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ther the stability or the smoothness of the surface.

#### CONCLUSIONS.

1. Mixes of soil - RC<sub>2</sub> cutback asphalt that have a stability load of 6000 Kg. or more, after seven days of capillary absorption, will give satisfactory service in the field if they are properly aerated previous to being placed, and provided that the soil under the stabilized mix has sufficient stability in the presence of water.
2. The suitability of a given soil for stabilization with cutback asphalt can be predicted on the basis of an area-plasticity index, and all soils having an index of 19.0 or less will have a stability load after capillary absorption of 6000 Kg or more when mixed with the proper percentage of RC<sub>2</sub>. This area plasticity index is computed by multiplying the specific surface by the plastic index and dividing by 1000. The area-plasticity indexes of the soils tested in this investigation varied from 0.0 to 169.9.
3. Soil should not be stabilized with cutback asphalt during a time of the year when frequent rains are liable to occur. In the tropics all soil stabilization should be done during the dry season.
4. Close control of the RC<sub>2</sub> content of a mix is not possible when the soil is mixed in place with road patrols. It appears that the

RC<sub>2</sub> content cannot be specified closer than plus or minus 2%.

5. Close control of the compacted thickness of stabilized soil is not possible when mixing and placing is done with road patrols. It appears that the thickness cannot be specified closer than plus or minus 2 cm.
6. Soil stabilized with cutback asphalt is capable of supporting very heavy loads, and the maintenance cost of such a surface is low.
7. The density of the compacted Laboratory samples of the soil asphalt mixes closely approximated the density of the corresponding field mixes.

#### ACKNOWLEDGMENT.

The testing of all samples described in this paper was done in the Materials Testing Laboratory of the Ministry of Public Works of Venezuela in Caracas. The author is indebted to Pedro Nicola's Doaz, Jose' Baldo and Carlos Luis Pacanins for their assistance in conducting the tests and preparing the tables.

Acknowledgment is made to Dr. Edgar Pardo Stolk, Minister of Public Works of Venezuela, for permission to publish the results of the investigation, and to Francisco J. Sucre, Director of Ways of Communication of the Ministry of Public Works, until October 1945, for his interest in and encouragement of the investigation.

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### AN INTERESTING BELGIAN REALIZATION OF "CLAY CONCRETE"

Paper presented in the name of the  
 "Société SOLVAY"  
 by Marcel THUILLEAUX  
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#### INTRODUCTION

As a result of the war, many roads remain devastated by belligerent armies, and the resources of state and Communes are exhausted; hence the special interest presently conferred to processes for restoring viability to these roads at as low a cost as possible.

One of these processes was first called "stabilized gravel", but is now better known under the name of "clay concrete", it consists of a coarse aggregate (or skeleton) with a granular composition following a well determined law and of a binder clay, the properties of which are stabilized by an hygroscopic salt. It was born in the United States and is used on a large scale in the Northern countries of Europe, especially in Sweden, but it remains nearly unknown in Western Europe.

For a few years however, Belgium has already realised some applications of it; the town of Tournay deserves a special mention as, in 1942-43, it rebuilt in this way about 2 Km of bicycle track; never had the builders considered its utilization by others than bicycles; now it admirably resisted the severe, unexpected ordeal to which it was submitted by the Liberation Armies; parkings for vehicles of any kind and weight were established there which

literally dug and deeply cut the approaches : however no repair at all was needed to the track itself, except removing the materials of any kind, unconsiderately thrown about upon the surface by the unexpected users x)

A hauling road had also been established in the same region following a similar formula, and the same kind of observations as those made in Tournay could be registered there.

#### ORGANIZATION AND GENERAL CONDITIONS OF ATHUS EXPERIMENT.

As they had been informed of these results, a delegation of the provincial and technical authorities of the Province of Luxemburg came there to make observations on the spot. This delegation gained such a good impression, that they decided to subsidize a wide experiment on roads. In order that technicians may form a good judgment about the value of the process, the most difficult place in the Province was intentionally chosen; the city of Athus, situ-

- x) A bicycle track of 6 Km long, built in France in 1939 between Douai and Valenciennes behaved equally well under military traffics of invasion and liberation.



ated at a few kilometers from the frontiers of the Great Duchy of Luxemburg and France (see geographical outline).

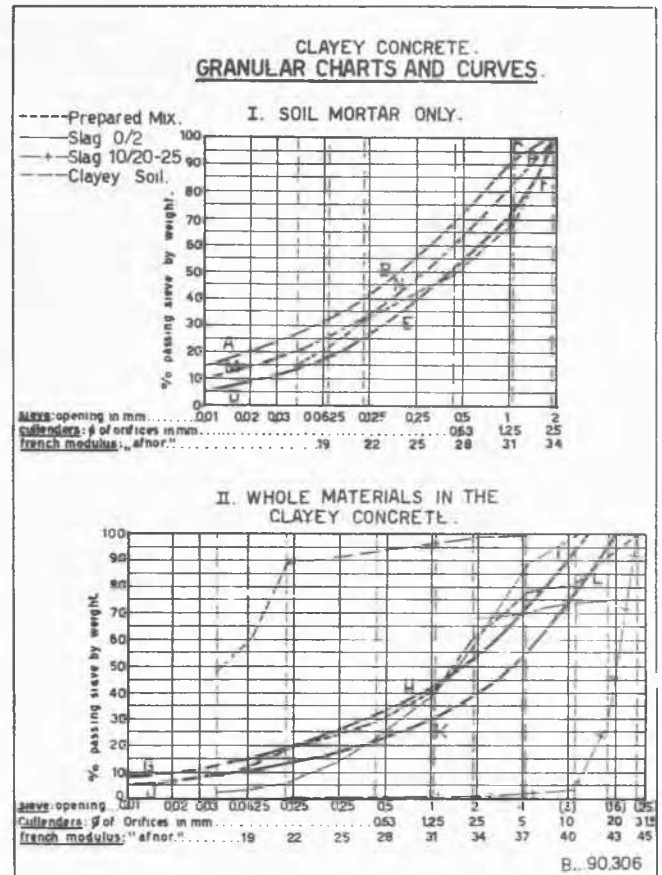
It is not exaggerated to say that the streets of this town, formerly built with water-bound macadam and maintained with tar, were in a lamentable condition in 1945: successive badly disposed reloadings had given excessive thicknesses and crown to the cross section, hydrocarbonated products had disappeared, ruts alternated with holes, some of which turning to bogs.

Moreover some streets offer a marked gradient of the order of 5% and for a small portion the grade of one of them reaches 7%. Finally the "rue des Usines", which deserves the works of "S.A. des Hauts Fourneaux et Acieries d'Angleur-Athus" supports a traffic of cars, which is considered as one of the most severe in the Province; it branches from the roads of Athus by an acute angle-turning and is characterized by a slight gradient and a small bottom before coming to the works intrances.

It must also be added that climate of the region is rigorous; if snow layers are only momentary, frost is every year very severe and persistent.

From the finances point of view, the situation of the town was delicate, and the rebuilding of the roads made borrowing absolutely necessary. This consideration, joint to the cross-section of the streets and bordering gutter-stones, limited the upper layer to an average thickness of 6 cm.

In these not very engaging conditions, it was decided to proceed to the experiment on an area of 16 000 m<sup>2</sup>, say round, 4 km of streets bordered with houses on both sides.



#### RESEARCH OF CONVENIENT MATERIALS - RATIOS FIXATION.

It was first necessary to proceed to an inventory of cheap materials of the region, with physical analysis.

For the skeleton (coarse aggregate), use was made of crushed slag from the works "Usines d'Angleur-Athus"; the choice of gradations, which resulted from trommel-screening, was rather laborious, because effective sizes did not correspond to denominations and because altering, of screening plates and diameters of holes were in process.

For the clayey elements, a deposit of clayey sand was discovered in a wood not far from Athus; samples from several layers were submitted to Laboratory examination and one of them was found satisfactory with its Plasticity Index (following Atterberg-Casagrande) of about 11, and its calcium and sodium contents as traces only.

It was finally decided that a mixture of slag dust "0/2", slag "10/20-25" and clayey sand of the Athus wood should be used. Physical analyses of them are given in following table.

Ratios to be worked up have been determined by endeavouring to meet as much as possible the gradation requirements of the Swedish State, which are recalled by the curves G.H.I. and J.K.L. of our graphic: the gradation curve of an ideal mixture shall remain entirely between those two curves and always turn its concavity upwards. Further, it was examined whether the "soil mortar" entirely composed of the grains smaller than 2 mm, did correspond to a similar specification based on old American works. Finally, as fine grains were present

WORKS CARRIED OUT IN ATHUS (BELGIUM) FOR  
CLAY-CONCRETE ROADS  
PHYSICAL CHARACTERISTICS OF UTILIZED MATERIALS

Gradation analyse xb)	Slag 0/2	Slag 10/20-25	Clayey earth xc)	Prepared mixture
Passing 0,064 . . . . .	3,1	(	60,4	12,7
0,064 - 0,118 . . . . .	2,6	)	28,7	6,4
0,118 - 0,250 . . . . .	9,1	( 1,3	2,8	5,8
0,25 - 0,45 . . . . .	8	)	1,5	4,7
0,45 - 1,06 . . . . .	18,8	(	3,3	12,2
1,06 - 1,92 . . . . .	17,2	)	2,9	18,2
1,99 - 4,08 . . . . .	30,8	0,3	0,4	17,3
4,08 - 8,30 . . . . .	10,4	1,6	-	4,2
8,30 - 14,95 . . . . .	-	26,3	-	10,1
14,95 - 23 . . . . .	-	70,5	-	8,4
Refused at 23 . . . . .	-	-	-	-
Apparent specific weight Kg/cm <sup>3</sup> . . . . .	1,49	1,28	0,97	-
Liquid Limit . . . . .	-	-	39	24
Plastic Limit . . . . .	-	-	28	21
Plasticity Index . . . . .	-	-	11	3
Centrifugal Moisture Equivalent	-	-	21	13
<u>Proctor tests</u>				
Maximum density . . . . .				2 113 Kg/m <sup>3</sup>
Optimum humidity . . . . .				11,6 %

- xb) See on enclosed graphic the granular curves of several materials.
- xc) This earth contains only traces of Ca and Na.

in the slag 0/2 the Plasticity Index was lowered in a reasonable limit: by the adopted ratios it was found to be of the order of 3.

When submitted to PROCTOR'S compaction test, the mixture revealed a maximum compaction of 2 113 Kg/m<sup>3</sup>, corresponding to a water content of 11,6 % .

CARRYING OUT OF THE WORKS (See photographs).

Technical relations from countries where clay concrete is currently used, usually describe its working up with special equipment often designed as "heavy", and built by American or Swedish firms. The Athus'works prove that the use of such an equipment may be dispensed with; only most current equipment of small concerns were utilized. The mixing of materials was simply operated in a small concrete-mixer of 250 L, elements being volumetrically dosed in previously gauges wooden cases; the clayey sand was dried in open-air and screened in a 10 mm meshed sieve for eliminating clods xa)

Particular attention was given to the renewal of the cross-section of the foundations and also to the sewage of rain water; care was taken to eliminate every upper stagnation. The cross-section, which is the same for foundations, has been circular : the concern only disposed of a 3 wheeled compression-roller, which did not permit adopting the generally preferred "roof"-type of crown (cross-section

xa) It would have been more orthodox to use a tighter meshed sieve.



Athus - clay concrete  
Centrale plant for concreting 25/7/1946



Athus - clay concrete  
Guerlanges street Schools place  
22/11/1946

in straight lines, dropping both ways from the centre).

Mixture composed of :

Clayey sand . . . . .	246 L
Slag dust 0/2 . . . . .	521 L
Crushed slag 10/20-25 . . . . .	233 L
	1000 L

Calcium Chloride . . . . . 10 Kg

Water for obtaining a small ball, coherent under strong handpressure, without adhering to it, was transported by dumping-body-car, delivered upon the spot, uniformly distributed by fork to an about 7 cm thick layer and then compacted by truck (with pneumatics). The final compaction was operated by a 3 wheeled roller of 14 tons: on account of the low thickness, three trips were sufficient.

Works began on the 6<sup>th</sup> July 1946 and were continued until the end of September with interruption in the middle of August due to paid holidays.

#### TECHNICAL RESULTS.

Athus' wearing courses first had to endure a trial due to exceptionnally rigourous Winter, then that due to a Summer still more abnormal, as regards dryness and temperature.

Besides, a violent storm happened on the 25<sup>th</sup> July, accompanied with diluvian rain, and caused complete submersion of a flat portion on the "Place des Ecoles" (Schools Place) just as the mixture had been put in place.

Traditional maintenance application of calcium chloride which normally is to be effected every year in the spring, could only be executed very tardily, on the 7<sup>th</sup> July 1947, and it was poorly made, being characterized by wide unevenness in the distribution.

Nevertheless, in December 1947 - after 15 months -, the clay concrete wearing course, taken on the whole, was impeccable. The condition of the slope sections, the turning leading to "rue des Usines" (Works Street) and the "Place des Ecoles" (Schools Place) deserves special mention for its excellency.

The borderers did not have to complain about dust during the summer in spite of the torrid heat, neither had they to suffer from mud after the snow falling and melting.

A delegation of Engineers, from Great Duchy of Luxemburg, who watched over the Athus' realization, showed some astonishment about its excellent behaviour during the summer of 1947: in Great Duchy indeed, excessive heat caused important failures in its tar-coated roads, which are however carefully maintained.

#### PRACTICAL CONCLUSIONS

Place being limited, it is not possible to mention here other experiments now in course in Belgium; from the roads point of view, they are less important than that of Athus, but fully corroborate it.

Athus' realization gains its full value from all disadvantageous factors, which were surrounding it :

- In very first rank, a daringly weak thickness imposed by local conditions;
- Very difficult and delicate general bringing in form of the road;
- Building by a shift carrying out such a work for the first time and led by an initially sceptic chief;
- A traffic considered as exceptionnally hard;
- Climatic conditions of nearly unknown severity.

In the present state of experiments and if clay concrete is limited to its own field, that of secondary roads and not of highways, we may conclude that clay concrete is able to bring remarkable results under the climatic and geological conditions prevailing in Belgium

Its use brings about the means of restoring secondary communal roads with a tolerable outlay of money.

If the cost of a clay concrete wearing course is taken as unit, it is believed that the corresponding cost of water bound macadam would be at least 1,33 and that of a tar-macadam 1,8 (under economical conditions prevailing in the Province of Luxemburg).

Calcium chloride treated clay concrete-surface courses remaining free from dust in summer, from mud in winter, being not sliding to horses, non-slippery to vehicles, inoffensive to animal feet, of no noxious effect upon the neighbouring vegetation, resisting to frost and thawing and needing no specialized workers nor special equipment for their working up, recommend themselves for communal streets and roads and could be usefully utilized for some roads supporting a chiefly touristic traffic. Let us incidentally point out a curious property of clay concrete that sends technicians of roads into dreams; that of the auto-mending of small local degradations under the only action of automobile vehicules.

The appearance of these roads is also to be considered as it is that of natural materials. At the moment, when there is so much talk of urbanism, this point is not to be neglected: thus "burnt dump-schists" show a red colour very pleasant to the eye and are very attractive for establishing garden-cities.

Finally, an application to point out is that to bicycle tracks: a smooth rolling layer very uniform, free from joins, altogether firm and unctuous is obtained in that way; indiscutably, the formula is much appreciated by wheelmen as well in Tournay as in France, near Cambrai.

We could however not close this brief relation without drawing attention to the fact that the making of clay concrete may not be left to anybody; it requires careful preparation, as to the choice of materials to be worked up and their dosage, and the working-staff must be conscientious and fond of their profession. If we have mentioned above the unfavourable conditions prevailing in Athus, on the contrary, we are pleased to mention that well deserved consideration should be given to the workers quality, as the excellent results obtained were based on the cooperation we found there.

#### THANKS

Before closing this brief description, we should like to thank everyone who promoted the Athus experiment or contributed to the successful superintending of the works :

- The Permanent Deputation of the Province of Luxemburg the experiment promotor;
- The Communal Council of Athus, who gave his adhesion;
- The Provincial Technical Service whose wide collaboration permitted this discovery of suitable clayey sand, determined the conditions of work and supervised execution and results;
- The contractor Mathieu and his workers-shift, responsible for an excellent building.