PUBLIC ROADS

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UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

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OFFICIAL DELEGATES TO SIXTH INTERNATIONAL ROAD CONGRESS

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GENERAL REPORTS SUBMITTED TO INTERNATIONAL ROAD CONGRESS

THE SIXTH CONGRESS of the Permanent International Association of Road Congresses was convened in Washington on Monday, October 6, and closed on Saturday, October 11. Prior to the congress, 69 papers written by engineers in 20 different countries were published and distributed to the members. These papers deal with the following subjects, which were included in the agenda of the congress:

FIRST SECTION

CONSTRUCTION AND MAINTENANCE

First question. Results obtained by the use of:
(*a*) Cement;
(*b*) Bricks or other artificial paving.
(Methods employed for road construction and maintenance in these materials.)

Second question. The most recent methods adopted for the use of tar, bitumen, and asphalt in road construction.

Third question. The construction of roads in new countries, such as colonies and undeveloped regions.

SECOND SECTION

TRAFFIC AND ADMINISTRATION

Fourth question. Ways and means of financing highways:
(*a*) Road construction;
(*b*) Maintenance.

Fifth question. Highway transport: Correlation and coordination with other methods of transport; adaptation to collective (organizations) and individual uses.

Sixth question. 1. Traffic regulation in large cities and their suburbs; traffic signals; design and layout of roads and adaptation to traffic requirements in built up areas.
2. Parking and garaging of vehicles.

The reports on each question were reviewed by a general reporter (two for the first question), and these general reports were read at the meeting of the congress. It is a custom to appoint general reporters from the country in which the congress is held. For each question an American authority of recognized standing was selected to digest and summarize the reports submitted. The papers submitted by these general reporters are here reprinted in full.

RESULTS OBTAINED BY THE USE OF CEMENT

General report submitted by FRANK T. SHEETS, Chief Highway Engineer, State of Illinois

A thorough study of the papers on this subject submitted by reporters from many countries shows that the use of cement in both rural and urban road construction is steadily increasing on account of the inherent advantages of this material.

CEMENT DEFINED

In this discussion the term "cement" is assumed to mean the standard Portland cements and the closely related special or high early strength cements which have been developed in recent years. No attempt will be made to discuss so-called bituminous cements.

GENERAL USES OF CEMENT

Cement has been most generally used in road work for—

(1) The construction of cement concrete foundation or base courses on which were placed the many varieties of bituminous, brick, and paving-block wearing surfaces.

(2) The construction of cement concrete pavements which carry traffic on the cement concrete surface itself. Such pavements have utilized both plain and reinforced concrete and have been constructed in both single and double courses.

(3) The construction of cement-bound macadam surfaces; in which case three general methods have been used.

(*a*) A dry mixture of cement and sand was rolled into a prepared stone surface and was then wetted and rolled until the resultant mortar flushed to the surface. After this set, the road was opened to traffic.

(*b*) A layer of plastic mortar composed of cement and sand was sandwiched in between layers of macadam, and then the whole mass was rolled until the mortar worked into both courses of stone and sufficient mortar worked to the surface to produce a proper finish.

(*c*) A thin grout composed of water, cement, and sand was poured into a previously prepared macadam surface, and the whole mass was then rolled and otherwise manipulated until a proper finish was secured.

CONCRETE ROADS SUITED TO HEAVY TRAFFIC

In general it may be said that cement concrete for foundation or base courses or for pavements which carry traffic directly on the concrete surface, as described in the foregoing paragraphs (1) and (2) has been used primarily on roads and streets which carry a large volume of vehicular traffic accompanied by frequent applications of heavy wheel loads.

CEMENT-BOUND MACADAM SUITABLE FOR MEDIUM OR LIGHT TRAFFIC

The cement-bound macadam types described in the foregoing paragraph (3) have been used with some success on roads and streets on which the density of traffic and weight of wheel loads were not inimical to the macadam type of construction. In such cases the addition of the cement binder seemed to give very good results, and greatly increased the traffic capacity over that which could have been carried successfully by ordinary macadam. The consensus of opinion seems to be that for light or medium traffic this type of con-

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struction, which costs less than regular concrete construction, has a place in the highway field.

STEEL-TIRED TRAFFIC REQUIRES SPECIAL DESIGNS

In some localities where steel-tired vehicles carrying heavy loads are frequent, cement concrete surfaces employing ordinary aggregates suffer seriously from abrasion. In such cases it has been necessary to supplement the structural strength or load-carrying capacity of the standard concrete pavement by using very hard coarse aggregate in the top or wearing surface of the pavement slab. This is the so-called 2-course method, and has given very good results at reasonable cost, provided the top course of concrete was applied before the lower course began to set. The 2-course concrete pavements seem to have met the abrasion problem satisfactorily and with much less first cost than that resulting from the construction of the bituminous surfaces or block surfaces on a concrete base.

SINGLE-COURSE CONCRETE PAVEMENTS SUITED TO RUBBER-TIRED TRAFFIC

Experience has shown that single-course cement concrete pavements which have been built carefully and with adequate thickness, but which have employed coarse aggregates ordinarily available rather than the excessively hard materials discussed in the preceding paragraph, withstand successfully almost unlimited amounts of rubber-tired motor traffic. This has been true even with frequent application of the heaviest wheel loads. The surface abrasion resulting from rubber-tired traffic is very small, and consequently in such a case the securing of adequate structural strength or load-carrying capacity at minimum cost is the primary function of a paving material. For this cement concrete is most suitable.

INHERENT ADVANTAGES OF CEMENT CONCRETE PAVEMENTS

It is obvious that the structural strength or load-carrying capacity of a pavement is measured by the strength of the supporting base, The various bituminous brick, or block surfaces with bituminous or sand fillers have little or no structural or flexural strength, and their primary function is to resist abrasion, reduce impact, seal the surface, or provide suitable appearance. Consequently, even when allowance is made for reduction in impact stresses due to such surfaces, the cement concrete base course under them must have approximately the same flexural strength, thickness, and cost as a cement concrete pavement which is to carry equal loads on the concrete surface itself. To state it simply, we must build practically the equivalent of a concrete road as a base for these other surfaces. This gives concrete pavements a great advantage in first cost. Of course where seasoned macadam bases are in place, this statement will not necessarily hold.

The selection of type of pavement to be used in a specific case can best be determined by the comparison of cost of service over a period of years. In such studies, first cost, interest on the investment, maintenance cost, and reasonable life of the pavements must be considered. Cement concrete, on account of its reasonable first cost with resultant low interest charge, its reasonable maintenance cost, and long life, shows up very favorably in such studies. This accounts for its increasing popularity and probably explains the fact that 59,000 miles of this pavement have been built in the United States of America up to the end of 1928, and 8,756 miles were built in that country in that year alone.

COMPETENT ENGINEERING SUPERVISION NECESSARY FOR GOOD RESULTS

Successful results from the use of cement concrete pavements or base courses can only be expected when all features of the work are performed under competent engineering supervision. This must include the preparation of the general plans showing modern grades, curves, drainage, and incidental structures, the rational design of the pavement slab to meet the conditions and to carry the loads which must be encountered, the preparation of rigid and detailed specifications to govern the work, and rigid inspection of the materials used and of the construction itself. This challenges the engineer to keep abreast of the times, to use scientific rather than rule-of-thumb methods, and shows the paramount necessity of a continuing and adequate program of research into the many unsolved problems yet confronting the engineering profession.

GENERAL SUMMARY OF PRESENT CEMENT CONCRETE PAVING PRACTICE

1. *Subgrade.*—The most important consideration in the preparation of subgrade is uniformity. Yielding areas should be replaced with soils of stable character. The subgrade should be well drained to eliminate surface water and that supplied from underground sources. The retention of smoothness of the finished pavement depends in large measure on care in preparing the subbase. The subgrade should be thoroughly wetted before concrete is placed, so as to avoid drawing moisture from the concrete during the setting process.

2. *Design of cross section (slab thickness).*—The minimum thickness of slab used has been approximately 6 inches. Theoretically, it should be of such thickness as will distribute the load from the surface to the foundation, so that the resultant pressures will not exceed the safe load for the foundation material. Earlier pavements have been uniform in thickness, or even thicker in the center than at the edge. More modern practice utilizes the extensive tests which have been made, which show definitely the need of the thickened edge section. Exposed corners and edges are obviously weaker than the interior of a slab having uniform depth. It is all but universally recognized that the thickness of the mid-portion of a concrete pavement need be only about seven-tenths of that near the edge, in order that the flexural strength throughout may be approximately equal. It is generally believed that if the edge thickness is proportioned in accordance with the formula $t = \sqrt{\frac{3W}{0.5M}}$ reasonable safety of design will result. In this formula, t = edge thickness, W = maximum expected wheel load, and M = modulus of rupture of concrete.

3. *Reinforcement and joints.*—The design of reinforcement should be in accordance with the weight of traffic. On stable foundations, pavements need but slight reinforcement; but on the other hand, where unstable foundations are encountered, steel reinforcement properly placed gives the slab increased resistance

to flexure. Reinforcement is effective also in preventing large shrinkage cracks.

The principal function of reinforcing steel as commonly used in pavements is to cause a dowel or shear action between edges at joints or cracks across which the steel passes.

Longitudinal joints in pavements have met with much favor, as they eliminate irregular longitudinal cracking. Practically no longitudinal cracking ever occurs in pavement slabs 10 feet or less in width. Best practice seems to call for such joints at about this interval. These joints are commonly doweled by means of the form of the concrete and by short transverse bars placed at frequent intervals.

Transverse expansion joints are commonly employed in concrete pavements, but opinions differ as to their location. The spacing varies from 20 feet in plain concrete on up. A large mileage of successful pavements has been built without such joints. Joints constructed on an angle to center line of the pavement in order to reduce vibration of traffic are not justified because of construction difficulties and the failure of the slab at the acute angles. The breaking of joints is not satisfactory, as cracks will continue across the adjoining slab. Pure bitumen or fibrous matter impregnated with bitumen are the materials usually employed in filling joints. Research should be directed toward finding a form of joint which will best transmit loading from one slab to another and a satisfactory form of joint material. Alternate bay construction has had some attention.

4. *Design of mixtures and materials.*—Advance in the art of concrete road construction has caused extensive research in materials and in the proportioning of aggregates. The scientific design of concrete mixes and the proportioning of aggregates by weight is gaining in favor. Standard specifications for aggregates can only be a form indicating certain points to be covered, as requirements must be adjusted to satisfy local conditions. It is universally agreed that only clean, hard, weather-resisting material, free from organic matter, should be used. Continued efforts are being directed toward the use of aggregates and cement in such proportions as will effect the greatest economy in design of the mixtures, strength, density, and cost, each being considered.

5. *Construction and equipment.*—Surface smoothness, correct depth of pavement, and the quality of the concrete are the principal items to be controlled in the construction of the pavement. Rigid specifications, thorough inspection, and penalties enforceable on contractors are necessary to get good results. Surfaces are commonly built so as not to vary more than one-fourth inch from a 10-foot straightedge. Beams and cylinders cast at the time the pavement is constructed are tested to determine flexural and compressive strength of concrete. Cores are drilled from the finished pavement to determine depth of pavement and also quality of the finished concrete.

The forms of curing commonly employed are:

(*a*) Ponding.
(*b*) Wetted earth, straw, or burlap.
(*c*) Surface application of calcium chloride.
(*d*) Surface application of sodium silicate.
(*e*) Surface application of bitumen.

Opinions vary as to the relative merits of these methods. In two or three different countries the surface application of a bituminous coat caused excessive cracking. Water curing is the accepted standard.

Most paving operations can easily be adapted to use of machines, and consequently paving equipment is constantly being improved to keep pace with modern construction practice.

6. *Maintenance.*—The increasing mileage of concrete roads has stressed the problem of maintenance. Cracks and joints are serviced at least once yearly, being filled with bituminous materials. Where pavement shows signs of disintegration it is covered with a mixture of bitumen and aggregate. General surface coats of bituminous materials, however, seem unnecessary and usually increase maintenance costs. If failure is of a critical nature, as in the case of sharp breaks, the area of pavement affected is replaced. High early strength cements are especially desirable for this type of patching work.

GENERAL STATEMENT OF CONCLUSIONS

1. Cement is becoming generally used as a paving material and has many inherent advantages.

2. It has been used successfully in the construction of cement concrete base courses for other surfaces, for cement concrete pavements, and for cement-bound macadam.

3. Cement concrete pavements and base courses are suited to heavy traffic.

4. Where a large volume of steel-tired traffic is encountered, 2-course concrete pavements, with the upper layer composed of very hard aggregates, have been necessary and successful. Other surfaces on concrete base courses have also satisfactorily met this condition.

5. Single course pavements have successfully carried maximum volumes of traffic and maximum wheel loads when the traffic was largely rubber tired.

6. Cement-bound macadam has been successful on roads carrying light traffic not inimical to the macadam type of construction.

7. Cement concrete pavements, when compared with cement concrete base courses surfaced with other materials, give equal load-carrying capacity or structural strength at less cost.

8. Competent engineering supervision of design, construction, and maintenance of cement concrete pavements is necessary to insure good results.

9. Subgrades must be uniform and stable.

10. Pavement slabs must be designated to carry expected loads. Edge thickening is necessary.

11. Longitudinal and transverse joints are commonly used and must be designed to meet traffic, subgrade and climatic conditions.

12. Scientific design of concrete mixes and weight proportioning of aggregates represent the most modern practice.

13. Construction operations are performed mostly by machinery, with resulting lower cost and better workmanship.

14. Thorough curing of concrete surfaces is essential.

15. Maintenance of concrete surfaces, properly constructed, is relatively simple and reasonable in cost.

RESULTS OBTAINED BY USE OF BRICKS OR OTHER ARTIFICIAL PAVING

General report submitted by P. J. FREEMAN, Chief Engineer, Bureau of Tests and Specifications, Department of Public Works, Allegheny County, Pittsburgh, Pennsylvania

From the information given by the reporters for various European countries, brick or other artificial pavements are not used to any great extent in Denmark, Italy, Irish Free State, Spain, Sweden, and Switzerland.

Brick is by far the most important artificial road material used in Holland, and the manufacture of brick has always been a very important industry. Of the national roads embracing in general the more important highways with a total length of 2,200 kilometers, more than 1,200 kilometers are made of brick, having a total surface area of approximately 4,500,000 square meters. In addition to the national roads a large part of the provincial roads are also made of brick. In municipalities, likewise, a brick surface has very frequently been used. About 52 per cent of the total surface of streets in Amsterdam are paved with brick and in The Hague 43 per cent of the streets are paved with brick. The annual production in Holland amounts, at present, to 500,000,000 bricks.

At the present time no uniform method of testing brick for all of Holland has been established. There are a number of tests prescribed by various authorities such as water absorption, compression, wear by means of a sand blast, drop test, and the ball compression test. Of all of these requirements the ball compression test appears to give the best indication as to the durability of the paving brick. The method is as follows: For the ball compression test six brick, of which one is broken in two, are laid with broken joints in three rows of two each in a shallow box lined with sand. The central brick is then loaded through a ball 19 millimeters in diameter and the applied load is gradually increased until rupture occurs. The mean load for 10 tests should be between 3,000 and 3,500 kilograms, with the minimum requirement of 3,000 kilograms for the lowest value permissible. The variations from the average value should not exceed 10 to 15 per cent.

In general, the depth of paving brick used in European countries has been less than that in the United States and the amount of vitrification has also been lower than in the United States.

In 1928 the Minister of Public Works of Poland sent experts throughout western Europe to study paving production with the idea of raising the standard of the industry in Poland to the highest technical level. Experience in Poland had shown that roads paved with brick having a good quality were durable under military traffic and with the recent development of high-class paving brick further extension of the use of that material for paving may be expected.

In Belgium, France, and Germany experience has shown that the durability of brick pavements is affected by the quality of the paving brick and more attention is being paid to the methods of making and burning paving brick.

Contrary to the practice in the United States, where paving brick is considered one of the most suitable materials for very heavy traffic, both as to number of vehicles and loading, it appears from reports that in continental Europe brick paving has been most generally used for light and medium traffic.

In many cases good European practice indicates that the paving brick should not be placed on a rigid base, particularly one made of concrete. Many of the brick pavements are laid directly on the subgrade or upon a heavy layer of granular material such as sand, which provides adequate drainage.

It has been found that unless the brick are of the highest quality they tend to pulverize under heavy traffic if laid on a solid base or foundation.

Under certain conditions it has been found unnecessary to fill between the brick with any material as the sweepings from the streets soon adequately fill the spaces between the brick. Pavements in the country are filled with sand or bituminous materials where traffic conditions make this necessary.

The countries of continental Europe are all developing paving brick of a higher quality than in the past and these countries are building experimental pavements under the most modern methods of design. This is also true of Great Britain, where the first experimental brick pavement was laid in 1922.

It would appear that the development of paving brick can be advanced if a uniform specification acceptable to the various countries could be developed. At the present time there does not appear to be any uniformity as to the physical requirements for paving brick used in various parts of the same country.

Through the efforts of the National Paving Brick Manufacturers' Association the rattler test for abrasion loss of paving brick has been made a standard by the American Society for Testing Materials and this test has done much to standardize the methods of production and the quality of paving brick in the United States. This test is used to a limited extent in European countries but it is not in general use.

An attempt will be made to summarize the general trend of methods for the construction of brick pavements in the various countries reporting:

It is agreed that proper drainage is a vital factor in the production of a durable pavement and that if the soil conditions are not favorable to proper drainage it will be necessary to provide artificial means for draining the subgrade.

It has been found in both Europe and the United States that in sections where drainage and climatic conditions are suitable it has been possible to construct satisfactory brick pavements on sand or well-drained earth subgrades. Where such foundations are inadequate to support the traffic the foundations are being constructed of brick, stone, blast-furnace slag or similar material, which is crushed, rolled into place and bound by means of fine materials, bituminous mixtures or Portland cement mortars.

For very heavy traffic plain cement concrete bases are commonly used, and in some cases the concrete is reinforced with steel bars.

There is no such thing as a standard adequate foundation for unit-type brick pavements. The facts in each instance must govern the design of the foundation and nothing should be overlooked to insure its being adequate. Best practice calls for a smooth base in which the variations shown on a 10-foot straight edge do not exceed one-fourth inch.

Fire clay and shale are used in the various countries for the manufacture of paving brick, and whereas the practice in European countries appears to be tending toward thicker brick, the reverse is true in the United States. Experience and tests in the United States have

shown that brick having a depth of 2½ inches placed on a very smooth concrete base may be adequate for heavy traffic.

Having prepared an adequate foundation, a bedding course of fine material is spread over this foundation or base. This may be sand or slag screenings and for the best practice the thickness has been reduced to 1 inch or less.

After the bedding course has been screened to a uniform surface the paving brick are laid carefully with the best face up, with all lugs in the same direction, in parallel straight courses at right angles to the center line of the pavement. In some European countries the practice is to lay the brick to make an angle of 45° with the center line. The brick are then inspected and culled, after which they are rolled with a power tandem roller weighing from 3 to 5 tons. After final rolling the brick are again inspected and all unsatisfactory brick removed and replaced with perfect ones. A 10-foot straight edge is then used at various intervals across the roadway and any inequalities exceeding one-fourth inch are corrected and, if necessary, the entire surrounding surface again rerolled.

Portland cement grout filler is no longer in general use. Experience in France as well as in the United States indicates that it is not so satisfactory as bituminous filler. Asphalt is generally used for filler and the best modern practice is to apply the filler to the pavement by means of small-wheeled buggies equipped with rubber squeegees which will fill the joints without leaving a coating of asphalt on the surface of the brick thicker than one-thirty-second of an inch. For the materials used in the United States it is very necessary that the temperature of the asphalt filler as applied be not less less than 177° C. Specifications require the use of a large thermometer fixed in the kettle so that the temperature may be known at all times.

Immediately after filling the joints a thin coating of sand or granulated slag is spread over the surface of the brick and rolled to bed in the coating. Additional dressing may be added or the excess removed after the road is opened to traffic if the conditions warrant.

RUBBER PAVING

An artificial paving material which may have unusual future possibilities is rubber, which has been used in Great Britain since 1913. Several different types of paving blocks made from rubber are being tried. Some consist of solid rubber blocks 9 by 3 by 3½ inches deep, which are placed directly on a concrete foundation or other existing base. Other blocks of rubber have been used having dimensions of 9 by 4½ by 1½ inches mounted on a concrete base and held by chaplets of steel. Rubber pavements have been tried in the United States to a limited extent but a method of holding the rubber surface to the base has as yet to be perfected. Such pavements are not slippery and appear to have wearing qualities.

STONE BLOCK PAVING

Stone block pavements are considered natural pavements by the European countries reporting rather than artificial materials. In the United States block pavements have been constructed of granite, trap, sandstone, and limestone. The method of laying block stone pavements is practically the same as for paving brick. The joints are usually filled with a mastic consisting of approximately equal portions of sand and asphalt filler rather than pure bituminous filler as is the case with paving brick. In some cases cement grout filler consisting of equal parts of Portland cement and sand are used. Block stone pavements on adequate foundations are considered suitable for the heaviest type of traffic.

THE MOST RECENT METHODS ADOPTED FOR THE USE OF TAR, BITUMEN, AND ASPHALT IN ROAD CONSTRUCTION

General report submitted by ROY W. CRUM, Director, Highway Research Board, National Research Council, Washington, D. C.

Reports have been received from 13 countries telling of the successful use of tar, bitumen, and asphalt. Many combinations and methods of use are described. The rapid increase in the adoption of surface treatments to produce thin mat surfaces upon gravel, stone, and slag roads for light and medium traffic is probably the outstanding recent development. The methods described are well worth the careful study of engineers responsible for planning highway improvements.

Your reporter is greatly impressed by the many combinations of materials and construction methods used to stabilize earth, sand, gravel, stone, and slag surfaces for light traffic, and to form wearing carpets for heavy traffic. In Europe most attention has been directed toward the surfacing of existing macadam or similar roads, while in the United States there has been a great development in the initial construction of low and medium type roads. The developments have come about principally through road trials, although the influence of research, particularly into the characteristics of the bituminous materials, is notable. Intensive research methods, particularly into the combinations of bituminous binders with other materials and into economic factors, must now be invoked in order to develop further refinements in serviceability and economy.

The principal impressions received through the study of these excellent reports are as follows.

TERMINOLOGY

The nations do not yet agree upon the terms used in connection with the materials covered by the second question, the principal differences occurring because of the divergence in commonly accepted trade terms in Europe and America. New trade terms will be very slowly adopted. In the meanwhile a classification based upon the manner of commercial production of the various materials, giving the names by which they are known in the different countries, would be of great help in promoting understanding. The following cementitious materials are recognized in all countries: (*a*) Tar; (*b*) the solid or semisolid binders secured from natural deposits; (*c*) the solid, semisolid, and liquid binders produced by the distillation of petroleum; and (*d*) natural rock impregnated with bituminous binding media. The use of the term "bitumen" to describe that part of these various materials which is completely soluble in carbon disulphide appears to be generally acceptable. The difficulties arise when exact scientific definitions susceptible of a single meaning are attempted. Similar classification is also needed for the various basic road types which are now described by

a great variety of trade names, many of which are not descriptive.

CONDITIONS OF USE

The reports describe the methods developed in the different countries, and give some information concerning traffic capacity, maintenance needed, and governing conditions necessary for success. Emulsions, owing to their adaptibility to use in wet weather, have had wide acceptance in Europe, while for use cold, cutback products are more common in America. New types of equipment include a machine reported from Sweden for spraying sand and bitumen simultaneously from adjacent nozzles, so that each sand grain is coated; machines similar to those used on Portland cement concrete for finishing mixtures; attachments for pressure distributors for spraying asphalt and dilute soap solution to form an emulsion; and mechanical distributors for both coated and uncoated aggregates. Considerable attention is given to methods for overcoming slipperiness, particularly by rolling bitumen-coated stone chips into the surface. Applications of laboratory research into the constitution of bitumens are discussed in the Dutch report. The German report describes methods, which also parallel American practice, for design of mixture with especial reference to determination of correct binder content. The nonsuccess of surface treatments on certain roads in Spain carrying intense traffic of heavy carts is mentioned. European reports indicate increasing use of asphaltic bitumen, bituminous emulsions, and mixtures of tar with asphaltic bitumen.

NEEDS

It is apparent from the reports that tar, bitumen, and asphalt have been found satisfactory for use in road improvement throughout the world, and many of the factors upon which success depends are indicated. However, the thought occurs that further detailed discussion of the prevailing conditions, upon the evaluation of which depends the decision as to the particular type, design, and methods to use in specific cases, would be extremely valuable. Doubtless full understanding of the factors involved will depend somewhat upon further research into such economic features as transportation costs (roadway cost plus vehicle-operating costs) and relation between maintenance costs and intensity of traffic, and also upon research into the fundamental characteristics of combinations of bituminous binders and mineral aggregates.

CONCLUSIONS

I have the honor to recommend the following conclusions, which are based upon the impressions received through study of the national reports, for your consideration.

I. Tar, bitumen, and asphalt are suitable materials for use in the improvement of all classes of roads, subject to the limitations imposed by the characteristics of the material, the intensity of traffic, and local physical conditions. Certain governing conditions generally recognized are:

(*a*) The use of the correct grade and amount of bituminous binder for the particular type of work and aggregates to be used is essential.

(*b*) Provision for prompt maintenance is necessary. In general, successful results are attained when the roads can be kept in good condition at reasonable cost by maintenance of the surface without the need of extensive repairs to the underlying roadway.

(*c*) Proper proportions, thorough mixing, and thorough compacting are required in construction of premixed types of surface.

(*d*) Especial care is needed in the construction of bituminous macadam, since careless workmanship or improper methods may not be apparent immediately after construction.

(*e*) Attention should be given to the reduction of slipperiness.

II. The need for research into the fundamental factors involved in the use of tar, bitumen, and asphalt in road improvement and maintenance is recognized. The attention of the Members of the Congress is especially directed to needs as follows:

(*a*) Research into the constitutions and characteristics of bituminous materials, and their combinations with other materials.

(*b*) Research into factors affecting the serviceability and durability of roads, such as climate, subsoil, traffic density, and road design.

(*c*) Data on economic factors such as:

(1) Cost of transportation over various road types, including vehicle-operating costs and roadway costs.

(2) Relation between maintenance costs and volume of traffic for various road types.

III. In order that mutual understanding and helpfulness may be promoted, there is need for an international classification of materials, combinations of materials, construction methods, and road types which will correlate the terms in use throughout the world, both commercial and scientific.

THE CONSTRUCTION OF ROADS IN NEW COUNTRIES, SUCH AS COLONIES AND UNDEVELOPED REGIONS

General report submitted by E. W. JAMES, Chief, Division of Highway Transport, Bureau of Public Roads, United States Department of Agriculture

Twelve reports have been submitted on Question 3. The points on which agreement is most general are the need of complete studies of prevailing local conditions, the advantage of first constructing a limited system of main roads, the immediate expectation of motor traffic and the requirement of designs to accommodate it, the construction of temporary structures narrower than final plans will require, the possibility in some favorable localities of temporarily omitting surfacing, and the principle of salvaging construction.

It is interesting to note the emphasis in some reports on the military and political aspects of colonial road development, but one writer definitely states that military roads form a poor basis for later development.

The construction of roads in undeveloped regions of relatively old countries is described in several reports, and practically all agree that motor traffic must be expected and provided for in the premises.

Management and financing are touched upon by several reporters and the use of a general revenue is

cited as required for initial work of a substantial character.

Standards suggested invariably reflect modern requirements for motor traffic roads. A 10-foot or 3-meter travel lane is preferred, but there is a marked difference of opinion as to whether first construction should consist of 2-lane roads or of 1-lane roads with passing places.

ALMQUIST reports for Sweden and describes the standards adopted by the Swedish Government for use in the land of the Laps in northwestern Sweden.

Widths of surfacing are 2.5 to 3 meters. Grades are limited to 10 per cent. A 100-meter radius is advocated for curves, but radii down to 10 meters are permitted when indicated by topography. Bridges are 2.5 meters wide. Passing places are provided along the roads at intervals of not more than 200 meters.

Roads built according to these standards are aided by financial grants amounting to 90 per cent of the cost by the National Government. The local communities pay the balance.

BOROWSKI advocates the completion of the highway net as earth roads for a country like Poland before hard surfacing any of the main roads.

He cites the difficulties experienced with poll-tax labor, and gives actual case figures indicating the economy of machine methods in the eastern districts of Poland.

He emphasizes the importance of a national plan, and gives the standards of design adopted by the First Polish Road Congress and notes the policies advocated by the second congress.

BRIX, reporting for Germany, refers to the political and military aspects of initial road construction in undeveloped areas. He points out that roads now built for the first time must be suitable for motor transport, but loads may be limited, and cites 2 to 2.5 metric tons as the maximum permissible.

Roads are preferred to railroads, but must correlate with them if they exist. Preliminary studies should include climate, materials, topography, soil, and economic needs of region. Main routes as a skeleton system are to be built first. In general 2-lane roads of 6-meter width should be designed. Surfacing may be narrow but must be placed to furnish all-weather service.

Narrow bridges are satisfactory temporarily, but clearances should be standard for single-lane traffic.

He describes the organization required and suggests financing by concessions, and believes, in general, that the same standards of design should be adopted as for road building in developed sections.

BRUCE and others, reporting on British and British colonial practice, point out especially the relevancy of the subject of undeveloped sections of old countries, and indicate the requirement in such cases of a thorough study and plan for correlating road construction with existing railroads. They emphasize the need of a high grade of personnel in such work, of the required permanence of alignment, and of sound, steady financing, suggesting the possibility of taxes on motor spirit and lubricating oils as a productive source for highway revenue.

The paper suggests also the value of airplane photographs in reconnaissance surveys, and in connection with location emphasizes the need of taking advantage of natural drainage.

Though temporary construction may be resorted to, the paper points the advisability of anticipating proper future bridge location and the elimination of railroad grade crossings. Although stating that the British Ministry of Transport has adopted the 10-foot unit traffic lane, the report indicates that widths of surface dictated by horse-drawn traffic are still used in several of the colonies.

The report advocates the abandonment of through intersections of minor roads with main thoroughfares, and proposes staggered intersections at such places. For intersections of two major roads, a square island is suggested for the purpose of developing rotating traffic. These proposals unquestionably reflect experience on a more highly developed road system in an older region, and from this point of view are interesting as details of location.

DE JONGE, reporting from Holland, describes the canal and highway transportation routes in the Province of Drenthe.

This was a typical undeveloped area in an exceedingly old country. Consisting of 266,000 hectares, the area had, in 1850, 82 kilometers of road; in 1928 it had 1,445 kilometers. The rights of way were 8 meters wide until 1917, and are now made 10 meters wide. Surfaces are 2.5 to 3 meters in width, and brick or stone setts are generally used.

Tables show the rapid recovery of agricultural land following road development, the rapid growth of population, and the increase of taxation.

DE SOLA, writing with a background of Cuban experience, emphasizes the value of surveys to locate suitable road-building materials in new countries in order to direct the intelligent selection of adequate types of surfacing and to determine economical methods of construction. He notes also the advantage of soil studies affecting the details of location. He calls attention to the requirement of developing the fullest possible use of natural drainage in fixing the location of new roads.

KURTZ reporting for Argentina furnishes a technical discussion of adequate mixtures for sand-clay road surfaces, basing his paper largely on Terzaghi's developments. He proposes a diagram to use the physical composition of mixtures, based on Terzaghi but using a metric scale, which he proposes to standardize so that comparisons of mixtures may be made by mere inspection after a physical analysis has been made and the results charted.

LAUZI describes the development of roads in Italian Colonies from the status of emergency construction for military purposes to the resurfacing with asphaltic tops of part of the permanent highway system of the Colonies. The use of macadam is emphasized and the development of local sources of stone. The road system is determined largely by local routes between existing sites, supplemented by militry routes required by the location of posts and camps.

PRINYAYOGAVIBULYA, reporting for Siam, describes the use of a cross section with reversed crown on new grade. This has been found useful in Siam, where heavy rains cause serious depreciation of new embankments. By this means erosion of the slopes is reduced; considerable rain water accumulates in the reversed crown, and expedites settlement of the embankments. Later, when the road is surfaced or further improved, a standard crown is constructed and the surfaces finished to usual cross section.

SKOGSTROM, of Finland, describes as an example of a development road the trunk line 229 kilometers long across Lapland, connecting the present road system of Finland with Petsamo Fjord on the Arctic coast.

VICAIRE cites especially development in Morocco where transitions are made directly to motor transport from pack trains. Development has followed closely the course in France. Main roads are very direct, with ample radius of curvature and low grades. Macadam 11 to 15 inches thick is used. Thirty-meter right of ways are required in open country, and not less than 16 meters even through settlements. Roadside planting is early promoted, and nurseries are already producing trees for this use.

Three trans-Saharan roads are projected, one of 2,100 and two of 1,500 kilometers. Two are open to traffic; one is under construction. Connecting laterals, 300 to 600 kilometers, are under construction.

In Tunis the completion of circuit routes for tourist purposes has been found expedient as first construction in undeveloped desert.

In Indo-China a principal artery 2,561 kilometers long has been built to penetrate a new area. Military trails, first used locally, show heavy loss in salvage value.

In West Africa, Togoland and Kamerun, the early use of bituminized surface is indicated as elsewhere in French colonies. The construction of single well-located cardinal roads for purposes of penetration, safety, trade, and administration appears necessary and adequate.

WHITE and others, reporting on the development of roads in well-settled agricultural areas in the United States, point out that any highway construction must advance in harmony with a possible, sound financial plan. Agricultural land can not carry required charges for extensive road system construction, and a supplementary source of revenue must be tapped. The anticipation of revenues of the future by resort to bond issues is considered sound.

Highway needs are increased by potential motor traffic in all regions, even the most sparsely settled areas. In a road system, third and second class, as well as first-class roads, must be made passable if they are to be of service. The very small amount of traffic indicates low-type improvement as adequate for the third-class group, but maintenance is needed in all cases to prevent deterioration.

Increase of traffic requires the heavier improvement, reclassification on a higher scale, and increased cost and maintenance charges. Types of surface treatment adequate for various densities of traffic are discussed, and standards of gradient and curvature are indicated.

A comprehensive highway system plan is the first essential. Right of ways 120 feet in width should be provided initially for main roads, 100 feet for secondary, and 60 feet for third-class roads. Directness of location without regard to property lines should characterize main roads. Only the third group of roads should regard ordinary land subdivisions. Alignment and profile should be made definite where possible; but surfacing should be determined by existing utilization.

HEWES and others, referring to road development in the sparsely settled western portion of the United States, consider method of financing of first importance, declare the sound principles of bonding an entire area (national or provincial) and of taxing developed areas to pay for first improvements needed in undeveloped areas. Maintenance and secondary construction should be carried by local administrative units. They cite development in western United States where automobile revenues have increased as a result of road improvements extended into undeveloped areas. Total motor revenues in 1915 of $2,800,000 have increased to $108,500,000 in same area in 1930.

The program of construction should be developed as early as practicable, should consider especially agricultural production, and recognize a forecast of automotive traffic. To avoid undesirable economies in construction, the program should not be forced in the early years. Final standards of grade and alignment should be introduced early. Bridges and surfaces may be made temporary on plans admitting salvage in later years. A method of oiling roads of light initial construction, composed of a variety of stone and gravel surfaces is described.

WAYS AND MEANS OF FINANCING HIGHWAYS: (A) ROAD CONSTRUCTION, (B) MAINTENANCE

General report submitted by ALVIN B. BARBER, Member American Society of Civil Engineers, Manager Transportation and Communication Department, Chamber of Commerce of the United States of America, Washington, D. C.

The subjects "Finance of the Construction and Upkeep of Roads" and "Provision of Revenues" were dealt with by the Third International Congress at London in 1913. The reports submitted in advance of the present congress contrast sharply with those submitted prior to the London Congress. The latter mainly considered highway systems as designed to carry the old forms of road transport and generally revealed no serious financial problems, whereas the predominant note in the present reports is the urgent need for extensive improvement, reconstruction, and new construction as well as better maintenance, to meet the demands of motor transportation.

The conclusions reached by the London Congress also presented a very different point of view from that reflected by the several reports submitted before the present congress. The discussion in the finance section at London, and the conclusions finally adopted, dealt chiefly with the financing of main routes of communications and those for long-distance traffic, whereas the present reports indicate that the main highway systems in most of the reporting countries are being fairly well provided for, but that financial problems of great magnitude are being encountered in the effort to accommodate secondary and local roads to meet the necessities of motor traffic. The motor vehicle is no longer a luxury or the exceptional case. It is essential in modern highway transport.

Where its use is well developed the motor vehicle is also able to pay its fair share of highway costs. In the sectional discussion at London a proposed declaration on the subject of a motor-vehicle fuel tax was rejected on the ground that conditions differed so much in different countries that no general statement on the subject was suitable for adoption by an international congress. The conclusions, however, suggested special taxes upon vehicles which, on account of weight or weight combined with speed or other exceptional circumstances, cause special damage to roads beyond the wear and tear of ordinary traffic. In contrast with that guarded expression the present reports show that practically all countries reporting now have motor-vehicle license taxes, while a majority have motor-fuel taxes and that they anticipate further great increases in highway reve-

nues from these sources as the use of motor vehicles increases. While in some countries such revenues are not entirely devoted to highway purposes, the almost universal opinion is that they should be so applied.

The reports also generally recognize that the benefit to the general public resulting from highway improvement warrants finding a considerable proportion of needed funds from general taxation. This is particularly true as to local roads and urban streets, since user revenues are generally collected and expended by or under supervision of the national or other higher jurisdictions.

Assessment of abutting or other immediately benefited property continues but with a tendency toward restriction of its application to urban districts or, in other cases, to a portion of the increase in value resulting from the improvement.

The principle of aid to the lesser political units is being extensively applied either through outright subsidies to assist in developing roads of general use or through loans which must ultimately be repaid by the smaller units.

Another tendency shown is toward simpler classification of highways, the essential groups being two—first, those of general use serving a substantial proportion of through traffic moving within or through more than one local jurisdiction and, second, those of local use, including city streets. There is growing recognition, however, of the responsibility of the authorities in charge of main highway systems for the sections of such systems lying within municipalities.

Finally, following the principle briefly stated in the conclusions of the London Congress, there is general recognition of the investment character of improved highways which, making possible large increases in motor traffic, afford the basis for added revenues from user taxes which can be paid from the economies to highway users resulting from the improvements. Thus the issuance of bonds, under proper safeguards as to soundness of the highway program and its administration, length of the loan period and assurance of proper maintenance, are approved as a means of financing improvements which can profitably be expedited.

Reports from 11 countries have been received. With two exceptions they are from European countries with relatively dense population and closely knit systems. To bring out further views of less developed countries which are to be represented at the International Congress, cognizance has been taken, in preparing this report, of the conclusions on financing of highways adopted by the Pan American Highway Congress held at Rio de Janeiro August 16 to 28, 1929.

Following are certain outstanding features indicated by the reports from the several countries, in addition to which most of the reports give statistical data as to the amounts of the different classes of roads.

Denmark.—In 1926 motor taxes paid about 58 per cent and general taxes 42 per cent of the road expenditures of four typical counties in Denmark. The taxes on the user consisted of a fuel tax and graduated registration fees.

Most of the proceeds of the motor taxes, which are collected by the National Government, went to the counties and parishes, lesser shares being allocated to the cities and towns and a small amount (1 per cent) to a fund for special works. At least half the amounts distributed must be used for improvement, including bridge strengthening, provision of clear view at intersections, and protection of railway crossings. Motor taxes may be used to pay interest and amortization on loans for highway purposes.

The main (county) highways are nearly finished, but work on the "byroads" (parish highways) is just beginning.

France.—France has found difficulties in highway restoration since the World War. Maintenance of the national system, 7 per cent of the highways of all classes, is reported as backward. The report shows that the Departments, whose own highways comprise only 2 per cent of all highways, control nearly half of the communal roads and draw upon the entire authorized amount of available communal resources for those roads, more than half of which are passably maintained. The communes are thus left with inadequate resources for work on their ordinary vicinal roads (over 50 per cent of the total road systems) and these are in an unsatisfactory state of maintenance, while the remaining "rural" roads have in many cases become practically impassable.

Steps have been taken to effect a reclassification of all highways, taking account of traffic characteristics, which will result in a greater proportion of expense being provided by the National Government. Only 43 per cent of the money derived from motor vehicles in 1928 was devoted to road expenditures, and the report points out that the additional National Government highway expenditures would be approximately met by allocation to this purpose of the remainder of the motor vehicle taxes. It is also pointed out that the total expenditures for highways by all jurisdictions (national, departmental and communal) which amounted to 2,252 million francs is exceeded by the total receipts of 2,300 million francs from all user taxes, including license, fuel, excise, and highway taxes. User taxes are mainly imposed by the National Government but the communes may levy on motor vehicles a tax equal to 17 per cent of the national tax and the departments up to 8½ per cent.

The French report makes but little reference to the use of loans as a means of expediting the provision of needed improved highways.

There is a system of national subsidies to departments and communes. Portions of through highways lying within municipalities are supported by the authorities responsible for such highways.

Germany.—In most of the German States the main highways are maintained by the States themselves; in Prussia by the Provinces. Throughout the country there are also district and town road jurisdictions. Each jurisdiction at present has some heavy, some medium, and some light traffic highways, but a reclassification is in progress to give to the States or Provinces the heavy-traffic highways in order, according to the report, to get them "under the most efficient authorities."

There is little new construction except by cities and towns in new districts and except for a few special roads such as that from Bonn to Cologne and Dusseldorf. Much reconstruction is, however, found necessary to meet increased traffic. It is recognized that the adaptation of the highway system to modern requirements has only begun. Maintenance is a first charge in the budget.

General taxes are the principal source of revenue for highways in Germany. Motor-vehicle taxes will not cover more than the major part of maintenance costs and opposition to increase in the rate of those taxes is reported. They are collected by the National

Government and distributed to the States in fixed proportions and by them to Provinces, districts, and municipalities as decided by the States. They are to be applied solely on roads and bridges. State subsidies from the general treasury are given to Prussian Provinces. Other sources of highway revenues are unemployed relief funds and assessments of benefited property. Tolls are opposed as disturbing traffic.

The report holds that general property and business are undesirably burdened and that it is not possible to make available all the funds required by the construction program. At the present rate 32 years would be required to complete the highway system. Improvement of this condition and supply of the funds needed can only be expected from the negotiation of highway loans which have been tried to a limited extent in most of the German States. In urging such loans the report states that, besides benefiting the motor industry and business in general, a highway system in good condition unquestionably reduces maintenance costs.

Great Britain.—In Great Britain there is no intermediate highway authority between the National Government and the local units. The National Government does not directly engage in highway construction and maintenance, but its Ministry of Transport has important supervisory and advisory powers and its Ministry of Health certain responsibilities as to bond issues of local units and local expenditures on national roads.

Highway revenues come from two main sources—local rates (taxes) levied on the annual value of occupied property, and National Government grants from the road fund. Grants to counties are on a fixed percentage basis of maintenance costs for each class of highway and special grants are given for new construction on a percentage basis. County boroughs (cities) and London authorities receive grants for special construction work but nothing for maintenance. The road fund is derived from general taxes and taxes on the motor vehicle and its use—fuel taxes and registration fees. Motor vehicle revenues are in part used for other than highway purposes but this diversion is criticized. Assessments on benefited property are applied only for street improvements. Tolls are generally being abolished but are being applied in a few major undertakings such as the Mersey Tunnel.

Local construction work or extensive reconstruction and improvement is normally financed by bond issues to be liquidated out of current revenues which likewise take care of all maintenance costs.

The belief is expressed that there should be the widest possible range of contributors to highway revenues, that not less than 25 per cent nor more than 75 per cent of the costs should be met out of general taxation, that the area of charge should be as wide as possible, that the owners of land should make special contributions on the grounds of benefits and that the remainder of the costs should be shared by all users.

Holland.—The report for Holland states that the increase of motor traffic since the World War has demanded a higher standard for most of the roads and has brought out the need for new main roads and for bridges over principal waterways. Superhighways costing 300,000 to 600,000 florins per kilometer and secondary improved roads costing 30,000 to 50,000 florins per kilometer are contemplated.

Highways were reclassified in 1926 into first class (national), second class (provincial), and other (commune and polder). There are grants from the national road fund to the Provinces, whose road schemes are subject to approval by the national authorities. Grants to lesser jurisdictions are for the present given only to promote abolition of toll roads which are regarded as undesirable on account of the cost of toll collection and the diversion of traffic. Fuel and tire taxes are not approved but motor vehicle license taxes provide a large share of the road fund which also receives grants and advances from the general treasury. Motor-vehicle taxes are not to be applied to maintenance of existing roads but they should provide for most of construction and improvement and for any increase in total maintenance costs due to growth of traffic.

Loans are used only for construction and are repayable within 30 to 40 years. Without loans only half the first and second-class systems could be completed in 55 years and it would require 12 years more to finish the work. A calculation has developed that capital invested in provincial roads during the period from 1929 to 1944 inclusive will be entirely redeemed in 1971.

Ireland.—The report from Ireland indicates that its plan of road administration by county and city councils is substantially the same as during the British control. The National Roads Department does not carry on construction or maintenance but distributes grants for the improvement and for a portion of the maintenance of main roads and exercises a degree of supervisory authority. All main roads are reported as in good condition.

Motor-vehicle taxes provide the national road fund, while general taxes are the source of revenue for county roads. Loans have been used to some extent.

Italy.—The Italian report emphasizes the financial difficulties met by Italy and other nations in providing for the enormous growth of highway traffic and describes the complicated relationships, sharing of costs, and distribution of subsidies which have prevailed in Italian highway work. It points out that the interest of the National Government in the main highway system, which was turned over to the Provinces upon the advent of the railways, has revived since the coming of motor transportation. An autonomous national highway administration (A. A. S. S.) was created in 1928 to control the national system of 20,000 kilometers of main roads which carry two-thirds of the total motor traffic. A reclassification of the remaining highways is expected under which the Provinces will provide for secondary and local roads, except in cities and towns, subject to increased supervision and allotment of funds by the A. A. S. S. The report recommends that sections of through roads lying within cities or towns be entirely paid for by the national or provincial government in charge of the particular road, instead of only repaving costs and part of the maintenance costs as at present.

Construction costs are paid out of general revenues and user taxes (license fees) cover only maintenance and improvement. Recently motor-vehicle revenues have been collected solely by the National Government, the Provinces and communes retaining only the right to tax animal-drawn vehicles. The A. A. S. S. has revenues from a variety of sources, including motor-vehicle taxes, fines, surface and subsoil privileges, advertising rights on highways outside cities, levies on industries using the highways, assessments on increment in value of property due to improvements, and annuities (loans).

Assessments have been applied chiefly in cities but provision has been made for their application else-

where, particularly in reclamation projects (except in southern Italy). Toll roads are generally being eliminated. Loans have been extensively used by Provinces and local jurisdictions.

With regard to the Milan-Italian Lakes autostrade, established as a private toll road with a contingent guaranty of the company's bonds by the Government, the report states that until now it has not been necessary for the Government to pay anything under this guaranty. For other autostrades, including two completed, two under construction and several projected, the Government goes further by making construction loans to the concessionaires. This aid is in addition to outright subsidies given by local administrations. The report finds in these more generous methods no contradiction to the conclusion of the Milan Congress which, the report points out, did not exclude Government subsidies necessary to attract private capital to an enterprise of recognized public utility.

Siam.—The report from Siam shows that highway construction and maintenance are generally financed by the State. Definite provision for maintenance is made in the national budget.

The policy has been to develop feeder roads to the railways and waterways in preference to trunk highways parallel thereto but the ultimate development of a national highway system with local roads under provincial control is envisaged.

Spain.—The specially surfaced roads of Spain were constituted as a national system (Circuito) by royal decree of February 9, 1929, and will be administered by a commission having citizen as well as official representation. The sections of these roads in cities are included in the national system.

Sources of revenue for the Circuito are derived from general taxes, special taxes on vehicles and a share of the license taxes, poll taxes levied against the municipalities, special taxes on motor carriers and revenue from the sale of land along the road. General taxation provides approximately 75 per cent of the highway income and motor vehicle taxes nearly all of the remainder. A very large proportion of improvement and maintenance costs for the next 10 years is to be financed from an advance from the general treasury.

The motor vehicle license taxes are distributed 25 per cent to the National Government, 25 per cent to the Circuito, 15 per cent to the Provinces, and 35 per cent to the municipalities. The need for largely increased funds for highway purposes is recognized in the report which recommends, among other things, fuel, oil, and tire taxes for exclusive application to highway uses. It is regarded as an important principle that the highway users through their organizations should have a voice in the administration of the funds contributed by them.

Sweden.—The report from Sweden recognizes the road problem as one of the most important questions in the country and states that nation-wide improvement of the heavy traffic main roads and the trunk highways of several cities is necessary in order to decrease their annual maintenance costs, increase their traffic capacity and decrease transportation costs. The report develops detailed figures as to the costs of construction and maintenance of different types of highways, showing that for heavy traffic the higher types are more economical and justify extensive capital investments.

United States.—The report from the United States points to the bond plan and the "pay-as-you-go" plan as the two principal methods of financing the cost of highway improvements in the United States, neither method being used in any State to the exclusion of the other. While the bond method involves greater total cost, the income produced by the economic improvement more than offsets the interest cost. The public benefits by reduced motor vehicle operating costs and by quickening of economic and social life. Recent State bond issues are generally retired from motor vehicle taxes, local highway bonds from general property taxes. "Funds raised from bond issues," states the report, "should be expended only for road improvements of a relatively permanent character; the maintenance of the improvement should be assured beforehand; and adequate provision should be made for interest payments on the bonds and for their retirement as early as possible."

The report further declares that bonding should not be resorted to except to the extent that may be necessary if highways can not be built from current funds by the "pay-as-you-go" plan. There is caution against too high type of construction not justified by traffic, especially when bond issues therefor are authorized through popular referendum; also that it is easier for government units to run into debt than to get out of it. Necessary highway improvements, however, under honest and efficient expenditure bring such benefits that either bond or "pay-as-you-go" method, whichever may be necessary for a given improvement, is justified.

The report points out the increasing part of highway income formed by motor-vehicle revenues, being used principally for maintenance and in many cases for interest and amortization of highway bonds. License fees and gasoline taxes are preferred to tolls as a means of collecting contributions from highway users.

The report includes three papers—Financing Highways with Bonds, Highway Finance by the Pay-as-You-Go Plan, and Motor Vehicle Revenues as a Source of Highway Finance—which present much detail.

The first paper shows that highway bonds have been issued by 31 of the 48 States of the United States and by many counties and local units. There are no Federal highway bonds. The bonds are usually of two types, serial or sinking fund, with increased preference for the serial type. Eight outstanding advantages of bond financing are presented, and two inherent objections to the financing of highways solely from current income.

The second paper, while recognizing that some bonding will generally be necessary and advisable, presents the viewpoint of those who advocate following the "pay-as-you-go" plan to the maximum practicable extent and outlines the objections to bond issues.

The third paper presents figures showing the increasing share which motor-vehicle revenues, exclusive of property taxes, contribute toward the total highway expenditures (46 per cent in 1928) and briefly explains the theory of taxing the two groups benefited by highway improvements, i. e., the general public and the highway users.

Attached to the report is an appendix containing a statement of the principles of highway administration and finance adopted by the American Association of State Highway Officials on November 20, 1924. The report states that, while wide variance in highway development in the different States prevents adoption of uniform policies of highway finance, the basic

principles contained in the statement, which were developed through experience in the United States, may perhaps be generally applied.

CONCLUSIONS

1. The motor vehicle with increasing use creates demand for large expenditures for reconstruction and improvement of existing highways to new standards, construction of new highways and effective maintenance of all improved highways. It justifies such expenditures through improved economy and efficiency of transportation within areas previously served by highway transport and through extension of economic commercial and social access to new and wider areas.

2. No country has as yet approached completion of its major highway system to the new standards and all countries face heavy demands for greater attention to accommodating their secondary and local roads to the needs of motor traffic. Though differing widely in character and degree in different countries, the problems of highway finance are universal and urgent.

3. To meet the large financial problems involved and to secure the fullest and quickest benefits from the new form of transportation, it is specially important that highways programs covering a period of years be set up well in advance and carefully budgeted. Adjustments to meet changing conditions and improved methods can readily be made as developments may require.

4. To facilitate financing and administration, and as a guide in determining the kind and extent of improvement, all highways should, as far as practicable, be classified according to the characteristics of their prevailing traffic as to origin, destination, and importance. Classifications usually applicable are:

(*a*) General use highways:
- (1) Main or national highways.
- (2) Secondary, departmental, provincial or, in countries of smaller geographical area, county highways.

(*b*) Local highways:
- (1) Local, vicinal, or communal roads.
- (2) Urban streets, including sections of main or secondary highways.

(*c*) Special highways: Military roads, autostrades, etc.

The first group includes the highways of general use, i. e., highways which receive traffic from a number of local roads or from a city or town and carry a considerable proportion of traffic into or through more than one rural jurisdiction. Every public highway should be definitely assigned to the appropriate class, and responsibility therefor should be fixed upon the authorities of the proper political unit.

5. In countries of vast area and sparse population financial limitations and traffic needs may direct primary attention to early development to minimum all-year standards of highways of secondary or local character to give access to rail or water transport lines. As highway development progresses, however, such secondary and local systems tend to integrate and through routes become identified with consequent demand and financial justification for higher type construction. It is important in the interest of ultimate economy that the requirements of the future main highway systems be considered in planning earlier highway development.

6. To promote efficiency of programming and administration highway authorities of higher jurisdictions should have actual supervisory or advisory relationship to the lower jurisdictions. The granting of subsidies or loans by the national to the lower jurisdictions under suitable conditions is an effective means of exercising the desired influence and of assuring financial possibility of carrying out highway programs in charge of lower jurisdictions having aspects of national concern, including special attention to undeveloped sections.

7. Provision for systematic maintenance of all highways after improvement is an essential feature of a sound highway program. If proper types of highways in relation to the character and volume of traffic are provided, maintenance costs should be less than with inadequate highways handling the same traffic. In making provision for maintenace, however, it should be borne in mind that traffic on improved highways tends to increase rapidly and, while the improvement thus benefits the users, it may increase the total of maintenance costs. For this reason maintenance of improved highways of general use, or at least any increase over the former normal maintenance costs, should be regarded as a first charge upon the user revenues.

8. The cost of constructing, improving, and maintaining adequate highway systems should be distributed equitably in relation to the direct and indirect benefits derived, taking into consideration the taxable capacity of those benefited. Wide difference of conditions and institutions in various countries makes it impossible to establish any fixed formula for general application but certain conclusions based on recent trends can be stated:

(*a*) Due to the benefits to society, business, and property in general the application of general tax revenues to highway purposes should continue, the amounts being dependent upon the needs for highways, the funds available and the demands for other purposes in the public budget. General taxes, carrying as they do a direct accountability to public opinion for efficient expenditure, are a particularly appropriate source of revenue for work on local roads, including urban streets.

(*b*) Assessment of abutting property should continue in urban areas but in agricultural areas only in proportion to actual benefit from the degree of improvement useful to such property. Thus where highways have been brought up to the standard needed for agricultural uses, special assessments on such land should where practicable be abandoned. Certain countries have already relieved agricultural lands of all taxation for highway purposes.

(*c*) Up to the limit where they become an undue burden upon users of the highways, user taxes, including license fees and fuel taxes, afford an important and increasing source of highway finance. If such taxes are made unduly high, or if the burdens upon vehicle owners are unnecessarily increased by excessive import duties in predominantly agricultural, nonmanufacturing countries, they tend to bring to bear the law of diminishing returns as well as to deprive the public of the benefits of normal development of motor transportation. For the same reasons user taxes should be applied exclusively for highway purposes. To provide uniformity over reasonable areas they should be imposed only by one of the higher jurisdictions. To maintain the sense of responsibility for collection and expenditure, they should in principle be expended by or under supervision of the collecting jurisdiction and, at least for the present, only on highways of general use (including the sections thereof within municipalities).

9. Because of the prevailing inadequacy of financial resources to permit prompt completion of highway systems corresponding to the economic requirements of motor transportation and because of the investment character of improved highways from which experience shows increasing returns in the form of user taxes may be expected, bond issues for highway construction and improvement are desirable in most countries. Such bond issues should, however, be limited to actual requirements for economically justified construction or improvement projects, under sound administration and with subsequent maintenance provided for out of current revenues. The bonds, if based primarily on user revenues for interest and redemption, which according to experience can be fully covered by such revenues under favorable conditions of highly developed motor transport, should nevertheless be backed by the full credit of the State. Bonds should be serial in form with maturities so arranged that annual requirements of principal and interest will be as nearly uniform as practicable. As more than half the cost of any highway represents grading, drainage, structures, engineering, rights of way, etc., which are of practically indefinite life, and as the other portions have life well beyond the period of amortization thereof under the serial form, the term of bonds for construction of main highways may be 30 years and for improved secondary highways 20 years. When the needs for expedited highway construction and improvement have been met, the use of bond issues should be discontinued and the pay-as-you-go basis followed, especially in cases where capital expenditures recur in each annual budget.

HIGHWAY TRANSPORT: CORRELATION AND COORDINATION WITH OTHER MEANS OF TRANSPORT; ADAPTATION TO COLLECTIVE (ORGANIZATIONS) AND INDIVIDUAL USES

General report submitted by HENRY R. TRUMBOWER, Professor of Economics, University of Wisconsin; Economist, U. S. Bureau of Public Roads

Highway transportation has in the last decade become firmly established in the general scheme of transportation in the important and progressive countries of the world. The people and government agencies of the several countries are beginning to investigate the possibilities of the coordination in the movement of persons and commodities by highway on the one hand and by rail, water, and air on the other. The coordination of rail and highway transportation is the more pressing problem. The development of highway transportation through the use of the motor vehicle has not been of equal intensity in all countries. To the degree that this development has gone on in a country to that extent has the problem of the coordination and correlation of highway and rail transportation facilities become the more pressing in its demand for a solution based upon broad economic and scientific principles so that the public as a whole may enjoy the maximum benefits of all of its transportation agencies.

Transportation by highway and transportation by rail are partly complementary and partly distinct services. Each one must be judged on its own merits. The considerations which govern the one are not the same as the considerations which govern the other. One can not be placed in a subordinate position as compared with the other.

In considering this problem of coordination it must be recognized that common carriers of both passengers and freight constitute but a very small part of the total highway traffic. Private automobiles, in the United States for instance, are handling most of the total travel and have taken from the railroads more than two-thirds of their local passenger business. Where such a condition occurs public authorities should permit the railways to adjust their train schedules so as to reduce passenger train miles as much as possible. Railroads find it advantageous to substitute for unprofitable trains busses owned by them or operated by one of their affiliated companies.

Bus operation, whether carried on by a railway company or by an independent operator, must be conducted as a regulated monopoly. Excessive competition results in less adequate service, with unnecessarily low rates, which aggravate the loss to competing railway lines.

In certain situations it is found that the small amount of traffic that highway common carriers might draw from the railways is largely compensated by the feeder service which they afford to main lines of railroads. This is especially true in mountainous countries where railway construction is extremely expensive. There the automobile, by superseding the old and slow means of transport, has brought about a revolution in traffic and has caused such regions to be better developed industrially and commercially.

In considering the various proposals for a closer coordination between rail and highway carriers, one of the following three plans is usually followed:

1. Voluntary cooperation between railroad companies on the one hand and operators of busses and common-carrier trucks on the other.

2. Inauguration of highway services by the railroad companies or obtaining financial control by the railroads of highway carriers.

3. Quasi-legal coordination with obligation placed on the different transport companies to agree to the creation of a system of cooperative operation and in case agreement is not reached the enforcement of compulsory coordination by governmental authority.

Motor-truck operations present a different problem from that of automobiles and busses because the freight carried by a truck might otherwise be hauled in a train, while passenger cars, including busses, have created an entirely new traffic a part of which railways never could have created or handled. On the other hand, it must be observed, trucks operating over good highways act as agencies for gathering freight which serve to increase the productivity of the farming areas and relieves the railways of short-haul freight upon which little or no profit could be made.

Common-carrier truck operations, as a whole, have not been profitable due to the competition of private and contract trucks. Common carriers of freight on the highways handle such a small part of the total traffic that the field does not appear sufficiently attractive for railways as a general proposition.

The average motor-truck trip is considerably shorter than the average passenger-automobile trip. Few hauls by truck exceed 100 miles and generally three-fourths of all movements are under 30 miles. These

results are shown by highway traffic surveys. The situation is quite different with respect to passenger-car operations. Surveys indicate that while nearly or about half of all passenger-car trips are under 30 miles in length, almost if not quite 25 per cent are longer than 100 miles.

Because of the peculiarity of highway traffic being free from specific road charges it is not possible without special effort to measure its volume as is done with railroad and other types of traffic. Estimates based on certain studies and investigations have to suffice.

For the further development of highway transportation that traffic should be financially self-sustaining. Monetary subsidies on the part of the State or of private interests should arise only in the opening up of certain regions or sections of country which are destitute of traffic. Otherwise, the motor vehicle should be in position to bear its own expenses and taxes in so far as they may be considered fair to the motor vehicle. This is true in particular with reference to the contribution for the maintenance of roads which the motor vehicle makes by the payment of motor-vehicle taxes. In this regard, it should be kept in mind that the highways are also at the service of other users and therefore the entire costs can not be imposed on the motor vehicle alone. Taxes should be measured very largely by the use made of highways and should not be such as would arbitrarily prohibit the use of the highways.

Railways and roads are now capable of rendering a service in excess of the traffic requirements of a given area. Cooperation between railroads and automobiles is one of the great requirements of the age. It is, however, much easier to demand a solution of the railroad-automobile problem than to present one.

1. TRAFFIC REGULATION IN LARGE CITIES AND THEIR SUBURBS; TRAFFIC SIGNALS; DESIGN AND LAYOUT OF ROADS AND ADAPTATION TO TRAFFIC REQUIREMENTS IN BUILT-UP AREAS

2. PARKING AND GARAGING OF ROAD VEHICLES

General report submitted by DR. MILLER M'CLINTOCK, Director Albert Russel Erskine Bureau for Street Traffic Research, Harvard University, Cambridge, Mass.

The control of street traffic in urban areas is generally recognized as a problem of great and growing importance, affecting vitally public safety and community economics. Relief is to be found in improved types of regulation and in a better design of physical facilities.

TRAFFIC REGULATION

The physical and financial difficulties involved in street reconstruction make it imperative that chief reliance be placed upon traffic control measures for the improvement of conditions in built-up areas.

Uniformity.—The rapid growth of intercity and international automobile traffic requires that serious attention be given to the question of uniformity in order that confusion may be avoided. Several countries are making definite progress toward national uniformity. A general similarity in the rules of the road would appear to make an international uniform code a practical possibility at the present time.

Basis for special regulations.—The design of traffic regulations to meet special local requirements demands careful investigation. Control measures based on guesswork may have serious economic consequences. Where properly applied, control measures have proved their ability to correct many difficult conditions. The design of regulations should be the responsibility of a competent technical agency of the Government. So far as possible traffic difficulties should be anticipated, studies made and regulations drafted, before conditions become critical.

Types of relief regulation.—For the improvement of conditions in congested districts emphasis is placed upon the use of rules to control pedestrians, to exclude certain types of obstructive traffic, to limit or prohibit parking, to provide better alignment of traffic, and to give the most efficient routing to traffic of all classes.

TRAFFIC SIGNALS

This title has been interpreted as including signs for the purpose of informing, warning and directing traffic, as well as signals used for the purpose of alternating traffic movements at intersections.

Uniformity.—The growing necessity for national and international harmony with respect to the design and use of traffic signs and signals is generally recognized. At present national standards with respect to signs show great variations. There is, however, an underlying harmony in principle. Thus all reporters emphasize the importance of shape, color, and symbols rather than text for the conveying of sign messages.

Practice with respect to traffic control signals shows a definite tendency toward uniformity. While there are several exceptions optical signals using the three colors, red, yellow, and green are generally favored. Flexible progressive timing is noted by several reporters as the most efficient type of coordination for signals located in congested districts.

Application.—The effectiveness of traffic signs and signals depends to a large degree upon the manner in which they are used. Adequate plans can not be designed by inexperienced persons. The function should be exercised by a competent public agency with technical experience.

DESIGN AND LAYOUT OF ROADS

The problems introduced by the automobile both with respect to volume of traffic and characteristics of movement have rendered street systems in built-up areas incapable of performing their services in an effective manner. For a correction of these difficulties emphasis is placed on details of design rather than upon comprehensive replanning.

Cross-section design.—The relation of width to effective traffic capacity is a mooted question. Decisions range from a conclusion that major streets can scarcely be too wide, to a belief that too generous widths have been used in the past. Similarly there is no general consensus of opinion as to proper lane widths.

It is recognized that there is a growing necessity for an accurate distribution of available roadway widths to the various classes of traffic demands and that where possible this division should be accomplished by the character of the design and construction. Traffic streams moving in opposite directions should be

separated by a neutral strip. Street car and automobile traffic should be protected from mutual interference by a physical separation of their operating lanes. Where possible, fast and slow traffic should be allocated to different operating areas.

Intersection design.—Several reporters express the belief that typical street plans provide too many intersections along main routes of travel and that future planning must provide less frequent access. All recognize intersection design as a critical problem in traffic difficulties.

Rotary traffic or provision for indirect, roundabout crossing is the relief most frequently proposed. It is generally accepted, however, that at the more heavily traveled intersections an actual separation of roadway grades will be desirable and ultimately necessary. Where a series of such intersections exists in close proximity this proposal leads logically to an entire elimination of grades through an elevation or depression of the main route. In highly congested districts the ultimate development suggested is a separation of rail, automobile, and pedestrian traffic by the use of three distinct levels.

General layout.—Planning should be based on a broad view of city and regional requirements substantiated by competent factual studies. In addition to adequate radial streets, the system should be provided with by-pass routes around the central congested areas and likewise with highway routes around the entire city so that through traffic may avoid the use of streets required for local traffic.

PARKING AND GARAGING OF ROAD VEHICLES

Parking is generally recognized as a secondary and inferior use of public streets and one which may be restricted or prohibited when it interferes with travel requirements. The elimination of all parking in congested business districts is a definite probability in view of growing traffic demands. The importance of parking from the standpoint of automobile use and business operations makes it imperative that alternative terminal facilities be provided.

Current developments indicate that such facilities will be supplied as demand arises in public or private parking lots or garages.

INTERNATIONAL ROAD CONGRESS ADOPTS GENERAL CONCLUSIONS

THE papers submitted by the general reporters to the Sixth International Road Congress were considered and debated in section meetings on Tuesday, Wednesday, and Thursday of the week of the congress, October 6 to 11. In these meetings the conclusions suggested by the general reporters were discussed, and various revisions and amendments were offered. The conclusions reached their final form in the section meetings of Thursday, and were submitted to the plenary session of the congress held at 2 p. m., Friday, October 10. The conclusions relative to the six questions which constituted the agenda of the congress are here printed in the form in which they were adopted at this plenary session.

QUESTION I-A: RESULTS OBTAINED BY THE USE OF CEMENT

1. Cement is becoming generally used as a paving material and has many inherent advantages. Rapid-hardening cement has special advantages in particular circumstances.

2. Cement has been used successfully in the construction of cement concrete base courses for other surfaces, for cement concrete pavements, and for cement-bound macadam.

3. Cement concrete pavements and also cement concrete base courses protected by appropriate wearing surfaces are suited to heavy traffic.

4. Where a large volume of steel-tired traffic is encountered, if cement concrete is adopted as a pavement material, a 2-course pavement with the upper layer composed of very hard aggregates should be used instead of a single-course pavement.

5. Single-course pavements have successfully carried maximum volumes of traffic and maximum wheel loads when the traffic was largely rubber tired.

6. Cement-bound macadam has been successful on roads carrying light traffic not inimical to the macadam type of construction. This method seems especially advantageous in locations where the condition of drainage or exposure are unfavorable to the use of ordinary water-bound macadam. A protective wearing surface seems equally indispensable on cement-bound and water-bound macadam.

7. In designing cement concrete pavements and cement concrete base courses to be surfaced with other materials the resulting pavements should have equal load-carrying capacity or structural strength, when similar traffic conditions are to be met.

8. Competent engineering supervision of design, construction, and maintenance of cement concrete pavements is necessary to insure good results.

9. It is desirable that subgrades be uniform and stable.

10. Pavement slabs must be designed to carry expected loads. Edge thickening is advantageous as a means of producing an economic and balanced structural design for concrete pavement slabs.

11. Longitudinal and transverse joints are commonly used and must be designed to meet traffic, subgrade, climatic conditions, and shrinkage of concrete, but in view of the fact that a number of concrete roads have been successfully constructed without joints, it is advisable that further research should be made on the whole subject of joints and cracks.

12. Scientific design of concrete mixes and weight proportioning of aggregates represent the most modern practice.

13. Construction operations are performed mostly by machinery, with resulting lower cost and better workmanship. The value of a cement concrete roadway depends to a large extent on the perfect execution of the work and, in particular, on the homogeneity of the concrete.

14. Thorough curing of concrete surfaces is essential.

15. Maintenance of concrete surfaces, properly constructed, is relatively simple and reasonable in cost. In particular, maintenance should comprise immediate filling with suitable material of the expansion joints and of any cracks which may occur.

QUESTION 1-B: RESULTS OBTAINED BY THE USE OF BRICK OR OTHER ARTIFICIAL PAVING

Brick paving.—Subject to suitable foundation, brick on edge will make satisfactory paving for light, medium, or heavy traffic according to the country in which it is used.

Specifications and tests for paving bricks should be prepared and submitted to the next Congress, with a view to standardization.

Rubber paving.—Rubber block paving has had limited application so far. It is, however, a silent paving and suitable for certain positions in large towns.

Research should therefore be continued in the following directions:

(*a*) Most suitable quality of rubber for street paving.

(*b*) Most suitable type of block and method of laying.

(*c*) Production and method of application of a suitable joining material.

(*d*) Reduction of costs.

QUESTION 2: THE MOST RECENT METHODS ADOPTED FOR THE USE OF TAR, BITUMEN, AND ASPHALT IN ROAD CONSTRUCTION

1. Tar, bitumen (asphaltic bitumen), and asphalt are suitable materials for use in the improvement of all classes of roads, subject to the limitations imposed by the characteristics of the material, the intensity of traffic, and local physical conditions. It is especially desirable to note the extended use in recent years of superficial coatings, in particular those effected with emulsions. Certain governing conditions generally recognized are:

(*a*) The use of the correct grade and amount of bituminous binder for the particular type of work and aggregates to be used.

(*b*) Suitable aggregates, correctly graded.

(*c*) Provision for prompt maintenance. When the foundation is adequate and when the surface can be maintained at reasonable cost, an advantage of the types of roads built with these materials is that they can be kept in good condition by maintenance of the surface without the need of extensive repairs to the foundation.

(*d*) Proper porportions of the constituent materials, thorough mixing and thorough compacting.

(*e*) Competent technical supervision of design, construction, and maintenance.

(*f*) Slipperiness. Attention should be given to the reduction of slipperiness. In some cases valuable results have been attained by the following methods:

(1) Adoption of suitable compositions containing the maximum permissible proportions of large aggregate.

(2) The rolling of plain or precoated chippings into newly laid surfaces.

(3) The use of minimum practicable camber of surface and proper degree of superelevation on curves.

(4) Treatment of existing surface with a suitable surface dressing compound, covering with coarse hard chippings, and rolling.

2. The need for research into the fundamental factors involved in the use of tar, bitumen, and asphalt in road improvement and maintenance is recognized. The attention of the Members of Congress is especially directed to needs as follows:

(*a*) Research into the constitutions and characteristics of bituminous materials and their combinations with other materials, with proper study of their application in the treatment of earth roads.

(*b*) Improvement of mechanical equipment for use with these materials and their combinations with mineral aggregates.

(*c*) Research into factors affecting the durability and serviceability of roads, such as climate, subsoil, traffic density, and road design.

(*d*) Data on economic factors, such as—

(1) Cost of transportation over various road types, including vehicle operation costs and roadway costs, with proper study of their application in the treatment of earth roads.

(2) Relation between maintenance costs and intensity of traffic for various road types.

3. In order that mutual understanding and helpfulness may be promoted, there is need for an international classification of materials, combinations of materials, construction methods; and road types which will correlate the terms in use throughout the world, both commercial and scientific.

QUESTION 3: THE CONSTRUCTION OF ROADS IN NEW COUNTRIES, SUCH AS COLONIES AND UNDEVELOPED REGIONS

1. It is desirable, in the first place, to form a central body with legal authority to coordinate and assist the general planning of the road communications of a country and the acquisition or reservation of necessary land.

2. The perfection which has been attained in the building of automotive vehicles often permits highways to render service in the exploration and development of new territories which formerly could be rendered only by railways.

3. The highway has over the railway the advantage of allowing the expense of construction and maintenance to be made proportionate to the importance of the traffic to be served. The present-day automobile being able to run on very difficult roads, at the beginning we can establish simple trails by nothing more than a primitive working over of the natural soil, the structures which are necessary being only those over permanent watercourses which can not be forded. The road will ultimately be improved by the construction of a roadway provided with an appropriate surfacing, and the construction of structures for crossing streams and valleys in proportion as the development of traffic makes available new resources for the execution of the work.

4. Adequate land should be acquired to provide for the eventual and ultimate expansion of the traffic as far as can be foreseen.

5. Before any actual construction is begun it is essential that the general highway layout should be prepared with due regard to the ultimate requirements of the permanent road system.

6. In countries of low density of population and where the construction of a large mileage of roads adequate even for light traffic is limited by the scarcity of available funds it is deemed advisable to adopt the progressive system of construction by stages. Every endeavor should be made to insure that the initial alignment, grading, and subsequent surfacing should

be such that all work executed should be capable of being ultlized in the ultimate development of the road structure.

7. In the first instance the actual traveled way should be so constructed as to be passable for motor traffic, but as economically as possible.

8. Locations in cut should be avoided when they have disadvantages from the point of view of drainage, and light fills are to be preferred.

9. Where traffic is light in numbers and unit weight earth roads have proved economical and satisfactory, but to conserve the surface of such roads until they can be improved, it is essential to restrict the weight per unit width of tire and speeds of individual vehicles to such an extent as may be necessary to prevent undue erosion or disintegration of the road surface.

10. For the establishment of roadways a width of 3 meters per traffic lane should be required. On structures a width of 3 meters, or even multiples of 3 meters, should be reserved for traffic.

It is recommended that from the beginning two-lane roadways be provided on important structures, at least in so far as the foundations are concerned.

11. Uniformly of design throughout the length of a location should be attained by avoiding heavy grades and sharp curves in stretches of road which in general do not contain them.

12. Some tests of mechanical grading of the roads have been made in desert regions; it is desirable that these tests be continued.

13. It is desirable also that systematic research be undertaken to determine the physical properties of mixtures of clays and sands which constitute the natural soils including soils containing hygroscopic salts, with a view to collecting useful data for the construction of earth wearing surfaces, appropriate for economic service in little developed regions having available few resources.

QUESTION 4: WAYS AND MEANS OF FINANCING HIGHWAYS: (A) ROAD CONSTRUCTION; (B) MAINTENANCE

1. The motor vehicle with increasing use creates demand for large expenditures for reconstruction and improvement of existing highways to new standards, construction of new highways and effective maintenance of all improved highways. It justifies such expenditures through improved economy and efficiency of transporation especially within areas previously served by highway transport and through extension of economic, commercial, and social access to new and wider areas.

2. No country has as yet approached completion of its major highway system to the new standards and all countries face heavy demands for greater attention to accommodating their secondary and local roads to the needs of motor traffic. Though differing widely in character and degree in different countries, the problems of highway finance are universal and urgent.

3. To meet the large financial problems involved and to secure the fullest and quickest benefits from the new form of transportation, it is specially important that highway programs covering a period of years be set up well in advance and carefully budgeted. Adjustments to meet changing conditions and improved methods can readily be made as developments may require.

4. To facilitate financing and administration, and as a guide in determining the kind and extent of improvement, all highways should, as far as practicable, be classified according to the characteristics of their prevailing traffic as to origin, destination, and importance. Classifications usually applicable are:

(*a*) General-use highways (including urban streets which form part of such highways):
  (1) Primary or national highways.
  (2) Secondary, departmental, provincial or, in countries of smaller geographical area, county highways.
(*b*) Highways of local interest:
  (1) Local roads.
  (2) Urban streets (except as indicated in subparagraph (*a*) above).
(*c*) Special highways: Military roads, autostrades, etc.

The first group includes the highways of general use, i. e., highways which receive traffic from a number of local roads or from a city or town and carry a considerable proportion of traffic into or through more than one rural jurisdiction. Every public highway should be definitely assigned to the appropriate class and responsibility therefor be fixed upon the authorities of the proper political unit.

5. In countries of vast area and sparse population financial limitations and traffic needs may direct primary attention to early development to minimum all-year standards of highways of secondary or local character, to give access to rail or water transport lines. As highway development progresses, however, such secondary and local systems tend to integrate and through routes become identified, with consequent demand and financial justification for higher type construction. It is important in the interest of ultimate economy that the requirements of the future main highway systems be considered in planning earlier highway development.

6. To promote efficiency of programming and administration highway authorities of higher jurisdictions should have supervisory or advisory relationship to the lower jurisdictions. The granting of subsidies or loans by the national to the lower jurisdictions under suitable conditions is an effective means of exercising the desired influence and of assuring financial possibility of carrying out highway programs in charge of lower jurisdictions having aspects of national concern, including special attention to undeveloped sections.

7. Provision for systematic maintenance of all highways after improvement is an essential feature of a sound highway program. If proper types of highways in relation to the character and volume of traffic are provided, maintenance costs should be less than with inadequate highways handling the same traffic. In making provision for maintenance, however, it should be borne in mind that traffic on improved highways tends to increase rapidly and, while the improvement thus benefits the users, it may increase the total of maintenance costs. For this reason maintenance of improved highways of general use, or at least any increase over the former normal maintenance costs, should be regarded as a first charge upon the user revenues.

8. The cost of constructing, improving, and maintaining adequate highway systems should be distributed equitably in relation to the direct and indirect benefits derived, taking into consideration the taxable capacity of those benefited. Wide difference of conditions and institutions in various countries makes it impossible to establish any fixed formula for general application, but certain conclusions based on recent trends can be stated:

(*a*) Due to the benefits to society, business, and property in general the application of general tax

revenues to highway purposes is desirable and should continue, the amounts being dependent upon the needs for highways, the funds available, and the demands for other purposes in the public budget. General taxes, carrying as they do a direct accountability to public opinion for efficient expenditure, are a particularly appropriate source of revenue for work on local roads, including urban streets.

(*b*) Any assessment of abutting or other benefited property, chiefly in urban districts and their environs, should be proportional to the actual benefit to such property.

(*c*) Up to the limit where they become an undue burden upon users of the highways, user taxes, including license fees and fuel taxes, afford an important and increasing source of highway finance. If such taxes are made unduly high, or if the burdens upon vehicle owners are unnecessarily increased by excessive import duties in predominantly agricultural, nonmanufacturing countries, they tend to bring to bear the law of diminishing returns as well as deprive the public of the benefits of normal development of motor transportation. For the same reasons user taxes should be applied exclusively for highway purposes. To provide uniformity over reasonable areas they should be imposed only by rules fixed by one of the higher jurisdictions. To maintain the sense of responsibility for collection and expenditure, they should in principle be expended under supervision of the collecting unit of government, and, at least for the present, only on highways of general use (including the sections thereof within municipalities).

9. Because of the prevailing inadequacy of financial resources to permit prompt completion of highway systems corresponding to the economic requirements of motor transportation, and because of the investment character of improved highways from which experience shows increasing returns in the form of user taxes may be expected, bond issues or other methods of borrowing for highway construction and improvement are desirable in most countries. Such bond issues should, however, be limited to actual requirements for economically justified construction or improvement projects, under sound administration and with subsequent maintenance provided for out of current revenues. The bonds, if based primarily on user revenues for interest and redemption, which according to experience can be fully covered by such revenues under favorable conditions of highly developed motor transport, should nevertheless be backed by the full credit of the unit of government concerned. The period of amortization of loans for highway construction should not exceed the life of the improvement. When the needs for expedited highway construction and improvement have been met, the use of bond issues should be discontinued and the pay-as-you-go basis followed, especially when capital expenditures recur in each annual budget.

QUESTION 5: HIGHWAY TRANSPORT; CORRELATION AND COORDINATION WITH OTHER METHODS OF TRANSPORT; ADAPTATION TO COLLECTIVE (ORGANIZATIONS) AND INDIVIDUAL USES

1. Highway transportation has in the last decade become firmly established in the general scheme of transportation in the important and progressive countries of the world. The people and government agencies of the several countries are beginning to investigate the possibilities of the coordination in the movement of persons and commodities by highway on the one hand and by rail, water, and air on the other. The coordination between different systems of transportation by land, by water, and by air should be so arranged that every transport should be done, as far as possible, through the most economical way and that most fitted to the particular needs. In this matter, the public authorities should adopt such legal and fiscal regulations as not to disturb the natural economic conditions of each transportation system.

2. The coordination of rail and highway transportation is the more pressing problem.

3. The development of highway transportation through the use of the motor vehicle has not been of equal intensity in all countries. To the degree that this development has gone on in a country, to that extent has the problem of the coordination and correlation of highway and rail transportation facilities become the more pressing in its demand for a solution based upon broad economic and scientific principles so that the public as a whole may enjoy the maximum benefits of all its transportation agencies.

4. Transportation by highway and transportation by rail are partly complementary and partly distinct services. Each one must be judged on its own merits. The considerations which govern the one are not the same as the considerations which govern the other. One can not be placed in a subordinate position as compared with the other.

5. In considering this problem of coordination it must be recognized that common carriers of both passengers and freight constitute but a very small part of the total highway traffic. In general, private automobiles form the most important part of highway traffic and it is they which compete most seriously with the railways in passenger traffic. Where such a condition occurs public authorities should permit the railways to adjust their train schedules so as to reduce passenger train-miles as much as possible. Railroads find it advantageous to substitute for unprofitable trains busses operated by them or others.

6. The operation of all Public motor omnibus services, irrespective of ownership, must be subject to adequate control by a responsible authority embracing a wide area so as to insure regularity, efficiency, and adequacy of service, safety of the public at large, and avoidance of excessive competition and uneconomic fares.

7. In certain situations it is found that the small amount of traffic that highway common carriers might draw from the railways is largely compensated by the feeder service which they afford to main lines of railroads. This is especially true in mountainous countries where railway construction is extremely expensive. There the automobile, by superseding the old and slow means of transport, has brought about a revolution in traffic and has caused such regions to be better developed industrially and commercially.

8. In considering the various proposals for a closer coordination between rail and highway carriers, one or more of the following three plans is usually followed:

(*a*) Voluntary cooperation between railroad companies on the one hand and operators of busses and common carrier trucks on the other.

(*b*) Inauguration of highway transport services by the railroad companies or financial and administrative control or participation exercised by these companies in the conduct of highway transport undertakings.

(*c*) Quasi legal coordination with obligation placed on the different transport companies to agree to the

creation of a system of cooperative operation and in case agreement is not reached the enforcement of compulsory coordination by governmental authority.

9. Automobile and bus operation, as well as motor-truck operation, produces new traffic, part of which the railroads could not handle, and which is enormously helpful in moving shipments of less than carload, and by introducing the use of containers, and thus helping to solve transportation problems between terminals in large cities. The passenger traffic created is both short and long haul, but the motor-truck traffic is in general short haul. It must be observed, trucks operating over good highways act as agencies for gathering freight which serve to increase the productivity of the farming areas and relieve the railways of short-haul freight upon which little or no profit could be made.

10. Common-carrier truck operations, as a whole, have not been profitable due to the competition of private and contract trucks. Common carriers of freight on the highways handle such a small part of the total traffic that the field does not appear sufficiently attractive for railways as a general proposition.

11. Traffic surveys, including studies of origin and destination of traffic, are of special value in revealing the true characteristics of various kinds of motor traffic and their relationship to other forms of transportation, whether as feeders thereto or supplementary thereof.

12. Highway transportation enterprises should be financially self-sustaining. Monetary subsidies on the part of the State or of private interests should arise only in the opening up of certain regions or sections of country which are destitute of traffic. Otherwise, the motor vehicle should be in position to bear its own expenses and taxes in so far as they may be considered fair to the motor vehicle. This is true in particular with reference to the contribution for the maintenance of roads which the motor vehicle makes by the payment of motor vehicle taxes, including gasoline taxes or duties.

13. Taxes for highway purposes should be borne not only by motor vehicles but by all interests which benefit from the highway system, and should not be such as would arbitrarily prohibit the use of highways.

14. Cooperation between railroads and automobiles, which has already been effected to some extent, is one of the great requirements of the age. In seeking such solutions the need of aviation by the provision of airdromes and roads leading to them must not be overlooked.

15. It is desirable for the convenience of the traveling public that there should be standard dates (with the minimum of exceptions) for new time schedules in public-road services, and that there should be universal as well as regional roadway time-tables.

16. The congress, considering that the question relative to the coordination of the various methods of transportation has received formal consideration at the International Congress of Railroads held in Madrid, May 5–15, 1930, under the title "Competition Between Automobile Transportation Systems and Railroads."

Not being able to proceed to the thorough study required by an examination of the conclusions of the Madrid Congress;

Resolves that hereafter the question of establishing coordination and harmony between the various systems of transportation by road, by rail, by waterways, and in the air be considered by the various international congresses that may be called upon to deal with it, and that reports be prepared by joint commissions of the accredited representatives of these various systems of transportation.

QUESTION 6: 1. TRAFFIC REGULATION IN LARGE CITIES AND THEIR SUBURBS; TRAFFIC SIGNALS; DESIGN AND LAYOUT OF ROADS AND ADAPTATION TO TRAFFIC IN BUILT-UP AREAS. 2. PARKING AND GARAGING OF VEHICLES

1. The congress confirms in general the conclusions of the congress of Milan on the fifth question relating to the layout of cities with regard to convenience and safety of traffic.

2. With respect to traffic signs and signals the congress urges the necessity for uniformity and adherence to the principle that shape and color shall be utilized to give indications.

(*a*) The congress recognizes the recommendations of the diplomatic conference held in Paris in 1926 and set out in Bulletin No. 57, May–June, 1928, as an important step toward this end, and it proposes that countries that have not accepted these recommendations should in designing systems of signs give due consideration to the principles contained in that bulletin. And the congress further proposes that an International committee be named by the permanent commission and the Executive Bureau of the Association of International Road Congresses to consider methods for the universal application of the principles contained therein.

(*b*) It is further recommended that the same international committee undertake to propose uniform standards for traffic control signals and other control devices. Pending the establishment of such standards, it is recommended that the color red in traffic control signals be used only for the purpose of stopping traffic; for other traffic indications, such as those marking obstructions in the roadway, the color red may still be used to indicate caution.

3. The Congress recognizes that the design of rules and regulations for the facilitation of traffic in congested districts is a problem of growing complexity and that specific control measures should be applied only after a competent study of local conditions by qualified officials and the cooperation of interests affected. Under suitable conditions the following types of regulations have been found useful:

(*a*) Parking restrictions through the application of space and time limits or prohibitions.

(*b*) Segregation of types of traffic through the exclusion of certain classes of vehicles.

(*c*) The regular alignment of vehicles en route through the use of traffic lane markings.

(*d*) One-way movement.

(*e*) Rotary movement at intersections where center islands of sufficient size and adequate visibility to permit easy rotation can be reserved.

(*f*) Control of turning movements at intersections and of U-turns between intersections.

(*g*) Pedestrian regulation.

4. The Congress recognizes the physical and financial difficulties involved in replanning congested and built-up districts in large cities. It believes, however, that substantial relief can be obtained through changes looking toward the adaptation of streets in such districts to the requirements of modern traffic. Among such adjustments are the following:

(*a*) Where economically possible public rail carriers should be removed from the street surface in such districts and placed in subways, or rapid transit, or

forms of transportation offering a minimum obstruction to traffic should be substituted, thus providing improved transportation and an increase in general traffic capacity.

(*b*) The passage of pedestrians across heavily traveled streets can be facilitated and protected through the construction of subways or bridges at street intersections or other natural places of crossing. In certain districts it may be desirable that such subways or bridges be sufficiently close together so that any crossing of the street surface by pedestrians will be rendered unnecessary. Where traffic is not sufficiently heavy to warrant such structures pedestrian traffic can be facilitated and protected by the use of definitely marked lanes at street intersections and other natural places of crossing.

(*c*) In order that prohibition or progressive restriction of parking may be applied without undue public inconvenience or economic hardship encouragement should be given to the provision of offstreet storage space economically and conveniently available. The congress holds that in certain cases it may be proper to require in the construction or remodeling of buildings the incorporation of suitable space for the offstreet loading or unloading and garagings of vehicles.

(*d*) The congress holds that traffic congestion and the resultant risk of accidents as well as economic losses are sufficiently great in certain instances to warrant consideration of expenditures for the construction of grade separation at intersections and indeed for the construction of elevated or underground streets.

5. As regards sections of the city in process of development, and suburban zones destined for future development, the congress urges the application of broadly conceived plans for their layout in order that the future may not result in a repetition of the difficulties now experienced in congested districts.

6. The congress holds that highway officials should give due regard to the amenities of the roadside and should be given such powers as may be necessary to give reasonable protection in connection therewith to highway safety and the recreational value of the road.

BUREAU OF PUBLIC ROADS ENTERS UPON NEW RESEARCH PROGRAMS

ORIGIN AND DESTINATION SURVEY OF MICHIGAN STATE HIGHWAYS BEGUN

In an effort to determine how much of the cost of local roads in Michigan should be paid by local taxpayers and how much should be spread over the State, the Bureau of Public Roads, in cooperation with the Michigan State Highway Department, is conducting an origin and destination traffic survey on all roads, local as well as main State highways, in sample townships in the 83 counties in the State.

The facts obtained by the survey will show to what extent the local roads of each local taxing jurisdiction are used by traffic originating within and without these jurisdictions; and will serve as a basis for the distribution of public funds now being made available for highway improvement. The survey will also determine the amount of tourist traffic in the State.

This investigation was begun on July 1 and will continue for one year, after which time the same agencies will make special studies for one month, in seven cities, to determine the relative use of city streets by city vehicles and by vehicles owned outside the cities. These studies will also be used as a basis for taxation. The cities selected are Ann Arbor, Detroit, Flint, Grand Rapids, Jackson, Lansing, and Niles.

DESIGN OF CONCRETE SLABS BEING STUDIED

To determine the relative efficiency of concrete pavements of several designs and to develop a more exact knowledge of the amount and distribution of stress in pavement slabs resulting from loads applied to them at different points, the bureau has constructed a number of full-size concrete pavement slabs at the Experiment Farm of the Department of Agriculture at Arlington, Va. The slabs will later be subjected to an elaborate series of tests.

A number of the slabs are of uniform thickness throughout. These are expected to give information regarding the relation between loads applied at various points and the stress and strain of the concrete at all points in the loaded cross section, and the relation between load resistance and slab thickness.

Other slabs are thickened at the edges and for a certain distance from the edges in accordance with the different designs used at present in several States. In some cases the thickening is provided for by excavating the subgrade under the edges of the slab. In others the surface of the concrete slab will be raised at the edges so as to form a low, rounded lip curb. In still others the lip curb is combined with a thickening of the edge of the slab at the bottom. Observations of these sections will give information regarding the relative load-resisting properties of designs now in use in various States.

The test slabs, which are 20 feet wide by 40 feet long, have central longitudinal and transverse joints, and one of the objects of the tests is to determine the efficiency of various methods in use for transferring load across these joints.

Other tests to be made include bond tests of dowel bars to determine the length of embedment necessary, the measurement of subgrade friction, with particular attention to the effect of edge thickening of transverse joints on resistance to the sliding of the slabs on the supporting surface, and the measurement of the movement of the slab in the subgrade as a result of temperature and moisture changes.

The work of constructing the slabs was begun early in July and is now completed. Preliminary strength tests will be conducted at the end of the 28-day curing period. Measurements of stresses caused by shrinkage were begun during the latter part of September.

ROAD PUBLICATIONS OF BUREAU OF PUBLIC ROADS

Applicants are urgently requested to ask only for those publiactions in which they are particularly interested. The Department can not undertake to supply complete sets nor to send free more than one copy of any publication to any one person. The editions of some of the publications are necessarily limited, and when the Deaprtment's free supply is exhausted and no funds are available for procuring additional copies, applicants are referred to the Superintendent of Documents, Government Printing Office, this city, who has them for sale at a nominal price, under the law of January 12, 1895. Those publications in this list, the Department supply of which is exhausted, can only be secured by purchase from the Superintendent of Documents, who is not authorized to furuish publications free.

ANNUAL REPORTS

Report of the Chief of the Bureau of Public Roads, 1924.
Report of the Chief of the Bureau of Public Roads, 1925.
Report of the Chief of the Bureau of Public Roads, 1927.
Report of the Chief of the Bureau of Public Roads, 1928.
Report of the Chief of the Bureau of Public Roads, 1929.

DEPARTMENT BULLETINS

No. *136D. Highway Bonds. 20c.
220D. Road Models.
257. Progress Report of Experiments in Dust Prevention and Road Preservation, 1914.
*314D. Methods for the Examination of Bituminous Road Materials. 10c.
*347D. Methods for the Determination of the Physical Properties of Road-Building Rock. 10c.
*370D. The Results of Physical Tests of Road-Building Rock. 15c.
386D. Public Road Mileage and Revenues in the Middle Atlantic States, 1914.
387D. Public Road Mileage and Revenues in the Southern States, 1914.
388D. Public Road Mileage and Revenues in the New England States, 1914.
390D. Public Road Mileage and Revenues in the United States, 1914. A Summary.
*407D. Progress Reports of Experiments in Dust Prevention and Road Preservation, 1915. 10c.
*463D. Earth, Sand-Clay, and Gravel Roads. 15c.
*532D. The Expansion and Contraction of Concrete and Concrete Roads. 10c.
*583D. Reports on Experimental Convict Road Camp, Fulton County, Ga. 25c.
*660D. Highway Cost Keeping. 10c.
*670D. The Results of Physical Tests of Road-Building Rock in 1916 and 1917.
*691D. Typical Specifications for Bituminous Road Materials. 10c.
*724D. Drainage Methods and Foundations for County Roads. 20c.
1216D. Tentative Standard Methods of Sampling and Testing Highway Materials, adopted by the American Association of State Highway Officials and approved by the Secretary of Agriculture for use in connection with Federal-aid road construction.
1279D. Rural Highway Mileage, Income, and Expenditures 1921 and 1922.
1486D. Highway Bridge Location.

DEPARTMENT CIRCULARS

No. 94C. T. N. T. as a Blasting Explosive.
331C. Standard Specifications for Corrugated Metal Pipe Culverts.

TECHNICAL BULLETIN

No. 55. Highway Bridge Surveys.

MISCELLANEOUS CIRCULARS

No. 62M. Standards Governing Plans, Specifications, Contract Forms, and Estimates for Federal-Aid Highway Projects.
*93M. Direct Production Costs of Broken Stone. 25c.
109M. Federal Legislation and Regulations Relating to the Improvement of Federal-Aid Roads and National Forest Roads and Trails.

MISCELLANEOUS PUBLICATIONS

No. 76. The Results of Physical Tests of Road-building Rock.

SEPARATE REPRINTS FROM THE YEARBOOK

No. *914Y. Highways and Highway Transportation. 25c.
937Y. Miscellaneous Agricultural Statistics.
1036Y. Road Work on Farm Outlets Needs Skill and Right Equipment.

TRANSPORTATION SURVEY REPORTS

Report of a Survey of Transportation on the State Highway System of Connecticut.
Report of a Survey of Transportation on the State Highway System of Ohio.
Report of a Survey of Transportation on the State Highways of Vermont.
Report of a Survey of Transportation on the State Highways of New Hampshire.
Report of a Plan of Highway Improvement in the Regional Area of Cleveland, Ohio.
Report of a Survey of Transportation on the State Highways of Pennsylvania.

REPRINTS FROM THE JOURNAL OF AGRICULTURAL RESEARCH

Vol. 5, No. 17, D- 2. Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements.
Vol. 5, No. 19, D- 3. Relation Between Properties of Hardness and Toughness of Road-Building Rock.
Vol. 5, No. 24, D- 6. A New Penetration Needle for Use in Testing Bituminous Materials.
Vol. 6, No. 6, D- 8. Tests of Three Large-Sized Reinforced-Concrete Slabs Under Concentrated Loading.
Vol. 11, No. 10, D-15. Tests of a Large-Sized Reinforced-Concrete Slab Subjected to Eccentric Concentrated Loads.

* Department supply exhausted.

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF PUBLIC ROADS

CURRENT STATUS OF FEDERAL AID ROAD CONSTRUCTION

AS OF

SEPTEMBER 30, 1930

STATE	COMPLETED MILEAGE	UNDER CONSTRUCTION					APPROVED FOR CONSTRUCTION					BALANCE OF FEDERAL-AID FUNDS AVAILABLE FOR NEW PROJECTS	STATE
		Estimated total cost	Federal aid allotted	MILEAGE			Estimated total cost	Federal aid allotted	MILEAGE				
				Initial	Stage	Total			Initial	Stage[1]	Total		
Alabama	2,185.0	$ 1,423,981.94	$ 698,828.28	66.0	8.2	74.2	$ 233,568.87	$ 74,516.46	9.3	3.4	12.7	$ 6,735,788.14	Alabama
Arizona	841.1	3,801,843.02	2,877,895.34	115.3	156.1	271.4	126,418.69	95,180.62	7.4		7.4	3,357,931.31	Arizona
Arkansas	1,758.3	6,292,192.35	2,941,684.25	201.7	46.9	248.6	1,540,747.32	754,671.24	41.9	14.0	55.9	3,048,828.19	Arkansas
California	1,893.8	8,921,624.43	3,617,771.56	154.8	28.0	182.8	1,731,506.38	992,791.97	80.2		80.2	4,565,455.56	California
Colorado	1,189.0	5,189,778.72	2,754,447.59	190.8	81.3	272.1	470,188.40	242,648.29	8.7	18.5	27.2	4,381,212.14	Colorado
Connecticut	243.3	2,595,633.60	1,099,282.57	14.0		14.0	1,102,981.71	299,475.70	14.1		14.1	1,275,603.64	Connecticut
Delaware	265.1	999,111.75	484,599.37	48.7		48.7	236,837.50	115,300.75	13.1		13.1	613,398.34	Delaware
Florida	533.8	4,357,695.12	2,067,901.37	68.7	5.5	74.2	204,596.52	102,348.26	2.8		2.8	2,952,084.34	Florida
Georgia	2,635.2	6,513,030.85	3,083,753.12	166.1	121.7	287.8	751,502.62	375,751.30	27.9	13.0	40.9	5,443,898.25	Georgia
Idaho	1,196.9	2,392,533.19	1,416,770.76	135.6	66.5	202.1	679,023.40	404,000.00	41.9	9.0	50.9	1,986,881.68	Idaho
Illinois	2,029.5	21,978,528.25	9,761,867.69	600.2	59.8	660.0	5,457,496.96	2,540,375.36	173.2	12.5	185.7	6,918,659.70	Illinois
Indiana	1,501.1	4,560,726.70	2,213,573.73	143.5		143.5	903,188.23	375,647.33	26.2		26.2	5,300,374.24	Indiana
Iowa	3,020.3	6,293,199.10	2,674,699.94	53.6	160.5	214.1	105,290.11	1,882.77		4.1	4.1	3,342,943.56	Iowa
Kansas	2,868.9	5,865,333.73	2,731,414.41	269.7	42.9	312.6	581,641.94	289,931.92	25.7	64.4	90.1	4,725,772.35	Kansas
Kentucky	1,351.3	8,020,105.08	3,477,907.07	165.2	182.4	347.6	1,647,449.83	721,196.77	35.8	66.3	102.1	2,159,516.56	Kentucky
Louisiana	1,389.1	4,227,372.00	2,044,306.69	159.0	20.9	179.9	338,235.46	167,617.68	10.6		10.6	2,821,022.08	Louisiana
Maine	537.2	3,613,823.09	1,345,397.65	88.1	1.6	89.7	578,520.39	285,808.09	.8		.8	1,996,257.84	Maine
Maryland	637.4	2,186,716.86	1,079,444.71	47.5	15.4	62.9	207,165.30	61,951.50	1.7	1.5	3.2	1,062,567.00	Maryland
Massachusetts	676.5	6,763,730.11	1,719,020.60	73.0	2.6	75.6	129,662.90	64,831.45	.3		.3	3,462,764.36	Massachusetts
Michigan	1,675.7	8,384,077.03	3,543,097.12	195.9	23.9	219.8	3,664,138.17	1,369,938.00	92.5	5.0	97.5	5,062,062.85	Michigan
Minnesota	3,938.3	11,265,966.45	4,122,963.71	223.7	263.1	486.8						3,512,038.03	Minnesota
Mississippi	1,839.7	639,084.13	319,245.57	36.1	7.7	43.8	319,042.54	159,521.27		13.5	13.5	5,592,293.28	Mississippi
Missouri	2,495.7	9,390,230.00	3,197,689.59	147.4	70.4	217.8	2,805,400.38	1,047,806.86	48.6	22.4	71.0	3,960,764.41	Missouri
Montana	1,791.6	7,529,443.42	4,247,199.90	540.1	58.1	598.2	1,622,711.98	892,903.64	151.2	26.8	178.0	5,118,410.38	Montana
Nebraska	3,692.8	6,953,887.70	3,199,958.77	288.5	166.0	454.5	760,799.61	294,614.52	17.4	39.6	57.0	4,592,523.07	Nebraska
Nevada	1,149.3	1,307,156.79	1,139,533.89	23.2	192.0	215.2	138,434.19	121,105.48	12.6	1.3	13.9	2,057,687.07	Nevada
New Hampshire	353.7	2,044,130.73	711,604.89	44.8	1.6	46.4	81,583.72	23,581.59	.1		.1	609,375.00	New Hampshire
New Jersey	525.7	4,909,506.35	1,209,046.32	48.9		48.9						2,547,196.76	New Jersey
New Mexico	1,930.0	3,814,042.23	2,569,046.44	203.3	56.3	259.6	712,070.87	501,076.98	14.7	1.7	16.4	2,432,674.88	New Mexico
New York	2,514.6	25,632,497.76	5,112,255.00	341.2		341.2	6,414,820.00	1,190,122.50	82.3		82.3	12,520,578.54	New York
North Carolina	1,841.9	4,422,488.49	2,163,801.05	161.8	28.9	190.7	215,495.42	84,433.76	23.5	4.9	28.4	4,764,268.94	North Carolina
North Dakota	4,357.0	2,244,309.44	1,155,395.71	337.2	168.6	505.8	1,068,973.70	534,192.97	122.5	157.1	279.6	2,872,713.86	North Dakota
Ohio	2,271.1	21,681,326.36	7,317,736.45	395.5	35.1	430.6	2,099,233.50	703,234.17	20.8	.9	21.7	4,593,489.21	Ohio
Oklahoma	1,875.3	5,887,078.98	2,698,204.75	195.9	85.3	281.2	565,163.93	265,375.89	10.5	12.0	22.5	3,017,320.73	Oklahoma
Oregon	1,161.2	8,234,903.47	3,673,761.76	256.3	85.2	341.5	143,535.04	89,321.02	14.9		14.9	2,068,408.08	Oregon
Pennsylvania	2,449.1	19,524,518.15	5,662,438.04	232.5		232.5	1,067,334.04	405,554.08	12.5		12.5	5,640,675.45	Pennsylvania
Rhode Island	200.2	2,051,112.63	816,911.64	32.1		32.1	200,206.21	100,103.10	3.7		3.7	619,426.42	Rhode Island
South Carolina	1,861.7	5,300,990.82	2,071,954.52	110.0	97.1	207.1	895,711.34	352,064.20	5.6	19.5	25.1	1,774,814.24	South Carolina
South Dakota	3,610.0	3,738,529.35	1,969,648.14	327.1	109.7	436.8	1,240,676.96	792,318.89	135.3	67.1	202.4	2,474,876.73	South Dakota
Tennessee	1,262.8	5,060,630.69	2,281,631.75	204.5	48.5	253.0	547,929.01	271,984.22	17.7		17.7	3,677,439.86	Tennessee
Texas	6,877.1	13,224,668.90	5,433,537.44	402.0	174.6	576.6	3,464,353.45	1,409,642.26	160.1	61.9	222.0	10,878,570.91	Texas
Utah	990.8	1,323,216.90	964,148.84	86.2	10.6	96.8	538,156.73	397,048.50	44.8	47.9	92.7	1,841,003.60	Utah
Vermont	264.7	2,018,787.08	651,008.71	39.1	2.6	41.7						824,276.71	Vermont
Virginia	1,506.7	5,042,651.57	2,404,014.84	211.6	9.7	221.3	707,736.74	295,194.20	26.4	3.0	29.4	2,581,842.72	Virginia
Washington	947.6	3,648,888.06	1,607,800.00	80.7	36.3	117.0	403,146.13	137,900.00	5.4		5.4	3,008,091.86	Washington
West Virginia	717.1	4,077,973.39	1,464,206.58	91.0	33.5	124.5	1,236,248.30	490,887.70	36.0	7.7	43.7	1,356,531.59	West Virginia
Wisconsin	2,255.2	9,030,206.39	3,719,751.29	212.7	65.1	277.8	1,179,243.19	489,200.00	31.0	3.9	34.9	2,977,034.41	Wisconsin
Wyoming	1,665.1	2,815,729.45	1,869,521.35	206.5	131.2	337.7	261,811.39	164,482.48	19.0	23.5	42.5	1,781,439.50	Wyoming
Hawaii	41.2	863,565.80	358,459.43	21.6		21.6	226,820.16	113,414.57	9.2		9.2	1,852,789.59	Hawaii
TOTALS	84,815.7	308,026,558.29	125,737,130.39	8,458.8	2,961.4	11,420.2	49,596,898.23	20,673,060.29	1,639.9	726.4	2,366.3	172,500,557.85	TOTALS

[1]The term stage construction refers to additional work done on projects previously improved with Federal aid. In general, such additional work consists of the construction of a surface of higher type than was provided in the initial improvement.

U. S. GOVERNMENT PRINTING OFFICE: 1930