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EARTH ROADS.

By S. G. Stubbs,

Secretary, Communications Board, Punjab.

In the Appendix I at the end of this paper is given the mileage of surfaced and unsurfaced roads and the number of motor vehicles in use in 35 countries in the world. It will be seen that the mileage of unsurfaced or very lightly surfaced roads is very large indeed in countries like North and South America, Canada, South Africa, Australia, etc., varying from about 80 % to 98 %, and in spite of this fact the number of motor vehicles in use is also enormous ranging from about 2 to 37 per mile of road. It is realised that in these countries the bulk of these motor vehicles run on surfaced roads, nevertheless a very large number indeed must also use earth roads ; on some earth roads in the United States of America this number is said to amount to 200 or 300 vehicles per day. In India the greater part of our metalled roads (outside towns and cities) do not carry half the traffic, and some of the metalled roads the writer has recently travelled on in the Central Provinces, United Provinces and Bihar and Orissa do not carry even 50 vehicles a day and in many cases considerably less than this. When it is considered that a rich country like the United States of America can only afford to maintain about 20% of her total mileage of roads as surfaced roads, it is difficult to understand how a comparatively poor country like India can afford to maintain 28%. The general view in India is that unless a road is metalled it is no road at all and an earth road was looked upon as a mere area of land reserved for metalling at some future date if and when funds became available. There are some 200,000 miles of roads of all classes in India of which roughly 60,000 are metalled, and the maximum annual increase in the metalled mileage the country is able to afford under the present order of things could not exceed 1,000 miles ; therefore if the opening up of the country is to depend entirely on metalled roads it would take 140 years ; I wonder the country is poor and continues to be poor ?

In the year 1904 in the United States of America there is said to have been only 154,000 miles of surfaced roads and 55,000 motor vehicles, water bound macadam as the highest type of surface ; in the last 25 years these numbers have increased to 24 million motor vehicles and 400,000 miles of surfaced roads. This increase of roughly 400 times in the number of motor vehicles has resulted in a correspondingly large increase in revenue and has enabled this country not only to have increased its previous surfaced mileage but to improve existing roads on a large scale, so that there is now about 90,000 miles of road

superior to water bound macadam. As Highway construction and maintenance is financed almost entirely from direct and indirect taxation on motor vehicles that country would never have had such a fine Highway system today if the maximum use had not been made of earth roads ; these have been used for building up the traffic load, opening up the country and providing funds for better types of surfaces when traffic justified them.

3. In pre-motor car days or when they were comparatively few in use in India the chief destructive agents to roads were bullock carts, but as the bulk of them transported agricultural produce the number using roads had some relation to the amount of revenue of the country, the cost of maintenance of roads was thus automatically provided for. When motor vehicles, private and public, began to be used on an extensive scale metalled roads wore out far more rapidly, thereby increasing the cost of maintenance, and as there was no corresponding increase in the revenues of Provinces there was great difficulty in providing for this increased cost.

4. When taxes (direct and indirect) were first levied on motor vehicles there were comparatively few such vehicles in use which did little damage to roads, moreover as the revenue derived did not amount to a great deal, it was absorbed unnoticed into the revenues of the Government of India. To-day the taxation on motor vehicles brings in about 3 or 4 crores to Central Revenues, and this is expected to increase at the rate of 50 or 60 lakhs a year. Owing to the rapid increase in motor traffic the sums required to be spent on the construction and maintenance have become so large that even now the financial resources of Provinces are taxed to their utmost limits, and that unless an appreciable percentage of this annually increasing revenue derived from taxation of motor-vehicles is distributed among Provinces for expenditure on roads the situation will become impossible, all new construction will have to stop and existing roads will rapidly deteriorate. It would therefore seem that sooner or later a fair share of this revenue must come to the Provinces. In addition to this, the Government of India has recen levied a surcharge of two annas a gallon on motor spirit for distribu among Provinces which is expected to bring in about 80 lakhs per an increasing at the rate of about 10 lakhs a year. It will thus be s in the near future the funds available for expenditure on road considerably more than what they are now and that the amou funds will be roughly proportional to the number of mo in use ; it is therefore obvious that motor vehicles are going t roads and in consequence everything should be done to number as rapidly and as economically as possible. The what policy should be adopted to ensure a maximum inc of expenditure. For instance, which would be more profit say 5 lakhs on building 1,000 miles of earth road at Rs. 500 ing the same sum on constructing 25 miles of metalled roa

macadam) at 20,000 a mile ; Obviously the former ; there are a number of earth roads in the Punjab carrying 10 or more motor buses a day, whereas there is not a single pure water bound macadam road in India that does or could carry 400 motor buses a day. The Lahore-Amritsar Road carried 250, but then it is not a pure water bound macadam road, its surface is painted with tar and costs about Rs. 3,000 per mile per annum to maintain as against about Rs. 70 per mile per annum for an earth road. It is not claimed that an earth road is the beginning and end of all things, but it is emphasised that the maximum use should be made of it, as it produces revenue for better type of roads, feeds railways, helps the agricultural and the motoring public, and opens up the country rapidly and economically.

PUNJAB.

Roads in Punjab are divided in 4 classes : (1) Arterial, (2) Class II or Main, (3) Class III, (4) Village.

Arterial Roads.—Comprise, as the name suggests, such roads that connect up headquarters of district with towns of over 20,000 population or with one another. The present mileage under this head is 4,720, of which 2,140 are metalled and 2,580 unmetalled. They are maintained by the Public Works Department from Provincial funds.

Class II or Main Roads.—These include roads that pass through more than one district, connect towns with a population of over 5,000, link up important pilgrim shrines, and trading centres with mandis, arterial roads, railways or with one another. They are maintained by District Boards from their own resources aided by grants-in-aid from Government, the latter is distributed by the Communications Board. The total mileage under this head is 8,160, of which 1,151 are metalled and 7,009 are unmetalled.

Class III Roads.—Include all other roads (excluding village roads) in districts and are maintained by District Boards entirely from their own resources. There is no accurate record of the exact mileage, but it is believed to be 11,000, of which 150 miles are metalled.

Village Roads.—These are mere connecting links to the Highway system and the responsibility for maintenance is supposed to rest with the villagers themselves. In actual practice the bulk of them are not maintained at all and are in a terrible state, such of them that have not been absorbed by encroachment are mere drains and are absolutely impassable in the wet weather. There is no record of their mileage but is said to be 40,000 miles.

Thus excluding village roads, which is not really part of the Highway system, there are about 20,500 miles of unmetalled roads and 3,600 miles of metalled on which a total sum of approximately 130 lakhs is spent on maintenance and increasing the metalled mileage by about 125 miles every year. If the opening up of the country is to depend entirely on metalled roads and the same metalling programme can be maintained it will take well over a century. Moreover owing to the increase in motor traffic and the consequent increase in the cost of maintenance of metalled roads it is exceedingly doubtful whether the present metalling programme can be maintained. It would, therefore, seem that at the present time the Province cannot afford a large increase in metalled mileage, and until it becomes a great deal richer, development will have to depend mainly on unmetalled roads and moreover as in the case of America, these very unmetalled roads, now largely ignored, are going to provide the money for building and maintaining better roads in the future.

As early as 1921, the Communications Board of the Punjab realised the very great importance of unmetalled roads and have been impressing upon District Boards that earth roads have a definite economic value and can be kept in excellent order if the soil is suitable and proper attention is devoted to them. With this object in view demonstration earth roads were constructed by manual labour in 20 districts (*see* Appendix IV). All these roads were already in existence, so the work really consisted of improvement ; this consisted of restoring the camber by about 6″ to 8″ earth filling, watering and rolling, repairing existing culverts and providing new ones where necessary. To give the experiment a fair trial the Communications Board entirely financed the cost of improvement, and subsequent cost of maintenance for a year. In all except 3 cases the present state of all these roads is excellent, there is some excuse for the Ambala-Naggal and the Nurwala-Aminpur roads which contain unsuitable soil and carry very heavy traffic but there is no justification for the poor state of the Gujranwala-Naushera road ; it contains excellent soil and was maintained in splendid condition as long as the Communications Board paid for the maintenance, but since then the District Board has neglected the road. Though the results obtained were very satisfactory, this method proved comparatively expensive, improvement costing Rs. 1,500 a mile and subsequent maintenance about Rs. 200 a mile. Therefore activities in this direction were somewhat restricted until the introduction of tractors and graders described in detail hereafter and sufficient successful work has been done to predict with some measure of certainty that the use of road grading plant will go a long way towards solving our road problems and further owing to the low cost of maintenance we can look forward to seeing the Province opened up at a very rapid rate. During the space of two years nearly 2,347 miles of earth roads will have been improved and if this progress can be maintained, it is not difficult to visualise the extent of the benefit that will accrue in a very short time.

SOIL ANALYSES AND ESTIMATES.

As already stated the present condition of most demonstration roads clearly showed that where earth roads received adequate attention and where the soil was suitable, they could be kept in such good condition as to permit a motor vehicle to travel over them at about 25 miles an hour. Unfortunately the quality of soil not only varied in different districts but in many cases in different places on one road, therefore whatever method (machinery or manual labour) was adopted for the maintenance of unmetalled roads even a moderate measure of success could not be obtained unless suitable soil was transported to places where the soil was bad. The first objective was therefore to ascertain what exactly was unsuitable soil and whether the transportation of soils was a practical proposition. A rapid reconnaissance made in a few districts showed straight away that the number of miles containing unsuitable soil was comparatively small and that carting good earth where it was needed was neither difficult nor expensive. It was therefore decided to make a soil analysis survey of all Class II unmetalled roads in the Province and to ascertain by observation and experiment the behaviour of various classes of soil under traffic. Observations showed that from the point of view of earth roads soil could be conveniently divided into the following four classes :—

(1) A soil containing not more than 30% of sand and 70% clay made a first class unmetalled road which could stand up to heavy traffic if properly maintained.

(2) A soil containing between 30% to 40% sand and the balance clay made a moderately good road, but was liable to break up under heavy traffic.

(3) A soil containing over 40% of sand was of no practical value for roads, it was found necessary to blanket such soil with good earth to render it fit for traffic.

(4) Soil containing saltpetre was of two classes—

(*a*) where excess of salts were deposited on the surface due to capillary attraction and subsequent evaporation ;

(*b*) where the soil was merely impregnated with salts.

The former is quite unsuitable for earth roads but can be treated in a similar way to Class III soil, the latter is excellent for earth roads, it tends to attract moisture, readily compacts and presents a hard surface.

The method of soil analysis is simple, for the purpose of determining the percentage of sand, it merely consists of weighing a sample of earth to be analysed then washing out, drying and weighing the residual sand. Though the method is simple it would have been obviously far too laborious to analyse the soils of all the important unmetalled roads in the

Province. Therefore classification had to be done by eye trained for the purpose. It was found by experience that after a Subordinate had analysed 40 or 50 samples he was able to tell by casual inspection what percentage of sand any soil contained. Saltpetre of the 4 (*a*) variety is readily detected even at a distance, and saltpetre of the 4 (*b*) variety was included in Class I. The classification of soils for each road was recorded in a linear map in the following manner. All parts of a road containing Class I soil were left uncoloured, Class II soil shown blue, Class III red and Class 4 (*a*) yellow, thus the soil conditions of every road surveyed was very clearly presented and these maps formed the basis on which the improvement estimates were prepared. The abstract of these estimates as well as soil analyses of 2,603 miles of Class II unmetalled roads that have been carried out up to date is set forth in Appendix V at the end of this paper. It will be seen that of this mileage 1,645 miles contain suitable soil, 430 miles moderately good soil and 528 miles unsuitable soil that requires to be covered with good earth transported from elsewhere. The cost of improving earth roads in the manner now generally adopted and described hereafter figures out at Rs. 517 a mile which figure includes all transportation charges of good soil where necessary.

ROAD GRADING IN THE PUNJAB.

History.

There are no accurate records regarding the early history of road grading in the Punjab, but it is said to have started with the purchase of a light Western Grader (weighing about 1,800 lbs.) about the year 1921. The original idea was to use animal power to haul the machine, but this was soon found to be very unsatisfactory, bullocks would never keep straight and it was very difficult to hire them when they were most needed, *i.e.*, during the rains. Therefore except for some experiments, about which there is no record, using a borrowed Fordson Tractor to haul it the grader seems to have been laid aside for a number of years; anyway judging from its condition at the end of 1927 the machine appears to have seen a good deal of service. Interest in road grading was revived when the following plant was purchased at the end of 1927.

(1) A Fordson Tractor to haul the light Western Grader.

(2) A No. 3 Standard Russell grader weighing 4,200 lbs. to be hauled by a 35 H. P. Hercules Steam Tractor.

Outfit I.—Though the grader was not in too good condition, the blade was blunt and the bearings of the wheels had worn out badly, experiments carried out in Gujranwala early in 1927 established straight away that this type of outfit had great possibilities for maintenance of earth roads that had been improved, but was much too light to do any improvement work, it tended to ride over rather than shave off hard spots; however as there were so few roads at that time in an improved condition there was little scope for it.

Outfit II.—This was a very much heavier combination and primarily intended for heavy improvement work, and just what was needed at that time. A factory representative of the Russell grader Company was sent out specially to demonstrate how to operate the grader and to shape earth roads. He remained at Hansi in Hissar District for about 10 days, improved about 3 miles of earth road himself and initiated the writer, his assistants and the local District Board staff into the mysteries of road grading. This outfit continued to do splendid work for about a month when the shaft of the 2nd gear pinion (about 3″ in diameter) suddenly snapped, a new shaft was fitted and this behaved in exactly the same way after a few days work. After close investigation it transpired that the tractor was quite unsuitable for heavy road grading as it was under powered and too high geared. Though the plant has continued to work from time to time it has never been satisfactory.

Several other machines were also purchased by Government for construction and maintenance of earth roads in the Nili Bar Colony but a great deal of use has not been made of them, partly because the soil in this area was not suited to earth roads, and the plant was not really what was wanted. Experience gained at this stage clearly showed that road grading had a great future but the machinery at our disposal was not really suitable.

SELECTION OF PLANT, ETC.

Though it was felt that experiments with other types of plant were immediately necessary, it would be folly to purchase any more plant without ascertaining by experience what was really needed. These considerations led to the introduction of what was called "Working on the depreciation basis" in about July 1928, that is, firms interested in the sale of road grading plant worked their own road grading machinery with their own staff for an indefinite period and charged a monthly sum for depreciation, plus actual running costs, a life of two years was assumed for the tractor and four years for the grader.

Four firms were enterprising enough to agree to these conditions and the following two outfits placed at the disposal of District Boards and commenced working in July-August 1928.

III. A No. III Highway Patrol weighing 1,800 lbs. drawn by a 12/20 H. P. Case Tractor.

IV. A Howard Grader weighing 4,000 lbs. (equipped with a 7′ maintenance blade as well as a 12′ maintenance blade) drawn by a 15-30 H. P. Nacormak Deering Tractor.

(A No. 7 leaning wheel Adams Grader was subsequently placed at the disposal of Disitrict Boards on the same conditions).

The object of this arrangement was fourfold :—

(*a*) To ensure the plant was properly handled.

(*b*) To train both supervising and operating staff how to run these machines.

(*c*) To ascertain the correct type of plant to be used.

(*d*) To demonstrate to District Boards the advantages of using road machinery for earth roads as opposed to manual labour and to eventually persuade these local bodies to purchase outfits of their own.

As far as (*a*), (*b*) and (*c*) are concerned the objects have been attained, the staff of the Communications Board, as well as District Engineers of districts in which demonstrations have been carried out have received a thorough training and it has been definitely established that for reshaping earth roads a grader weighing about 4,000 lbs. is required, anything lighter is unsuitable and tends to ride over hard spots. In addition to the ordinary 7 or 8 blade for heavy grading the machines can be fitted with a 10 or 12′ maintenance blades. A heavier grader than 4,000 lbs may conceivably give slightly better results but there will be difficulty about securing a powerful enough tractor. A tractor of about 15 (draw bar) H. P. is the most powerful in general use in India for which spares and service is readily available and the heaviest grader that can be hauled by such a tractor without overloading weighs about 4,000 lbs. Therefore as far as heavy road grading is concerned the outfit that has been selected as being the most suited to the Punjab is a 15 (draw bar) H. P. coupled to a grader weighing 4,000 lbs.

Though these heavier machines now perform the dual function of heavy grading and maintenance, it is the ultimate aim that each District Board will have one or more light maintenance set as well as a heavy outfit. The two maintenance outfits with graders weighing about 1,800 lbs. have given satisfaction but experience in America points to the conclusion that much better results will be obtained by using a special machine known as a maintainer, and it is proposed to experiment with it very shortly. This machine operates on a slightly different principle to that of an ordinary grader, it is fitted with 5 shallow blades set at various angles which scrape the surface and in so doing fill up all ruts and holes. This machine leaves far less dust on the surface which is an advantage.

Progress.—As the result of these demonstrations object (*d*) has in a large measure been attained, there are only perhaps 4 or 5 District Boards in the whole Province that are not thoroughly convinced that road grading is the most economical and efficient method of reshaping and subsequently maintaining an earth road. Thirteen District Boards have purchased outfits of their own which are at work, two have actually ordered outfits so that 15 districts, more than half the number of districts in the Province, will have tractors and graders working presently. These

exclude the demostration outfits which will be used in districts not yet convinced or who cannot afford their own plants. In addition to these, three districts are thinking of purchasing their second outfits.

The enterprise of these four firms have certainly borne fruit and have been responsible for the birth of road grading in the Punjab, and in consequence Government has now decided to purchase these demonstration outfits from the firms concerned at cost price minus what has already already been paid by District Boards on account of depreciation.

Maintenance of Plant.

To ensure that the plant was properly handled, the supervising and operating staff of District Boards were properly trained before assuming complete control, and to safeguard District Board's interests the suppliers of new road machinery were expected to run the plant for six months with their own staff, District Boards paying actual running expenses and if the plant proved satisfactory District Boards were expected to purchase it.

From the point of view of the suppliers these conditions appear somewhat drastic and were by no means popular but it was felt that unless District Engineers and their staff were thoroughly trained the machinery would be ruined in a very short time. Also during this probationery period of six months the District Engineers and their supervising staff were trained to operate the plant with their own hands. A daily log is maintained for each outfit showing fuel and other stores consumed and work done, this enables the Engineer Secretary of the Communication Board to keep in very close touch with the performance of each machine. In addition frequent inspections are made by Assistant Engineers and the Mechanical Overseer of the Communications Board as well as by the engineers and mechanics of the suppliers, by this means those in local control are kept up to the mark and serious break downs have been reduced to a minimum.

Graders.—Except for the Howard grader which is really an experimental machine and gave a certain amount of trouble until defects were rectified, no great difficulty was experienced with their working once the operators got accustomed to them. Of the meachines used so far the No. 7 Adams grader is perhaps the best, its controls are very easy to operate and it is fitted with leaning wheels, this reduces the tractor effort required and practically eliminates skidding during heavy grading, the absence of a suitable scarifier attachment however detracts from its usefulness. In an appreciable area in the Punjab soil is very hard and it is essential to scarify before heavy grading to relieve the strain on the machine as well as to prevent the cutting edge of the blade from wearing out too quickly. This is quite an important consideration as the present life of a cutting edge is barely three months and costs Rs. 60 to replace. The Russell, pound for pound, is a cheaper machine than the Adams, it is not such a refined looking article nor is it fitted with leaning wheels nevertheless it is a sound business like machine and up to its job. There are three

models in use a No. 3 standard weighing 4200 lbs, a No. 2 standard weighing 3,000 lbs. perhaps a bit too light for heavy grading, and a No. 3 Highway Patrol weighing 1,800 lbs. Both the standard models have suitable scarifier attachments.

Tractors.—The whole business of road grading hinges on the efficient and continuous working of tractors, and considering how easy it is to wreck a tractor, and the lack of knowledge and experience of the operating staff it is most surprising that such consistently good results have been attained—accidents there have been but surprisingly few.

The total working periodupto September1929 aggregates 4004 hours and is spread over 569 working days, during this time there have been four major mishaps, one case of big ends being burnt out and three cases of broken differentials. The former is due to sheer carelessness and incompetency of the driver, and latter generally to the grader blade fouling the root of a tree not visible on the surface, the remedy is greater vigilance and fixing a safety catch on the draw bar coupling of the tractor.

Among the tractors of which we have record of performances are—

5 No. 15-30 H. P. Macormack Deering Tractors.

2 No. 18-32 H. P. Case Tractors.

1 No. 12-20 H. P. Case Tractor.

It is early to express any opinion on the relative merits of the two makes of tractor as the maximum time worked by any Macormack Deering is about 1200 hours and that of any 18-32 H.P. Case is less than 500 hours, both have worked satisfactorily so far. The 12-20 H. P. Case has not proved very satisfactory for road grading as it is underpowered though it does not show up too badly in running costs (excluding establishment and depreciation). Moreover it was shockingly overloaded at times.

A list of plant used and the detailed cost of working the tractors (and graders) is set forth in Appendix III. Operating cost figures out on an average of Rs. 3·5 per mile. This is more than it should be especially as a number of tractors are new, the high costs are mainly accounted for by the fact that there are only 569 actual working days in a period of 1204 which corresponds to only 172 working days in a year, a poor average. We should reckon on about 200 or more with more experience in handling the machines and better planning out of the programme of each outfit. The performance of the Ambala outfit is very disappointing, the cost of running at 2·12 per mile, excluding depreciation and establishment, is very high and is not entirely accounted for by the high repair bill.

The cost of operating the outfits (excluding depreciation and establishment) will increase as the outfits become older so that even though Rs. 3 per working day has been allowed for replacements, it would be safer to allow Rs. 4 per mile for the purpose of calculations.

PROCESS OF IMPROVING THE SURFACE OF EARTH ROADS.

Manual Labour.—Whether we use machinery or not there are certain items of work that must be done by manual labour and they are as follows :—

(*a*) Repairing or constructing bridges, culverts causeways, etc., and improving the approaches to them.

(*b*) Filling all places liable to flood and where big holes and depressions occur.

(*c*) Blanketing with 6″ of good earth all stretches containing unsuitable soil, an alternative is to grass the surface but this is expensive to maintain.

(*d*) Removing jungle and other obstructions.

(*e*) Providing milestones consisting of 3″ × 3″ angles 4 feet long.

The essential difference between work done by machinery and manual labours lies in cambering and improving the surface, the latter involves obtaining earth from borrow pits and the former does not, therein lies the main source of saving.

Grading Operations.—Generally speaking all earth roads have not only lost their camber, but the centre is very much lower than the sides through years of neglect. There is no outlet for the water which soaks into and softens the soil, the surface is therefore readily spoiled even by the lightest traffic. It is not difficult to visualise what a road surface is like when cattle have walked over it while in a sodden state. The first object of road grading is therefore to restore the camber. In the Punjab where the rainfall is light and most months of the year are dry excessive earth filling may take a year or more to settle, and in the interval of settling the road is a quagmire in the rains and very dusty in dry weather. Past experience shows that the best results can be obtained with the minimum inconvenience to traffic by making three separate gradings at an interval of two months between each allowing traffic to consolidate each layer. Excellent results are obtained if the first two gradings are done just before and during the rains and the third immediately after the rains.

First Round of Grading consists of making a 4″ to 6″ deep (maximum) cut at an angle of 1 in 30 on either side of a road. Only 1/3rd of the width is graded on each side and the middle third filled with earth from the sides. As the filling in the centre is not excessive it quickly settles down. Moreover after the 1st grading is done traffic is generally attracted by the two graded strips at the sides which is hard and smooth. It is generally necessary to run the grader eight or ten times up and down a road during the first round.

Second Round of Grading.—An appreciably lighter cut is made on this occasion and the sides are still further lowered and the centre

raised and the road begins to assume some semblance of shape but as the centre is still loose, and water can saturate the soil, the surface is quickly cut up by traffic. Nevertheless the road does not generally lose its shape. This round only requires about six to eight gradings.

Third Round of Grading consists of making a still lighter cut for the purpose of filling up ruts, and depressions that have occurred through settlement. This round only requires four to six gradings. Experience shows that the road remains in good condition from eight to ten weeks after this round depending on soil conditions and traffic.

Cost of Improving the Surface and Restoring camber per mile.

Ist round of grading nine miles of travel at 4/-	..	=36
2nd round of grading seven miles of travel at 4/-	..	=28
3rd round of grading five miles of travel at 4/-	..	=20
Total	..	84
Add 10% for movement of plant when no work is done	..	8·4
		92·4
	say	95/-

Maintenance.—This consists of making three gradings at the following five periods in the year; December-January, February-March, June-July, August,-September, October-November and has been found sufficient to keep earth roads in good order under average soil and traffic condition. In normal years we can safely reckon on sufficient moisture being in the ground in three periods out of five. February-March and October-November is inclined to be troublesome on account of dust, but this is difficult to avoid under the climatic conditions of the Punjab unless watering is done just before grading. Investigations are being made and experiments carried out to ascertain the possibilities of watering roads before grading in the dry periods, and information available at present seems to show that watering will not increase the cost of maintenance by more than Rs. 20 to Rs. 30 per mile per annum.

Cost of maintenance, three miles of travel, five times a year	..	=15
Add 10 % movement of grader when no work is done	..	1·5
		16·5@4/-
		=66
	say	70
		per mile.

TRANSPORTATION ON EARTH ROADS.

Passengers.—Hitherto motor buses have been confined to metalled roads but during the last few months these vehicles are now making use of not only the newly graded roads but are beginning to use earth roads even before improvement. The average number of buses using earth roads in various districts is given in Appendix No. II. These figures show that nearly 500 travel on 124 roads daily which averages out at four per road. No census of figures have been received from Multan, Shahpur, Montgomery and Gujranwala where it is known a large number of motor buses use earth roads. It is therefore reasonable to assume that the number of buses is nearer 600 than 500.

Except in Karnal, Gujrat and Sheikhupura districts the mileage on which motor buses run is appreciably larger than the actual number of miles improved, this figure appears to establish that travelling by motor buses even on earth roads is becoming more popular that there is a growing demand for more such roads, which at present carry about two million passengers annually.

Generally speaking buses plying on earth roads travel about 30 miles a day on an average or 10,000 miles per annum and making two journeys a forward and a return ; therefore the number of buses actually plying is about 300. Petrol consumption is generally heavy, not less than 15 miles to the gallon, even for a 3/4 ton bus the type in general use on earth roads. It is therefore reckoned that each of these vehicles consume about 650 gallons per annum. By virtue of the newly imposed 2 annas a gallon tax on motor spirit each of these buses will contribute $\frac{(650 \times 2)}{16}$ Rs. 80/- per annum to Provincial Revenues ; in addition there is a charge of Rs. 80/- per annum on account of the Provincial tax and road certificate. Therefore each of these buses contribute Rs. 160/- per annum to Provincial Revenue and the 300 of them contribute Rs. 48,000/-. Observation shows that under average soil conditions about five maintenance gradings per annum will be sufficient to keep an earth road, carrying 15 motor buses and 100 bullock carts daily in quite good order. There are very few unmetalled roads in the Province that carry 100 bullock carts a day, the general average is about 50 or 60. We could therefore safely increase the number of buses now plying on these roads to four times their present number. Therefore if the number of motor buses increases to this extent, of which there is every indication, motor buses plying on these particular 124 roads will contribute nearly two lakhs towards Provincial Revenues against only (2,000×70) 1·4 lakhs required for proper maintenance. It follows that it is not only necessary to increase the mileage of earth roads as much as possible but to encourage motor buses to use them.

Goods.—It has been shown that up to the limit of their carrying capacity the more motor vehicles that used earth roads the greater the benefit to the Province, and moreover if it were possible to replace the

bullock cart by goods lorries a great benefit would not only accrue on account of taxes they would pay as in the case of passenger buses but maintenance costs would be reduced as a pneumatic tyred lorry would damage an earth road less than a bullock cart. The greatest obstacle to the more extended use of motor vehicle for the transportation of goods is the deplorable state of village roads. Unless the latter are improved very little progress in this direction can be expected as double handling of goods will be involved. Moreover the cost of transportation of goods by say, a ton or 30 cwt. lorry figures out at 6 annas a ton mile, the transportation by bullock cart is pretty much the same. It is therefore unlikely that the present type of motor vehicle will ever oust the bullock cart from carrying goods especially as the number of agriculturist using the same bullocks for ploughing and transportation is very great. Unless therefore the cost of transportation of goods by mechanical means could be reduced to say, 3 annas a ton mile, the bullock cart will continue to hold its own.

The cheap transportation of goods throughout the British Empire has been engaging the attention of the Empire Marketting Board and as the result of their endeavours a Directing Committee was appointed by the Secretary of State for Dominion Affairs and for Colonies (of the late Government) at the end of October 1928 with the following terms of reference :—

"To study every aspect of mechanical transport likely to further the economic development of the Empire." The main objective was to produce a unit of large carrying capacity capable of transporting goods at low cost on earth roads without unduly damaging them. This committee has carried out investigations on existing types of vehicles in use or those projected throughout the world, and it has been realised that though immense strides have been made in improvement of design there is no vehicle in existence that will serve this purpose.

The trend of investigation seems to suggest hauling one or more trailers with several pairs of wheel shod with large pneumatic tyres may be a suitable unit.

Experiments are being carried out with—

(*a*) Various engines using Diesel oil or producer gas.

(*b*) Various types of trailers with pneumatic tyres.

(*c*) Various types of pneumatic tyres, one particular experiment deals with a tyre particularly designed to soft roads in which deep ruts occur.

(*d*) Various types of metal tracks.

Considerable progress has been made towards the production of a 15-ton unit consisting of a tractor hauling a number 8-wheel trailers.

It is expected that experiments with a 50-ton unit will be carried out in the near future.

As far as the Punjab is concerned experiments with 50-ton unit will be of purely academic interest (our bridges will not be strong enough) a 10-ton unit will be nearer the measure of the capacity of our bridges. Developments with the smaller unit will be watched with a good deal of interest as it will fit in admirably with the scheme of improving earth roads.

Judging from the extensive experience gained in operating agricultural models of kerosine-driven tractors on road grading in the Punjab it would seem that a suitable transportation unit for earth roads might possibly consist of such a tractor (15 H. P.) geared to run six to eight miles an hour on top, and too pneumatic tyred trailers of five ton capacity. Calculations (attached *vide* Appendix VI) show that it would probably be possible to transport by this means at 4 as. a ton mile, eventhough the unit only worked 800 hours in the year (the average duration of the period in which agricultural produce is carted to market) and obtained no return loads. Unless earth roads were converted to and maintained as gravel roads, it would not be safe to rely on obtaining return loads, but it is fairly certain that the tractor by itself, the whole unit, or even the establishment could be employed during idle periods, thus appreciably bringing down the percentage of fixed charges. It is therefore very probable that such a unit could transport at 3 as. or even less a ton mile and it is still more probable that "The Directing Committee on Overseas Mechanical Transport" will be able to produce a suitable unit to operate even more cheaply.

Selection of Surfaces.—Even though a good beginning has been made in the Punjab, where a beginning should have been made years ago, *viz.*, on the improvement and subsequent maintenance of earth roads there is still a very big jump between the cost of maintenance of an earth road at Rs. 70 a mile per annum and that of a 9′ wide metalled road (previously the beginning) which costs Rs. 600/- or Rs. 700/- per mile per annum to maintain, even the cost of the proper maintenance of kankar roads 9′ wide is beginning to approach this figure under present-day traffic conditions. With the limited funds at our disposal it would not be making the maximum use of our resources, to lay a road with a surface that costs say, a Rs. 600/- or Rs. 700/- to maintain when the traffic that was likely to use it for the next four or five years would probably not exceed twice the carrying capacity of an earth road. In India the value of a traffic census has not been fully appreciated; if such were taken on all roads throughout the country, and the selection of surfaces were governed by the volume of traffic, it would be found that there are hundreds of miles of metalled roads that are not justified and a correspondingly large mileage of earth roads that ought to have a superior surface. It is most essential that intermediate type of surfaces between an earth road and a metalled road should be introduced and their carrying capacity determined so that the types of surfaces could be selected to correspond with traffic conditions. The next stage after an earth road is a gravel road but the areas in which gravel is available locally in the Punjab is strictly limited and railing it

long distances will be out of question on the score of expense. Therefore experiments are being carried out with substitutes. In the Sheikhupura district 3″ of quarry sweepings from Shahkot quarry was spread on two miles of road about a year ago and where the gauge of the stuff was small, *i.e.*, about half an inch very good results have been obtained. In the Ambala district about one furlong of road was covered with 3″ overburnt brick ballast and here again good results have been obtained In both cases the original surface consisted of soil containing appreciably over 30% sand and was quickly cut up by bullock cart before the experiments were carried out. In addition to this a mile of gravel road has recently been laid on the approach to the new Railway Station of Rupar at a very low cost as gravel was obtained locally and the results obtained so far are promising.

In the United States of America the next stage after a gravel road is an oiled gravel road and hundreds of miles of gravel road are being so converted every year. No experiments with this type of road have been carried out in this country; road oils are expensive, it is therefore not definitely certain whether such a road would be a practical proposition. Experiments are however now being carried out with a cheaper and improved form of surfacing for metalled roads; it is expected that a type of surface will be devised that is much cheaper to renew than water bound macadam and yet have an appreciably longer life; if these expectations are fulfilled then this will probably be the third stage of development of surfaces.

APPENDIX I.

Statistics of Road Mileages and Motor Vehicles of Main Countries in the World.

Country.	Road Mileages.				No. of Motor Vehicles.		
	Earth or gravel.	Surfaced.	Total.	Percentage of surfaced.	Total.	Per mile.	Persons per vehicle.
	1	2	3	4	5	6	7
1. Argentina ..	18·6	·4	19·0	2·1	268·0	14·0	37·3
2. Brazil ..	46·5	·4	46·9	·9	136·8	2·9	223·9
3. Canada ..	417·1	6·9	424·0	1·6	957·1	2·3	9·8
4. Chile ..	22·2	2·6	24·8	10·5	19·4	·8	202·7
5. Mexico ..	1·2	·3	1·5	20·0	57·6	37·7	268·7
6. United States ..	2·4	·6	3·0	20·0	24·0	8·0	5·1
7. British East Africa (*see* also Jubaland) ..	13·7	2·7	16·4	16·5	14·0	·8	831·3
8. Egypt ..	3·2	·1	3·3	3·0	25·1	7·5	563·7
9. South Africa .. (excluding the Union).	7·3	·4	7·7	5·2	7·5	·9	366·6
10. South Africa, Union of.	67·4	·6	68·0	·9	133·2	1·9	53·1
11. Ceylon ..	11·0	4·8	15·8	30·4	17·3	1·0	288·9
12. China ..	17·3	·4	17·7	2·3	23·8	1·3	18,744·7
13. India ..	150·7	60·3	211·0	28·6	109·9	·5	2,900·1
14. Japan ..	72·7	·1	72·8	·1	72·5	1·0	881·4
15. Turkey (including Turkey in Europe).	18·5	·3	18·8	1·6	7·4	·4	1,844·6
16. Austria ..	·6	20·6	21·2	97·2	51·6	2·4	126·4
17. Belgium ..	..	6·3	6·3	100·0	139·0	22·0	56·7
18. Denmark ..	28·0	4·0	32·0	12·2	105·9	3·3	32·4

APPENDIX I.—*concld.*

Country.	Road Mileages.				No of Motor Vehicles.		
	Earth or gravel.	Surfaced.	Total.	Percentage of surfaced.	Total.	Per mile.	Persons per vehicle.
	1	2	3	4	5	6	7
19. France ..	415·4	24·6	440·0	5·6	1,114·0	2·5	36·6
20. Germany ..	102·6	25·6	128·2	20·0	861·0	6·8	73·4
21. Greece ..	4·6	1·8	6·4	28·1	14·3	2·2	416·0
22. Hungary ..	22·1	8·6	30·7	28·0	17·9	·6	472·3
23. Irish Free State ..	..	46·7	46·7	100·0	44·6	1·0	381·7
24. Italy ..	27·2	86·4	113·6	76·0	212·1	1·9	191·2
25. Netherlands ..	..	10·8	10·8	100·0	102·8	9·5	73·2
26. Northern Ireland ..	..	12·9	12·9	100·0	30·8	2·4	108·6
27. Norway ..	22·5	..	22·5	..	38·0	1·7	73·3
28. Rumania ..	22·3	32·4	54·7	59·2	21·7	·4	789·9
29. Russia (including Russia in Asia).	415·1	15·1	430·2	3·5	25·8	·06	5,690·9
30. Spain ..	..	50·0	50·0	100·0	194·2	3·9	1,121·1
31. Sweden ..	80·2	·5	80·7	·6	147·8	1·8	42·4
32. Switzerland ..	..	8·4	8·4	100·0	85·0	10·0	46·6
33. United Kingdom ..	..	178·7	178·7	100·0	1,856·7	10·4	23·8
34. Australia ..	319·9	40·1	360·0	11·1	508·2	1·4	12·3
35. New Zealand ..	*	44·3	44·3	..	169·4	3·6	8·0

* Figures not available.

Note.—Figures in columns 1, 2, 3, 5 shown in thousands.

Note.—In the year 1904 there were 55,000 Motor vehicles and 1,54,000 miles of surfaced roads in the U. S. A.; therefore in the space of 25 years the surfaced mileage has increased nearly four times while the number of Motor vehicles has increased nearly 430 times.

APPENDIX No. II.

Statistics regarding Motor Buses plying on Class II Unmetalled Roads in the Punjab.

No.	District.	Roads used.		Mileage of road improved.	No. of Motor Buses.	
		Mileage.	No. of roads.		Total.	Per road.
1	Hissar ..	249	15	110	44	2·9
2	Rohtak ..	..	..	14	..	..
3	Gurgaon ..	..	..	12	..	..
4	Karnal ..	37	3	50	1	·3
5	Ambala ..	87	6	60	28	4·6
6	Simla ..	..	..	..	..	..
7	Kangra ..	..	..	..	..	..
8	Hoshiarpur ..	165	6	24	25	4·1
9	Jullundur ..	50	2	7	10	5·0
10	Ludhiana ..	22	1	12	1	1·0
11	Ferozepur ..	140	10	60	16	1·6
12	Lahore ..	15	1	15	5	5·0
13	Amritsar ..	122	7	44	37	5·2
14	Gurdaspur ..	140	10	80	86	8·6
15	Sialkot ..	147	6	116	11	1·8
16	Gujranwala ..	Census report not received.				
17	Sheikhupura ..	124	18	145	74	4·1
18	Gujrat ..	81	9	106	33	3·6
19	Shahpur ..	Census report not received.				
20	Jhelum ..	Census report not received.				
21	Rawalpindi ..	Census report not received.				
22	Attock ..	107	8	72	40	5·0
23	Mianwali ..	45	2	4·5	15	7·5
24	Montgomery ..	Census report not received.				
25	Lyallpur ..	180	8	120	20	2·5
26	Jhang ..	154	6	116	31	5·1
27	Multan ..	Census report not received.				
28	Muzaffargarh ..	103	6	90	20	3·3
29	Dera Ghazi Khan ..	Census report not received.				
	Total ..	1,968	124	1,257·5	497	4·0

APPEN

Detail of Cost of Work

District.	Name of Plant.	1 Period. From	To.	No. of days.	2 Actual Working Time. Days.	Hours.	Hours p.diem	3 Miles Travelled. Total	Per Diem.	4 Fuel Oil. Gallon	Cost.
1. Hissar	15-30 H.P.McCormick Deering Tractor. No. 3 Standard Russell Grader weighing 4,200 lbs.	February 1929.	September 1929.	233	107	618·5	7·6	1,632	15·2	1598	1506
2.Ambala	15-30 H. P. McCormick Deering Tractor. No. 7 Adams, Leening Wheel Grader weighing 4,000 lbs.	July 1929	September 1929.	75	49	279·5	5·7	784	16	890	833
3.Karnal	15-30 H. P. McCormick Deering Tractor. No. 3 Standard Russell Grader weighing 4,200 lbs.	April 1929.	August 1929.	153	51	421·5	8·3	717·25	14	724	632
4. Ferozepur	18-32 H. P. Case Tractor. .. No. 2 Standard Russell Grader weighing 3,000 lbs.	April 1929.	June 1929.	74	56	339·5	6·1	767	13·7	756	674
5.Lahore	15-30 H. P. McCormick Deering Tractor. Howard Grader weighing 4,000 lbs.	December 1928.	January 1929.	31	18	134	7.4	283	15·7	178	216
6. Sheikhupura.	12-20 H. P. Case Tractor. Russell Highway Patrol No. 3 weighing 1,800 lbs.	August 1928.	January 1929.	164	71	437·5	6·2	587·5	8·3	536	515
Ditto.	15-30 H.P.McCormick Deering Tractor. Howard Grader weighing 4,000 lbs.	July 1928.	February, 1929.	243	101	771·25	7·6	1210·0	12·0	1,201	1,145
7. Gurdaspur.	15-30 H. P. McCormick Deering Tractor No. 7 Adams, Leening Wheel Grader weighing 4,000 lbs.	June 1929.	August 1929.	78	44	316·0	72	623·0	14·2	585	512
8. Jhang	18·32 H. P. Case Tractor. No. 2 Standard Russell Grader weighing 3,000 lbs.	April 1929.	August 1929.	153	72	486·5	6.7	987·25	13·9	755	676
	Grand Total ..			,204	569	,004	7·0	7,590	13·3	,223	,708

DIX No. III.
ing Tractors and Graders.

5		6		7	8	9	10	11	12	13	14
WORKING COST.											
Lub. oil		Petrol.		Running repairs.	Miscellaneous.	Total.	Cost per mile.	Establishment.	Dep. & Repl.	Grand Total.	Cost p. mile tr.
Gallons.	Cost	Gallons.	Cost								
140	599	31·5	51	..	161	2,317	1·42	1,340	1,658	5,315	3·26
48·5	170	16	28	238	396	1,665	2·12	431	760	2,856	3·64
69	263	16	27	..	8	930	1·29	880	1,790	2,600	3·62
44	227	18·5	30	11	21	963	1·25	426	868	2,257	2·94
31	124	10	15	2	2	359	1·23	178	279	816	2·88
62·5	263	30	46	24	65	913	1·55	943	1,100	2,956	5·03
119.5	478	50·5	76	42	49	1,720	1·48	1,397	1,565	4,752	3·92
33	158	11·6	18	..	7	695	1·11	449	1,680	1,824	2·92
40·5	147	22·5	38	260	20	1,140	1·15	880	1,116	3,136	3·18
588	2,429	206·6	329	577	29	10,772	1·42	6,924	8,816	26,512	3·50

REMARKS.

1. *Establishment*—

	per mensem Rs.
Driver ..	100
Grader Operator	40
Coolie ..	15
Chaukidars ..	15
Total ..	170 or say Rs 5-12-0 per diem.

2. *Depreciation and Replacements*—

The cost of the plant used in different districts vary and include experimental plant that will not be used in the future. Therefore the charge under this head is based on cost of plant that has been found suitable. A life of 500 days has been assumed for the Tractor and 1,000 days for the Grader.

Plant.	Cost.	Depreciation per diem.
Grader	3,350	3·35
Tractor	4,650	9·30
Total ..		12·65
Add for Replacements of Parts		=3·00
Total		15·65

or say Rs. 15-8-0 per diem.

NOTE. Item I is spread over the period of working (Col. I).
Item II is confined to the actual No. of days worked (Col. II).