid distribution and fluid flow behaviour in the porous media (Morrow, 1990). Many simulation studies and experimental studies have been conducted in these topics. Many of these studies used uniform wetted porous media and very few have used nonuniform wetted porous media. Besides that most studies conducted so far were at the macroscopic scale. So far there is very few studies conducted using nonuniform wettability porous media at the microscopic scale (Yadav et al, 1987, McKellar et al, 1988). Much is yet to be understood on the distribution of oil, water and gas and their flow behaviour in nonwetted porous media. In order to understand better these area we plan to carry out investigation at microscopic and macroscopic levels using nonuniform wetted porous media. Both artificial and natural porous media will be used in our experiments.

EXPERIMENTAL WORK

At this moment the experimental work is still at early stage. The materials and methods are described here. Basically the methods of developing the artificial cores in this work fall into three groups.

Method 1 - Compacting mixture of sand and moist sodium silicate and passing through carbon dioxide

Sand was washed cleaned, dried and sieved. Sand with grain size between 150-250 micron and 250-500 microns were used. Sand was mixed with a solution of sodium silicate. The mixtures were compressed at varying pressure and using different amount of sodium silicate. Simultaneously carbon dioxide was passed into the mixture. The process was done at ambient temperature with no heating. The sodium silicate reacts with carbon dioxide to form compound that will bind or cement the sand grain. The process was done for six hours. After six hours the constructed porous media was taken out and its porosity and air permeability were measured. The schematic diagram of the apparatus is shown in Figure 1. Results from these experiments are shown in Table 2.

Method 2 - Compacting mixture of sand with moist portland cement.

Moist portland cement was mixed with sand and the mixture was compressed for three hours. The tests were carried out at different weight force.

Method 3 - Compacting glass beads and sand with epoxy resin

This method is planned but not done yet. Glass beads and sand will used as raw material. Epoxy resin and araldite will be mixed thoroughly and toluene will be added to dilute the mixture. The mixture of glass beads, epoxy resin, araldite and

toluene will be put into the filter press apparatus. The apparatus is shown in Figure 2. The vacuum will suck excess mixture of resin, araldite and toluene. A little weight is placed to compress the mixture. The process was done for three hours.

Method 4 - Compacting and heating of teflon beads/teflon powder

This method of construction is also planned but not done yet. Teflon (polytetrafluoroethylene, PTFE) beads and powder will be compacted at very high pressure (10,000 psi). Simultaneously the teflon powder will be heated at 500 °C. By this process the teflon powder will fuse and form a porous media. The process will be carried out for three hours.

Characteristics of the constructed porous media.

The porous media that has been constructed were tested for their porosity and absolute permeability to air. Later we plan to measure the wettability of the porous media by Amott's Test and relative permeability test.

Experiments to alter the wettability of the porous media.

These experiments are planned but not done yet. Porous media made from glass beads and sand are water-wet. Some of porous media already constructed will have their wettability altered by treatment with oil wetting agent. The oil wetting agent to be used is called 'repelcote'. It is an organochlorosilane solution. We plan to construct mixed-wet porous media by the following method. Porous media at irreducible water saturation will be aged in crude oil (obtained from St. Joseph Field Sarawak) for a period of 8 weeks. The aging will take place at ambient condition.

RESULTS AND ANALYSIS

So far experiments using Method 1 and Method 2 were done. The characteristics of porous media produced from Method 1 (compaction with sodium silicate and carbon dioxide) is given in Table 2. The porous media is one inch long and one inch diameter.

Table 2 : Characteristics of constructed core made using Method 1

A. Size of sand: 125 micron to 250 micron

Compacting pressure, psi	porosity	absolute permeability, darcy
300	0.33	3.5
400	0.35	3.0
600	0.33	1.7
800	0.29	1.0
1000	0.26	0.5

B. Size of sand: 250 micron to 500 micron

Compacting pressure, psi	porosity	absolute permeability, darcy
300	0.34	3.5
400	0.30	2.4
600	0.26	1.9
800	0.23	1.5
1000	0.19	0.8

C. Size of sand : 125 micron to 250 micron

Compacting pressure : 300 psi

Amount of used sodium silicate, gm	porosity	absolute permeability, darcy
5	0.46	25.3
10	0.40	16.6
15	0.33	8.9
20	0.28	1.3

D. Size of sand : 250 micron to 500 micron

Compacting pressure : 300 psi

Amount of used sodium silicate, gm	porosity	absolute permeability, darcy
5	0.40	1.0
10	0.32	0.8
15	0.24	0.6
20	0.15	0.5

An experiment was also carried out in which calcium oxide was used with sodium silicate. The result of this experiment is shown below.

Table 3 : Characteristics of cores made using sodium silicate and calcium oxide

Size of sand : 125-250 micron

Compacting pressure, psi	porosity	abs. permeability, darcy
500	0.34	1.6
1000	0.31	1.2
1500	0.27	0.9
2000	0.23	0.6
2500	0.20	0.5

Plots of compacting pressure versus porosity and permeability, amount of cementing agent used versus porosity and permeability are shown in Figure 3, Figure 4 and Figure 5.

DISCUSSION

The results obtained so far are as expected. The porosity and the permeability decreased linearly with increasing compacting pressure. The same thing happened when the amount of cementing agent is increased. This proves that we can control the porosity and the permeability of the product by varying the compacting pressure and/or amount of cementing agent. The time of pressing is not critical.

One problem we are having with the produced porous media is that it is not stable when contacted with fluids such as water. Also the products have low compressive strength. Thus the quality of the constructed porous media does not meet the specified requirement yet and cannot be used in displacement experiments. To overcome this problem we proposed to include heating during and after the compaction process. Low heating will be used during compaction (75 °C) and high heating up to 500 °C is used after the compaction.

Another method that will be employed so that we can produce a strong and stable porous media is to use epoxy resin as the cementing agent. The amount of the resin used will be controlled so that we get the correct porosity and permeability. This method will use a filter press apparatus with vacuum. We expect the construction of porous media by Method 3 and Method 4 to yield a stable porous media.

So far only preliminary experiments have been conducted. After we have mastered the technique of construction, we will 'fine-tune' it so that we can produce porous media according to the specification required. When a satisfactory porous media has been constructed then we will adjust the wettability of the cores. This work is planned in six months time.

CONCLUSIONS

From the results of literature review and the experiments conducted, we can make the following conclusions:

1. There have been many attempts to construct artificial cores but the product are tailored to specific need only.
2. We have constructed artificial porous media having porosity between 0.10 and 0.40 and absolute permeability between 0.25 darcy to 5.0 darcy.
3. The porous media we have constructed is not stable when contacted with fluids.
4. Heating is thought to be needed in order to stabilise the product. In the future work we will incorporate heating as well as we will use epoxy resin and teflon bead and teflon powder.

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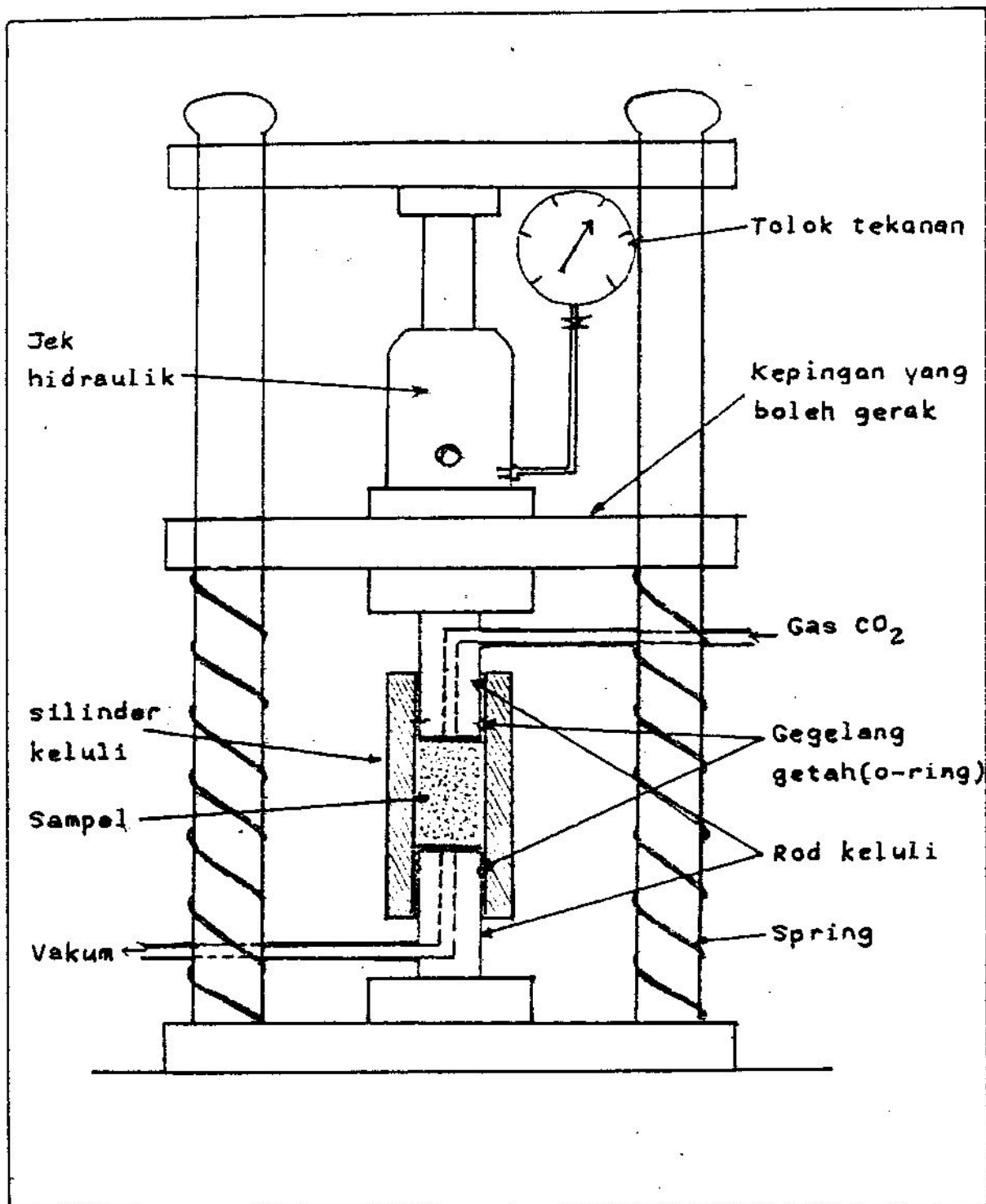


Figure 1 : Schematic Diagram of Apparatus for Constructing Artificial Cores Using Compacting and Passing CO₂ Method.

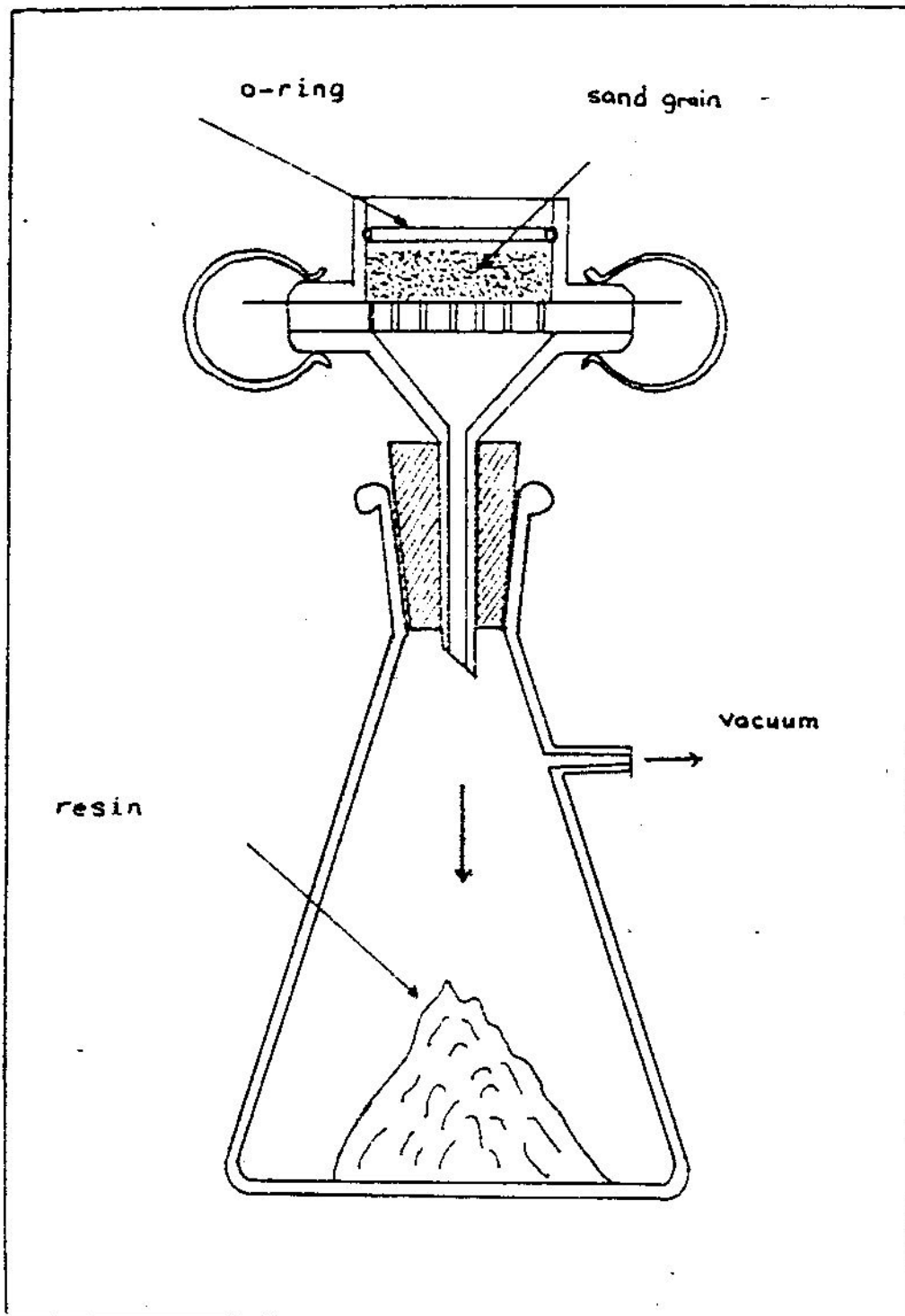


Figure 2 : Schematic Diagram of Apparatus For Constructing Artificial cores Using Laboratory Press with Vacuum Method

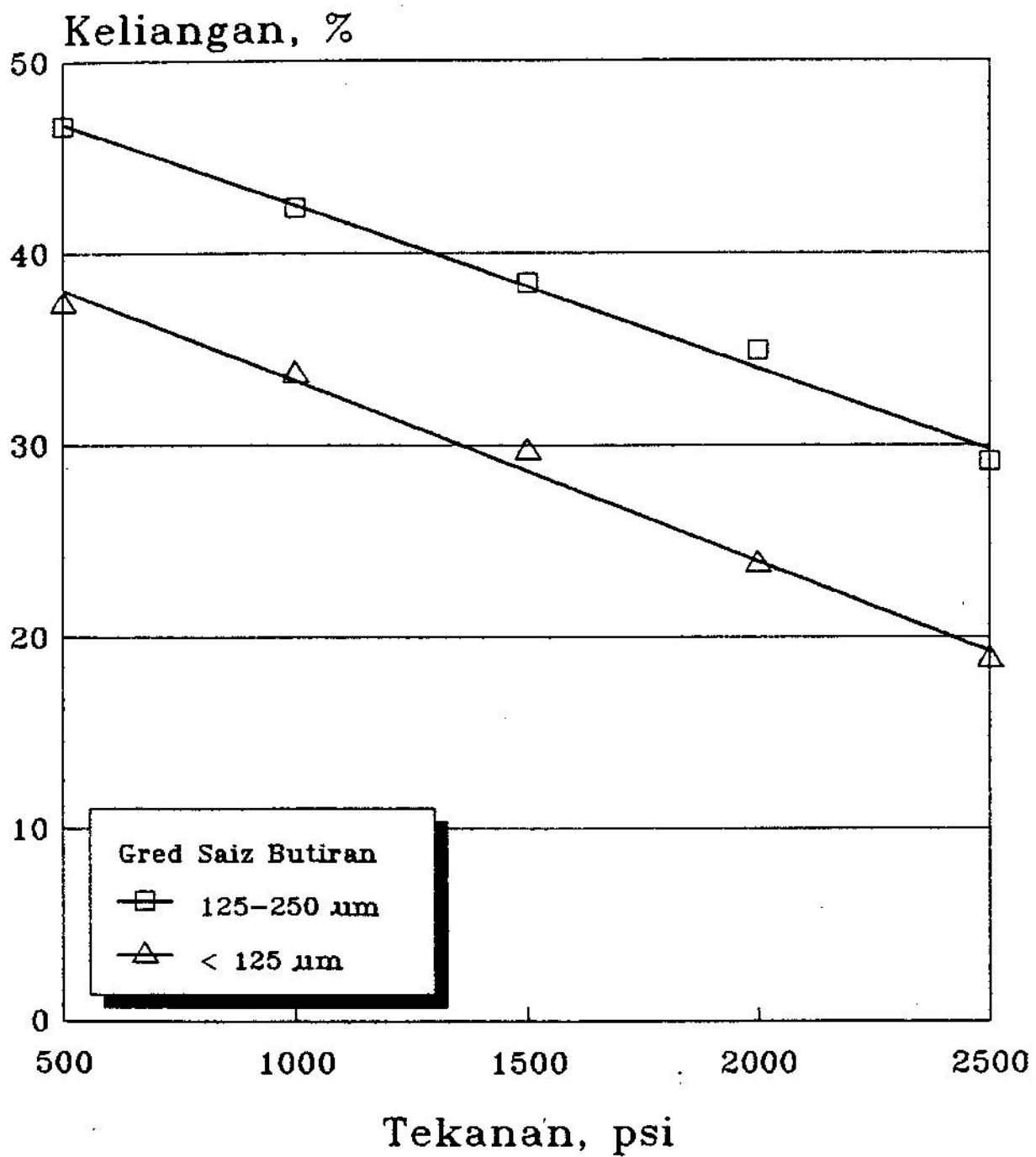


Figure 3 : Plot of Porosity Against Compacting Pressure
(Plot Keliangan Lawan Tekanan Pemasakan)
Size of sand is 125-250 micron with sodium silicate
and calcium oxide being used.

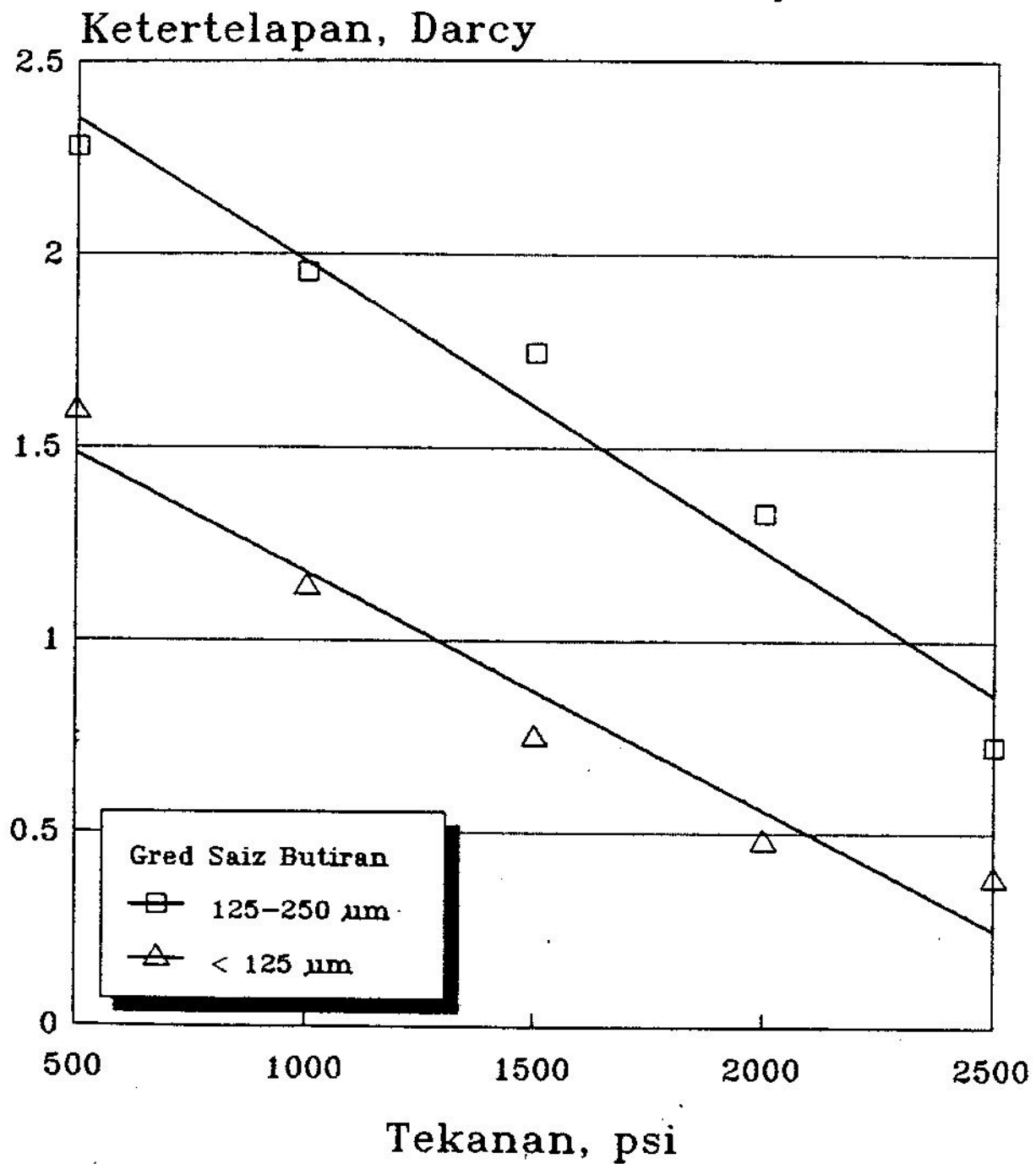


Figure 4 : Plot of Porosity Against Compacting Pressure (with Two Size of Sand and sodium silicate used)
(Plot Keliangan Lawan Tekanan Pemadatan (di mana Dua Saiz Pasir dan nitrium silikat digunakan))

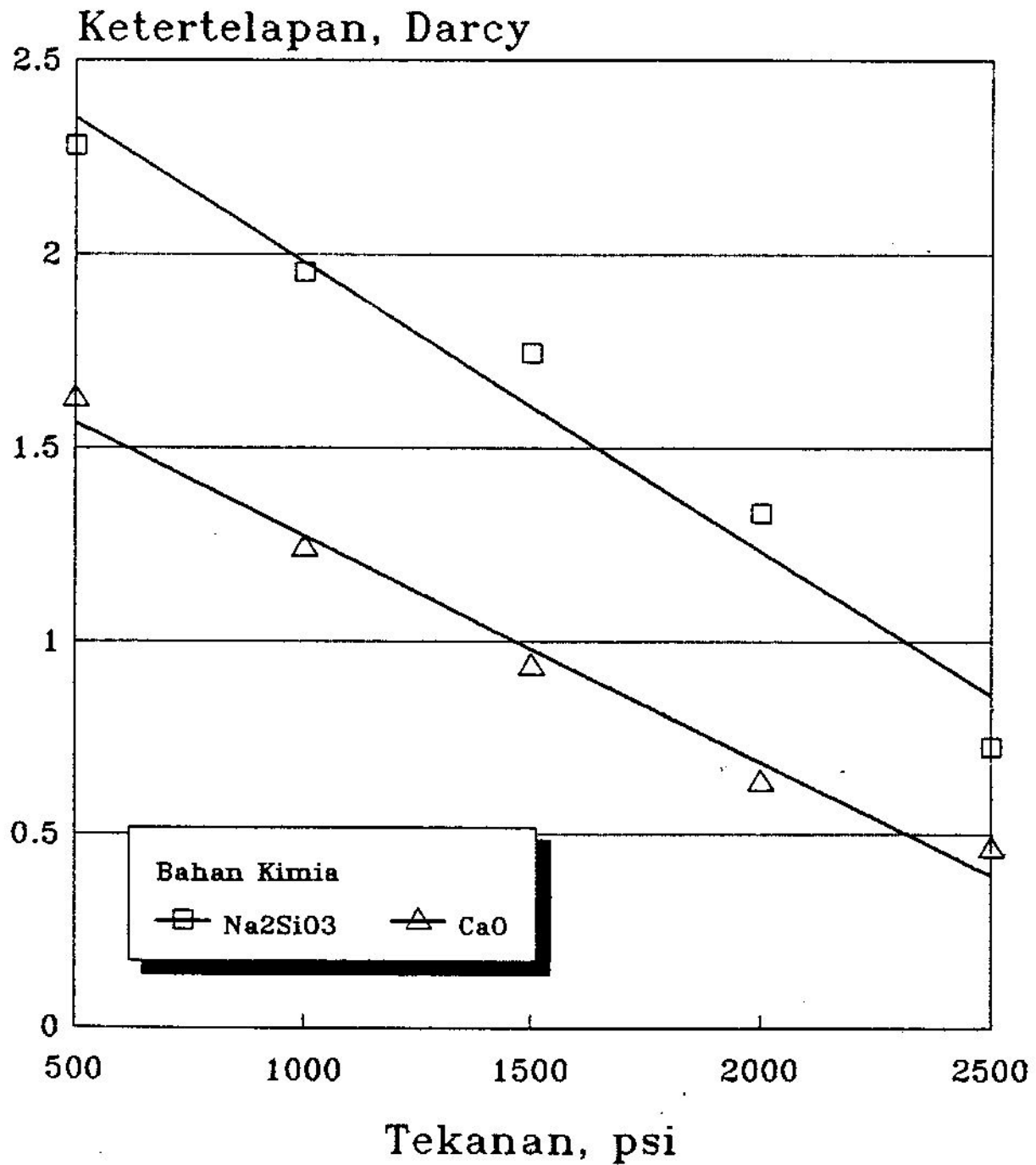


Figure 5 : Plot of Permeability Against Compacting Pressure
(Plot Ketertelapan Lawan Tekanan Pemadatan)
Size of sand is 125-250 microns with sodium silicate
and calcium oxide being used.