widening existing pavements with respect to cost, durability, distortion and minimum separation of the new and old bases during the life of the improvement.

(b) The economical and practical treatments of unstable subgrades in connection with pavement widening.

(c) The extent to which the repair of the existing pavement at the time of resurfacing is justified

(d) The treatment of cracks and joints in the existing pavement prior to resurfacing to assure a minimum of carry-through to the new surface.

(e) The question of justification for removal of old bituminous surface treatments from the existing pavement prior to resurfacing.

4 Continued friendly and cooperative study with equipment manufacturers in connection with the improvement of existing models or development of new items of equipment for use in pavement salvage is justified and desirable

SECONDARY ROAD SURFACING PROBLEMS IN IOWA

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SYNOPSIS

This paper reports some observations and conclusions of a joint committee of County Engineers and Engineers of the Iowa Highway Commission that has been studying the secondary road surfacing problems for the past five years The problem is that of building and maintaining 79,000 miles of all-weather roads in a glacial territory for a uniformly distributed population that has a high cultural development This must be accomplished in the face of a growing scarcity of material sources and the consequent rapid depletion of known deposits of road-building materials

The County Engineers' Association recognized this problem and requested the assistance of the Highway Commission in its solution As a result a Joint Committee of County Engineers and Highway Commission Engineers was formed to direct the solution of the problem This Committee has been active in the promotion of the stabilization of the local materials available in the various counties The Committee was also active in the development of a bill "for an Act to Establish a fund for financing engineering studies and research projects in connection with construction and maintenance of secondary roads " This bill, under the sponsorship of the County Engineers' Association, became a law by act of the last legislature

A total of 3,095 miles of secondary roads were newly surfaced in Iowa during the last year The problem of material resources is illustrated by the fact that the material required for this new construction, plus that required for the maintenance of previously surfaced roads, would require a volume equal to a depth of almost 7 feet over an area one mile square. We are now passing out of the pioneer stage and a more rapid exploitation of present resources by expanding production will only aggravate the situation

Any truly economical solution of the secondary road surfacing problem in Iowa must be based upon thorough field and laboratory studies of local conditions to evaluate the effect of such factors as the type of subgrade soil and its drainage requirements, to guide in the proper selection and use of subgrade soils and of stabilizing materials, and to give consideration to new processes and methods of construction It will also require the help of trained geologists, prospecting for new sources with specialized equipment and methods, and the continued cooperation of all our road administrators

The demand for all-weather secondary roads and the rapid depletion of surfacing material sources in Iowa is causing our Secondary Road Administrators—the County Boards of Supervisors and the County Engineers—a great deal of concern. This concern is not so much for the present as for the future.

The Secondary System of Iowa has some

93,000 mi of roads that serve a rural population composed of some 1,450,000 persons with a high standard of living who are distributed uniformly over 56,000 sq. mi of territory. The average is 1 73 mi. of secondary roads per square mile, varying from a maximum of 1.98 mi. in one county to a minimum of 1.24 per sq. mi. in another. The rural population averages 26 persons per sq. mi., and varies by counties only from a maximum of 35 persons to a minimum of 16 persons per sq. mi., except for the county in which Des Moines is located with its rather extensive urban fringe About 79,000 mi. of these secondary roads are necessary to provide access to every farm home not now served by the 8660 mi. of Primary Roads. The remaining 14,000 mi. of secondary roads might be abandoned without causing serious inconvenience.

Transportation is a year round necessity to agriculture in its present state of development in Iowa A modern farm is not a self-sufficient unit producing finished food products, but a unit specializing in raw food products, and it is nearly as dependent upon food processing factories as is the urban home. Seeds, farm supplies and equipment must be hauled to the farm One item, pulverized limestone fertilizer, to the extent of 4 tons per acre is often applied during the early spring or fall months when growing crops do not interfere with its application. During 1947 over three million tons of limestone fertilizer were applied in Iowa. Scheduled routes for mail, Sunday papers, milk and bread are dependent on all-weather roads. The abandonment of railroad lines has caused many small communities to be dependent on transportation over secondary roads for the delivery of supplies. The main farm products—corn, cattle and hogs—must be transported to market and these finished products must be moved over the roads at any time, rain or shine, to take advantage of favorable market conditions.

The social aspect of farm transportation needs is certainly not the least in importance. Regular attendance at local schools and rural churches requires all-weather roads The secondary roads provide a vital link in the statewide need for transportation The problem of providing satisfactory roads that produce little road use revenue is mightily influenced by the natural materials locally available for their construction and maintenance.

The fundamental bases of our secondary road construction and maintenance problems in Iowa were laid down thousands of years ago by four glacial visitations as shown in Figure 1.

The first continental glacier that invaded Iowa was the Nebraskan. It covered practically all of the State, but the till it deposited has been buried by other drifts and wind-blown materials so deeply that it is naturally exposed only in the deepest valleys over small areas. This material is predominantly a clay and is encountered in highway construction work only occasionally in the deeper cuts in southwestern Iowa

The second glacier to enter Iowa was the Kansan. It covered all of the State except for a few square miles in the northeast corner, and is exposed in the area as shown in Figure 1. The topography of this area that has not been covered by later glacial invasions is, generally speaking, marked by deep valleys and heavy erosion. The till deposited by this glacier is a clay with a Highway Research Board classification of A-6 or A-7. Another feature of this drift sheet of importance to the highway engineer is that it is quite generally covered with a mantle of loess varying in thickness from a few feet to nearly two hundred feet. The loess is predominantly silt. A highly unstable area is a certainty when the grade line of a road is placed on this loess where its depth is less than 6 ft. above the clay.

The third glacier to enter Iowa was the Illinoian which overspread a narrow strip along the Mississippi River in the southeastern part of the State. Its topography is similar to that of the older drifts on which it lies.

The fourth glacier to enter was the Wisconsin with its two separate advances, the first being the Iowan and the latter the Mankato. The Iowan had a surface distribution nearly across the northern part of the State and spread out to within one or two counties of the bounding rivers. The valleys present gentle slopes in contrast to the sharp and larger valleys of the older drifts. This drift is also predominantly a clay having a HRB classification of A-6 or A-7, although it contains large boulders and numerous sand pockets (Classification · A-2) that require drainage when encountered in road construction. The topography is rolling.

The extension of the Mankato is down the valley of the Des Moines River, covering about one-half of the Iowan glacial drift. The topography is fairly level, with drainage poorly developed and numerous small areas of peat. The main body of the drift is again a clay having a HRB classification of A-6 or A-7, although pockets of upland gravel of varying size are common, and all streams within or even partly within its boundaries have their channels choked with sand and gravel washed out of the upland material.

One newspaper writer in our State described the muddy roads in southern Iowa as being the result of a tired glacier. By this he meant that the only glacier which carried important quantities of granular materials stopped at Des Moines (as shown in Fig 2) while the others covered the country rock with so many feet of glacial till as to make road building material obtained from them expensive. It should be noted that the few known gravel deposits in southern Iowa were accumulated in the inter-glacial period between Nebraskan and Kansan time. These are known as the Aftonian gravel, and are buried deeply under the Kansan drift The stripping on the quarries in southern Iowa ranges from 3 to 4 ft. of soil per ft. of limestone, while in the remainder of the State it varies from practically nothing to 1 ft of stripping per foot of limestone.

The first secondary road surface, other than soil was planks. This type of roadway was used for only a small mileage of roads in the southeastern part of the State, but has long since been abandoned due to the exhaustion of the slender timber resources. In the same part of the State a few miles of water-bound macadam were built many years ago. Aside from the types just mentioned, the first attempts to provide road surfaces that would not become muddy in wet weather consisted of the application of bank-run gravel to the surface, depending upon traffic to obtain compaction Since the only method of transportation of surfacing materials was by horse-drawn wagons, such roads were built only in areas close to gravel deposits as shown in Figure 3.

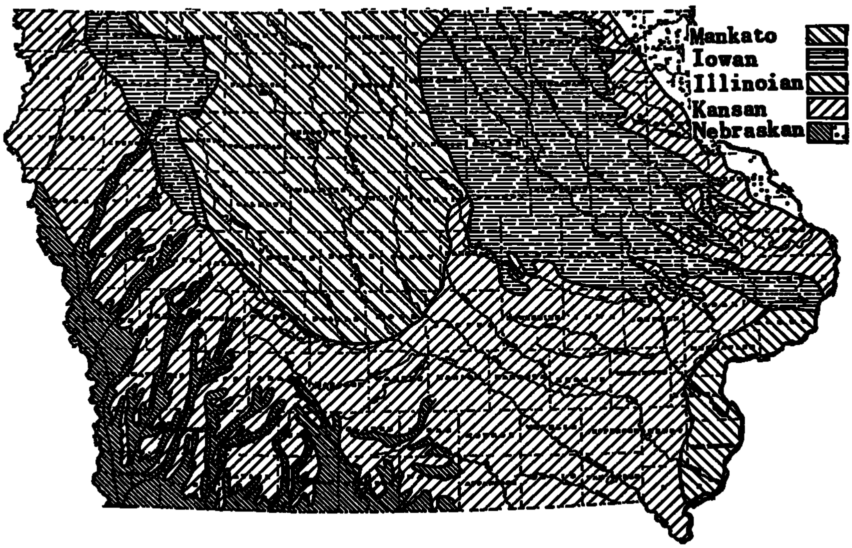


Figure 1. Map Showing Surface Distribution of the Five Drift Sheets in Iowa

The problem, briefly put, is then that the rural need for highway transportation is uniformly distributed over the State, while the supplies of road material are not well distributed. Even in those areas where materials have been plentiful in the past, the known deposits are now being rapidly depleted due to the great demand for increased mileage of improved roads In the final analysis the problem becomes an attempt to provide good highway facilities at reasonable and justifiable cost for every farm production unit in the State. Any solution of this problem must inevitably

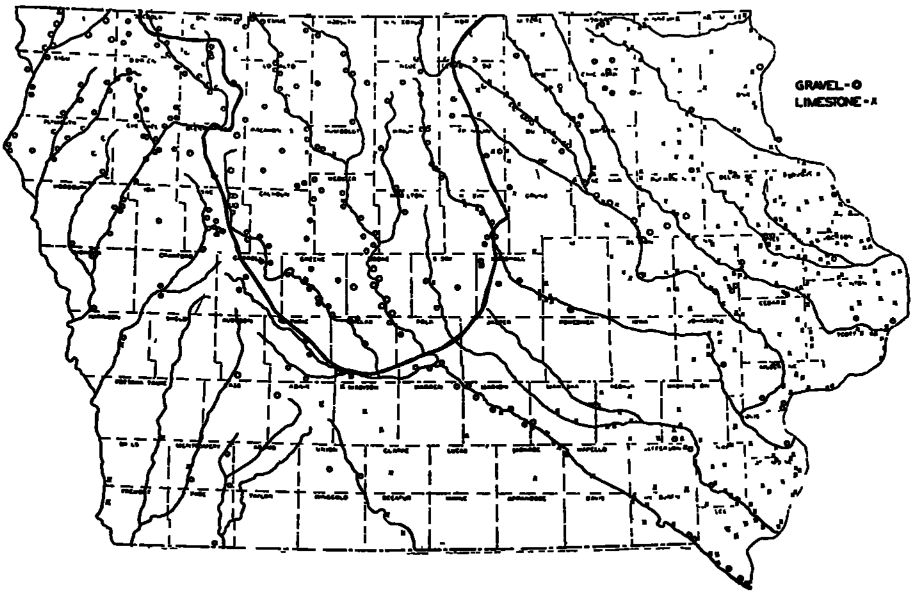
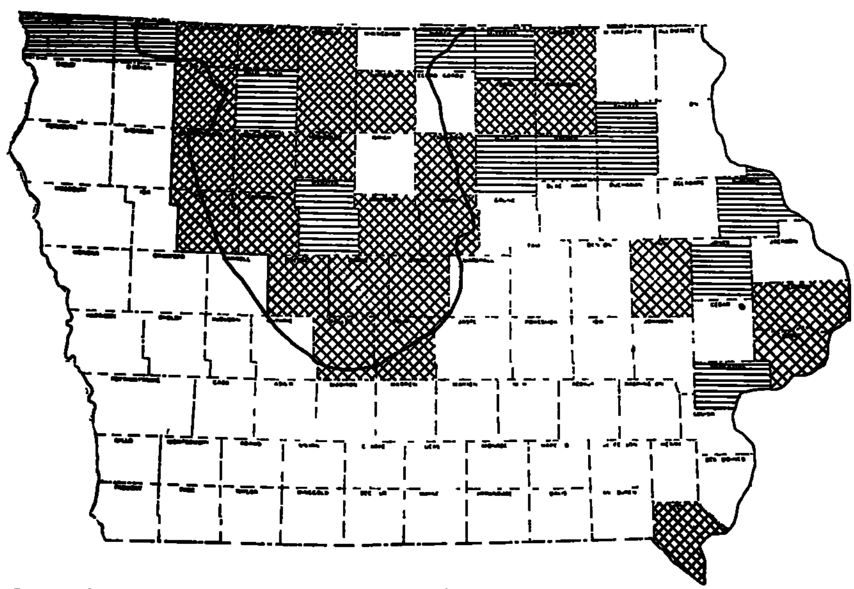


Figure 2. Map Showing Distribution of Gravel and Limestone Sources in Iowa



Less than 1 mile ▭ Less than 5 miles ▤ More than 5 miles ▦

Figure 3. Map Showing Mileage of Surfaced Secondary Roads in Iowa as of January 1, 1919—Total 553 mi.

be based upon the most economical use of locally available materials

The problem of providing the mileage and the type of road surface desired within the limitations of funds available has become statewide in scope, especially since maintenance costs are on the increase Records in Linn County show that since 1923 resurfacing material has been applied at an average rate of 84 cu yd. per mi. per yr. The county engineer estimates that, if the demands had been fully met, the application should have been at the rate of 100 cu. yd. per mi. per yr In other words, the losses due in a large part to dusting under traffic, require the replacement of all the surfacing on their entire system each decade.

Iowa Highway Commission records show that since 1941 the average delivered price of gravel surfacing has increased 37 percent, from $0.98 per cu. yd. in 1941 to $1 34 in 1949. Similarly, the average price of crushed stone has increased 70 percent, from $1 54 per cu. yd. in 1941 to $2 62 in 1949. The reason for the larger increase for the crushed stone is that the distribution of road surfacing work has been more uniform over the State in recent years, and crushed limestone has been more generally used than gravel in the areas where surfacing costs are higher (as shown in Fig. 4).

These increasing maintenance costs on secondary roads caused the County Engineers' Association to appeal to the State Highway Commission for assistance in studying the problem. This action came quite naturally since cooperation between the state and county highway authorities has always been close in Iowa As a result a committee to study this problem was formed. The President of the County Engineers' Association appointed one county engineer from each of the six Highway Commission districts, and the Chief Engineer of the Highway Commission appointed three engineers from his staff to this committee which became known as "The Joint Board for the Study of Secondary Road Surfacing Problems." It will be noted that the Board was composed of County and Highway Commission engineers who undertook this work in addition to their regular duties They had no funds dedicated to experimental or research work. They did have the services of an engineer assigned to this work by the Highway Commission and the facilities of the Highway Commission laboratory were made available for the performance of routine tests of materials. The engineer assigned full-time by the Highway Commission to the study of these problems, and who has worked under the

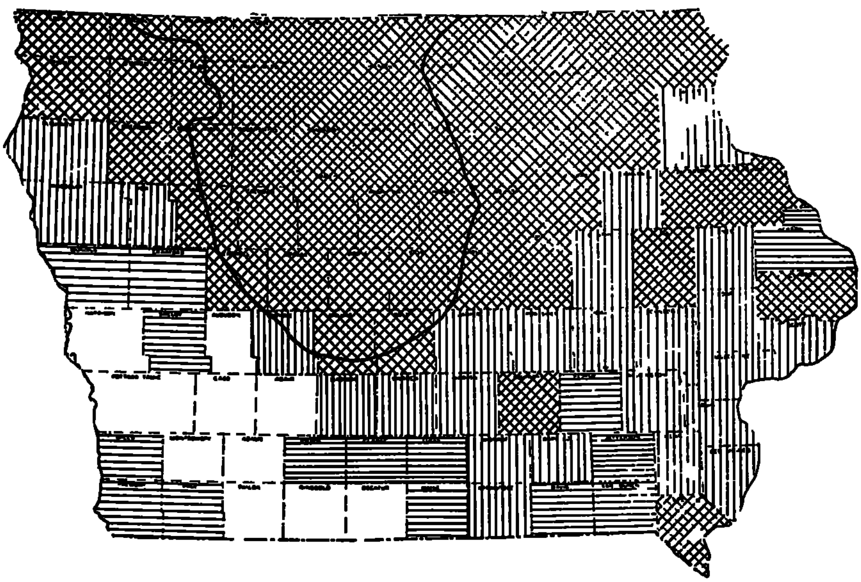


Figure 4. Map Showing Mileage of Surfaced Secondary Roads in Iowa as of January 1, 1949—Total 55065 mi.

direction of the Board, has been referred to by the board as "Director."

Through its director and the laboratory facilities mentioned, the Board has been able to furnish consulting engineering service to the counties in their efforts towards the solution of their surfacing problems. Because of the lack of funds the Board has not proposed any bold experiments to be undertaken by the counties. Rather, they have limited their activities to suggesting to the counties how well-established principles could be applied to the solution of specific problems under certain well-defined conditions.

Early in its existence the Board became convinced that the problem was of such magnitude that considerable funds should be made available to advance the work then underway and to provide for additional study. The Board recommended passage of a bill for "an Act to establish a fund for financing engineering studies and research projects in connection with construction and maintenance of secondary roads" Under the sponsorship of the County Engineers' Association, this bill became a law by act of the last legislature. This law will provide funds to support a research program directed toward the solution of secondary road problems in general.

The Board has been active in assisting the county officials in the selection, design and construction of various types of road surface to meet specific conditions. For the reasons previously stated the kind of work most actively promoted by the Board has been the stabilization of the materials that are commonly used for road surfacing in the State. In a few cases the Board has provided assistance in the design and construction of somewhat higher types of surfaces. To a considerable degree this paper is based on the work of this Board.

The Board has held meetings at intervals of 2 to 3 months. Many of these meetings have been inspection trips to various parts of the State to view the road building problems that are peculiar to those areas, and to note both successful and unsuccessful surfacing procedures.

Another one of the major activities of the Board has been the promotion of the construction of various types of road surfaces. The various types of surfaces involving stabilization have been sand with limestone dust, sand with clay, gravel with clay, and mixtures of crushed limestone and gravel with clay. Other types used on short sections of road where increased traffic required better than ordinary surfaces are soil-cement, cold-laid asphaltic concrete and portland cement concrete slabs placed with a concrete laying machine. This machine which was invented by Mr. James W. Johnson and developed in the Highway Commission laboratory, is capable of placing and finishing a concrete slab without the use of fixed forms.

The Board is made up of practical highway engineers who profess no great knowledge of soil science. Their concept of the principles involved in the kind of work they have been doing is as follows· Perhaps the simplest satisfactory road surface is one that can successfully resist the tendency of traffic to displace its component particles. This requires that it possess the ability to resist abrasion or raveling and to distribute traffic loads so that the bearing power of the subgrade will not be exceeded. In either case, the most desirable property of the surfacing material is its resistance to shearing stresses. This condition can be produced by sticking the particles together with some strong cementing material such as portland cement, which is expensive. Water, in very thin films, is an exceptionally strong cementing material. Beach sands provide a surface sufficiently stable to make a satisfactory race-course for automobiles for a brief period after the tide goes out, during which time the sand grains are held together by very thin water films.

It is obvious that the shearing resistance of a mass made up of individual solid particles without any cementing material will depend upon the extent to which each particle is supported by adjacent particles. It is also obvious that large particles will be more effectively supported if the spaces between them are filled with smaller particles This principle applies successively for each size of particle from the largest to the smallest. In other words, the best mutual support is obtained in a mixture of materials which has the amount of each size which will produce a mass having the highest percentage of solids, or the lowest percentage and the smallest size of voids. This grading of the material in a compacted road surface has two other advantages. The spaces through which the water can travel into and out of the material are made smaller and less continuous and the water films between the particles are made thinner, and thus stronger.

The proportioning and mixing of natural materials having particles of various sizes to produce a mixture which can be compacted to a high density has been called "stabilization," or more accurately, "mechanical stabilization," which indicates that the mixture will be more stable than any of its ingredients alone.

Iowa gravels usually contain only a small percentage of particles of the size which will pass through a No 40 sieve. It is a matter of common observation that such a material is very porous. As dumped on the road, it contains about 33 percent of voids, and it cannot be compacted to any considerably greater density unless some of the particles are crushed to provide the finer sizes in which it is deficient When such a gravel is placed on an earth surface and exposed to weather and traffic it becomes mixed with soil and produces a mixture which will be more dense than the gravel alone. The density of such a mixture will depend upon the extent to which the soil provides those particle sizes in which the gravel is deficient, without producing an excess of some of the smaller sizes.

However, the depth of the stable layer that can be produced by this method is very limited. If a mixture of any considerable stability is produced, a compacted layer having a thickness about equal to the diameter of the largest pebble, is formed This layer effectively resists the penetration of more of the granular materials and prevents their mixture with the subgrade soil. It is not likely that all of the soil represented in the surface of a section of road of any considerable length will provide the range of particle sizes required for stabilization.

It is possible to compute the percentages of the different particle sizes which will produce the most dense mixture This would call for a material that could not be produced at any reasonable cost. However, experience has proved that something less than the very densest possible mixture will produce a satisfactory road surface for light traffic roads, or a satisfactory base course. Particularly in the field of low-cost roads we are interested in mixtures that can be produced from materials locally available. It has been demonstrated by the experience of several Iowa counties that, in most cases, some combination of the gravel ordinarily available and soils that are available within a few miles will produce a road surface that will withstand displacement by traffic.

During this past year some 350 mi. of secondary roads with adequate drainage have been surfaced with stabilized material in 22 counties by the addition of clay to the surfacing materials In almost all of these counties the clay has been hauled on the roads. Some information on the way this work has been handled in the various counties is given below.

In one part of Muscatine County the top soil is a sand soil, underlain by gravel. The County has stabilized bases for bituminous surfaces in this area with remarkable success by the addition of limestone dust to the sand in the road surface to produce a base having a compacted thickness of 3 in These roads are used by trucks that haul aggregate from nearby gravel plants Their satisfactory behavior provides a striking demonstration of how much an adequate subgrade aids in reducing the thickness of base required for a bituminous surface to carry the present day loads. In other parts of this county where plastic soils predominate roads of this type have failed to carry the traffic

In Audubon County one of the local materials available for surfacing has been a clayey sand that has been used with varying success in the past. This local material has been mixed in equal parts with crusher-run limestone, all passing the ¾-in. sieve, to provide surfacing material on a 7-mi surfacing project. The results obtained have been satisfactory. The addition of the limestone reduced the plasticity index from 16 to 10 Another local material is sand which is available in large quantities. A combination of this sand and clay, with a crusher-run limestone, all passing the ¾-in. sieve, has given an economical mixture that has become stable under compaction by traffic.

In Hamilton County the local materials available for surfacing, generally speaking, are pit-run gravels. The results secured by stabilizing these materials with glacial clay have been very satisfactory. The amounts commonly used are 1000 cu. yd. of pit-run gravel and 300 to 500 cu. yd. of clay per mi. The production of the gravel and its delivery to the road are performed by contract The delivery of the clay and its pulverization, the mixing of the materials, and the spreading are done by County forces Check samples taken from the road have shown a range in plasticity index from 5 to 10

In Cerro Gordo County the clay for stabilization is hauled from clay pits onto the roads that carry 35 or more vehicles per day. On lesser traveled roads in those areas where the subgrade is predominantly a clay, the practice is to scarify the subgrade to obtain the quantity of clay required for stabilization as determined by laboratory tests The amount of clay secured by scarifying is difficult to control and varies considerably. In order to guard against an excess amount of clay the tendency is to secure an insufficient amount The number of miles of stabilization work that has been done during the past few years, together with the different ways of securing clay are shown in Table 1.

TABLE 1
STABILIZATION IN CERRO GORDO COUNTY

Year	Hauled Clay	Subgrade Clay
	mi	*mi*
1945	9	
1946	26	3
1947	24	19
1948	27	6
1949	20	5
Total	106	33

The quantities of material being used this year vary somewhat from those used in preceding years. On the heavier traveled roads 980 tons of gravel, all passing the ¾-in. sieve, and 980 tons of crushed limestone, all passing the ¾-in. sieve, are stabilized with the amount of clay necessary, as determined by laboratory tests, to give a plasticity index of eight or more The amount of clay required varies from 550 to 700 tons per mi. The production of the gravel and crushed limestone, along with their delivery, and the delivery of the clay to the road are done by contract The pulverization of the clay and the mixing and spreading of the material are then done by County forces. The County Engineer reports that the annual requirements for maintenance gravel on these roads have been reduced from 100 cu yd required for gravel surfaces not stabilized to 50 cu yd per mi per yr for roads surfaced with the stabilized mixtures

The expanding practice of several counties in using material reclaimed from the surface of roads that have been previously surfaced with gravel or crushed stone, and now are being re-graded, has become well established as being both successful and economical. This reclaimed material makes a very desirable base on which the imported surfacing materials which are becoming more expensive, can be placed.

Last year 58 mi. of road were surfaced with burned mine shale, 1952 mi with gravel, and 1085 mi. with crushed limestone on construction of secondary roads in Iowa This total of 3095 mi. compares with a total of 2250 mi. in 1947 An average of 1000 cu. yd. per mi. gives a total of 3,095,000 cu. yd. of surfacing material used on construction on secondary roads in 1948 The estimated quantity of material required for the maintenance of roads previously surfaced is 4,024,000 cu yd. This gives an estimated total of 7,119,000 cu. yd. of surfacing material used on the secondary roads in Iowa last year This is a volume equivalent to a depth of almost 7 ft. over an area of 1 mile square. No mention has been made of the quantities of such materials required for the many other uses for which these valuable natural resources are required.

We are passing out of the pioneer stage in which natural resources can be used as if they were inexhaustible. Many of our road administrators can chart the rate at which the average distance which surfacing material must be hauled has increased with the exhaustion of the smaller well distributed deposits. Many of our counties can foresee the time when the known deposits of surfacing material within their boundaries will be completely exhausted. Any truly economical solution of the secondary road surfacing problem in Iowa must be based on thorough field and laboratory studies of local conditions to evaluate the effect of such factors as the type of subgrade soil and its drainage requirements. The stabilization of our surfacing materials, along with the use of chemicals to reduce the loss of fines, and the more extensive and proper use of sand which are relatively plentiful, will be a step in the right direction Further progress will be made by the development of new kinds of surfacing material along with methods of rendering soils stable This is a relatively unexplored field It will also require the help of trained geologists prospecting for new sources with specialized equipment and modern methods, and the continued cooperation of all our road administrators.