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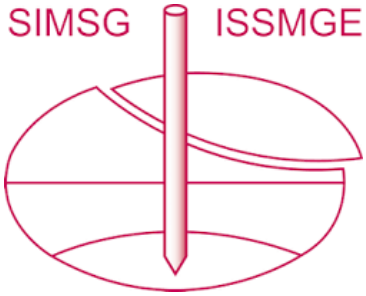

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Cheap All-weather Roads from Soil and Soft Aggregates

Routes Économiques Construites avec des Sols et des Agrégats Tendres

by S. R. MEHRA, M.I.C.E. (Eng.), M.I.E. (Ind.), Director, Central Road Research Institute, New Delhi, India

Summary

A special method of the use of soft local aggregates for low-cost road construction has been advocated. The behaviour of a full scale experimental road constructed in 1944 has been described. The scientific background of the method has been given.

The method has been further developed by including surface dressing and stone grafting for heavier traffic.

On the basis of experience gained during the last 12 years over the construction of more than 250 miles of road in India, it is advocated that the method is usable in most countries of the world where blending of soils is an economic possibility and soft aggregates easily available.

Sommaire

Une méthode spéciale pour l'utilisation d'agrégats locaux tendres dans la construction des routes économiques est présentée. Le comportement d'une route expérimentale à grande échelle, construite en 1944, est décrit. La base scientifique de cette méthode est indiquée.

Cette méthode a été perfectionnée par addition d'un tapis superficiel ou incorporation superficielle de pierres dures, en case de trafic plus lourd.

Sur la base de cette expérience, portant sur ces douze dernières années, et sur plus de 250 miles de telles chaussées construites dans les Indes, l'auteur estime que cette méthode peut être utilisée dans la plupart des pays du monde, là où le mélange des sols est économique, et où l'on trouve des agrégats tendres.

Introduction

This paper is a continuation of the paper entitled 'Soil Stabilization with soft aggregates', presented at the Second Conference at Rotterdam in 1948 (pp. 262–267), *Proceedings of the Second International Conference on Soil Mechanics and Foundation Engineering*, Vol. 4.

The object is twofold: first to report on the behaviour of the experimental road and further development of the process and secondly, to give a scientific backing to the theory that if soft aggregate is suspended in a cohesive elasto-plastic medium, to form a road crust, it can be utilized to give high bearing value without risk of detrimental crushing of aggregate within the crust.

The method of low-cost stabilized soil road construction described in the paper referred to above was evolved to satisfy the following conditions prevailing generally in the vast alluvial plains of India:

(a) Hard gravel is scarce and the only aggregate universally available locally is rather soft and liable to crushing within the crust, if used as such.

(b) Due to large variation in soil texture at short intervals of distance, the blending of soils to produce desirable grading is an economic possibility.

(c) Possibility of capillary action from the subgrade, at certain times of the year.

(d) There are long periods of dry and wet seasons, the total annual rainfall being of the order of 30 to 40 in.

(e) Desirability of the process lending itself to work by manual labour, to improve the employment potential of the country.

Scientific Background of the Method

The method involves the following special features:

(1) The road crust consists of two courses, the base and the upper course. The base course soil has less clay and more sand and the upper course soil has more clay and less sand, as usual. The base course consisting of graded soil rich in sand is designed to protect the upper course from capillary action of subgrade moisture during the wet season.

(2) About 40 per cent of broken brick aggregate (or other soft local aggregate like kankar, laterite, moorum, etc.) is incorporated into graded soil in the upper course only with a view not only to increase the shear resistance and consequent bearing value of the matrix as much as possible but also to ensure that excess of aggregate does not cause its own crushing under load and vibration, within the road crust.

The following laboratory report supports the preparation of about 40 per cent of soft aggregates into the top course graded soil:

Table 1 gives the typical manner in which the laboratory *CBR* value and the aggregate crushing value both increase as a result of incorporation of increasing percentages of soft aggregate into graded soil. The aggregate crushing value against 40 per cent, i.e. 23·48, corresponds with that of good road stone; also, the CBR value against 40 per cent, i.e. 36·5, is a reasonably good value for low-cost roads not exposed to heavy traffic.

Table 1

The effect of soft aggregate on aggregate crushing value and CBR value of resulting road crust

L'influence d'un agrégat tendre sur la valeur d'écrasement de l'agrégat et la valeur CBR de la route

S. No.	*% brick ballast in the mixture*	*Aggregate crushing value*	*CBR %*	*Remarks*
(1)	20	4·65	25·0	
(2)	40	23·48	36·5	
(3)	50	30·03	46·0	
(4)	60	33·05	64	

Furthermore, the typical change in plate bearing values of road crusts with varying percentages of soft aggregates in the upper course is shown in Table 2.

It will be seen from Table 2 that above 40 per cent aggregate the values of K start falling, and from the curve drawn therefrom (Fig. 1) that the optimum aggregate percentage is about 40 per cent.

(3) A simple method of design of soil mixtures for blending has been adopted for the reason that a very large number of

Table 2

S. No.	% brick aggregate in the mix	Coefficient of subgrade reaction K lb./sq. in./in.	Remarks
(1)	20	520	The K values are for a crust consisting of 3 in. base course and 3 in. top course, the base being graded soil alone and the top course being soil plus aggregate. The K value of soil without the aggregate is 200.
(2)	30	594	
(3)	40	604	
(4)	50	579	
(5)	60	411	

such mixtures has to be designed and the methods in use elsewhere involve long calculation.

This method assumes that when two soils are mixed together, the resultant plasticity index and sand content (− 40 + 200 fraction) are of the order in which the two soils are mixed, i.e. it bears a straight line relationship. The justification for using the straight line relationship is provided by six typical curves in Fig. 2, three of them showing the fall in plasticity index of

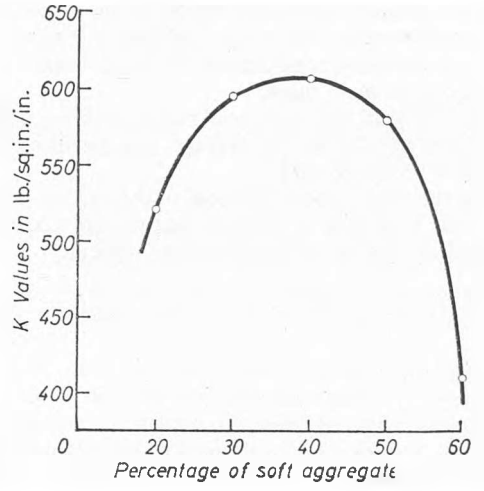

Fig. 1 Relation between percentage of soft aggregate in the upper course of a stabilized soil road crust and the K value in a plate bearing test

Relation entre le dosage en agrégat tendre dans le couche supérieure d'une route en terre stabilisée et la valeur K dans l'essai à plaque portante

clayey soil to which sand is added in increasing amounts, and the other three showing the effect of addition of clay to a sandy or silty or less clayey soil.

Behaviour

The following significant points were noticed in the behaviour of the experimental road as a result of detailed periodical observations:

(a) Generally speaking, the road gave uniformly satisfactory service all the year round, under mixed pneumatic and steel tyred traffic. In dry weather the surface was slightly dusty, and during heavy rainfall some lengths were slightly slushy; but the road crust remained perfectly sound and at no time was traffic inconvenienced in any way.

(b) Maintenance consisted of patch work only, as on water bound macadam, and no grading or blading was ever required.

(c) There was no progressive rutting whatsoever. What little tracking took place during the dry season was put right during the wet season and as a result the section wore out uniformly at the rate of about ½ to ¾ in. per year depending on the intensity of traffic, which to start with was about 200 ton per day and increased steadily to about 400 ton per day in 3 years. A detailed measurement of the thickness of wearing course taken

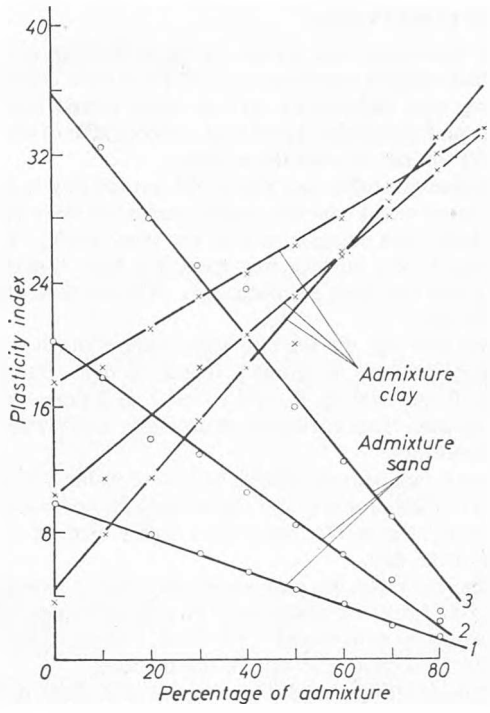

Fig. 2 Relation between plasticity index and percentage of admixture in six typical cases

Relation entre l'indice de plasticité et le pourcentage d'additions dans six cas typiques

4 years after construction showed that an average thickness of ½ to ¾ in. was still there and that the road camber was intact.

(d) The gaps, or depressed portions of road for passing cross drainage during monsoons, were surface dressed, with a view to seeing whether such a road could take such treatment to make it more lasting and dust proof.

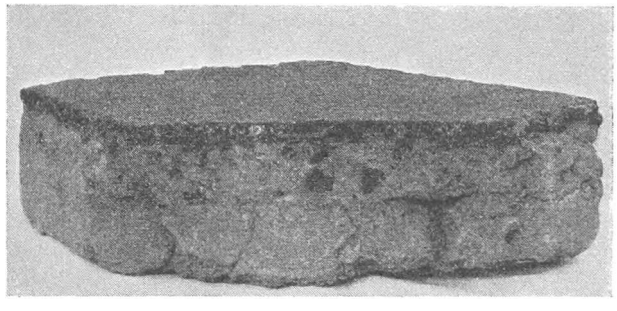

Fig. 3 A section cut from the treated surface after 11 years of service

Echantillon pris dans une surface avec revêtement après onze ans de service

When the rest of the road was provided with a new upper course and surface dressed, the gaps, being in good condition, were left untouched. These gaps which take drainage water every monsoon and have received renewal coats of bituminous surfacing as a normal maintenance measure have behaved very satisfactorily up to date, and have proved that the process does lend itself to the cheapest form of bituminous surface treatment.

A piece was cut out from one of the gaps recently after traffic had passed over it for more than 11 years and it was found in perfect condition. The aggregate embedded in the soil is intact and the bond between the road crust and the bituminous dressing is healthy (see Fig. 3).

Development of the Process

Since the last paper was written, a large mileage (over 250 miles) of black-topped stabilized soil road has been constructed and is giving very satisfactory service under mixed iron tyred bullock cart and pneumatic tyred high speed traffic of the order of about 150 ton per day on the average.

For more intense traffic, say about 500 ton per day, a method of grafting stone metal over the upper course has been evolved, the surface treatment being done over the stone graft. The use of a tack coat before surface treatment has been found to be unnecessary and has been discontinued. The method of grafting is as follows:

(1) On the first day the uncompacted upper course together with the layer of stone 1 in. gauge is spread on the surface at the rate of 7 cu. ft. per 100 sq. ft. and rolled 2 to 3 times over the whole length and then sprinkled thoroughly with water and left till the next day.

(2) The next day, without adding any more water, the surface of the road is rolled properly and thoroughly for at least 6 times over the surface; the surface again thoroughly watered and left for the rest of the day.

(3) On the third day the surface of the road is rolled again without any addition of water and this is continued till the road is thoroughly compacted. Of these 3 days, rolling and re-rolling on the second day will be the heaviest.

(4) After completing the rolling for the first three days the road should be kept heavily sprinkled with water for nearly 4 days and after that kept moist by sprinkling 2 to 3 times during the day. The curing period should be restricted to 10 to 15 days.

For a 6 in. thick road crust, the present average rates in the Punjab are:

Water bound macadam with surface treatment	Rs. 35,000/- per 10 ft. wide mile
Stabilized soil, with stone graft and surface treatment	Rs. 20,000/- per 10 ft. wide mile
Stabilized soil with surface treatment but without stone graft	Rs. 18,000/- per 10 ft. wide mile
Stabilized soil without surface treatment	Rs. 9500/- per 10 ft. wide mile

Recommendations

As a result of large-scale experience over the last 12 years, it can be predicted that the method could be usefully and economically exploited in most South Asian and other countries where the need of low-cost roads is great and the blending of soils is an economic possibility.

For very low-traffic village roads surface dressing is not necessary but may be advisable for easy maintenance; in any case, it will be no more expensive in the long run, as the life of surface dressing under very light traffic will be proportionately long.

For minor district roads, carrying traffic up to about 150 ton per day on the average, the surface dressed stabilized soil road should be an adequate replacement for water-bound macadam at half the cost in most cases.

For major district and provincial roads, carrying traffic up to about 500 ton per day on the average, the specification with a stone graft is recommended.

Whereas the employment potential of the process is very high indeed, it has been seen in practice that partial mechanization, where required, can be adopted without difficulty.