

# Scientific Achievements of the Highway Research Program

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In evaluating the highway research program of the past as well as of today, one might try to find those really significant changes or improvements in highway activity which can be traced to research. In preparing this presentation that was my first plan of attack. But such an approach did not prove fruitful. Many important changes in the highway field have occurred and they—as most changes in any field—resulted from uncountable bits of knowledge developed over many years by many individuals from research. Specific significant events were hard to identify.

Dr. Ralph Landau, a recognized entrepreneur in the chemical industry and vice president of the National Academy of Engineering in 1983 and 1982, suggested in a 1982 paper that those kind of significant accomplishments for which I was looking are “breakthrough innovations.” Such innovations change the direction of a whole industry and create new industries and new jobs. They also change the rate of growth of our economy significantly. In the transportation field he suggests only three such breakthroughs since World War II—jet airplanes, space vehicles and lead-free gasoline.

Such accomplishments of research, of course, are not the usual product. Most often the accomplishment of a research project is the production of new knowledge—and that is what should be expected for that is the objective of research. Basically and foremost of all, research is the search for new knowledge, for new information. Any topic is researchable about which total knowledge is not known. Research is the search for total truth. So wise a man as Aristotle noted “The search for Truth is in one way very hard and in another way easy. For it is evident that no one can master it fully nor miss it wholly. But each adds a little to our knowledge, and from all the facts assembled there arises a certain grandeur”.

In evaluating the accomplishments of research then, the measure that we should use must include an evaluation of the knowledge found—and therein lies great difficulty. Very often new knowledge is not implemented immediately and even if it is, more valuable implementation often results years later when combined with other bits of new knowledge.

The development of some better way of doing things often results from the integration of a bit of knowledge from research here, another bit from research there, etc. If any one of several bits of knowledge had not been found by research, the new development, the better highway, the improved transportation, the better quality of life would not have resulted.

With this knowledge, I decided the wisest approach to my task was to explore important changes in highway activities which have occurred and try to relate them to research activities.

Scientific roadbuilding in this country dates from the early 1890's and first was primarily concerned with the building of earth roads. Developments then were by experiment with surfaces of earth, earth-oil mixtures, portland cement, or paving brick. Early road materials testing laboratories also came into being during this period, 1890-1910, and good construction practices for building roads became known, largely through the Office of Public Roads. Methods of construction developed in France strongly influenced these early construction practices.

A major result of the experiences of this period from a scientific point of view was the need for far more systematic knowledge about the characteristics of soils and bituminous products and how best to use them to construct a quality road. This, of course, was the beginning of the science of soils engineering and pavement design.

Constant maintenance of these dirt roads, if there was much traffic, was required to eliminate ruts and to promote run-off of water. Such smoothing and shaping of roads had been periodic for many years. (Figure 1.) The development of the "King" drag about 1905 and its application



**Figure 1. Road Maintenance in the Early 1900's**

served as a major impetus for the application of routine road maintenance throughout the developing country. Again, French practice was used experimentally to determine desirable maintenance practice in this country. Although effective practices resulted they were more costly than most local road authorities could bear. More important, for development of roads in this country, was the conclusion that except for very lightly travelled roads more durable surfaces than soil were necessary.

It was also about 1910 that experiences in several local areas of the country and from maintenance demonstration projects conducted by the Office of Public Roads (OPR) resulted in the knowledge that competent engineering supervision of all phases of road work was very desirable. Educational programs for civil engineering students in the science of road-building had their birth in the OPR and in colleges and universities about this time to satisfy the developing needs for highway engineers.

By 1910, it was clear that good roads depended on the application of scientific principles by knowledgeable persons for success. The result was the development of scores of organizations promoting good roads and good roads practices. Much publicity in news media and influential magazines provided information on the need for good roadbuilding practice. Road conferences, road schools and "Road Improvement Trains" spread good roads information throughout the country. Just prior to the first World War, Good Roads Congresses beginning in 1911 and held annually through 1914, promoted the use of scientific roadbuilding, the need for highway research, and the principles of good roadbuilding that guided the highway movement in this country to the beginning of WWI.

The years 1890-1915 can be noted as the developing period for scientific highway engineering in this country. The great need for good roads was clearly developing, the basic principles of how to build good roads were becoming understood and the development of a strong constituency among the growing population of the country for good roads was initiated.

Few of us really realize the isolation which rural residents of the 19th century and before endured in this country. There was no rural mail delivery, no telephones. Newspapers were available only in the towns. Because of bad roads, especially in the spring and winter, children could not get to school except by long walking, often with great difficulty. Churches were often only partially filled. Neighbors could communicate with each other only with difficulty. The only really eligible husbands available to the young ladies were those within a few miles from where they lived. The choices available to our great grandparents and even our grandparents were few. Under these conditions and for the purpose of eliminating this terrible isolation of the rural population, the development of good roads became a major goal of the country—a goal with strong people support.

I provide this picture of rural transportation before 1900 because

I want you to compare it to the picture of highway transportation in the U.S. today—the huge improvement is probably the most significant accomplishment of scientific highway development in this country.

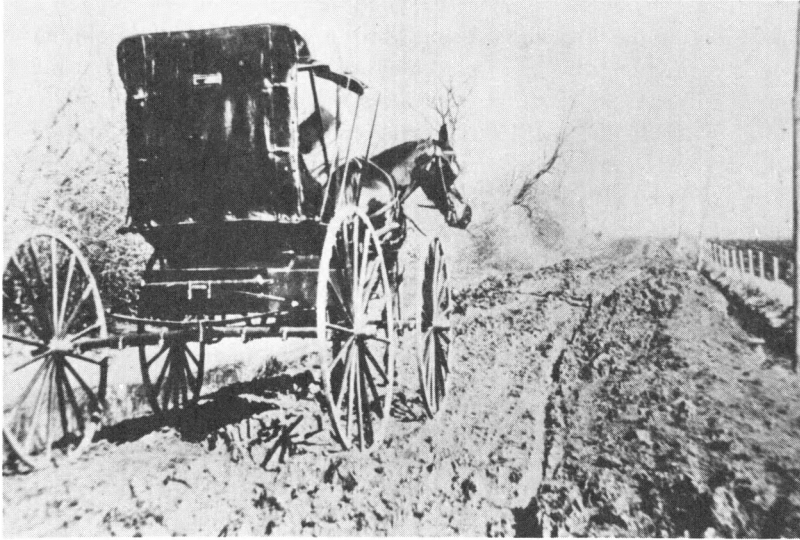


Figure 2. Roads in the Early 1900's and Today

Between 1920 and 1980, the art and science of highway transportation developed significantly. Much of the progress is unquestionably the result of the continuing highway research program throughout this period.

Since 1921, when federal fiscal support of highway research was first authorized on a sustained basis and especially since 1934 when the Hayden-Cartwright Act authorized the use by the states of 1 ½ percent of all highway federal aid funds for “surveys, plans and engineering investigations”, research in the highway area has steadily developed. By 1964, this provision in federal statute became a mandatory one—the 1 ½ percent must be used for planning and research or lost.

Prior to 1920, an understanding of the physical behavior of road materials largely was developed by trial and error and criteria and tests were largely based on empirical relationships. Very little of a scientific nature about road materials was known except as to their reaction under travel on the highway.

During the 1920's and 30's, emphasis by the Bureau of Public Roads and many state highway departments on obtaining accurate scientific information regarding the characteristics of road materials, especially soils, relative to load carrying ability led to the development of various materials tests. One significant development was the development of a soil classification system for soils relative to load bearing characteristics. It was also during this period that soil research developed tests for measuring compaction during construction and the important moisture content needed.

In the 30's and 40's, the uses of electrical resistivity and aerial photo interpretation were developed through research to provide effective information on what was on or below the surface without excavation or ground surveys. Widespread use of these methods, much improved through continuing research, is common today.

During the early years of research and continuing even yet, research has developed much knowledge in the area of asphalt technology. Standards for such materials and test method specifications in use today developed are still being fine tuned to provide guidelines for the procedures and uses of bituminous materials. In the 1940's, the development of standard tests to predict the amount of hardening of hot-plant mix asphalt and another to evaluate the effect of moisture on compacted bituminous mixtures provided valuable knowledge on the control of these two major causes of highway failures.

In the area of concrete technology, continuing research by many organizations since the early 1900's with much emphasis in the 20's and 30's resulted in many bits of new knowledge which were utilized in other research to develop tests on the cement, aggregates and paving mixtures. The result is the several tests, procedures of construction and uses of this material in road building as we know it today. Additional knowledge produced from continuing research today provides for improvement of these tests and procedures so as to provide for better concrete roads.

Research on aggregates, especially since the 1930's, has permitted

the development of standard aggregate sizes and desirable grading combinations for bituminous and concrete construction. Research also produced over the years much knowledge about characteristics of aggregates necessary to provide a durable product. The development of air entrainment techniques and air entraining agents from research during this period has also been very important.

Much research on paints for highway use over the years has produced many developments in this area. This includes more durable materials for structure as well as for traffic control. New knowledge from research in each decade and still continuing has led to continuous improvements in this area. More recently, the development of plastic materials and methods for their application, often by industry, has provided the highway with more durable traffic control materials.

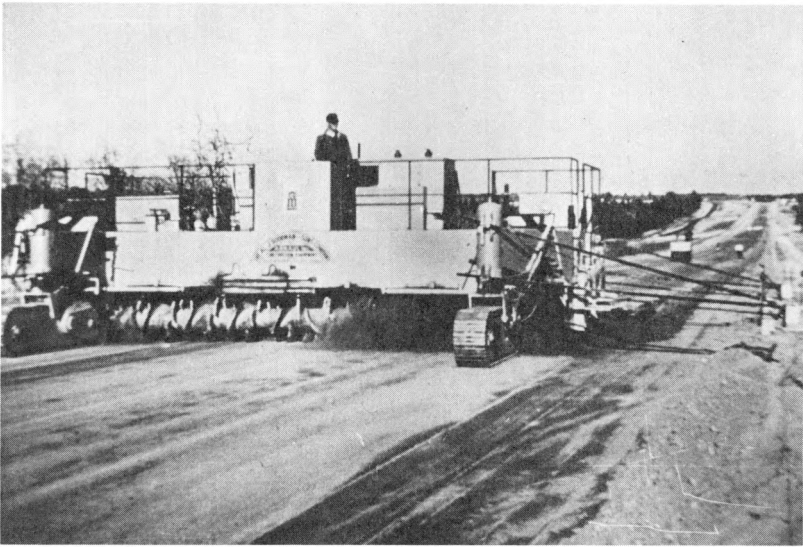
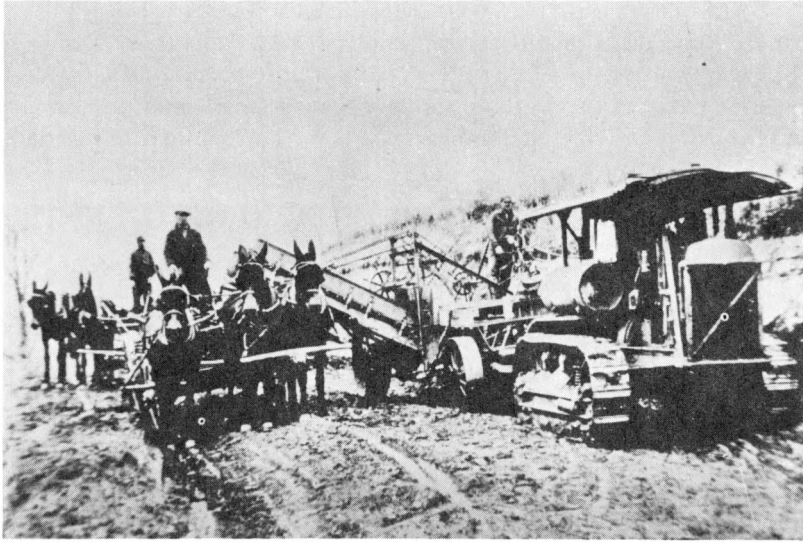
Pavement design today has developed to its present art as the result of research by many individuals and organizations. The use of experimental roads using new or modified design concepts and their evaluation over the years has produced much new knowledge which has been used by others to develop the pavement design techniques in use today. In recent decades, knowledge known has resulted in the development of continuously reinforced concrete and prestressed concrete pavements.

Evaluation of pavement condition has been the topic of much research in recent decades. Knowledge gained has resulted in equipment to measure pavement roughness, slipperiness, and deflection under loads. Service life of pavements has also been the subject of much research. Knowledge obtained from this research in the 50's and 60's enables highway authorities to provide wiser management of their system.

Bridge research, especially on the characteristics of the materials to be used, has produced many bits of knowledge which is utilized today in the design and construction of these facilities. Bridge model research, materials research, welding and joint research, the use of prestressed concrete, research on curved girder design and many more subjects have provided the knowledge which today permits the design and building of bridges unheard of a few decades ago.

The series of large road tests conducted in this country, the first one initiated in 1918 and culminated with the large AASHO Road Test completed in the 1960's were major research activities which produced important knowledge about highways. Much of this knowledge is used in many ways in the designs of highways today.

In the construction area, the developments in construction management and of much special purpose equipment has resulted from knowledge produced in many research projects by many individuals, organizations and industries.



**Figure 3. Roadbuilding 1920 and 1980**

Highway operations has experienced much research which has produced many important results. Research on the effects of roadway geometrics and development of equipment to measure operational factors has produced standards of geometric design relative to road widths, curves, shoulders, grades, and other features. Research on signing has resulted in the development of national standards.

The development of knowledge in highway capacity, led by BPR's O.K. Norman in the 40's and 50's, has enabled the wiser design of highways capable of serving the growing traffic volumes. The highway capacity manual was certainly a mile-stone in highway development, and research to refine and improve it has been continuous to this date.

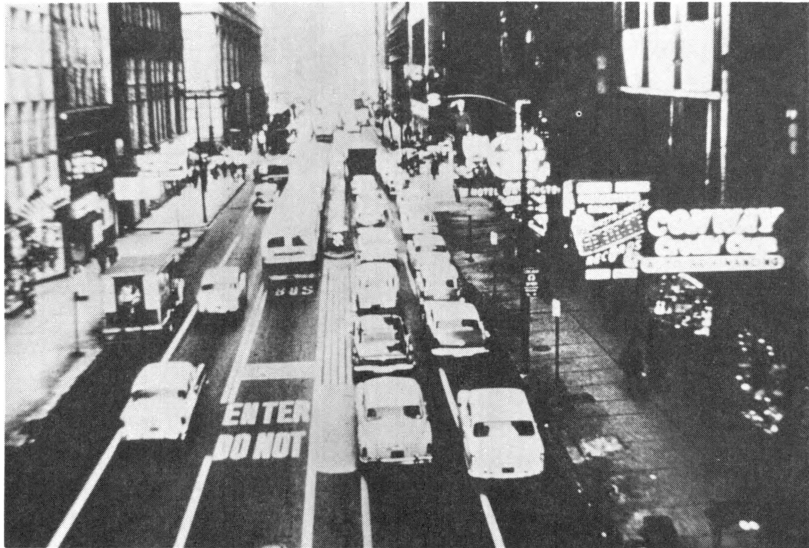
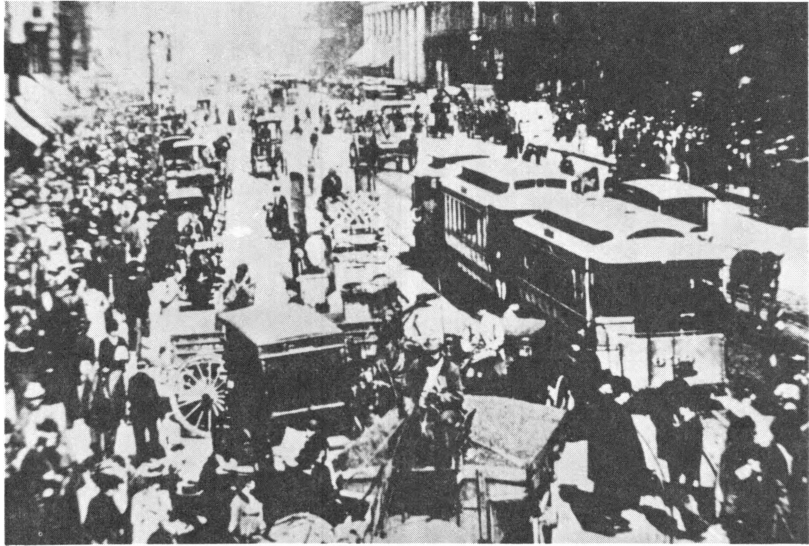


Figure 4. Travel in Chicago—Before and After the Automobile



The development of traffic control devices in recent decades was necessary because of the tremendous growth of traffic. Safety of the motorist required the provision of controls which could and would be obeyed. Research, again by many, constantly produced, and still produces, much new information in this area. The development through research of simple as well as sophisticated control equipment has resulted in traffic controls which can be utilized today and which permit safe, efficient flow of high volumes of traffic. Standardization of such controls and constant addition of new developments have been possible because of the continuous flow of new knowledge resulting from many research activities throughout the nation.

Modern successful freeway control systems, illumination of highways, control of access, and control of roadside hazards have all become operational as the result of knowledge gained through research. Each is very important today in the provision of highway transportation. Research on the driver and human factors in driver performance have been significant in producing the improved safety record of this country as well as benefiting the vehicle driver and passengers in other ways—comfort, reduced stresses, etc.

Research in the area of hydraulics and hydrology, an area of great importance to highways, has produced knowledge which permits estimation of realistic run-off, improved design of culverts and bridges permitting adequate storm flow, and road and shoulder design and maintenance which control erosion. Research in roadside development has provided standards which result in a highway environment pleasing to vehicle occupants, in refined vegetation management, and in an improved aesthetic environment for the adjacent land occupants. Control of air, noise and water quality, snow and ice, and provision of necessary services to the motorist are all developments for which much of the progress must be credited to knowledge produced by research.

Finally, one must mention the importance of research in recent years of means to accelerate the utilization of knowledge from research to practice. And one must also note the significant research recently completed or currently still in progress.

In reviewing a listing of current research program outputs prepared by FHWA one finds many important results which have and are occurring. Time will not permit mention of all but a sampling of recent accomplishments includes:

- Improved breakaway luminaire supports
- Improved concrete median barrier shapes
- A self-destroying barrier guardrail
- A system for inventorying road surface topography
- Improved ice detectors

A practical method for removal of unwanted pavement markings  
 An inexpensive non-toxic, whiter yellow paint which appears yellow at night  
 An effective system for applying salt brine for snow and ice control  
 New guidelines for using changeable message displays  
 Self-powered vehicle detectors  
 High strength, low water-cement ratio concrete overlays for bridge decks  
 Polymer concrete overlays  
 A technical manual for use of shale in embankments  
 Computer programs which evaluate embankment stability  
 A method of weighing-in-motion utilizing existing bridges  
 New seismic design guidelines  
 Prestressed concrete highway pavements  
 Pavement management systems  
 An equipment management system  
 A construction engineering manpower management system  
 Breakaway barricades  
 And many, many more.

What have been the accomplishments of highway research over the years? When we compare highway transportation today with that prior to 1900, there is no argument to a conclusion that great progress has resulted in the highway systems we use today. Today we have great mobility. We can and do travel long distances or short distances from where we are to where we want to go—and we do it in relative comfort, with reasonable speed and safety.

Dr. Robert H. Cannon, Jr., former executive of the U.S. Department of Transportation, described these changes as follows:

“I chose transportation because it is exciting and because it is absolutely pervasive to human endeavor and human interaction. “It was not always so, of course: there was a time when the individual homesteader stayed put, growing and making what his family needed, and having littler interaction with his neighbor, let alone the rest of the world. In economic terms, there was at that time no “demand” for transportation. Notwithstanding, the *opportunities* transportation presented would not be denied—the opportunity to specialize economically and exchange with one’s neighbor to the clear advantage of both (one raising wheat and the other cattle, for example). And so interaction and transportation grew together, each fostering the other; and with them grew the various facets of the quality of

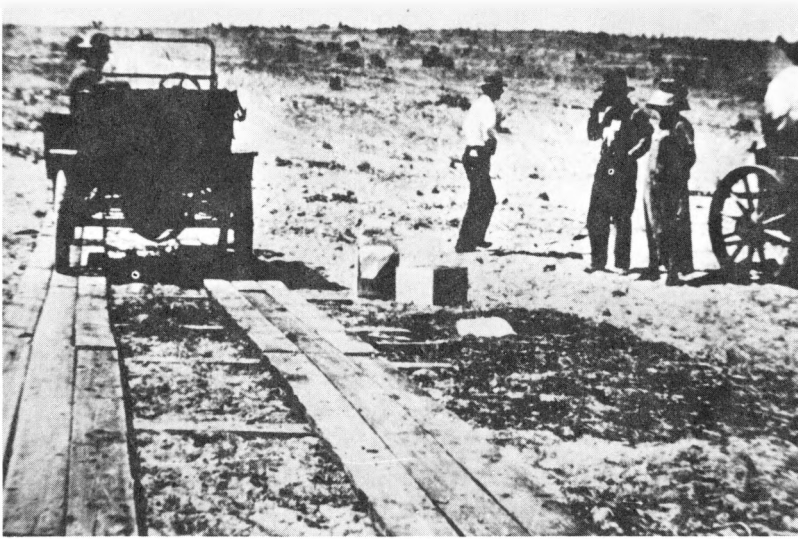


Figure 5. Early Roads and Modern Highways

life—material wellbeing, security, and social and cultural quality as well. “Today we are an intimately and ubiquitously interdependent people, each specializing to his heart’s content; each *totally* dependent on the others and on the viability of the *system* of which we are all a part. “Transportation is the life’s blood of that system.

It carries the goods and services on which we depend so totally; and it carries *us*, as we interact with one another, as we make our own contribution to the others. And new technological opportunities . . . will and must continue to make possible undreamed of new levels of transportation service.”

Unquestionably this tremendous mobility system we have today—the U.S. highway system—is the greatest scientific accomplishment of highway research. It is the product of knowledge developed heavily by research by many individuals and organizations over many years.

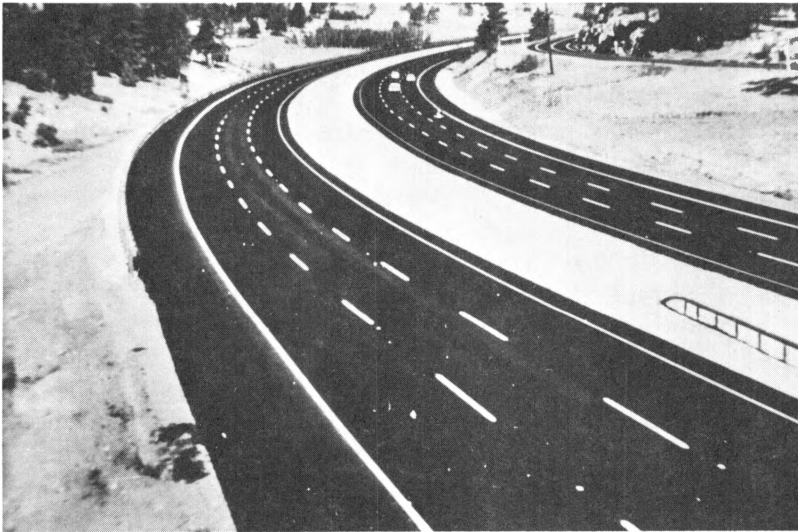
The development of this great highway system we have would not have been possible, however, without another great benefit of research—the development of capable leaders in highway transportation. One of the great accomplishments of research is the development of the finest minds to become the leaders of tomorrow and the developers of additional new knowledge about highway transportation through research.

The accomplishments of research through this education process of new minds and the nurture of their enthusiasm in the search for new knowledge is well illustrated by the documented case of a researcher at MIT, Professor Morris Cohen. Professor Cohen for the past 35 years has had continuing research projects funded by the Office of Naval Research. During this time, he has guided 40 graduate students. The research has been in the materials science area and has resulted in the development of new knowledge of outstanding significance. These 40 research projects resulted in 98 professional papers, 15 of which have received awards for outstanding achievements.

But those immediate results are just the tip of the iceberg. A survey of 19 of the 36 students in this program who have graduated revealed they since have published 891 professional papers in the materials science and related areas. They now have their own students in academia and industry and the chain reaction continues. This example is similar to many others throughout the U.S. including several in the transportation area here at Purdue—K.B. Woods for example. And that leads to the mention of another major accomplishment of research—the inevitable development of the technology leaders of tomorrow. They move extensively throughout their profession to all parts of the country. They apply their knowledge and train others in ever expanding numbers.

The production of much new knowledge and the education of many new researchers, basically directed at solving highway problems, have been major reasons for the development in this country of the finest highway system in the world, a cornerstone of the excellent quality of life which we enjoy.

Highway research has produced significant accomplishments but as Deputy Director Lamm of FHWA said yesterday here at Road School



**Figure 6. Progress 1920 to 1980 Has Been Spectacular**

the 80's and the 90's must include an expansion of highway research and development in the country. There still is much which is not known and much that is known that is not fully applied.