IV. THE TEST OF THE CANAL LINING BY THE SOIL CEMENT

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YOJU MATSUYA

Irrigation & Drainage Expert

TAKAKIMI MIYATSU

Land Consolidation Expert

Mae Klong Pilot Project, IADP.

TEST OF THE CANAL LINING BY THE SOIL CEMENT

1. Preface

Agriculture is the foundational industry of Thai Economics. According to the statistic of Ministry of Agriculture and Cooperatives for 1977, farmer house population numbers 29.213 million in 66.6 % (in Japan 19.9 %) of the total population of 43.847 million and people engaged in the profession of agriculture, forestry and fishery reaches 63.2 % (in Japan being 10.6 %) of the total employed population of 24.417 million. In the meantime, the agriculture products, forestry products and aquatic products shares 79.7 % of the total export of Thailand. Though it appears that the industrialization is in progress. So that it is safely to say that the agriculture takes up important place for Thailand. In the agriculture, the paddy is not only depended as principal food but also held as the agricultural yield for export which supports the economics of the country, the requirement for consumption is likely running over the bound of that for export so that to try to increase paddy production becomes the pressing need of the country in any way.

Fortunately, Thailand has been blessed with extensive cultivated land. Should this land of about 12 million ha. will be fully irrigated, increase of yield per unit is a matter of course and the production of 2nd parts of the double cropping held as less than 10 % can be expanded, the increase of rice production may be greatened in rapid progress. At this time, construction of irrigation and drainage facilities are proceeding in urgent pitch and the dam and head works in large scale are the matter of course smaller irrigation and drainage canals etc. and various projects are executing nationally. On the area equipped with irrigation facility, land consolidation has been executed and the target of about 10,000 ha.

per year is made. However, for the year of 1980, in this immense region, only about 30 % has been constructed with main irrigation and drainage facilities and the present situation is that the equipment of facility is more in the tendency to expand facility rate than of mainterance of quality.

The national construction of irrigation and drainage facilities are performed by the Royal Irrigation Department (RID), Ministry of Agriculture and Cooperatives as the central organization and the matters relating to running, operation of the facility after construction, works of maintenance, repair are also performed by RID but the works of operation and maintenance belonging to the government are in the scope of main canal, lateral and sub-lateral canal. In fact, for the on-farm level reaching to the farm, it should be worked by the hands of the farmers themselves but the present situation is that the farmers themselves can not afford both of man power and fund. On the other hand, the places using O & M so far are merely the device so that the problem is whether the irrigation water can be sufficiently supplied or not.

As to the field, from our fact-finding survey on supply and utilizing of irrigation water on on-farm level, we understand that it is necessary to demonstrate the absolute quantity of irrigation water facility for supplying water and the measure of the public users in one body. However, at the present, the organization of water users' group of farmers is not quite perfect. For making the facility completed, we consider that to line the irrigation canal for on-farm level is a link for the completion of facility.

2. Purpose

As to the irrigation canal on the on-farm level, at the present, the unlined ones are used as it is and as the RID has tried to lessen the expenses, except the special case (Remark 1), the canals are not lined. However, on the incline of 1/5,00 or 1/10,000, the unlined canal can be extended to more than 1,500 m or 2,000 m is not uncommon matter (Remark 2) but it is selfevident that there are various disadvantages in the unlined canal comparing with that of lined canal (Remark 3). Consequently, the present situation is that the unlined canal causes obstacle to the smooth flow of the irrigation water on the dcwstream and also becomes the source of insufficient water supply.

On the time of executing the On-Farm Development Project in Mae Klong Pilot Project of IADP, according to the data took from the construction site thoughout the design, construction, maintenance and management of these unlined canal, we understand that to construct the soil cement lining canal is cheaper and simpler than to line them with concrete. We, therefore, should like to introduce the result of study and propose the imformation provided the lining of canal will be considered.

(Remark 1)

In case of lining will be made for the on-farm level.

1. Underdrain part ..... most being concrete pipe

2. Diversion works ..... diversion point towarding to Sub-lateral diversion or irrigation ditch.

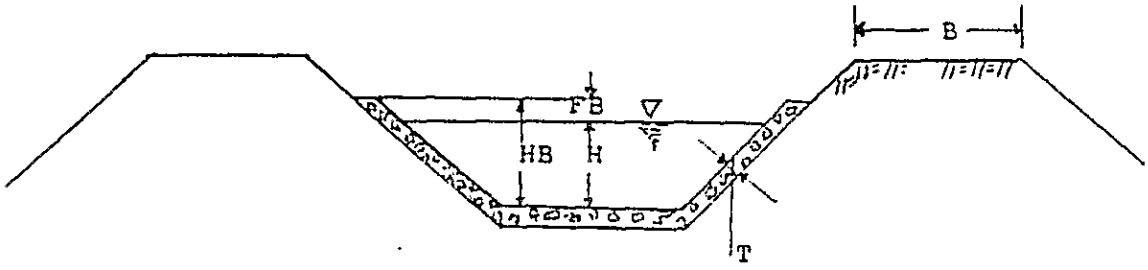
3. Curved part of irrigation ..... when it curves in right angle it will be lined in front (1.0 m) and rear (2.0 m)

4. In case of that the irrigation canal passes the place of Banking more than 1.0 m.

5. Cn the place, soil is expected to be washed away remarkably resulting from drift of rapid current.

(Reference) According to standard of RID, in principle, the main irrigation canal, sub-main irrigation canal shall be made to concrete lining and in such a case, the thickness of concrete and width of the banking shall be as follows :

Depth of water + Freeboard HB(m)	Thickness of lining T(m)	Least of Maximum width B(m)
less than 0.95	0.05	1.00
1.00 - 1.60	0.05	2.00
1.65 - 2.50	0.05	3.00
2.55 - 4.00	0.07	3.00
4.05 - 6.00	0.08	4.00



HB = H + FB

(Remark 2)

Extension of irrigation canal in case of Mae Klong Pilot Project.

Pilot No. 1

Name	Length	
L1-1 (Sub-lateral)	1,800 m	Maximum length is sub-lateral + on-farm irrigation ditch being ℓ ℓ 2,750 m.
L1-2 "	950 m	
L1-3 "	1,800 m	
L2-1 "	2,150 m	
L2-2 "	1,100 m	
TL1-1.2 (Irrigation Ditch)	600 m	

Sub-lateral is the irrigation canal within the on-farm canal from which the irrigation ditch makes diversion.

Pilot No. 2

Name	Length			
T009	935 m	Including	sub-lateral	2 line
T011	1,535 m	"	"	4 "
T015	1,795 m	"	"	4 "
T008	1,370 m	"	"	2 "
T007	570 m	"	"	1 "
T010	1,050 m	"	"	2 "

(Remark 3)

Problem of unlined canal at the field

1. In the dry season, the irrigation canal will become dried, if the drought continues, the soil will shrink and the canal will crack.
2. The water current or rain will wash away the soil; make the slot surface (法面 HORI MEN) fallen; make the water passing section deformed; make bottom of canal worsened.
3. The weed will be easy to grow thick, especially, on the place be often short of water or the ending part on which the drift of current is small, the growth will be remarkable.
4. The buffalo will stroll over and the crab will make hole on the canal thus will damage it.
5. The expenses for maintenance and management will be high up comparing with that of concrete lining canal.

3. Plan of Execution

About to make execution of soil cement on the construction site, in order to know the nature of the laterite soil and set up the target of match, we have carried the laterite soil'(obtaining from the field)to the Research & Laboratory Division of RID and request them to make a test on it.

3-1. Laboratory test of Soil Cement

.....Please see the Request of Test affixed.

3-2. The result of laboratory test.

.....Please see the result of test affixed.

a. Physical test of laterite soil

1. Specific gravity	2.91
2. Natural moisture content	7.2 %

3. Soil classification SC ..... Please see result of test affixed

4. Liquid limit 41.7
5. Plastic limit 24.4
} Plasticity index 17.3

b. Mixing

1. Optimum moisture content 13.2 % (cement = 4% dry soil weight)

Moisture content - from moisture - dry density curve

2. Unconfined compression test ..... Please see result of test affixed

When optimum moisture content is 13.2%, let the cement quantity changed in 2%, 4%, 6% and we will seek the cement quantity when it shows the compressive strength 30 kg/cm^2, then cement quantity is estimated as 10.8%

c. Examination of test

(1) From the laboratory test, we know the quantities of water cement and laterite soil, when it show the compressive strength in 30 kg/cm^2. As execution at the construction site is our propose, and, on consideration of economy on soil cement, we fear the cement quantity of 10.8% may be too much we take compressive strength for 20 kg/cm^2 thus we determine that cement quantity of 7.7% = 8% will be apply at the scene.

(2) Should the specific gravity 2.91 be the associate of soils, the 2.55 - 2.65 in common clayey soil compare with 2.65 - 2.75 in sandy soil shows a quite large difference. The reason is that soil hold much gravel (the gravel with diameter over 2 mm. in weigth of 5% remain in the soil).

(3) When we consider the gradation analysis curve on the mechanical analysis, it is safe to say that they are equal match of graining but the soil holds much gravel so that it can also be held as aggregate and, further, it also composes silt and clay in about 10% and that how can it effect or the soil cement compared with that on the mixing cement and water is an interesting matter.

(4) To have liquid limit in 41.7% is a tendency of the nature of sand and also has plasticity limit in 24.4% and has plastic index in 17.3 so that it shows a stable state as a soil.

(5) The nature moisture content is 7.2% and for the optimum water content is 13.2% on the solidity test, if the water of appropriate quantity is added, it will have good condition and easy to adjust.

DATA OF REQUEST & RESULT OF LABORATORY TEST

กองวิจัยและทดลอง
กรมชลประทาน

ว.ท.0 - 01
(พ.ศ. 2520)

แบบรายงานผลการทดสอบ

เรื่อง รายงานผลการทดสอบ

เสนอ ผจท. ผ่าน หคว.

งานทดลอง ดินก้นวิศวกรรม ขอรายงาน
ผลการ ~~วิเคราะห์~~ ทดสอบ ตัวอย่าง ลูกรัง เป็นจำนวน
รวมทั้งสิ้น ๑ ตัวอย่าง ซึ่งได้จัดส่งมาโดย โครงการ, ~~สำนักงานชลประทาน~~
พัฒนาเกษตรชลประทานแม่กลอง จ.กาญจนบุรี

สัญญาที่ - - รายละเอียดผลการ ~~วิเคราะห์~~, ทดสอบ ได้แนบมาด้วยแล้ว
ตามรายงาน

Lab. No. (ลำดับงานที่) =

Memo. L.81/2524

ค่าทดสอบเป็นเงิน - บาท

จึงเสนอมาเพื่อโปรดพิจารณา.

๒ มิ.ย. ๒๔

(ลงชื่อ)
๒ มิ.ย. ๒๔
(นายวันชัย สินสวัสดิ์)
วิศวกรโยธา ๖

ผจท. แม่กลอง
เสนอ
3.มิ.ย.24
ผจท.

พิมพ์ที่ ฝ่ายเผยแพร่และการพิมพ์ กรมชลประทาน (น.603-ส.ค.2522-5,000.)

(สำเนา)

กองวิจัยและทดลอง ที่ จห.๔๒๓ วันที่ ๑ พค.๒๕๒๔
สวนราชการ โครงการพัฒนาเกษตรชลประทานแม่กลอง
วันที่ ๒๔ เมษายน ๒๕๒๔
เรื่อง ขอให้ทดลองดินลูกรัง
เสนอ ผู้อำนวยการกองวิจัยและทดลอง

เนื่องจากรัฐบาลญี่ปุ่นได้ให้ความช่วยเหลือโครงการแม่กลองใหญ่ โดยก่อสร้างโครงการแม่กลองใหญ่ โดยก่อสร้างโครงการจัดรูปที่ดินตัวอย่าง และ Trial Farm ในพื้นที่ฝั่งขวาของโครงการแม่กลองใหญ่ และได้ส่งผู้เชี่ยวชาญญี่ปุ่นมาดำเนินการทดลองทาง ๆ ทางด้านเกษตร ตั้งแต่ปี ๒๕๐๓ เป็นต้นมา จากการดำเนินงานที่ผ่านมาพบว่า คูส่งน้ำ คูระบายน้ำ ในแปลงทดลอง ชำรุดเสียหาย เนื่องจากดินพังทะลายเมื่อส่งน้ำ และในหน้าแล้งดินแตกตัวทำให้มีรอยแตกร้าวน้ำรั่วซึมไปหมด

เพื่อที่จะป้องกันปัญหาดังกล่าว ฝ่ายผู้เชี่ยวชาญญี่ปุ่นจึงมีความประสงค์จะทำการทดลองใช้ Soil Cement คาดคูส่ง และคูระบายน้ำ โดยขอให้กองวิจัยและทดลองทำการทดลองทาง ๆ ดังต่อไปนี้

1. Test for Specific Gravity of Soils
2. Test for Moisture Content of Soils
3. Grain-Size Analysis of Soils
4. Test for Liquid Limit of Soils
5. Test for Plastic Limit of Soils
6. Mix design
   - Test for Moisture Density Relations of Soils Using Rammer, Deside the optimum moisture content
   - Unconfined Compression Test of Soil Cement

     Water : Optimum moisture content decided

     Cement : 2 % x dry soil weight

     4 %Xdry soil weight

     6 %Xdry soil weight

Note : When the result of compression test showed more than 30 kg/cm^2 no more percentage of dry soil weight is needed.

จึงเสนอมาเพื่อโปรดพิจารณาอนุมัติ พร้อมนี้ได้ส่งดินลูกรังตัวอย่างมาให้ทดลองแล้ว ๒ ตัวอย่าง เมื่อได้ผลทดลองแล้วโปรดแจ้งให้โครงการฯ ทราบด้วย

(ลงชื่อ) รุ่งเรือง จุลชาต
(นายรุ่งเรือง จุลชาต)
ผจก.แม่กลอง

งานทดลองคินค้านวิศวกรรม กองวิจัยและทดลอง
วันที่ ๒๙ เมย.๒๔
ผู้สั่งตัวอย่าง (ลงชื่อ) ชาญ อินทรไพบูลย์
ตำแหน่ง นายชางโยธา ๔ สังกัดแมกลองใหญ่
ผู้รับตัวอย่าง (ลงชื่อ) อุบลรัตน์ สวัสดี

เสนอ ผจท.
เพื่อโปรดพิจารณาสั่งการ
(ลงชื่อ) วันชัย สินสวัสดิ์
แทน หคว.
๒๙ เมย.๒๔

หคว.
เพื่อดำเนินการ
(ลงชื่อ) ลออ สุนทรฉาย
แทน ผจท.
๑ พค.๒๔

คุณวันชัย
เพื่อพิจารณาดำเนินการทดสอบต่อไป
(ลงชื่อ) มณเฑียร กังศศิเทียม
๔ พค.๒๔

สำเนาถูกต้อง.
อนงค์

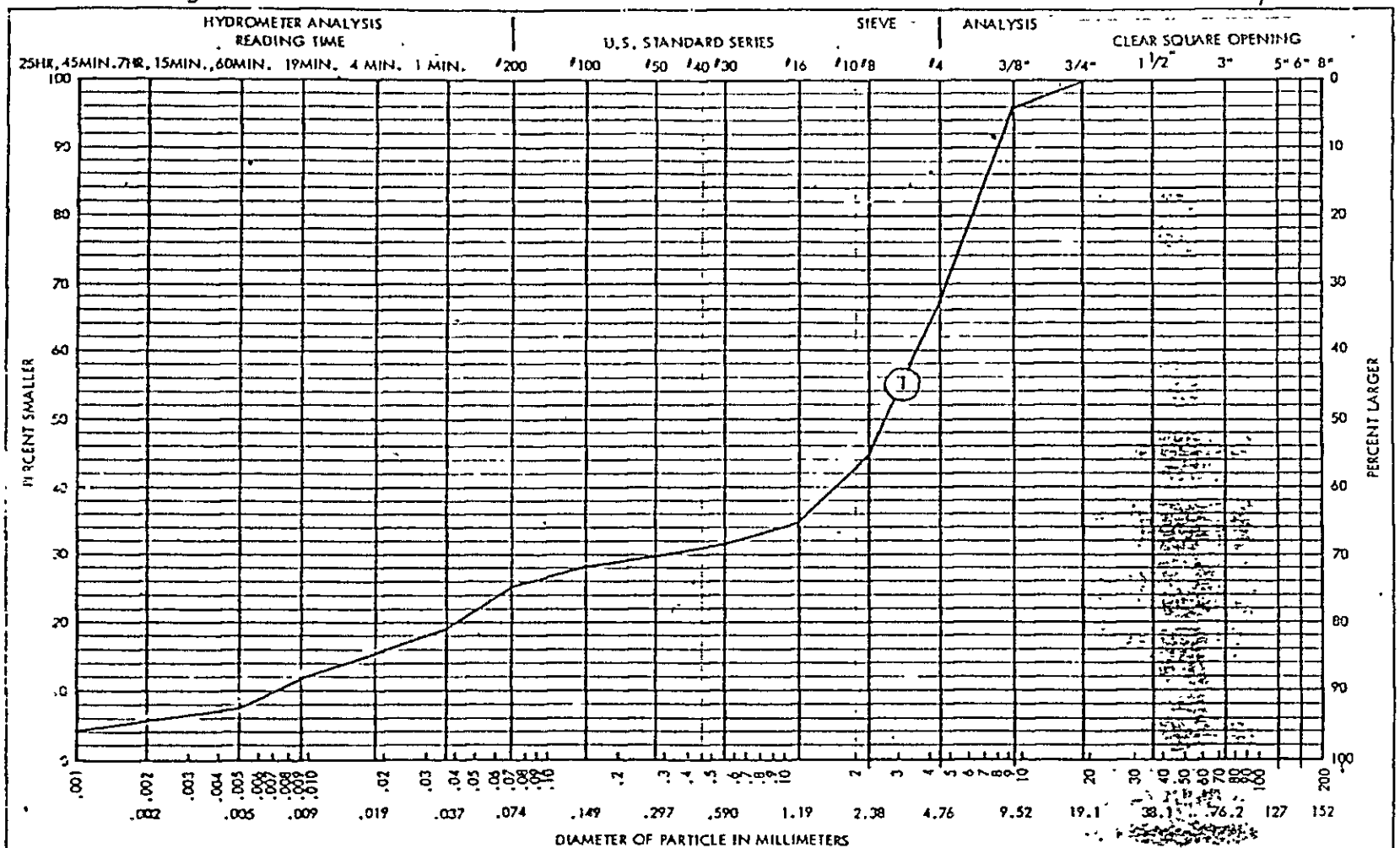
Royal Irrigation Department

Project [illegible]

GRADATION TEST

2,11,4-38
(พ.ศ.2517)

Memo. ล.81/2524



CLAY (plastic) TO SILT (non-plastic)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Notes :

No.	Sample No.	Atterberg Limits L.L.	P.L.	P.I.	Soil Classification	Nat. w	Sp. Gr.
(1)	L81/24	41.7	24.4	17.3	SC	7.2	2.91

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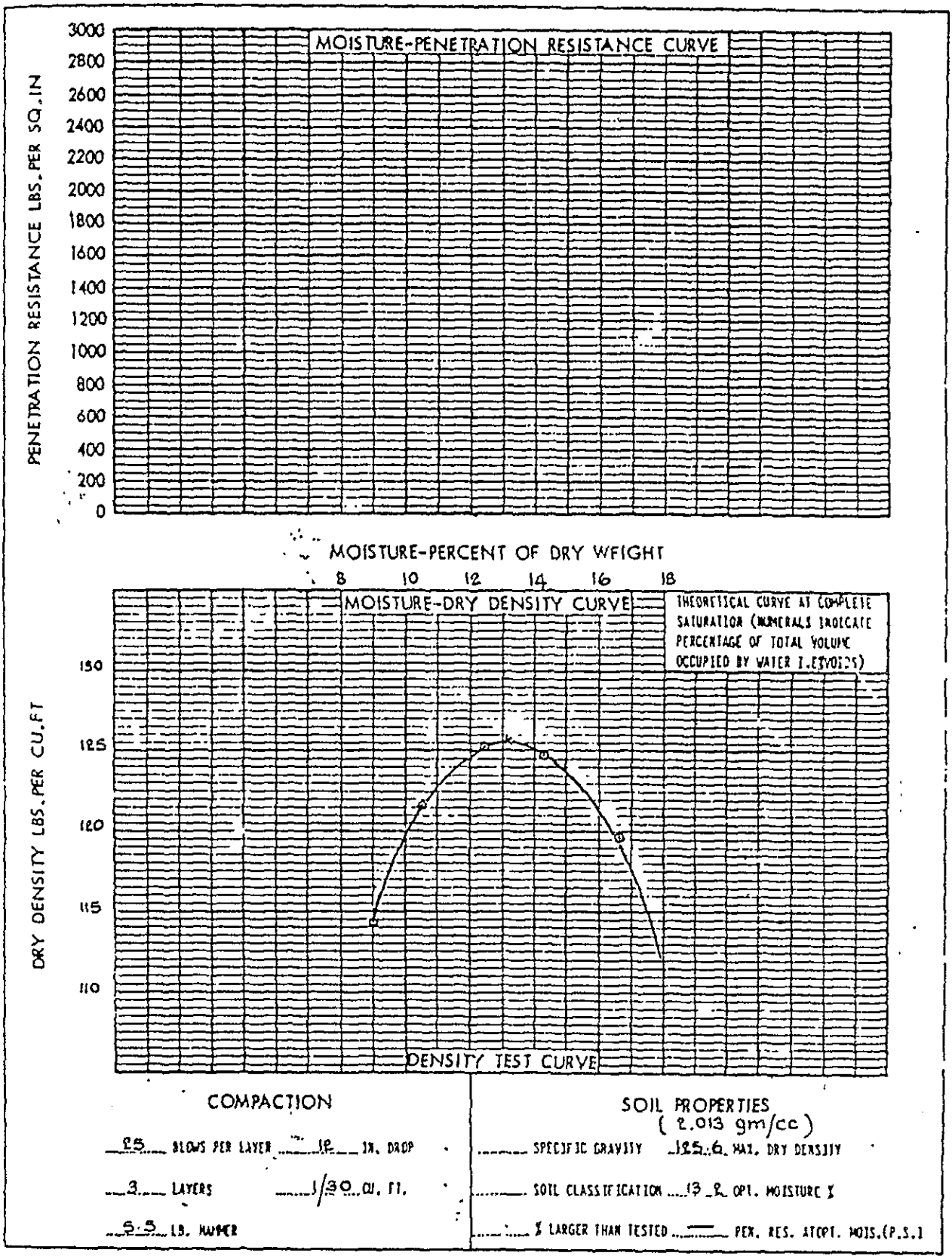
COMPACTION TEST CURVE

Project. [illegible] + 4 % Cement Memo. L.B1/2524



COMPACTION

25 BLOWS PER LAYER 12 IN. DROP

3 LAYERS 1/30 CU. FT.

5.5 LB. RAMMER

SOIL PROPERTIES
(2.013 gm/cc)

_____ SPECIFIC GRAVITY 125.6 MAX. DRY DENSITY

_____ SOIL CLASSIFICATION 13.2 OPT. MOISTURE %

_____ % LARGER THAN TESTED _____ PEN. RES. AT OPT. MOIS. (P.S.I.)

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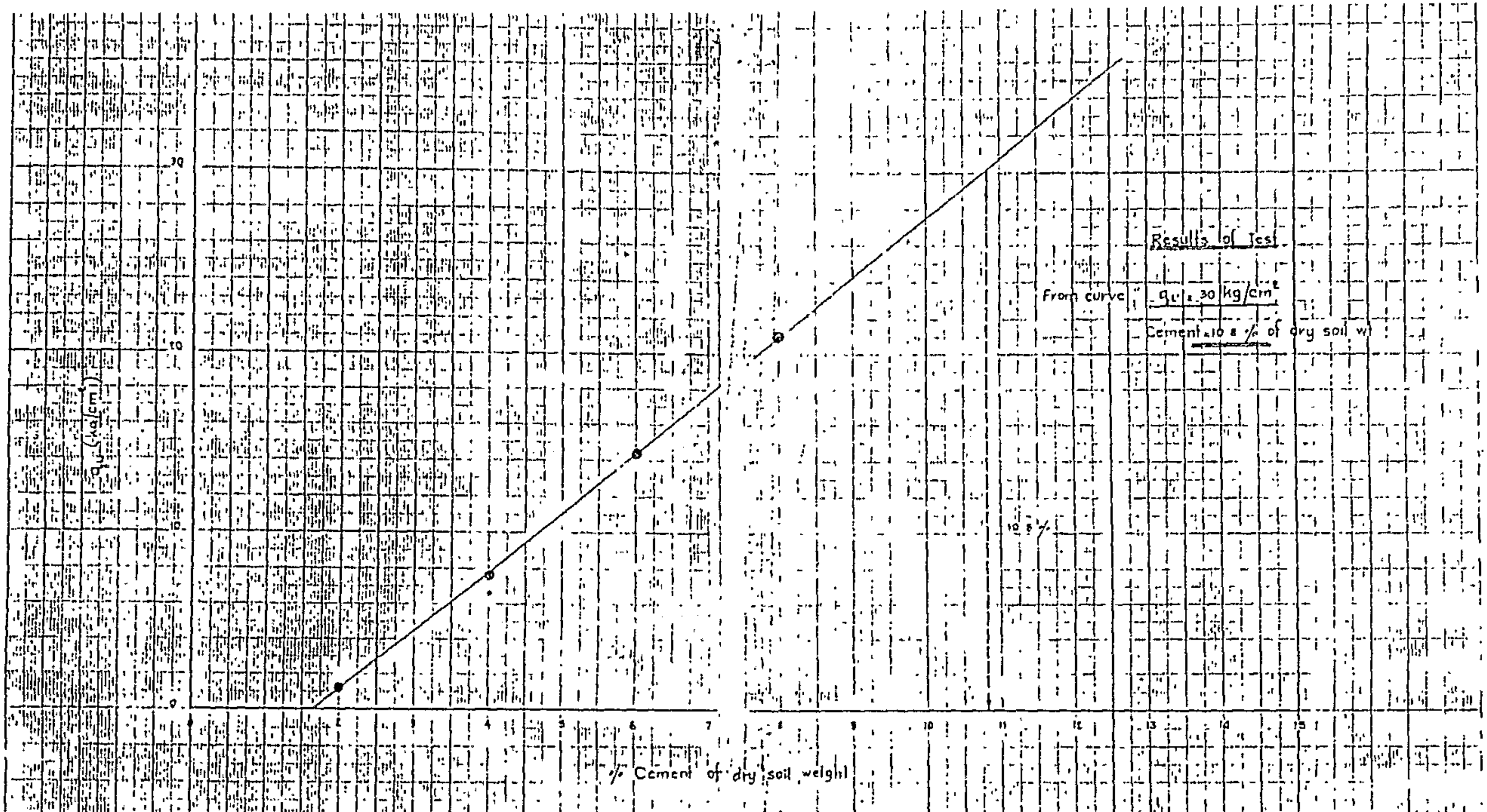


Specimen	No.	Cement (of dry soil wt.) %	Dry Density (gm/cc)	Moisture Content %	Unconfined Comp. (kg/cm²) 1	2	Avg	Remarks
[illegible]		2	1.020	12.6	1.06	1.22	1.14	1) Size of specimen ø 1.5" x 3.00"
[illegible]		4	.997	14.1	6.04	7.15	6.60	2) Curing 3 days in air and 4 days in water
[illegible]		6	.996	14.2	12.56	16.15	14.34	
[illegible]		8	.987	14.71	21.88	20.07	20.98	

3-3. Plan of execution on the construction site

1. Preparation of materials

Water

Cement .... Common Portland Cement in bag packing

Laterite Soil .... Any soil can be carried in near by exclusive that with diameter over 20 mm.

2. Preparation of instruments

6 pcs. portable simple mixer ... 1 time of mixing capacity = 0.1f2 m^3

Bucket .... 10 buckets (as the selling at market)

Screen (20 mm. measure) .... 2 pcs. (indeed unused)

Flatiron ..... Wooden metal iron 3 pcs.

3. Mixing

(1) Put in about 2/3 of the whole quantity of water

(2) Put in the whole quantity of laterite soil

(3) Put in the whole quantity of cement

(4) Let the mixing gone on sometime and keep the round in definite speed until you ascertain that the matters have been equally mixed and, then put in the remaining water.

(5) The time of mixing in the mixer shall take 1.5 minute as yardstick and see it not to be extremely short or long time.

Remark :

As to confirmation of weight, you shall know the weight of each kind of the materials in a bucket and calculate from the time of bucket to be put in.

4. Forming

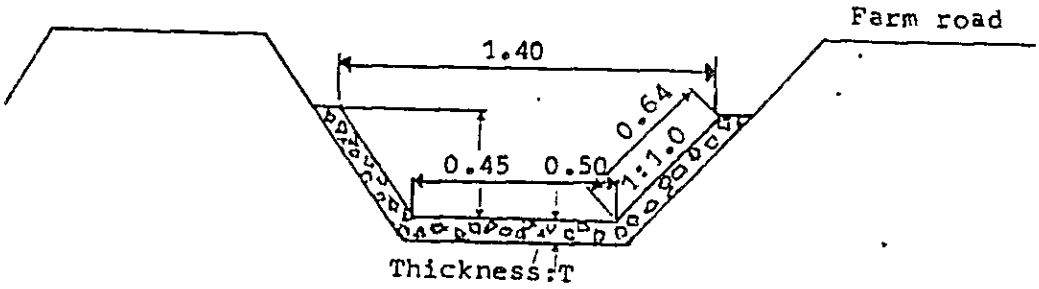
(1) Make use of cart of bucket to the materials and put them in the water canal.

(2) Use the flatiron to press the cement and finish the shape. Use the fixed ruler to measure the thickness of the side of canal by measuring in each interval of 2 m.

5. Construction place and number

In the sake of test and as the place of construction, we have chosen the place on the straight line because of that (1) The section of canal is not too less. (2) The water can be controlled and it is easy to observe after construction.

(1) Section of construction



(2) The thickness of the soil cement are made to 3 kinds of 10 cm, 15 cm, 20 cm.

(3) Length of test from the upper stream, the extension is constructed to each in 10 m continuing in total of 30 m.

(4) Number

$$V = (0.50 + 0.64 \times 2) \times T \times 10 = 17.8 \times T$$

1). T = thickness of 10 cm $V_{10} = 1.78\ m^3$

2). T = " 15 cm $V_{15} = 2.67\ m^3$

3). T = " 20 cm $V_{20} = 3.56\ m^3$

total $V = 8.01\ m^3$

The materials on the time of that the natural water content is made to 8% (see the plan of match on the scene).

Water $8.01\ m^3 \times 102\ kg/m^3 \times 1.10 = 899\ kg$

Cement $8.01\ m^3 \times 158\ kg/m^3 \times 1.10 = 1{,}392\ kg$ (cement 35 bag)

Laterite $8.01\ m^3 \times 2{,}112\ kg/m^3 \times 1.10 = 18{,}609\ kg$ (11 ton dump car in 2 cars)

$$1 \text{ dump car } 8\ m^3 \times 1.8\ t/m^3 = 14.4\ t/car,$$

$$18{,}609 \div 14.4 = 1.3$$

4. Plan of Mixing of Soil Cement

1. Specific mix

Materials	Specific gravity	weight per m^3	absolute capacity per m^3
Water	1.0	W^{kg}	W^{m^3}
Common Portland cement	3.15	3.15 C	C
Laterite soil	2.91	2.91 S	S
Interrupt air	-	-	assuming 0.20 (2%)
		total	1.00 m^3

Mixing condition ..... from the result of soil test by RIĎ

(a) Cptimum water content : 13.2%

(b) Cement is made to 8% (21 kg/cm^2) of weight of laterite : 8% x dry weight of soil.

From above mentioned subject, the following relative formula can be sought.

(1) $W + C + S = 0.98$

(2) $W/2.91S = 0.132$ ..... from (a)

(3) $3.15C = 0.08 \times 2.91S$ ..... from (b)

To solve the above mentioned formula

$W = 0.258\ m^3$

$C = 0.050\ m^3$

$S = 0.672\ m^3$

Spceific mix per 1 m^3

Materials	absolute capacity	weight of mix
Water	$0.258\ m^3 \times 1.0$ =	$0.258\ t/m^3$ (10.9%)
Cement	0.050×3.15 =	0.158 " (6.7%)
Laterite	0.672×2.91 =	1.956 " (82.4%)
Air	0.020	
total	$1.000\ m^3$	$2.372\ t/m^3$ (100%)

2. Plan of mixing on the construction site

Providing the nature water content of laterite soil is made to 8%, the materials will be adjusted to the follows :

			weight after adjustment
Water	258 kg - 156 kg	=	102 kg
Cement		=	158 "
Laterite	1,956 x 1.08	=	2,112 " (weter weight 156 kg)
Air		=	0
	total		2,372 kg/m^3

According to these conditions, in case of using the 6 volumes mixer (capacity 0.162 m^3), 1 time of mixing operation will be as follows :

Water	102 kg x 0.162	=	17	kg
Cement	158 " x "	=	26	kg
Laterite	2,112 " x "	=	342	kg
Air			0	
	total		385	kg/time

3. Mixing at the construction site

3-1. Preparation

(1) Measure the natural water content of laterite soil.

α %

(2) Measure the weight of laterite soil

A kg

(3) From the above menticned subject 1, 2, we can know the dry weight of laterite soil and weight of water

Dry weight $Bd = A \div (1 + \alpha)$

Weight of water $Bw = A - Bd$

$(A = Bd + Bw)$

(4) Measure the weight of cement

$C = Bd \times 0.08$

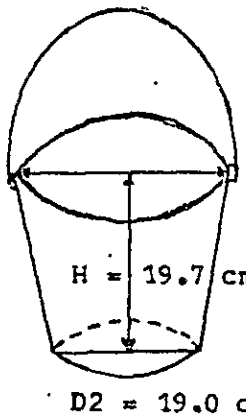
(5) Measure the water

$W = Bd \times 0.132 - Bw$

3-2. Weight measuring

On mixing the soil cement, it is in the same way of mixing the concrete and the simple mixer is used. The weight will be calculated per the time of bucket putting into the canal.

(a) Shape of the bucket (as that selling at market)



Capacity

$$\frac{\pi \left(\frac{D1 + D2}{2} \right)^2}{4} \times H = 8,113.6 \text{ cm}^3$$

average weight of 1 bucket = 800 g

(b) Weight of a full bucket.

Prepare bucket in 10 pcs. and when you will seek the average weight to these buckets, fully fill the bucket with various materials to fullness with a shovel and measure the weight by seeking the weight of each kind of the materials in a full bucket in average.

Laterite soil	12.3 kg - 0.8 =	11.5 kg.
Cement	10.6 kg - 0.8 =	9.8 "
Water	8.9 kg - 0.8 =	8.1 "

3-3. The times of putting in of bucket need for 1 time of mixed up quantity on the mixer.

(1) When we make 1 time of mixed up quantity as 80% of the capacity of mixer (full capacity = 0.162 m^3)

$$0.162 \text{ m}^3 \times 80\% = 0.13 \text{ m}^3/\text{time}$$

(2) Mixing.

	Per 1 m^3	Per 1 time Mixing of Mixer ($0.13\ m^3$)	Laterite soil, in case of water content in 8%	Time of putting in per bucket said in the Left
Laterite soil	1.956 t/m^3	254 kg.	(remark 1) 275 kg.	24 times
Cement	0.156 t/m^3	21 kg.	21 kg.	2.1 "
Water	0.258 t/m^3	34 kg.	(remark 2) 13 kg.	1.6 "
Total	2.372 t/m^3	309 kg/0.13 m^3	309 kg.	

(remark 1) : 275 kg. = 254 kg. x (1.08)

(remark 2) : 13 kg. = 34 kg - (275 - 254)

5. Execution at the construction site

5-1. Execution of work

Basing on the Plan of Plan of Mixing mentioned in last paragraph, we have executed the experiment of mixing ..... please see the volume of picture affixed.

(1). Measurement of water content

In case of planing the mixing, the water content of the laterite soil must be known. As a method can be performed simply, in short time neverthless without great error at the field, we used the means of floating the soil in alcohole and, then lichting it to dry.

Meaurement on June 16, 1981

Measurement by means of alcohole requid		Measurement on Laboratory test (by pyrostat to dry)
Sample (1)	9.2%	sample (1) 8.57%
" (2)	8.9%	
" (3)	8.6%	
average	8.9	

In the laboratory test, the sample used has been only one piece and when the result of the simple method is compared with it, there is no great difference. Moreover, there is small dispersion on the result of simple method. So that we adopt this method.

(2) Kneading

Basing on the water content of laterite, we have made experimental kneading instead on mixing and got a result which has been estimated as workable, then executed it at the field.

5-2. Construction at the field

We carried in various instruments, materials to the construction site and divided the works of construction to 17th, 18th, 19th of May 1981.

(1) First mixing

Optimum water content	13.2%	According to the first plan of mixing
Cuantity of Cement	8%	

Materials	Weight per m^3	1 time of mixing on mixer	Laterite soil natural water content 8%	Weight of 1 time putting in per bucket	Number of time of put ting in of bucket
Water	258 kg	41 kg	16 kg	÷8.1 kg/time	2 times
Cement	158 "	25 "	25 "	÷9.8 "	2.6 "
Laterite	1,956 "	313 "	338 "	÷11.5 "	29.4 "
Total	2,372 kg/m^3	379 kg/ 0.16 m^3	379 kg		

According to the above mentioned condition, the mixing work was commenced as follows :

1) As it was short of water, the soil solidified to grain (having grain in about diameter of 10 cm) and formed unevenness in the mixing.

2) Although the mixer was turned inclined but soil would not fall down and stayed in the mixer.

3) On the forming, it was not workable and the surface could not be levelled and there are other defects, we decided that it is difficult to mix it in a mixer so that we tried to knead the soil on a small hill making with man power. But this time, it become raggedness and it would be disadvantace in the forming of slot surface when it was constructed so that the water was added (increasing water content).

(2) Second mixing .... we repeated the work many times and, then determined as follows :

Water content 22%

Quantity of Cement 8%

$$\begin{cases} W + C + S = 0.98 \\ W/2.91S = 0.22 \\ 3.15C = 0.08 \times 2.91S \end{cases}$$

The above mentioned formula is solved to

$S = 0.572$, $C = 0.042$, $W = 0.366$

Materials	Weight per m^3	1 time mixing in mixer	On the time of natural water content being 8%	Time of putting in of bucket
Water	366 x 1.0 = 366	59 kg	38 kg	5 times
Cement	42 x 3.15= 132	21 kg	21 kg	2.2 "
Laterite	572 x 2.91=1,665	266	287 kg	26.0 "

Total 2,163 kg/m^3

According to the above mentioned proportion, we mixed the soil in mixer and commenced forming in the same time. Comparatively, it was easy to make forming so that we were finishing the surface and speading water over it in the same time and plastering the surface with liquid of melted laterite in water. We also tried to make forming of the slot surface by means of the form. Of course, we used rammer to thrust from the upper part so as to fill the hollow inside. But the hollow occurred in a part of it, especially, on the place near the bottom but the hollow could be filled up after the mould frame was taken so that it would be no problem. However,

when we suppose that the lining for long distance will be performed without delay, it may be not having as much advantage in the view of economy.

According to the mixing mentioned above, we tried it continuously. As we feared the strength of lining, we added a little more cement.

(3) Third mixing

We made mixing by adding a little quantity of cement.

Cuantity of cement 21 kg (8%) 25 kg (9.1%)

	1 time mixing on mixer	time of putting in of bucket
Water	59 kg	5.0 times
Cement	25 kg	2.6 "
Laterite	266 kg	26.0 "

According to the condition mentioned above, we made forming of soil sement in thickness t = 10 cm, 15 cm, 8 cm from the upper stream.

Thickness	Proportion of mixing	Date of forming
t = 10 cm	1st mixing and 2nd mixing	June 17th
t = 15 cm	2nd mixing and 3rd mixing	June 17th, 18th
t = 8 cm	3rd mixing	June 19th

and, for June 17th and 18th, we inspected and supervised on the construction site but, for the last day, as the mixing had already been fixed and the forming work had also been

accustomed, we were not present to the scene. At the evening when we went to inspect after the line was formed, we found that it had been formed with relatively high water content than the indicated proportion. On the dry season, when the shrink survey was made, great crack occurred on it, this made us more believed the though mentioned above.

Remark :

The laterite soil can be gathered from the hill on the skirt of Kanchanaburi and loaded and carried by all tons truck for about 30 km. to the yard of the construction office and placed in the open air from where the soil was loaded with 2 tons truck to the construction site for about 1 km and, then used up. According to the first plan, we scheduled to take away the gravel over 20 mm. but, actually, we did not waste so much time and labour and we took away only the greater size which is remarkable (that in about 5 cm. or 10 cm.) thus the soil might include that in over 20 cm. The laterite soil would have different color or different gravel and it might be difficult to take away the gravel over 20 mm. Actually, it is not necessary to take away the gravel of such size.

Investigation on Soil Cement Forming

We have made a record for arrangement of staff and working on the 2nd and 3rd mixing as follows :

1. Arrangement of staff

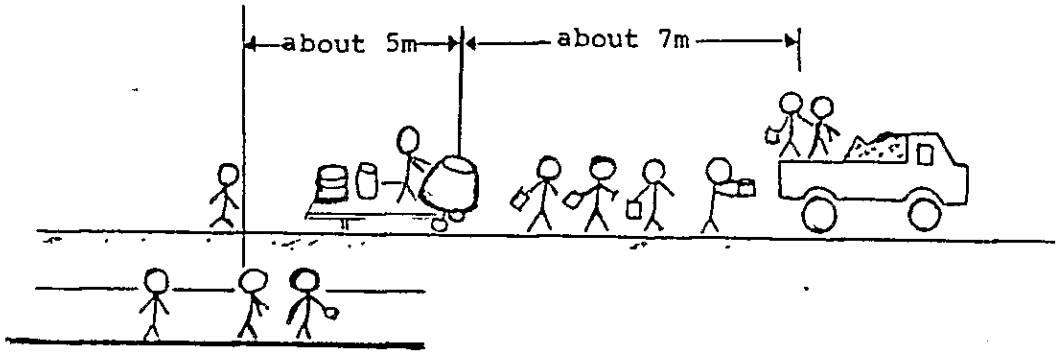
o 1 cycle of work flow

Soil throwing from truck → Soil carrying → Mixer operating → Short distance soil carrying → Forming

Man power .... 2 men | 4 men | 1 man | 4 men | 3 men

same persons

Labour 10 men + foreman 1 man = total 11 persons



O Period of 1 cycle

The following works were repeated and approximately time were as follows :

	Putting in materials	Mixing	Carrying, forming	total
1st time	7 min.	5 min.	11 min.	23 min.
2	10	3	7	20
3	6	6	8	20
4	9	3	7	19
5	6	4	10	20
6	8	5	7	20
7	10	2	6	18
8	5	2	18	25
9	5	4	12	21
10	5	4	9	18
total in average	71(7.1)	38(3.8)	95(9.5)	204(20.4)

The time needed in 1 each cycle 20.4 minutes

The time needed for other works beyond the work mentioned above.

Time for water supplying

Time for removing and installing the mold frame (in case of using the form).

These period of work depend on the distance of short distance carrying and state of working etc.

oWorking quantity for 1 day (estimating)

Details of time in 1 day's working (7.30 - 16.30 = 9 hours)

(1) Preparation	10 min.
(2) Carrying in instrument, materials and check	30 min.
(3) Rest at noon	60 min.
(4) Recess (2 times each 15 min. at morning and afternoon total 30 min.)	30 min.
(5) Putting things in order	20 min.
total	150 min.

(6) Working time 9 hours - 2.5 hours = 6.5 hours

The time needs for 1 cycle will be much different depending upon the time of removal of mixer may take less or more difficultty thus it will depend on the distance of short distance carrying, scaffold and the condition of the scene. Moreover, during the time needed for 1 cycle mentioned, if the laterite soil carrying can be made immediately after the short distance carrying of soil cement are

ended and the soil cement work may be performed within the same time of putting in the materials and mixing, thus the time needed may be shortened to less than 20.4 min. but the time for water supply shall be counted so that it may be 20 min. for 1 cycle.

- Number of cycle per day 390 min. - 20 min. = 19.5 cycles
- Mixing quantity per 1 cycle 6 pcs. mixer : 0.16 m^3
- Mixing quantity per day 0.16 x 19.5 = 3.12 m^3
- Extension forming of thickness t = 10 cm soil cement per day

  3.12 $m^3 \div$ (0.178 m^3/m x $\frac{\text{loss}}{1.10}$) = 15.9 = 16 m/day

  In case of thickness (t) = 15 cm 3.12 ÷ (0.267 x 1.10)

  = 10.6 m/day

  " " (t) = 8 cm 3.12 ÷ (0.143 x 1.10)

  = 19.8 m/day ≒ 20 m/day)

5-2). Estimate of expenses for soil cement lining

Basing on the result mentioned above, the expenses of soil cement lining is sought and, also, compared with that of concrete lining.

(1) Proportion of soil cement

We adopt the 2nd mixing (water content 22% cement quantity 8%) made on the construction site.

	mixing per m^3	mixing on the time of natural water content	counting up loss of materials on estimate	number counted up on unit price
Water	366 kg	233 kg	233 kg	233 kg (free)
Cement	132 kg	132 kg	15% loss 152 kg	152kg ÷ 50kg=3 (bag)
Laterite	1,665 kg	1,798 kg	20% loss 2,158 kg	2,158 ÷ 1,417 ≒ 1.52 m^3
Total	2,163kg/m^3	2,163 kg/m^3		

Remark :

As to the unit weight of laterite soil in natural state, if it be the weight according to bucket it is 11.5 kg/ 0.0081136 m^3 = 1,417 kg/m^3

(2) Proportion of concrete lining

According to the common plain concrete lining made at the construction site

(3) Concrete forming and other.

With regard to mixing of the matter beyond the materials, carrying, forming, curing expense, in the case of both lining soil cement and it is held as in the same expenses.

(4) Comparison of unit price

Basing on the above mentioned conditions, the unit price per m^3 will be as follows : (see the unit price list affixed)

Soil cement unit price per m^3	980 ฿
Concrete " "	1,390 ฿
difference	410 ฿

However, when we convert the unit price to extension construction, the figure will be as follows :

(a) Lining unit price per m.

Soil cement

t = 10 cm	0.178 m^3/m	x 980 ฿	= 174.4 ฿
t = 15 cm	0.267 "	x "	= 261.7 "
t = 8 cm	0.142 "	x "	= 139.2 "
t = 5 cm	0.089 "	x "	= 87.2 "

Concrete

t = 5 cm 0.089 m^3/m x 1,390 ฿ = 123.7 ฿

In case of lining in the same thickness, the soil cement is cheaper for 36.5 ฿/m.

(5) Observation

In case of in the same lining thickness, although the unit price of soil cement is cheaper. When we compare it with concrete lining on the aspect of durability or mainterance, management, there may be question provided we consider whether it is advantage. However, as to lining of small irrigation canal, should the laterite soil or substitution can be gathered from place near by, it may be worthwhile method to be tried.

COMPARATIVE PRICE
BETWEEN
CONCRETE LINING WORK AND SOIL CEMENT WORK

No	Description	Unit	Vol. of material		Unit Cost		Price of material	
			Conc. lining	Soil-c lining	Conc. lining	Soil-c lining	Conc. lining	Soil-c lining
1	Crushed stone	m^3	1.2	-	172	-	206.4	-
2	Laterite	m^3	-	1.52	-	60	-	91.20
3	Sand	m^3	0.7	-	101	-	70.70	-
4	Cement	bag	6.5	3.00	64.76	64.76	420.94	194.28
5	Wooden form fee	m^3	0.0215		6,050.00	6,050.00	130.07	130.07
6	Installation & Removal wooden form		-		--		43.25	43.25
7	Labour fee		-		-		281.08	281.08
8	Curing work		-		-		72.00	72.00
9	Machinery spare parts		-		-		41.27	41.27
10	Fuel		-		-		103.41	103.41
11	Repairing fee for machinery		-		-		10.80	10.80
12	Miscellaneous		-		-		12.31	12.31
							1,392.23 ฿	979.67 ฿

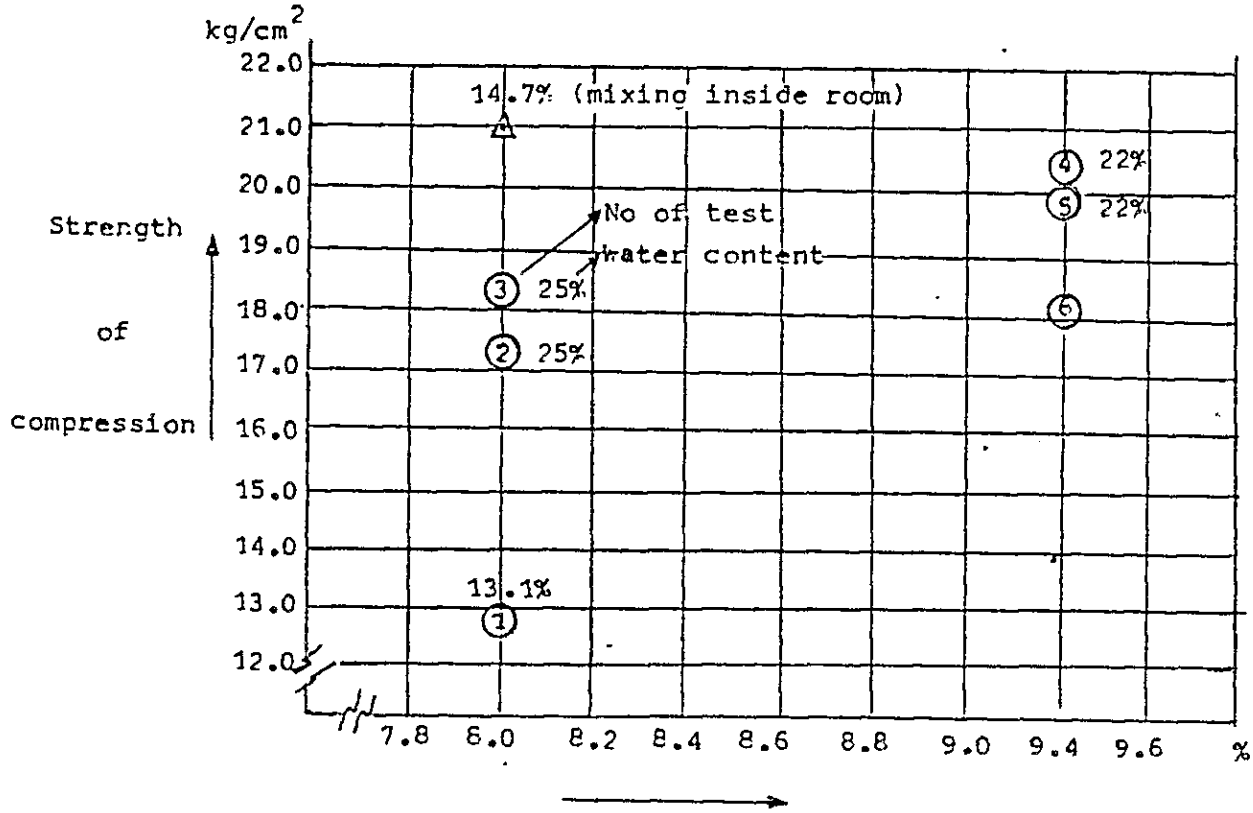
412.56 ฿

6. Various Survey

6-1. Laboratory test of soil cement

After the soil cement has been mixed at the scene ard brought to slump test, we made a piece for compressive test and made reservation by putting it into water in the air (inside the room) for 4 days and made compress test. The result are as the following list.

(1) Relation of strength of compression and the quantity of cement.



Quantity of cement (percentage by weight against dry soil)

As tendency of that mentioned above

1). It has been guessed that if the quantity of cement is greater, the strength of compression shall be greater but, for the relation with water content, it can not be started only on this test. For the cement in the same weicht, we have thought that it has less water content is that has much strength. As for this case, the relation of sample (1) and (2), (3) shows the contrariness and, from the test piece in the laboratory, the tendency mentioned above is clearly found.

THE TEST OF SOIL CEMENT

Speciment No.	Making test pieces		Date of putting into water	Date of Unconfined Comp. test	Result of Unconfined Comp. test	Remarks
	Date	Time				
1	June 17	10:30	June 20	June 24	2,400 kg 12.92 kg/cm^2	W = 13.1% C = 8%
2	"	15:00	"	"	3,300 kg 17.63 kg/cm^2	W = 25% C = 8%
3	"	15:00	"	"	3,400 kg 18.22 kg/cm^2	"
4	June 18	15:30	June 21	June 25	3,800 kg 20.53 kg/cm^2	W = 22 % C = 9.4% sL = 11.0 cm
5	"	15:50	"	"	3,800 kg 20.48 kg/cm^2	sL = 8.0 cm
6	"	16:05	"	"	3,400 kg 18.32 kg/cm^2	sL = 8.0 cm

Curing of test pieces

1. After making test pieces, they should be kept 3 days in air (room) and 4 days in water.

Test (Unconfined compression test)

1. When curing of test pieces have finished, they should be tested (unconfined compression test).
2. To weigh a weight of test pieces before putting in water and confined comp. test.

(2) Measurement of weight

We have measured the weight of test piece before it has been put into the water and after it has been raised from water. The measurement are recorded as follows :

Sample	Water content	Weight before putting into water	Weight on the time raised up from water	Increased weight
1	13.1%	12.8 kg	12.9 kg	0.1 kg
2	25	12.1	11.2	0.1
3	"	11.9	11.9	0
4	22	12.0	12.2	0.2
5	"	11.8	12.1	0.3
6	"	11.9	12.3	0.4

Change of Soil Cement on Dry Season After Construction

About a week after the construction was finished, on account of coming of the rainy season of 1981, water was flown into this canal as it is to be irrigation canal and, later, the water flow was cut off on November 5th of that year. On the dry season, February 3, 1982, there was no rain and both of the irrigation canal and paddy field were dried, the state of crack, growth of weeds or soil and sand piling were found and reported to us. Therefore, on the beginning of March, water was flown to irrigate the dry season crop.

1). State of Crack

a). On the time of construction, June 1981 and soon after the construction, the cracks took place and were found on down stream side of the upper stream part t = 10 cm. and the crack width was 1 mm. to 2 mm. but the width of cracks did not changed, when it came to dry season.

b). On the middle course, hair crack under 1 mm. was found after construction and some lines of cracks in maximum width under 2 mm. increased, when it came to dry season but it was observed as no effect to the structure.

c). Although the down stream part was constructed in the same plan of match as the middle course, owing to that operator thought that it might be easier to work if plenty of water was applied. However, we inspected the state of work when the dry season came and could see the maximum cracks of 6 mm. occurred on both side of the central part. Although these cracks did not

sink through to the bottom, it was expected that the soil will drop in and the weeds will grow and their roots will thrust in and cause the cracks widened in the future. The other cracks were less than 2 mm. which was held as not too wide but it was interested to find that the cracks occurred in same interval for both sides.

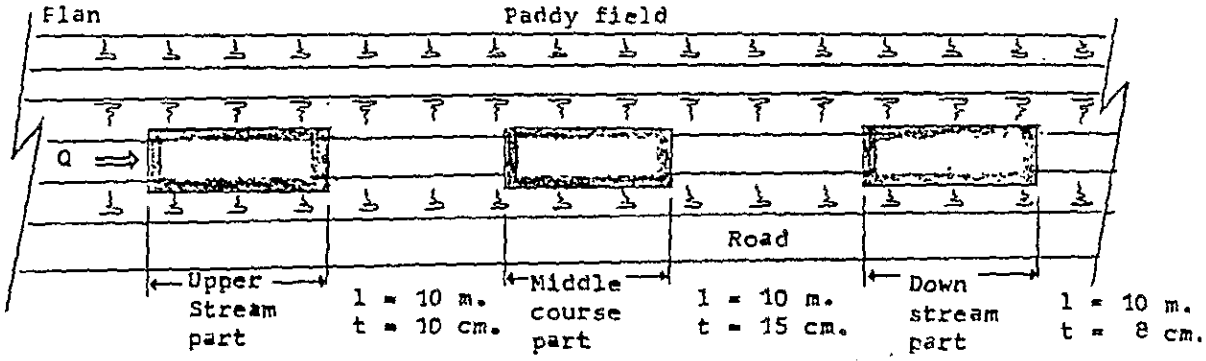
2). Weeds, soil, sand and others.

The weed did not grow on the soil cement. The soil and sand piled up on the bottom of irrigation canal in the thickness (as per the record in the affix) in 15 cm., 13 cm., 8 cm. ranked from the upper stream. The soil sand piled much on the upper stream. The soil sand could be removed with a shovel etc. If it was once wet with flowing water it may be more easy to remove. The color of soil cement surface is whitish, when it was washed with water, it returned to whitish color, when dried. We found some cave on the surfaces in equal intervals and on the same hights on the surface. When we inquired in the cause, it was explained as that when the soil cement has just finished certain farmer drew some instrument over the irrigation canal and caused the caves on both sides of it. Still, the fact is unknow. As to the strength, although we have not tested it on the scene, we thought it would be in the same strength as the test piece.

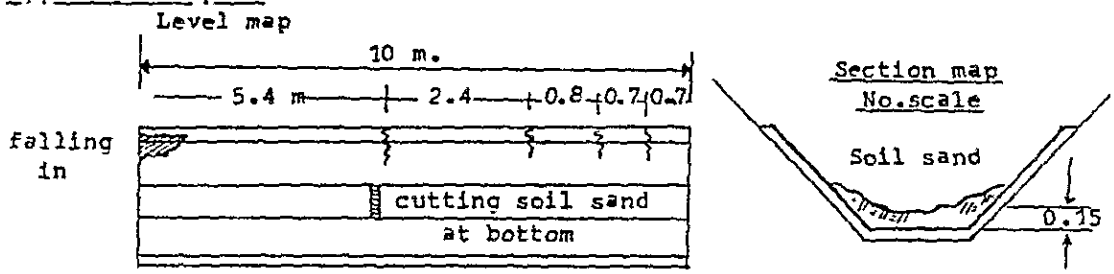
The state of soil cement after construction

Feb. 3, 1982.

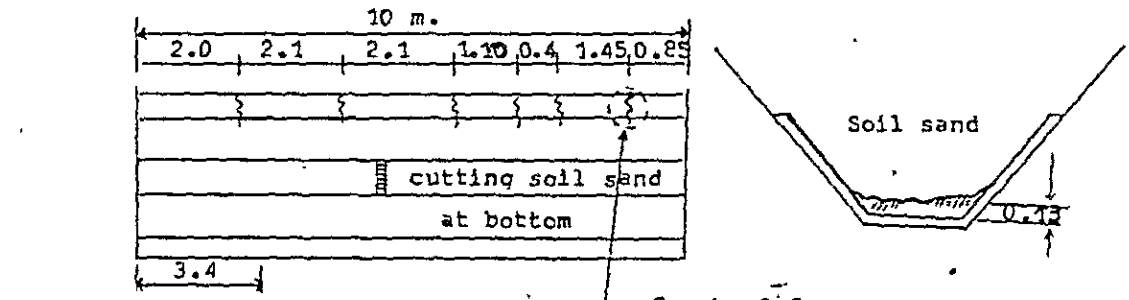
After construction 230 days passed
After cutting of water 90 days passed
Dry Season



Upper stream part

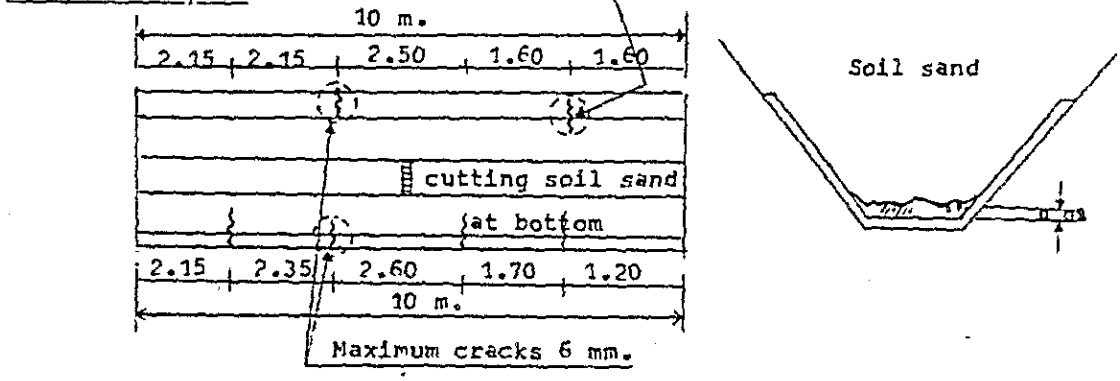


Middle course part



- Cracks 0.2 mm.

Down stream part



Maximum cracks 6 mm.

Subject on executing soil cement on the construction site

As for the soil cement test of this time, it was performed only for extension of 30 m. Whether this works can be applied to various irrigation canal and because of that we have traced the data for only about a year so that we have to watch whether there will be any change on the dry seasons in the future.

1). On the economic view point

At the present, the cost of lining with soil cement is cheaper than that with concrete and when it is linked to the extension in lining, it is considered as advantage.

2). Obtainment of materials

The use of water and cement are in the same circumstance as that in concrete. The laterite soil is easier to obtain and in cheaper price than gravel and sand. In case of that the laterite soil has to be carried from long way, it is considered to use the soil can be obtained near by or the aggregate for mixing with cement as a release.

3). On the construction

(1) In the time of mixing with mixer, in order to avoid the soil pie will occur, it has to make it to a greater water content and, on the test, 20 to 25% is considered as appropriate which is also appropriately workable on the point of forming work. Should the water content be too great though it will be easy on operation but the cracks might occur on it. In case of the thickness of structure T = 8 cm., the cracks occurred in the

position of interval of 1.6 m to 2.5 m whether these positions were concerned to the water content and thickness of structure is a result of matter which will be obtained later throughout the construction in the future.

(2) As the soil cement will be one body with the soil at the field, the easiness to grow accustomed with the soil may be a great advantage than that of concrete. However, as the strength is week and cracks will occur, when the rainy season and dry season repeats over and over, in the future, whether the soil cement will change and weeds will grow with it root digging in and damage it, it is an unknown.

PHOTOS OF SOIL CEMENT TEST

① Various Test

② Execution at the Field

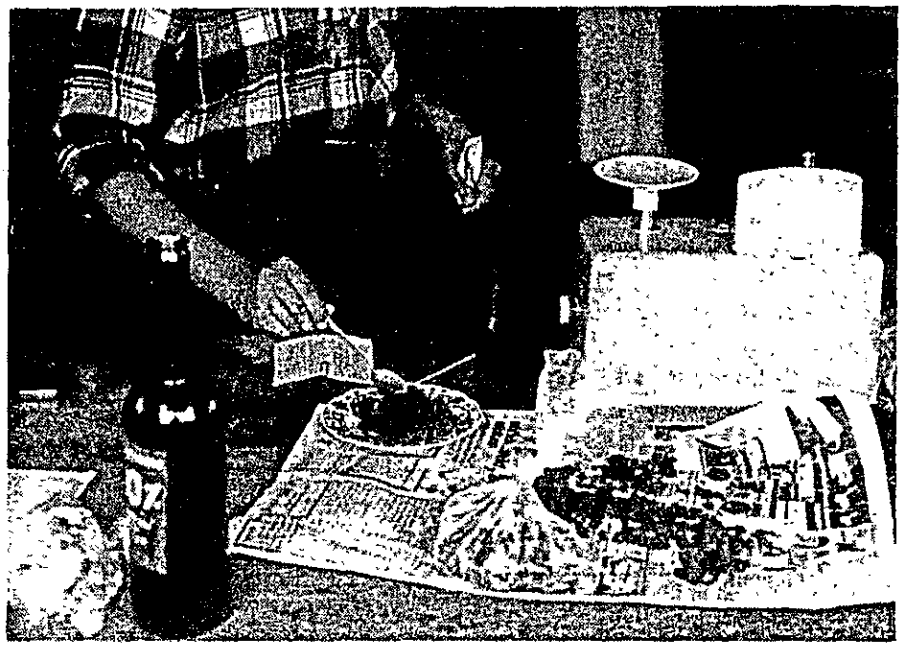
③ State of Soil Cement after Execution

JUNE, 1982

MAE KLONG PILOT PROJECT No. 2

I A D P.

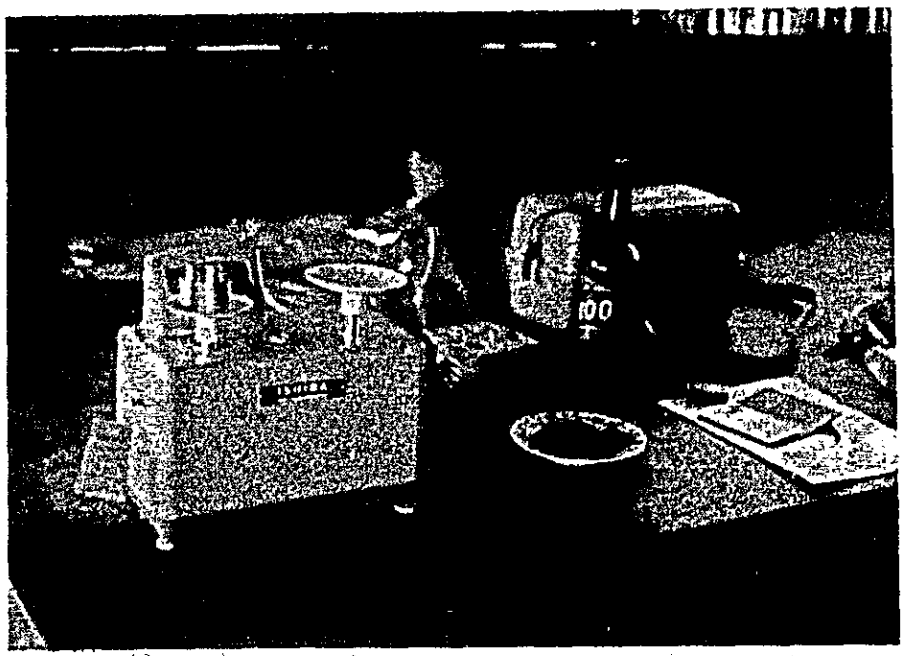
1 VARICUS TEST.



measurement of natural moisture content of laterite soil.

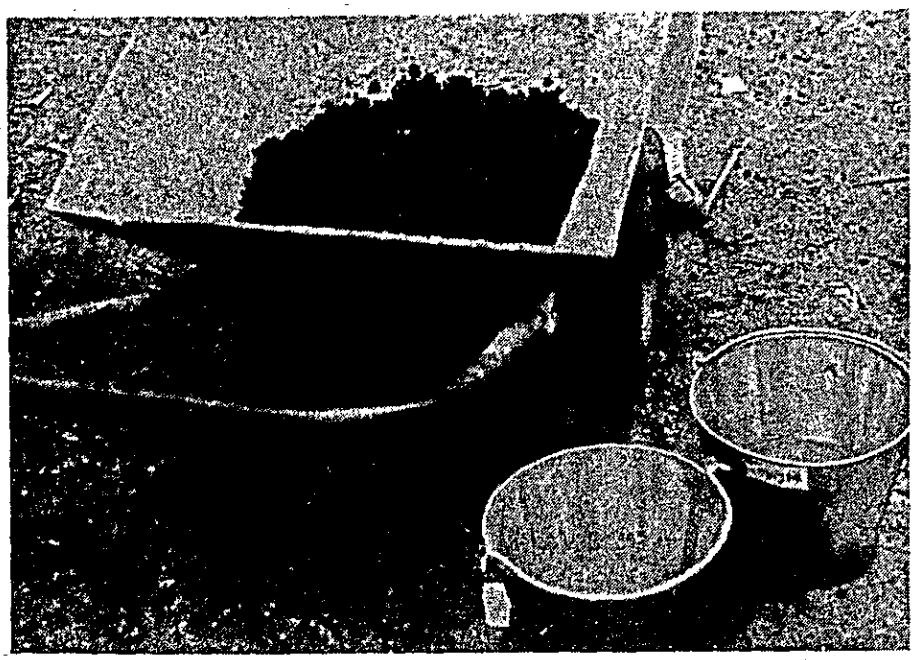
(by the simple method by alcohol requid)

June 17-18, 1981.



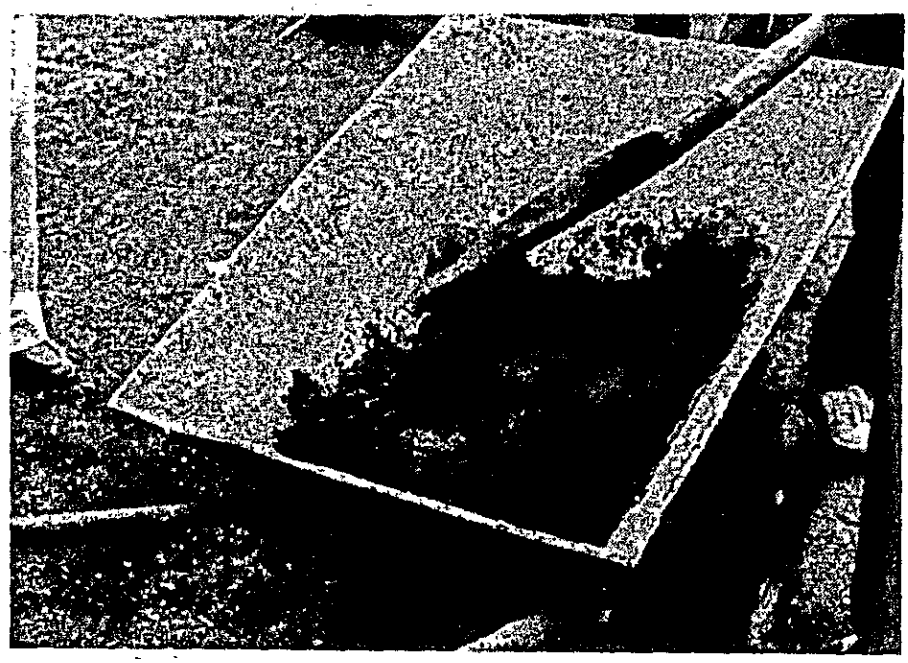
DITTO

June 16, 1981



TEST MIXING

June 16, 1981

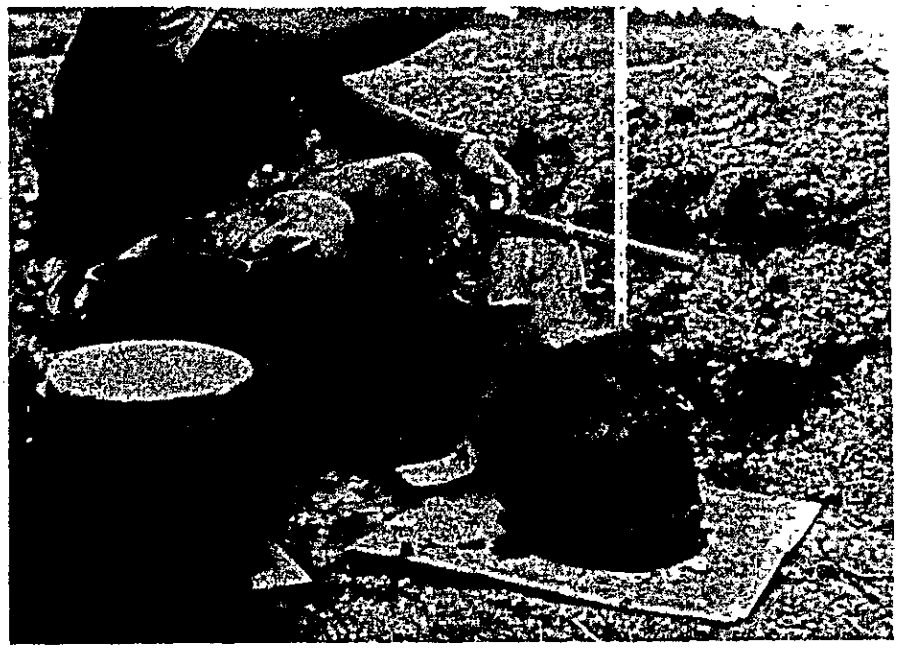


DITTC

June 16, 1981

Slump Test of soil cement

June 17, 1981

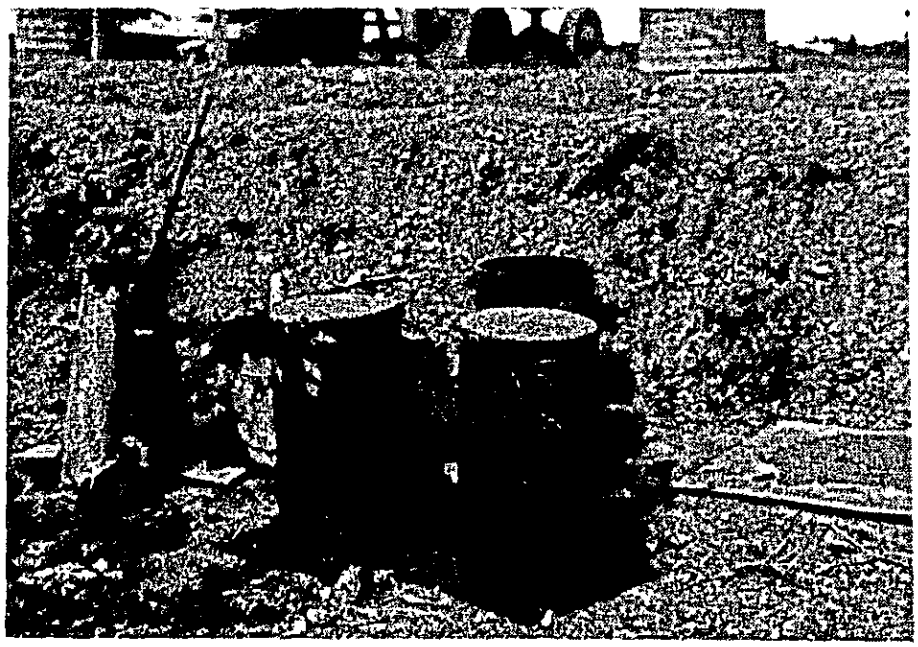


DITTO slump SL = 8 cm.

June 18, 1981

Slump SL = 11 cm.

June 18, 1981

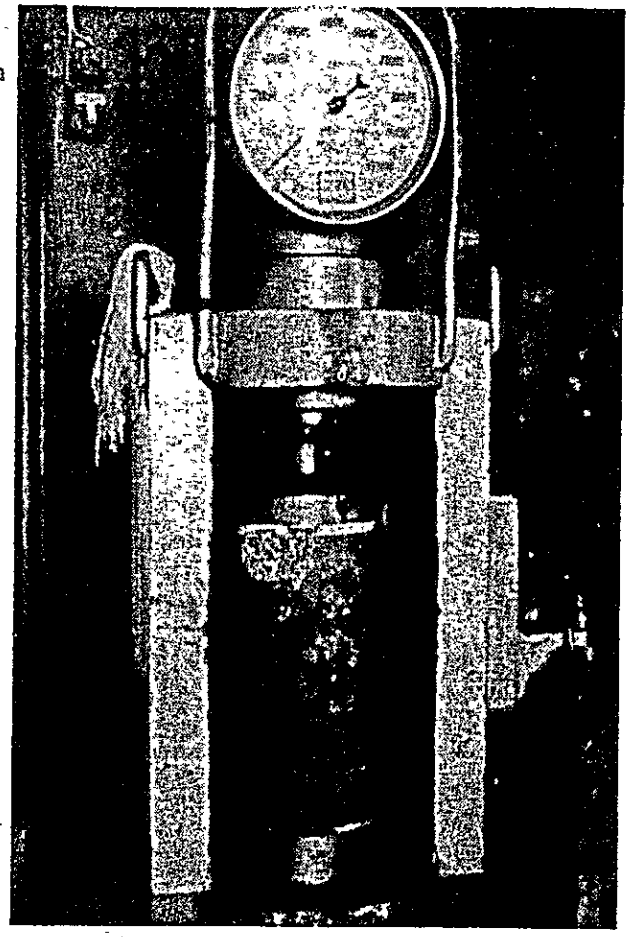


Making test pieces

June 18, 1981

Unconfined compression test (after curing of 3 days in air & 4 days in water)

June 24, 1981



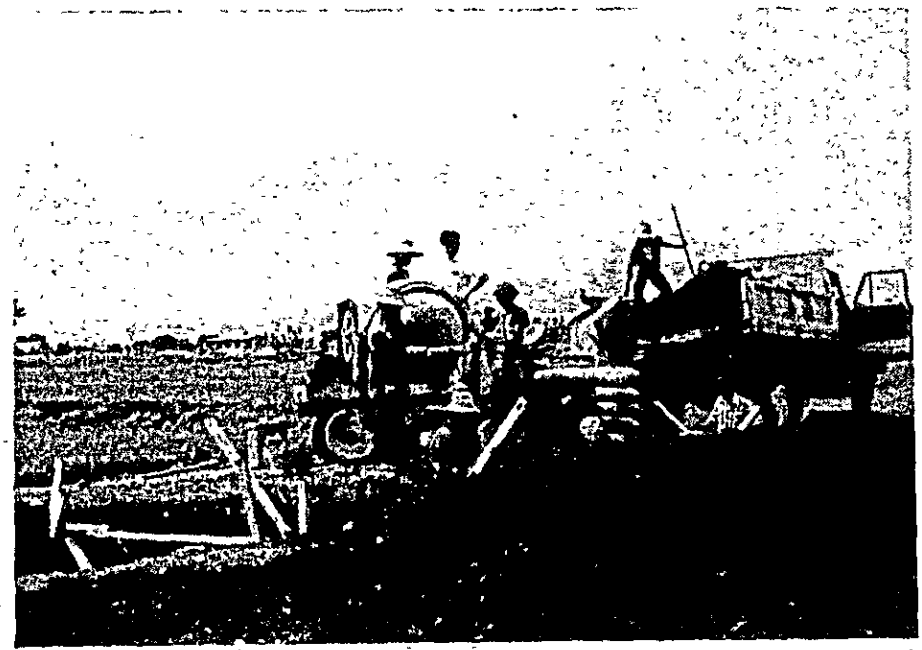
After test mentioned above

June 25, 1981

2 EXECUTION OF SOIL CEMENT AT THE FIELD

Excavation

June 16, 1981



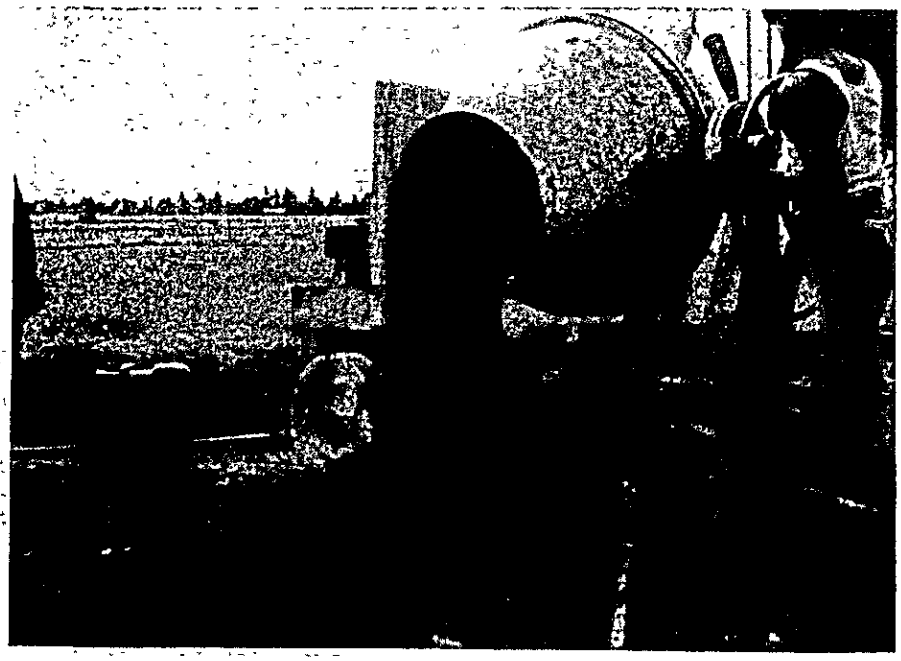
Preparation of instrument, material

June 17, 1981

Putting materials into the mixer

(capacity : 0.162 m^3)

June 17, 1981



State of soil cement after mixing

(1st. mixing)

June 17, 1981

Compaction by a hoe and finishing of surface by a wooden flation

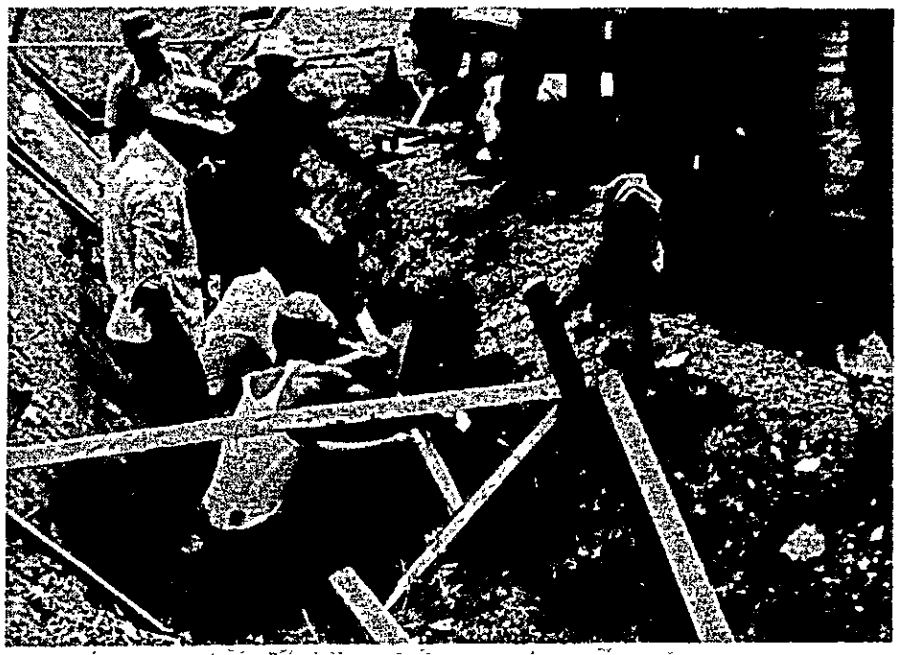
June 17, 1981

Finishing of surface by a brush for supplying water

June 17, 1981

Mixing on the ground

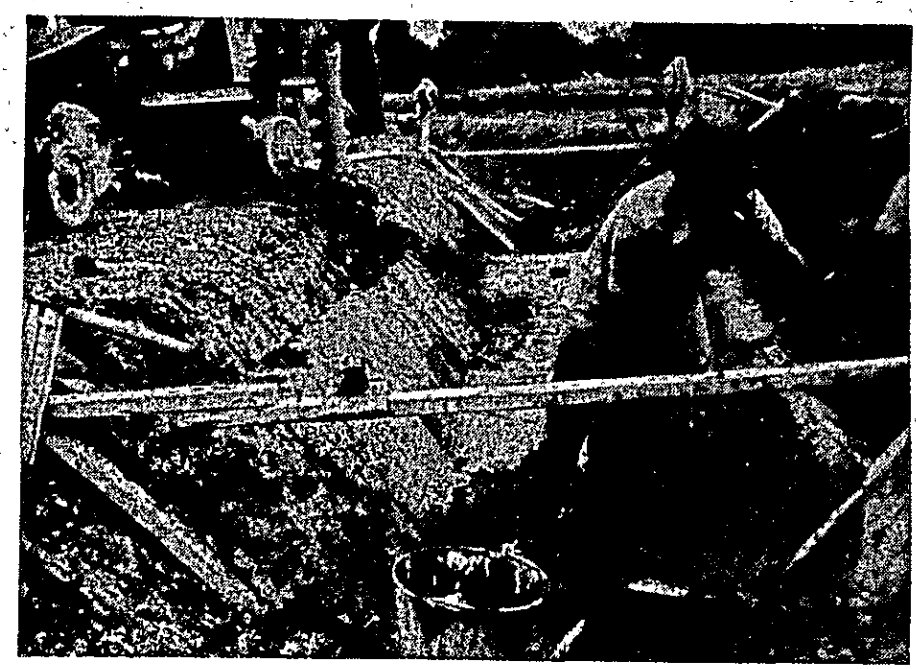
June 17, 1981



Lining of upper stream part

(it takes long time because the soil become small lumps and firm)

June 17, 1981



Finishing of surface by the materials mixed water & soil

June 17, 1981

State of lining at upper stream part (A=10cm)

a color of lining is different because of means by different proportion, method of mixture, lining & finishing

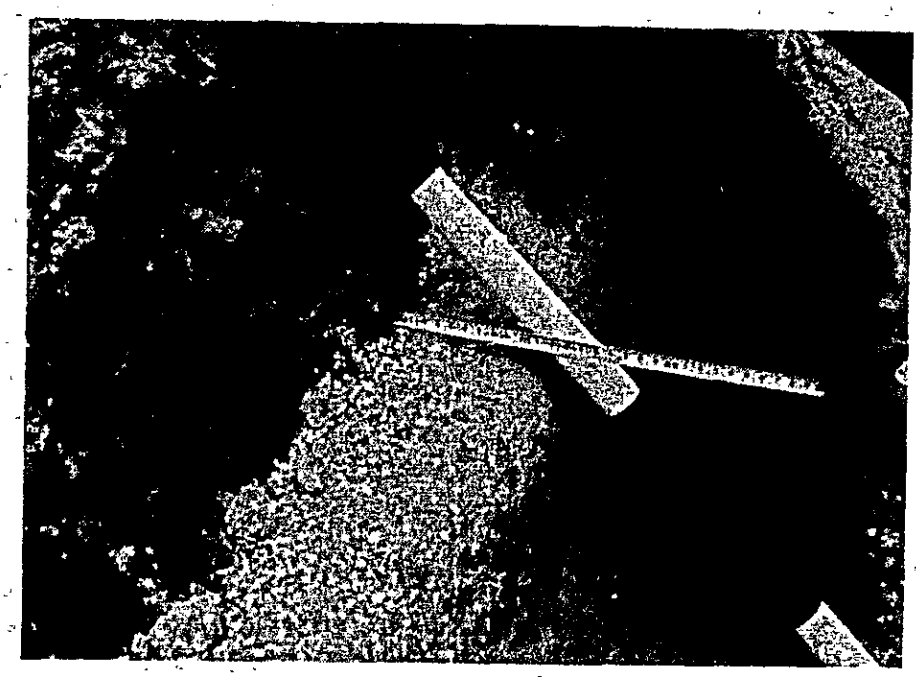
June 17, 1981

Checking the size of lined canal

Bottom width : 0.5 m

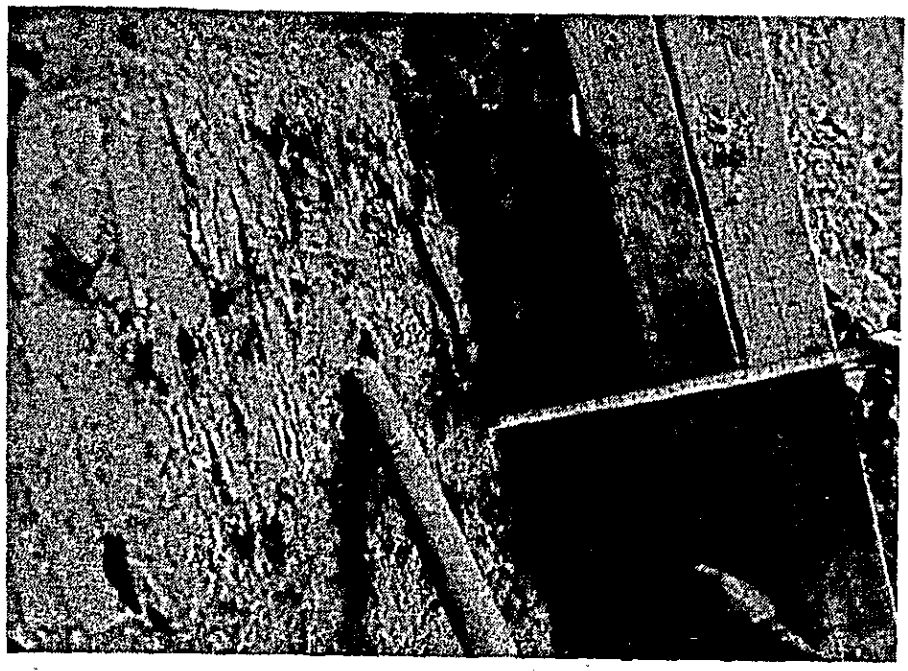
height : 0.45 m

top width : 1.4 m



DITTO

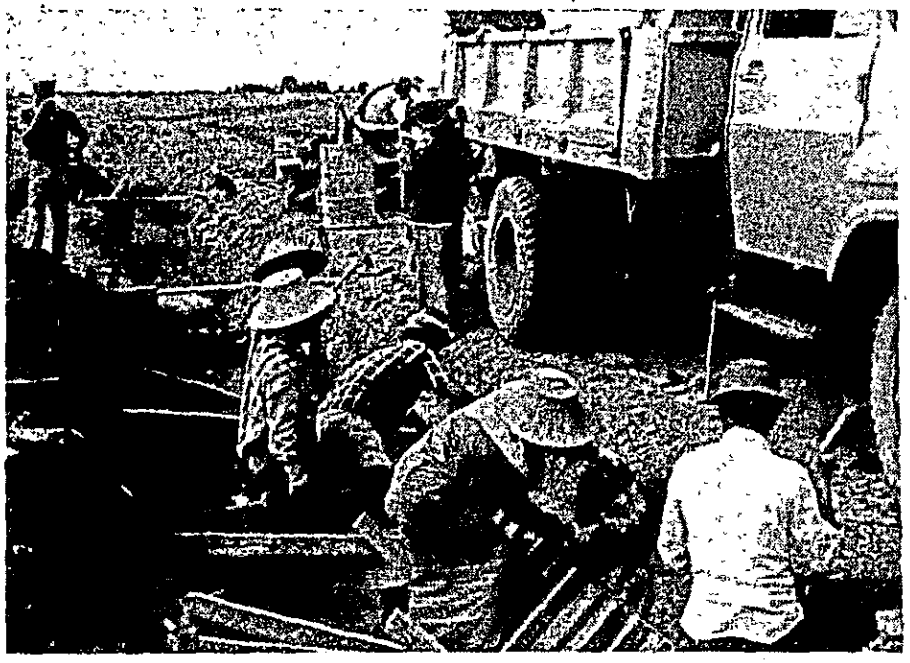
(thickness t = 10 cm)



Middle course part

(thickness of lining T = 15 cm and the wooden form)

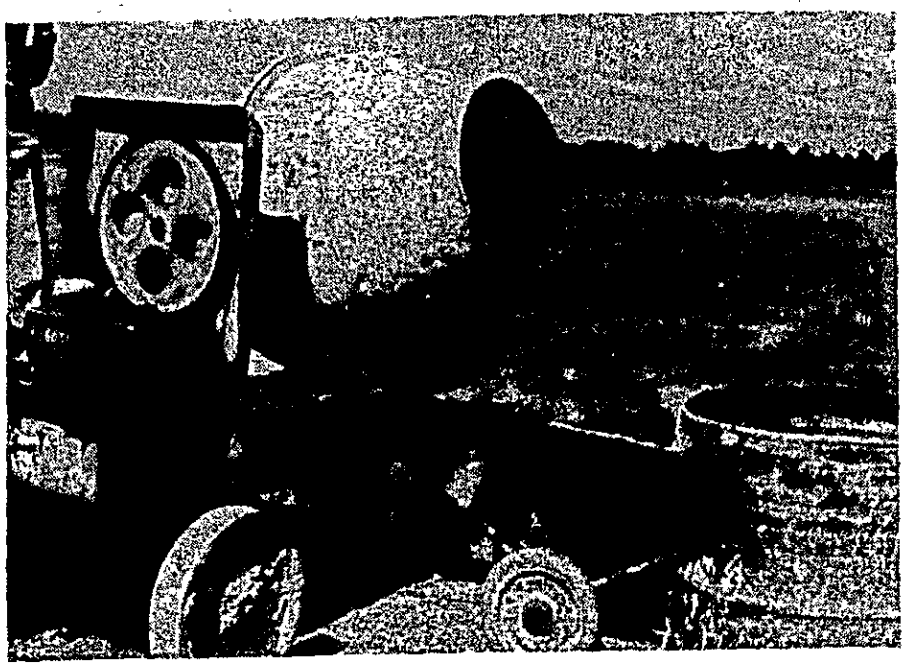
June 18, 1981



DITTC

lining work

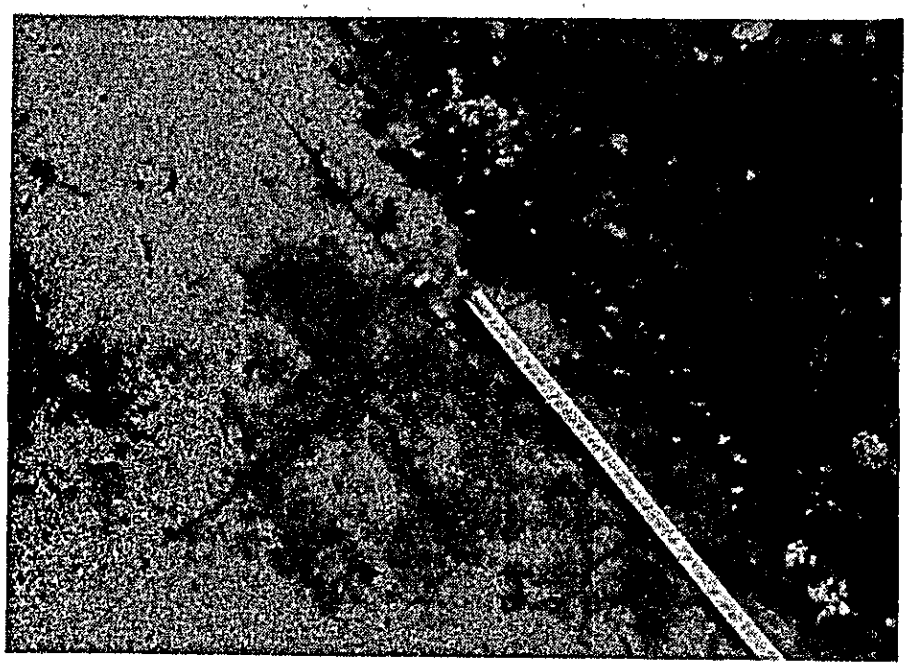
June 18, 1981



Soil cement after mixing with containing much water

June 18, 1981

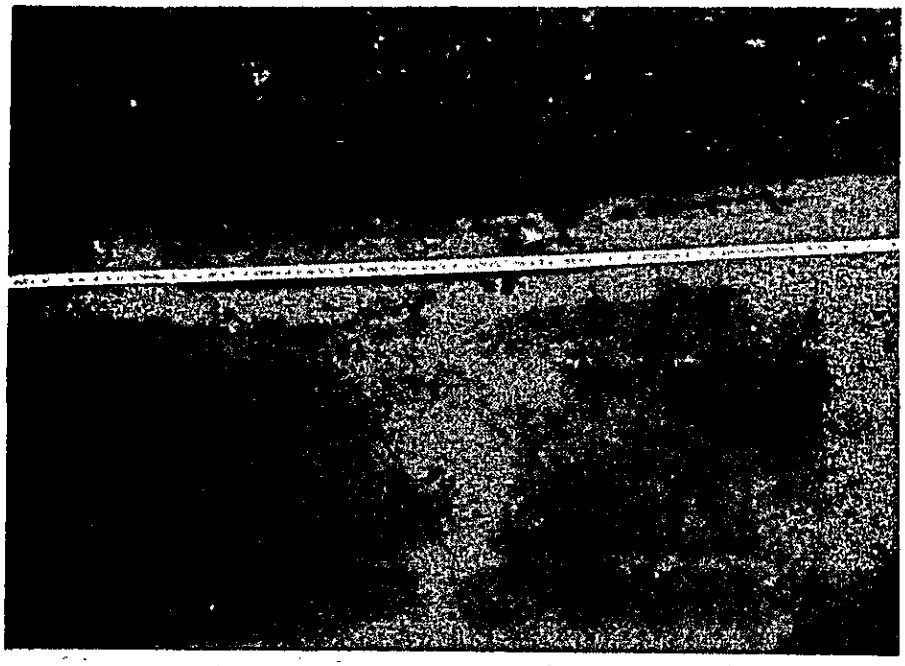
3 State of after execution



After construction 1 day passed

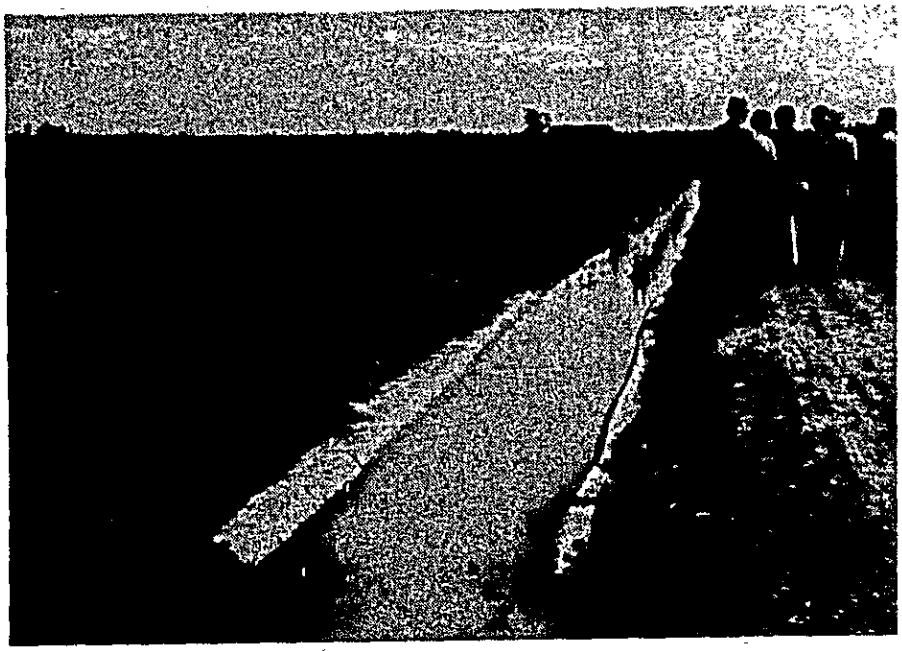
(Max. width of crack 2 mm.of soil cement which has much moisture content)

Aug. 18, 1981



Ditto (state of lining where has designed moisture content 8 - 9 %)

Aug. 18, 1981



State of canal after water supply 12 days passed

June 30, 1981

State of canal after construction 345 days passed.

In the dry season crop in 1982

May 28, 1982.

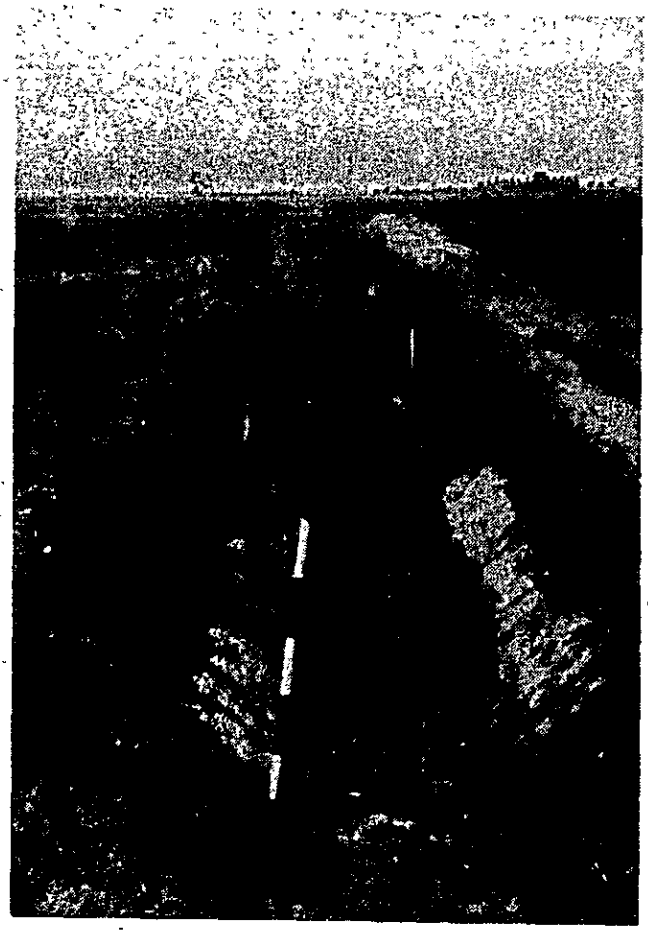
Dry season 1982

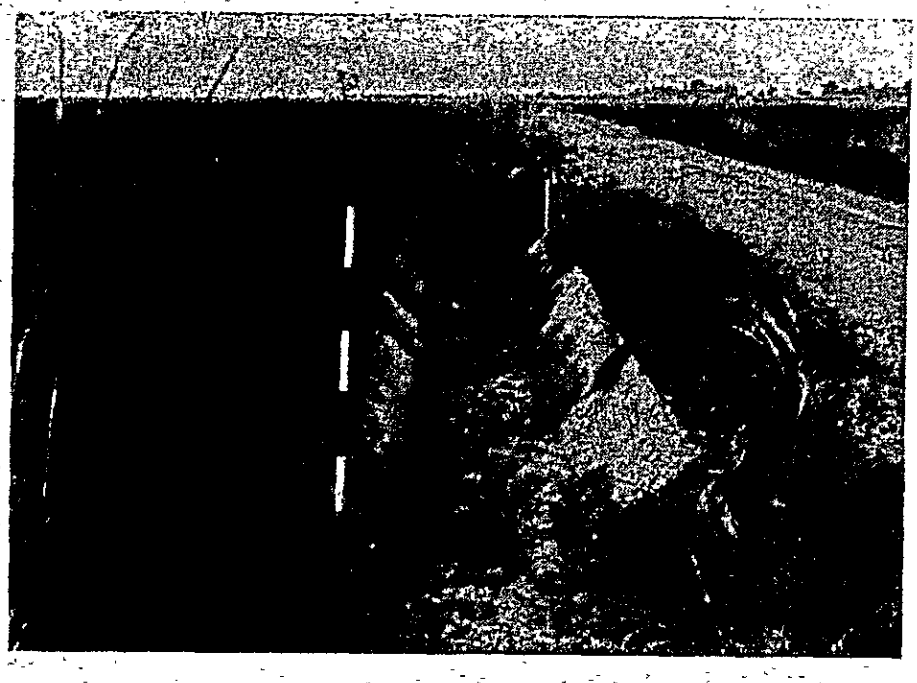
After construction 230 days passed.

After cutting of water 90 days passed

Upper stream part (t = 10 cm)

Feb 3, 1982.





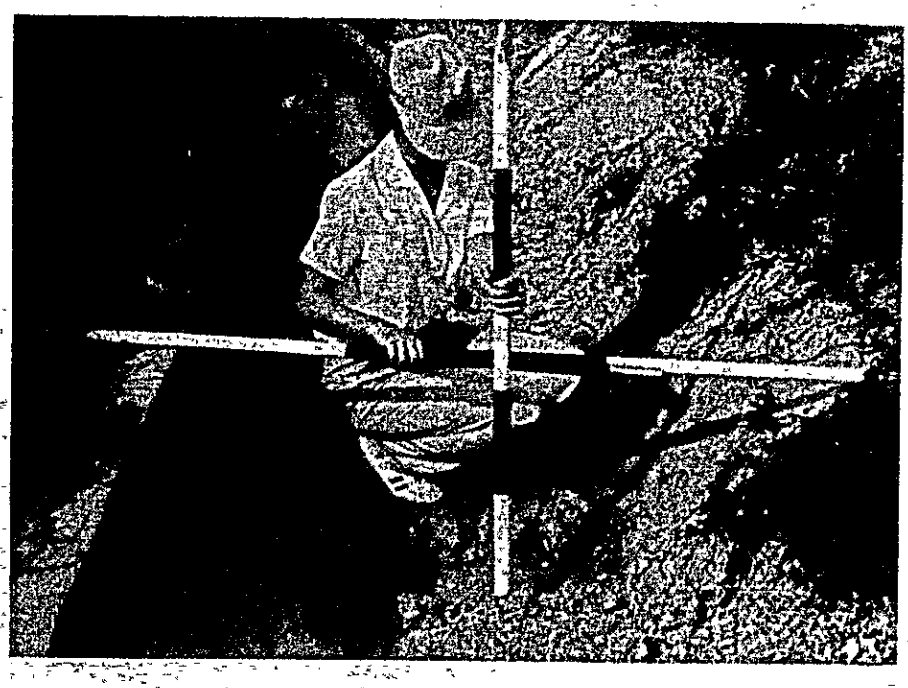
DITTO Middle course part (t = 15 cm)

Feb 3, 1982

DITTO

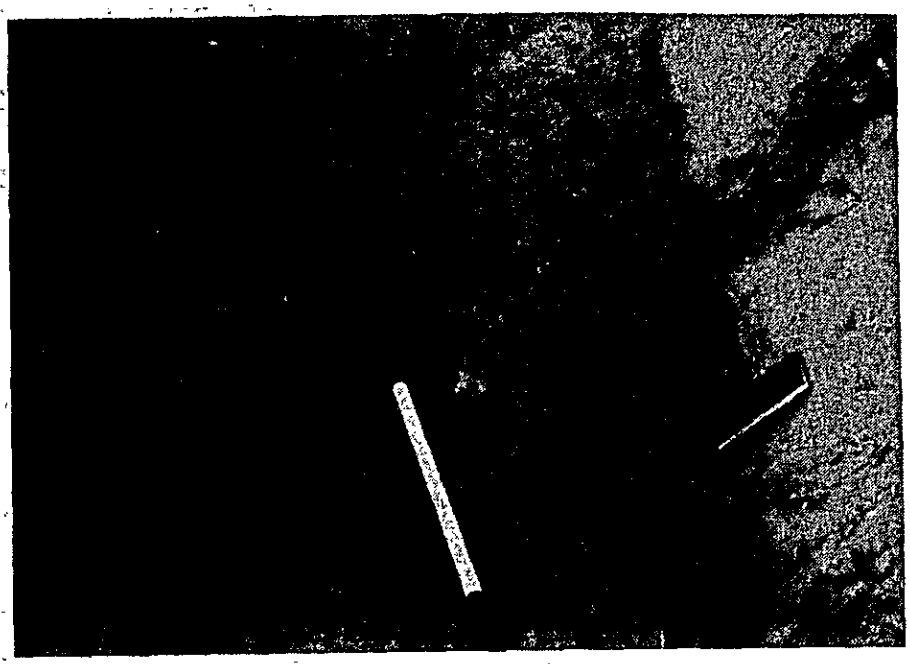
Down stream part (t = 8 cm)

Feb 3, 1982



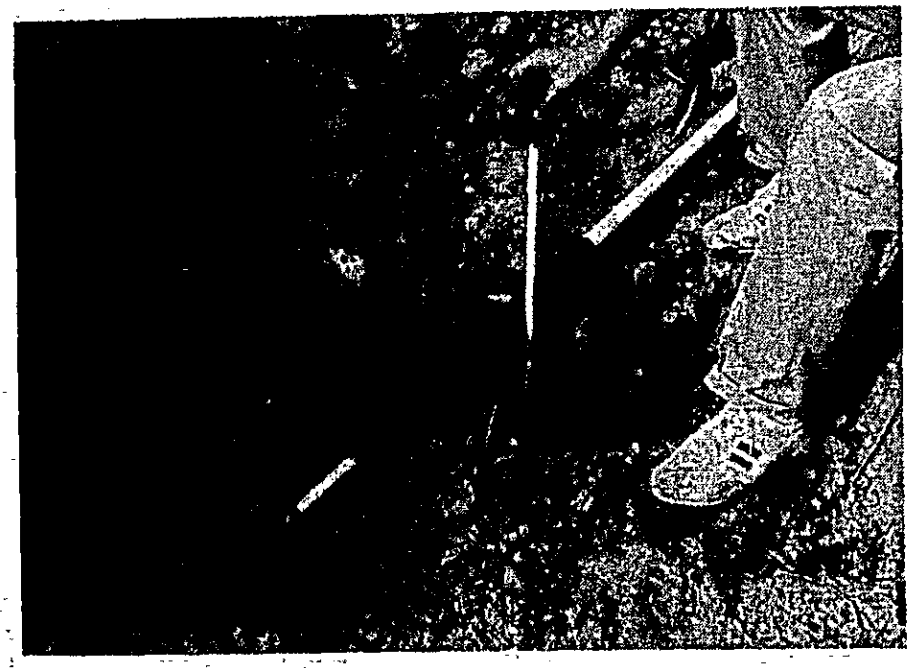
Section of middle course part

Feb 3, 1982



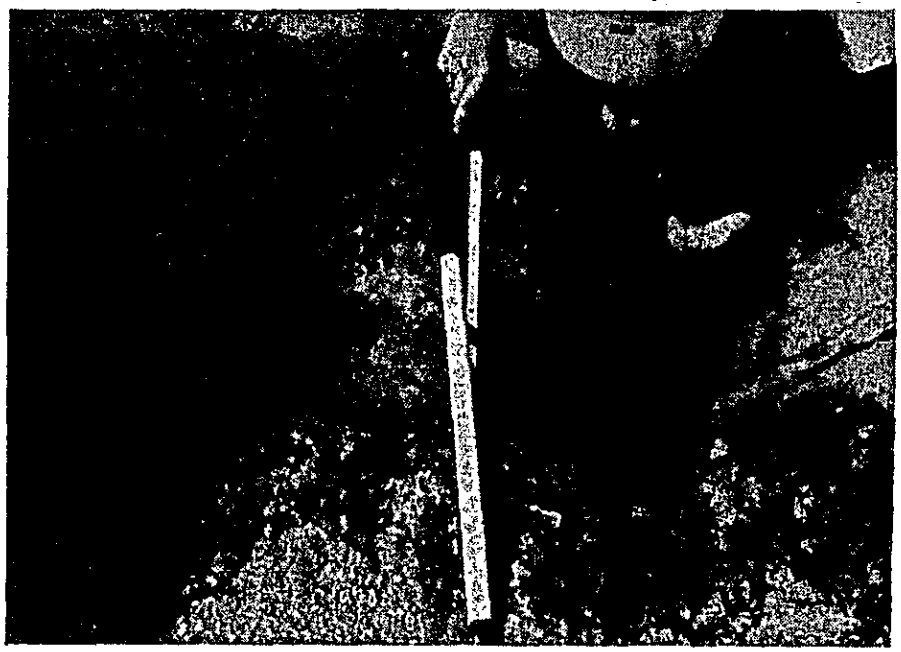
Inside of canal

Feb 3, 1982



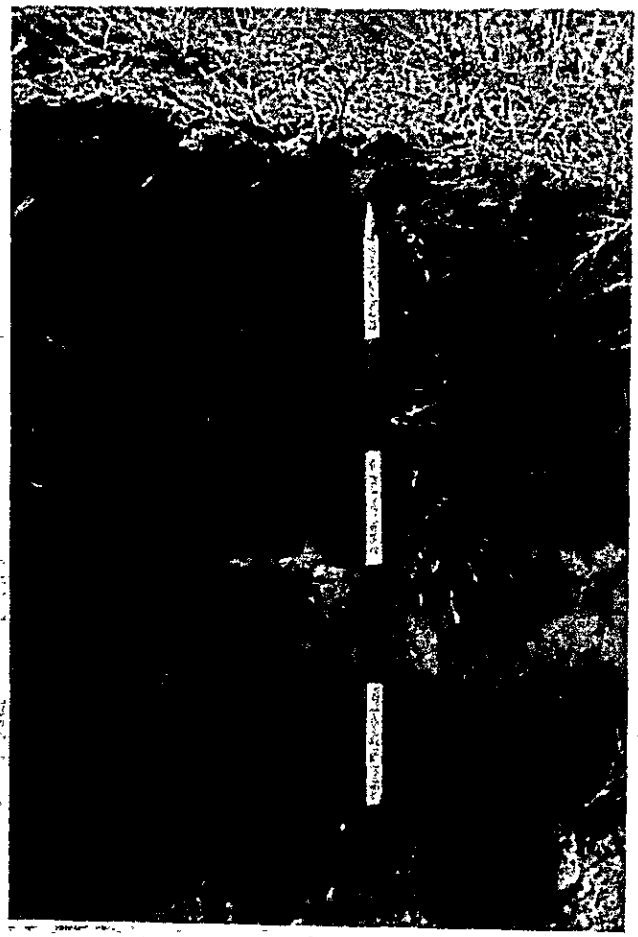
Upper stream part, piled up soil at the bottom of canal thickness of soil T = 15 cm.

Feb 3, 1982



Middle course part, ditto (T = 13 cm.)

Feb 3, 1982.



Soil cement and cracked

dike

Feb 3, 1982.

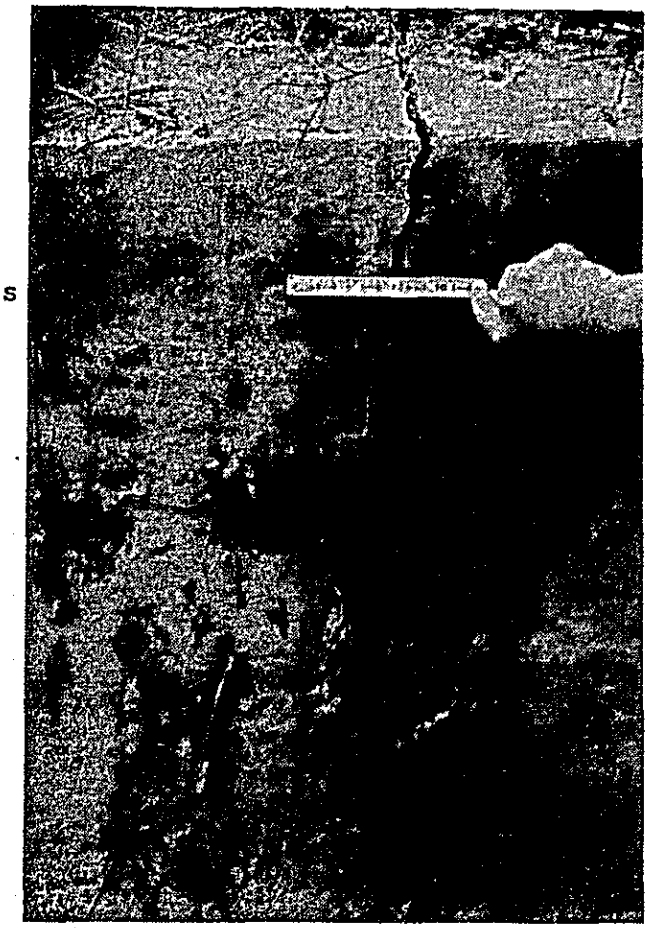
Down stream part

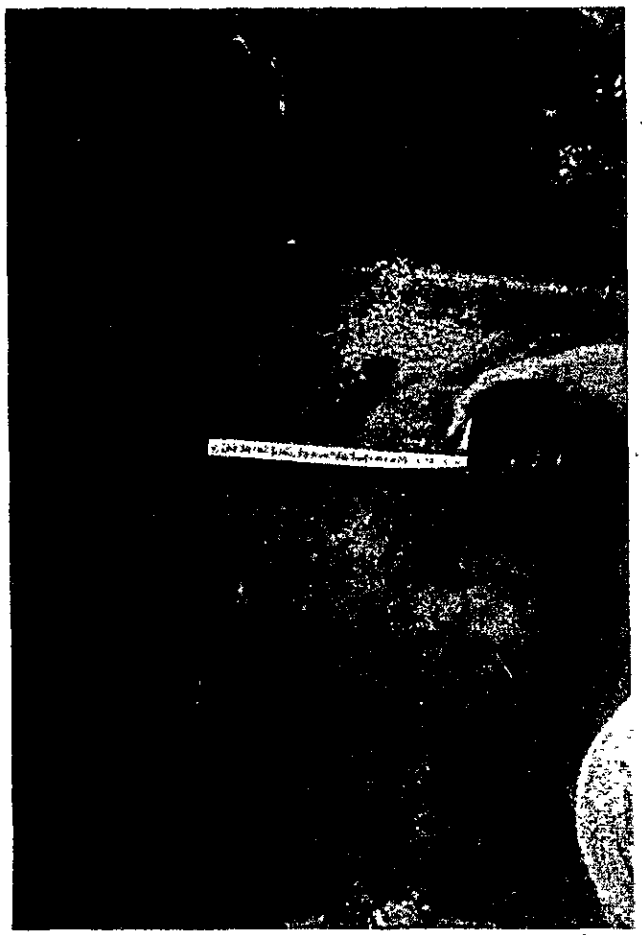
(t = 8 cm.)

Max. crack width was

6 mm.

Feb 3, 1982





Ordinary crack

width 1-2 mm.

Feb. 3, 1982

JICA