highway improvements lags behind the need for improved highways and is not a desirable solution of the problem

3 Shift part of the burden of highway improvements from real property to other sources of revenue

By substituting other sources of revenue for a portion of the real property revenue, we cannot decrease the total revenue raised by the various units necessary for purposes other than highway improvement A reduction in the amount of highway improvement revenue raised from the taxation of real property without raising a like amount from some other source of revenue would result in a reduction of the total highway funds below a necessary minimum The logical solution is to increase the total revenue raised from old or to create new sources of revenue for highway improvement to replace the revenue lost by the lowered taxation of real property The source of this increased revenue is the highway user, whose demand for highway service is largely responsible for highway improvements

Charles M Upham, State Highway Engineer of North Carolina, gave an illustrated discussion on

RESEARCH PROGRAM OF THE NORTH CAROLINA STATE HIGHWAY COMMISSION

The immediate necessity in research work is the practical application of our present knowledge already obtained by research We now have vast funds of knowledge that have been obtained through research, but the benefits obtained by the present knowledge have not been developed to an extent commensurate with the labor and money expended The reason for this is the non-application of the knowledge already supplied Therefore, our problem is not necessarily a problem of research alone, but also a problem of application

Probably there is nothing new in the fact that North Carolina has a research program, because every state, county or municipality that is carrying on the construction of highways has, to some degree, at least, a research program In addition to this, laboratories scattered throughout the United States are also carrying on various researches A survey by the Highway Research Committee disclosed the fact that many hundreds of projects are in operation Some of them, of course, were duplicates, but the fact was disclosed that a great amount of research is being carried on

The difficulties of a research program are numerous, but probably no more important problem exists than that of keeping research within practical limits and carrying it on in such a manner that when completed it may have a practical application and serve as a step in working out economically some of the highway problems Already a vast amount of research knowledge has been acquired, and this information is written into bulletins and distributed, but, unfortunately, many times the bulletins are of little practical value, because they do not reach the proper persons, nor are they written in a manner that will serve the busy official who generally organizes programs Our research problems are still unsolved because the important step—the application of highway research work—has not been accomplished.

The problem of research seems to divide itself into two minor problems—research of the problem itself and the application of the research results The application of the results obtained is such an important step that it could almost be considered a research problem in itself, and a proper study of this application would be well worth while We find that a great amount of research has been carried on, but as yet a vast amount of the knowledge gained has not been applied to road-building, and consequently the economical value of the research has been lost

In North Carolina every attempt has been made immediately to apply the results of research Almost every step in construction is being studied in detail, and when anything of value is discovered it is immediately applied to construction on a large scale

Not only does research include problems that may be carried on by the laboratory, but it includes transportation problems, problems that will ultimately render road service to the user of the highway The great research problem is to render road service to the public so that transportation may be more economically carried on These major problems of transportation and road service are, of course, influenced by other problems, such as the problems of construction, maintenance and operation In all highway research there should be constantly kept in mind the question of how the results of this research can influence the road service rendered to the user of the highway

Sand asphalt pavement—One research that has recently been carried on has been the development of progressive type roads Certain localities in North Carolina furnish practically no road-building material, with the exception of sand The problem in this instance was to devise some means whereby these large quantities of sand could be used in road construction The answer came in the construction of the sand asphalt road, which is made up of approximately 88 per cent sand and 12 per cent asphalt These roads may be constructed in either single or double track, according to the needs of the traffic, and are generally constructed 4½ inches in depth This method of construction affords a moderately low cost road, which renders very satisfactory road service to the locality It is not expected that this type of road will stand up under a large amount of heavy truck traffic, but it is a development road and is satisfactorily rendering road service to the user of the highway Though this type of road is, of course, the result of laboratory research, it is more particularly the result of the proper application of laboratory research

Marl rock base—Another locality in North Carolina furnishes no stone for road aggregate, but it does have an underlying strata of marl rock, the result of a large deposit of shells Although at some time this deposit must have been on the seashore, at the present time it lies some 8 or 10 miles back from the ocean and about 4 or 5 feet underneath a swamp This marl rock is being quarried and crushed and is furnishing an excellent base for a sand asphalt surface While the details of this construction were taken from earlier road work, still the use of this marl rock means the practical application of investigative research

Subgrades—The studies of subgrades have been demanding considerable attention during the past few years, but there seems, even at this time, to be a lack of proper application of the findings It has already been determined that different soils are affected differently by the varying amounts of moisture In some cases, however, no attempt is made to select the best soils for subgrade purposes In many localities a proper selection of soils will not only furnish an ideal subgrade, but will serve as a road, a subgrade highway, to take traffic up to as high as 400 vehicles a day These selected soil roads may be maintained for a period and then used as an excellent subgrade for the next better step in construction

Capillarity—Recent research has brought to light considerable information regarding the capillarity of different soils For a long period it seemed as though a poor subgrade or a clay condition might be best remedied by the construction of a Telford foundation Now it appears that the Telford foundation served as a drain to carry away the free water, but was of little, if any, value in taking care of the capillary moisture Recent experiments have shown that a layer of material similar to sand is more effective as a means of cutting off capillary moisture This explains why excellent results have been obtained in the construction of macadam roads on clay subgrades when screenings have been spread on the subgrade It also explains the excellent results obtained with bituminous roads constructed on a gravel and sand foundation

Research has shown that capillary moisture in the subgrade is not cut off from the overlying road surface as efficiently by coarse material as it is by ordinary sand The reason probably is that the subgrade material finds its way into the interstices of the coarse material and the capillary tubes of the subgrade material continue to act through the interstices of this coarse material whereas, in the case of the sandy material, the subgrade material of high capillarity is excluded, and therefore the capillary action of the sand is not so great This is an important point and one that can be taken advantage of and easily and economically applied to road work on a large scale much more so than is commonly done

Veneer surface—Another important application of research work is in the construction of stone veneer on earth roads In the south there is an exceptionally large mileage of earth roads, consisting mainly of the sand clay, topsoil and gravel types The bearing power of these roads is high and the strength is great, yet maintaining these roads is a problem, since they offer little resistance to abrasion Thus the problem in this particular instance is to secure some means of protecting the surface against abrasion and to abate the resulting dust nuisance The answer seems to be the stone veneer surface in which the quality of an asphalt wearing surface is combined with the strength of an earth road Several attempts have been made in applying bituminous material to earth roads The results, in general, have been unsuccessful because, even though the bituminous material was sufficiently light to penetrate the surface, it had no binding power or strength whatever, and if the bituminous material was sufficiently heavy to have a binding value, it would congeal on the surface and peel off, owing to a dust mat that formed underneath the bituminous material With the veneer surface, a layer of stone of approximately three inches in size is applied to the earth road and rolled partly into the surface, after the surface has been scarified or loosened This veneer surface of stone is then penetrated with a bituminous material having a consistency to give sufficient strength to hold the stone in place and afford resistance to wear This bituminous material is then covered with proper sized stone, is rolled and then opened to traffic The stone is held in place from below by the earth road and has become an integral part of it The bituminous material holds the stone in place on the surface and affords resistance to traffic abrasion Thus we have a combination of the strength of an earth road and the wearing qualities of an asphalt pavement—another instance of the practical application of research work

Hard surface types—coarse aggregate—Another problem in construction is the ideal construction of hard-surfaced roads Much laboratory research has determined that the aggregates must be of certain qualities and properly graded Recent experiments in concrete work have shown that much depends upon the grading of the aggregate Although the early tests indicate that a large aggregate gives a higher strength value, long-time tests seem to show that the aggregates below an inch and a half give higher strength values In this instance we have a research giving one result, yet it is impossible to apply this result in its entirety, since the present arrangement of crushing plants and aggregate production machinery does not furnish economically an aggregate that gives the highest ultimate strength Therefore the proper application of this research demands a compromise approaching the ideal conditions

Core drill—Considerable research is being carried on attempting to correlate the laboratory tests of materials to the final product as found in the pavement by the core drill At the present time it seems there are so many variable factors that it is impossible to control all of them, and, as a consequence, the final product varies considerably

Not only have studies of the coarse aggregate been made, but a new test for fine aggregate has been developed, which seems to permit a wider range of fine aggregate to be used, or, in other words, aggregate that would be condemned under the standard test can now be used with safety This test consists essentially of testing the aggregate in compression and transversely rather than in tension, as is done in many of the present-day standards

Investigations in cement also show that this material varies considerably, and that the final strength of the road depends primarily upon the quality of the cement used It seems that individual brands may vary considerably. This may not be only a question of manufacture, but also one of handling and storage until the cement is used

Surface finish—Possibly no single demand on a pavement is so great as that of impact of traffic Impact depends entirely upon the smoothness of the road surface, therefore considerable study has been given to obtaining smooth surfaces This has been put into practice by devising various means of finishing the surface

In the case of concrete, it is found that the smoothness of the surface depends upon many factors, chief among them being the consistency of the concrete and the character of the subgrade The subgrade, after being wet by the concrete, expands or contracts and the green concrete in the road surface does the same Various types of check templates are being used to check the surface before it sets up, so that it may be corrected while still plastic In the case of the bituminous roads, test-boards and straight-edges are used during construction After the road has been opened to traffic it is again tested. Recently, experiments have been carried on with the vialog, an instrument devised for measuring unevenness of road surfaces

There has been much discussion relative to the detailed construction and maintenance research problems, but probably the most pressing problem and the most immediate need is a solution of the proper methods for taking the research work that has already been done and giving it practical application This leads us to the problem of organization and personnel, the varying results obtained in the work show the influence that personnel has on any undertaking Research in construction and maintenance problems deals with definite quantities, but research in organization and personnel, since it deals with varying factors of the human mind, is more difficult so solve The proper and economical application of research work still involves research in the matters of personnel and organization It is useless to spend time, money and effort in carrying on research unless the results are applied in such a way that our highway problems will be more economically solved than they otherwise would be In order that the facts may be used to the greatest advantage, they must be presented to the proper persons in a way that is definite, concise and easily understandable

Third Session

The meeting was called to order at 9 30, Friday morning

Chairman Johnson The Board has received a report of cooperative work being carried on in Iowa on "Impact in Highway Bridges," by Prof Fuller, Chairman of the Subcommittee of the American Society of Civil Engineers on Impact in Highway Bridges His report is upon the cooperative program between the U S Bureau of Public Roads, Iowa State College, and the Engineering Experiment Station of Iowa State College Dr Hatt will read this report

Dr Hatt Mr Fuller's report is as follows

Cooperative work was begun in the summer of 1922 An important item at that time was the adaptation of existing instruments or the development of new instruments for measuring dynamic stresses A number of instruments were tried out, with the result that only those best adapted to the purpose were used in 1923

A description of the 1922 work, discussion of the various instruments used, and a portion of the results have been published as Bulletin No 63 of the Engineering Experiment Station of Iowa State College The greater portion of this bulletin was included in the 1922 report of the Committee on Impact in Highway Bridges of the American Society of Civil Engineers and published in its Proceedings for March, 1923

The general scope of the work for the summer of 1923 is indicated in the following

Structures investigated

1 One-hundred-and-fifty-foot span, 20-foot roadway, through curved chord steel truss with concrete floor on steel stringers, known as the Skunk River Bridge, on the Lincoln Highway, located about three-fourths of a mile east of Ames

2 Thirty-three-foot span, 20-foot roadway, consisting of concrete floor on steel stringers This is an approach span to the main Skunk River Bridge

3 Seventy-foot span 24-foot roadway, through plate girder, with concrete floor on steel stringers This is known as the Squaw Creek Bridge, on the Lincoln Highway, and is located within the city limits of Ames

4 Forty-foot Pony truss bridge, 18-foot roadway, with reinforced concrete slab resting directly upon transverse floor beams, located on county road near Roland, Iowa, about twenty miles from Ames

Loads

1 Two 15-ton trucks with solid rubber tires, with about twelve tons on the rear axles and three tons on the forward axles

2 A 10-ton Holt caterpillar tractor (on structures 1 and 2 only and only for about two hours)

Range of work

Floor —Rather complete work was done on the stringers of structures 1, 2 and 3 and on the floor beams of 1, 3 and 4 This includes impact on smooth floor, over one-inch obstructions and over two-inch obstructions, and also distribution data for static loads which show the actual unit stresses on all of the stringers for one and for two trucks

Trusses —Readings have been taken upon the greater portions of the web members of structures one and four, of the chords in structure four, and of the girder flanges in structure three

Time —Field-work was started on July 1 and ended September 15

Instruments

1 Three Turneaure recording extensometers

2 Five West direct reading extensometers

3 One photographic mirror recording extensometer developed by the U S Bureau of Public Roads, available after August 1

4 Six electrical remote reading and recording strain gages, in which records of all six instruments are photographed on one roll of paper—developed by U S Bureau of Standards and made available for one week in September through courtesy of that Bureau

Calibration of instruments

Before the field-work was begun the instruments were calibrated for static stresses No suitable equipment was then available for dynamic calibrations Two more or less impromptu devices have since been developed which have given, within reasonable limits, positive as well as comparative calibrations under rapidly changing conditions These have been, first, an impact machine in which a weight was dropped upon a tension bar to which the instruments were attached, and, second, a vibrating device which produced known changes in length in very short but known increments of time The work of calibration, while yet not complete, has been carried far enough to insure a reasonably accurate interpretation of results, which will be compiled as soon as practicable

Chairman Geo E Hamlin presented the

REPORT OF COMMITTEE NUMBER 4, ON HIGHWAY TRAFFIC ANALYSIS

During the year many states have carried on, to a greater or less extent, highway traffic censuses Attached to this report is an analysis of the characteristics of such surveys, with data obtained The detailing of this data shows that the various states realize the importance and value of traffic information and are each year increasing the census records to specify additional information of movement, commodity and length of haul

In this connection, the chairman wishes to call particular attention to Prof Blanchard's recommendation, that this committee strongly differentiate between a highway traffic census and a highway transport survey The traffic census will give information pertaining to the traffic using the highway at the time the census is taken, the purpose of the highway transport survey is to determine the probable amount and character of the future traffic which will use a given highway during the lives of its several component parts Up to the present time, the information collected by the various states has given traffic census information, but as far as the chairman has been able to determine, no state has extensively taken up the highway transport survey