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# LOW-VOLUME ROADS: SECOND INTERNATIONAL CONFERENCE
## ADDRESSES AND RESEARCH NEEDS

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FOREWORD

The Second International Conference on Low-Volume Roads was held at the Scheman Continuing Education Center, Iowa State University, Ames, Iowa, August 20-23, 1979. It was conducted in order to facilitate the exchange of information on the practical application of engineering principles and current practice in the design, construction, and operations of low-volume roads. Proceedings of the Conference were published in Transportation Research RECORD 702. Dr. Ray Milland's keynote address was also published in RECORD 702.

This circular contains some material presented at the conference but not published in that RECORD. The presentations at the Plenary session regarding the federal, state, and county views of low-volume roads appear in Part I. The summary from the session on technology transfer to developing countries is Part II. Part III contains the summaries of the Conference from the national and international view. Research needs and implementation items are presented in Part IV while Part V contains the list of conference participants. Part VI Errata for RECORD 702.

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# Part I
# PLENARY PRESENTATIONS

## FEDERAL VIEWPOINT

Lester P. Lamm, Federal Highway Administration

Good morning, ladies and gentlemen. I think people have a right to ask what is the federal role in low-volume roads? In fact, many of you, particularly those of you who traveled here from other countries, might even ask, what's the interest of the United States, in general, in low-volume roads.

If you read about the highway system in the United States, you obviously see heavy concentration on the interstate highway system--if you landed at the airport in Des Moines and traveled here by way of high-speed highways, you don't really get a flavor for the bulk of the highway and road network in the United States. I'm happy to see that the program includes a tour, so that those of you who are not familiar with United States highways, particularly in the Midwest States, will have a chance to look at the part of the system that feeds onto the interstate system. These roads don't get nearly as much attention as the interstate system, although they have their own problem, and there are a number of financial requirements on all levels of government.

The federal interest, in general, stems from some authorization by the United States Congress. That is, we in Federal Highway Administration can't invent an interest in low-volume roads or in any other phase of highway development. We need to be authorized to get into that activity by the Congress, and, in general, Congress follows the United States Constitution. In the case of the highway program, it's the Constitutional requirement to provide for interstate travel and also for national defense.

That, in turn provides a reason for the federal government to be involved in highways in general; and if you want to go back into history, in 1916, Congress first recognized that the state and local governments were not able to completely finance the development of a road network around the country, and, therefore, they began a program of federal aid to state and local governments to help finance the improvements that the lower levels of government desire. I want to emphasize that the federal funding is to help state and local governments in correcting system deficiencies that they see. The Federal Highway Administration has no role in managing the highways once they are completed; has no role in developing the priorities around the state or around the country.

The initial goal of the federal aid highway program beginning in 1916, was to provide something that the United States didn't have then--in fact, almost nobody around the world had, and that is an interconnected system of highways tying together towns and cities around the country.

In 1916 obviously all roads in the country except in some of the largest cities were low-volume roads, so you might say that we have been involved in the federal aid highway program with low-volume roads since 1916. Congress, though, began to realize that there were too many roads to really tie together a system of improvements, so beginning in 1921 the federal funding was directed to a small portion of all the roads and streets around the country, a seven percent system. The principle was that the federal government's role in seeing that highways were improved should start with the ones that carried the heaviest traffic. So even though everyone's volumes in the 1920 period were really low, we were working on the highest-volumes highways.

Then about thirty-one years after the initial federal aid activity Congress saw some other problems that were not being solved, and in 1944 authorized federal funding beyond the seven percent system, for a new federal aid secondary system. The concept here, the overriding goal of these dollars, was to provide an efficient way for farmers to get produce to market or for any other rural activity of production, timber or ore, or anything like that, to be delivered to the marketplace. The concept again was that within the ninety-three percent of all roads and streets that didn't previously have any federal aid on them, we would look to a system of collector highways that would serve as the principal feeders into the arterial network that we had been working on for thirty years. In 1944 the original federal aid secondary highway system generally included low-volume roads. Even today, about fifty percent of the system is classified as low-volume roads, if you break at, say, four hundred vehicles per day. One other feature of the 1944 legislation was that on the secondary system, for the first time, the county level of government was given a proper role in the identification of where the problems are and how they want to solve them with the federal funds. Beginning in 1944, we had a three-party system in managing federal aid highway funds. The funds are provided through us, through the Federal Highway Administration, but they are used either at the state or the local level.

Another thirty years, roughly, passed after 1944 and Congress again retailored the federal aid system to try to take care of some problems that the earlier programs hadn't done. Beginning in 1973 and carrying through last year, Congress began to provide federal funding for the large numbers of highways that previously hadn't had any funding available. Roughly seventy-five percent of all the roads and streets in the country are not on the federal aid primary or secondary system. Until 1973, it was totally a state and local problem to correct any deficiencies in those systems. However, in 1973, Congress authorized new programs, not for routine maintenance activities, but to take

care of the non-repeating very high costs that are involved when you resurface a road for the first time in twenty years, or perhaps rebuild a bridge that was initially built in the 1920's.

These programs again were focused primarily on activities that are the responsibility of the local level of government; and the principal goal that Congress was reflecting there was not so much interstate travel, or national defense, but it was recognizing that these occasional high costs are beyond the capability of most local levels of government to finance. Most counties cannot budget for a once-in-a-lifetime two million-dollar bridge repair project, and, consequently, a lot of problems were being deferred and bridges were being closed.

Now, in today's market, we have a battery of federal aid highway programs, some of which go back sixty years, some of which go back thirty years, but which in total are designed to take care of some of the severe problems on any eligible road and street around the country. There are two points worth making. The first is that the level of attention that's being given to the top segment of the highway system is still greater, because given the interstate program, federal aid primary and other programs, many times the number of dollars are made available per mile of highway on the primary system, the seven percent system, as there are at the eighty percent level. In other words, Congress still recognizes considerably more of a federal role in the larger traffic-carrying parts of the system, than in the local roads. And the second is, that in no case is there enough money to do all of the improvements that are required--not at any level--not at the state level--not at the county level--not within cities--so that everyone who has a part in the federal aid highway program management in the United States has as his principal role to try and decide what improvements he is going to make with the dollars that are made available.

Looking at what might happen in the future, I think it's been somewhat of a coincidence that the earlier actions by Congress seem to fall in a thirty-year cycle, so I would say there isn't necessarily another big change coming twenty-four years from now. It may well be that Congress will keep the current battery of programs for a long period of time. I'll repeat again that the dollars that exist now are not sufficient to correct all the problems in the years ahead. By 1995 or the year 2000, we can still forecase that the highway and bridge needs of the country are going to be very considerable. In fact, at our current level of spending--federal, state, and local, given the impact of inflation and other financial problems we have, we'll be lucky to even keep up with the deterioration that takes place in the system each year. Beyond the money, there are other activities at the federal level that are worth mentioning to this group. They tie into a number of sessions that you are going to have later on in the program. The principal one of these that I would like to mention is an effort on the part of the federal government to take care of roads and streets that the federal government owns and maintains. I mentioned that the federal aid program involves no federal maintenance, no federal operating requirements. However, within such areas of land as national parks or national forests, or military reservations, which are under the control of the federal government; federal agencies also have a responsibility to operate, maintain, and rebuild highway and road systems to provide access within their areas. One role of the Federal Highway Administration is to act as an engineering resource to the other federal agencies, to help in the design and construction of road and bridge improvements. Roughly 300,000 miles of road and street around the country are under federal control and just about all of those could be classed as low-volume roads, so we have in effect our own little laboratory, our own little group of facilities on which we can practice what we might preach on other terms. We also manage a very small program for highway dollars to concentrate on economic development. The reason that the pool is so low is that by comparison with the road networks in most developing countries, our road and street network is almost all in place. We don't look for a number of years of increasing system expansion. We look to try and make better use of the system that we have.

Another FHWA activity that is very significant to the meeting here is in the area of transportation-planning and in highway research and development. Here, there is a principal federal role. A lot of activities are cooperative through the Transportation Research Board, through the state organizations, and with NACO, and some other local organizations. We have a level of federal interest in identifying the best or most productive areas of research over the next few years and to report to Congress periodically on the long-term highway needs on this local segment of the system, which primarily includes low-volume roads. We also have projects underway to study local and state level financing capabilities, again at the request of Congress.

Another activity which we have underway relating to your program includes research projects designed to improve maintenance, or engineering equipment, or construction, or design methods, or just our general level of knowledge of how to get the most improvement for the limited number of dollars which we have.

A final area in which the federal role is very significant is in the area of highway safety. Even though on an absolute basis, there aren't many fatalities on a typical mile of low-volume road, simply because there isn't very much traffic, the accident rate on low-volume roads is twice as high as on higher-volume roads. Our total national accident picture is one that we cannot live with for a long period of time.

So, to summarize, the federal interest that we have might be surprising to those of you making your first visit to the United States. There is a very extensive mileage of what anyone would consider low-volume roads in the United States, and there is a fairly extensive federal role in trying to identify the proper methods of correcting deficiencies on this part of the system. As mentioned, I have to leave for another meeting in a different part of the country; but before I leave, I would like to point out that there are staff people here from Federal Highway Administration, and they'll be available for the entire conference if you have any questions about what we are doing, or if you would like us to do something. I would like to ask the FHWA staff people to stand up so that your neighbors in the audience can have a look at you. I enjoyed being here, and I wish you a very successful conference.

## STATE VIEWPOINT

Darrell V Manning, Director, Idaho Transportation Department, Boise, Idaho

In transportation today we coordinate development of our systems with nearly every organized group in society. We have formalized coordination into complex systems which are unbending and sometimes cast in legal and regulatory stone. Today, as a result, our greatest need is for flexibility.

For the last quarter-century the United States has been engaged in the greatest public works project in the history of man. During this 25-year period, we have built most of the 42,500-mile network in this country called the National System of Interstate and Defense Highways. It has had the greatest impact on the economy of the United States of any single public works project. It has had the largest impact on the lifestyle in the United States in the last 25 years. As great as the Interstate System is, it still relies on a well developed system of primary, secondary, and low-volume roads in order to feed it. It has done something else: It has raised the expectations of the people who use all classes of roads. They now expect the same superior standards used on the Interstate System to be employed in building low-volume roads on the primary and secondary systems. The public expects a much higher level of overall highway service than any nation or government, at any level, can provide. This is one of many vexing problems facing us today.

We definitely need good highway systems at all levels, but frankly we don't need the same high standards for all roads, nor do we need a single uniform standard for all roads in order to serve the people. Each of us has a responsibility in his own jurisdiction to keep foremost in the minds of the citizenry that investments in these road systems must be maintained at a high rate because they are an investment in the basic means of production! Too often, our citizens think of road expenditures as "cost" and not "investment." There is a difference. We need to turn public thinking around so the people support our transportation investments.

Guidelines -- in the form of standards -- are extremely important and we definitely need well thought-out-guidelines to make fitting transportation decisions. We need standards which provide roadways that can be maintained efficiently. We need standards which minimize the vulnerability to tort liability and insurance claims. We need standards which help revitalize existing low-volume roads and, finally, we need standards which provide guidelines for accommodating new development. In the United States especially, many of the new roadway developments are made by private investors which are then turned over to some local jurisdiction. We need minimum standards to guide such private investors in order to prevent sub-standard developments and to prevent their becoming a burden on local governments later on.

Throughout the world, those charged with the administration of low-volume roads might not be highly skilled technically, but, generally, they are very practical people. They understand the relationship between a road, and the economy of their jurisdiction and the understanding of that relationship is essential. They might not be familar with, or care about, functional classification; however, they will know what kind and what level of service is needed for the people they serve!

In the United States, with proper guidance provided by a minimum standard designed for low-volume roads, responsible administrators can exercise proper judgment in investing the limited dollars available for these roads so as to maximize the transportation improvements that are needed for their jurisdiction. Today standards range from the high-volume interstate or freeway to a very low-volume standard such as we use in Idaho to share state-raised revenues with local jurisdictions. That standard is simple; the road must be graded and drained. Even with this minimum requirement, we get complaints about the standard. Perhaps it is too high. We have one county that has a road which was made first by cattle, then by wagons, and finally by automobiles and trucks. The road has never been improved and yet the county commissioners in that county want credit for it to increase their allocation based on improved road mileage. We say, "We can't give money to you because the road isn't graded and drained." They say, "But if you don't give us the money, the road will never be graded and drained." Which comes first? We need in this county, and perhaps in every jurisdiction, a source of development money. Again, the problem comes back to transportation providers informing people about the need for continued investment in our basic means of production!

Perhaps one of the most difficult things we face in living with the high standards which we try to impose upon ourselves can be illustrated by comparing the land forms of Idaho and Iowa. In Iowa, the roadway lines are almost a perfect grid -- they follow the section lines. I am sure you noticed the nice geometric patterns when you came in on the airline! A uniform design is easily followed in those areas, of course; but we have different problems in the West. If you follow those Iowa section lines west, eventually you will run into the mountains where you can no longer follow a straight line. We must follow the rivers! Often, we have mountains which are almost vertical on one side of the road and rivers on the other. With current environmental constraints, we are not able either to fill into the stream or cut into the mountains. We are faced with a dilemma, -- do we pave this 20-foot road between the river and the mountain, or do we continue to maintain it as a graveled road? The user would rather have it paved regardless of the width, even though they drive 14-foot bunks with logs down that 20-foot pavement! We believe that, in our sparsely populated western states, some changes in roadways standards are necessary. We think that some reasonable departure from standards should be allowed in some instances.

Incidentally, a short time ago, a bridge in northern Idaho was hit by one of those large logging trucks. Traffic was stopped as our crews were repairing it. A lady who was stopped phoned me and said she wanted the two men who were working on that bridge fired immediately for using such atrocious language in her presence. I called the District Engineer and asked for a verbatim statement of what those two gentlemen had said that so incensed this lady. He contacted the workmen and the workmen sent back this letter which said: "Jim and I were fixing a damaged girder and Jim was throwing red-hot rivets up to me and I was catching them in a pail. He threw one up and I missed the pail so I caught it in my

bare hands, but I immediately got rid of it and hollered, 'Look out below, Jim,' but he didn't hear me and the rivet went down his shirt and into his trousers and he looked up at me and said 'for heaven's sakes, Joe, please try to be more careful.'"

Now, I am sure that those from other countries never get letters from ladies nor phone calls from irate citizens telling them how to run their departments. It could be a uniquely American story. But I think not.

Those of us here charged with the administration of low-volume roads can use standards as a defense in what is becoming a real problem in the United States -- "lawsuit-happy" citizens. We are becoming more and more involved in lawsuits at every level of government. Good standards can help us. Without a documented basis for construction -- no matter how minimal -- court battles become more difficult and an adverse court decision can result in jeopardizing the already short supply of funds available for low-volume roads.

There is no doubt that we need some kind of identifiable standards, but those standards should be flexible and allow local knowledge to prevail. Local conditions should temper the general rules whether they are promulgated by the federal government, AASHTO, the state, or by other jurisdictions. The local authority must be allowed sufficient latitude to adjust standards to local conditions, so long as we are definitely improving the safety of that facility.

Many times we look at the standards and say, "Well, if we can't meet the standards we'll do nothing." In so doing we deprive the road user of safety improvements. For example, a decision might be made to not improve a road from a safety level of 2 to 7 on a scale of 10, because we can't reach the ideal of 10. Obviously, that is not a reasonable, logical solution to the problem. We should move as rapidly as we can to make everyone of our facilities safer, and our safety standards should be designed to allow us to do that!

Standards for low-volume roads must be viewed as guides -- not maximums, nor minimums. They must be adaptable to the many changing circumstances and needs as interpreted by knowledgable public officials working with the local road jurisdictions.

Good low-volume roads don't cost -- they pay.

For the farmer or the factory they are an investment in production.

Thank you very much.

## COUNTY VIEWPOINT

Howard E. Schwark, Kankakee County, Illinois

Attempts have been made by many persons to define a low-volume road. When discussing low-volume roads today we still find a rather broad spread in traffic volumes making a precise definition nearly impossible. This is understandable when considering the vast differences that can be found in traffic volumes as you move about the world. A low-volume road in an urbanizing area, for example, may have a traffic count that exceeds the traffic count on what may be considered a high-volume road in open country. A low-volume road classification in any given location is basically relative to the traffic volume on the balance of the roads within the location under consideration. This classification, with some exception, is the road classification that is under the jurisdiction of local agencies and is their responsibility to construct and maintain. For this reason it is obvious that counties do have an interest in low-volume roads.

The evolution in development of our total transportation system from the early paths and trails laid out many years ago to accommodate man and horse and wagon to the present system of paved roadways which converted these paths and trails into an integrated transportation system that can accommodate motor vehicles has taken place in a relatively short period of time, most of it within this century. Even though the early pioneers of our road system recognized that all-weather travel for motor vehicles required some reinforcement of the earth roadways with logs, flagstones, bricks and other innovative materials to make the roads passable during inclement weather it has been only in recent years that we have seen dramatic progress in the use of concrete, asphalt and steel as materials to provide a network of surfaced highways for the motorist.

What does this have to do with counties' interest in low-volume roads? I feel this relatively rapid change from paths or trails to the present highway system and the phenomenal progress in road building technique has a direct relationship to and has a considerable effect on the low-volume road system.

In the beginning of the development of our transportation system virtually all of our roads were low-volume roads by today's standards. We would have to make some exceptions and not include the interstate, tollways, bypasses and other roads constructed on new alignments. There was not always the millions of cars and trucks using the highways as there is today. Traffic escalated from a few motorized vehicles in the early part of this century to the present high volumes as the demand for more and more vehicles by the public developed. There became a need to provide a highway facility of higher standards to accommodate these vehicles. The paths or trails were gradually transformed into highways which were improved by upgrading the surfaces improving the geometrics, etc., all of which required the expenditure of more and more funds. As traffic continued to increase, some of these low-volume roads were becoming high-volume collectors and primary routes. It soon became too costly for local governments to construct and maintain these roads. The motorist was traveling long distances which required some continuity in routing so he could find the way to reach his destination. Local governments sought help from their respective states for financial aid and in addition requested them to take over part of the system of highways for purposes of contructing and maintaining them as state marked routes. The need for continuity on a national basis arose as traffic and the length of trips increased, eventually resulting in the federal government aiding states in a federally-marked system designed for transcontinental travel. A good example of the progression in changing roles is the first transcontinental highway in the United States. It was called the "Lincoln Highway" and it was conceived in 1912. After twenty years of construction with what we could now call primitive tools it was finally completed and stretched from New York to San Francisco, a distance of 3,385 miles. A little over 40 years later a project

consisting of over 40,000 miles which connected every major city in the country was completed nearly in the same length of time it took to build the Lincoln Highway. This feat could not have been accomplished either by the counties individually or by the states individually. It had to be planned and coordinated at the federal level. The great progress we have seen in building an integrated transportation network is affecting the low-volume road system in many ways.

In round figures, there are approximately 3.1 million miles of rural roads in this country today. Of this 3.1 million-mile system, approximately 2.3 million miles are still under the control of local agencies and it is estimated that approximately two-thirds of this mileage can be classified as low-volume roads with a traffic count of approximately 400 vehicles per day. Through several procedures of development, low-volume roads have been integrated into the national highway network and have become significant collectors of all types of traffic which feed the main arteries of the national transportation system.

During the process of developing national state and local highway systems there were also the attending laws, funding constraints, standards, and other requirements which each layer of government required in the administration of its respective highway program. When the states began working with the counties, standards were developed and policies were written to uniformly guide both the state and the county on the best use of the funds made available. The basic consideration each state and its respective counties had to determine was how to obtain the maximum benefit from each highway dollar and still provide as uniformly designed and as safe a road system as possible. Each project undertaken by the counties was designed with the economics of the area, topography, traffic, traffic volumes in mind and was constructed using state standards that were reasonably flexible. The low-volume road systems throughout the country generally bear the variable characteristics of the particular state in which it is located.

In the first years when federal funds became available for counties before the interstate project was undertaken, counties were able to use federal funds very much as they had been using state and local funds. However, the interstate project had tremendous impact on this simple and workable procedure. Environmentalists, safety groups, labor interests, minorities, to name a few, all had a hand in molding self-serving laws and directives which were intended to apply to a national highway program, the interstate, which was to cost billions of dollars. I do not question the need for special consideration for a project of this immensity which crisscrosses the country on new alignments. It should be considered differently from highways on existing alignments that have been in existence for many years. The trouble counties are experiencing is that the laws and directives were attached to the federal dollar and not to the type of project as I feel it should have been. When using federal funds a county must go through a process very much similar to the process required for major highway construction even though the county may be working on a low-volume road.

The reason for the ever-growing mountain of red tape, the oftentimes unnecessary spending of highway funds, and a continued attempt to develop uniform standards nationwide for the low-volume road system is, I believe, understandable when we realize that there is a large segment of highway administrators who are not familiar with a low-volume road system. They have no idea what counties must do in the way of planning and prioritizing of projects to keep in as safe an operating condition as possible their share of the 2.3 million miles of roads which are under their jurisdiction. The political realities are in themselves overwhelming when you consider, for example, in the county in which I am located there are 28 elected county board members who have employed me to administer a 265-mile county highway program. This results in one elected official for less than 10 miles of county roads. The township road system, on the other hand, consisting of 878 miles of roads which are almost entirely in the low-volume category is administered directly by 17 elected highway commissioners with my assistance when required as specified by statute. In addition, each township has five elected officials serving on the town board of auditors who have certain statutory functions concerning the commissioners' position. This results in one elected official being directly responsible for an average of 52 miles of township roads and, indirectly, one elected official for an average of 10 miles of township roads.

The interest of the counties is to work side by side with both local state and federal governments to formulate laws and directives which fit the low-volume system and not encumber the progress of its development with unnecessary red tape.

The traffic count on the low-volume road is at the bottom end of our transportation system. Instead of using the same laws, policies, and directives designed for the top of the system, we should realize that problems will occur and consideration should be given to this divergent traffic pattern. Low-volume roads may be an insignificant title, but pause for a moment and think what would be the result if all of the low-volume roads in the country were closed for a day. factories, farms, businesses, industry, schools, hospitals--and the list could go on--would all be adversely affected. The low-volume road is important and it should be recognized that it is a category of roads which needs special attention just as the interstate was given special attention.

I have not directly addressed those in attendance who have traveled here from other countries. I express the appreciation of the counties in this country for your attendance. We are extremely pleased that you could be with us. The need for funding highways must be somewhat the same in your land as we are experiencing here in the United States. We are aware of the proliferation of automobiles and trucks all over the world. Problems, I am sure, will vary from country to country. I realize that when receiving financial aid from any segment of our government, the acceptable philosophy is that with the money certain restrictions on how it is to be spent are included in the grant, I personally do not agree entirely with this philosophy because government is not really paying the bill. The taxpayer who really is paying the bill is the one and same person who pays his local, state and federal taxes. He expects the work to be done, and could care less what the name of the government that furnished the funds might be. It is sometimes difficult for government officials especially if they are so far removed from the actual location of where the money is to be spent, to realize that they might do things differently if it really was their dollar that was being invested in the work.

To briefly summarize, counties do have a very real interest in low-volume roads. The counties are, in the main, responsible for the construction

and maintenance of these roads. It is only logical that counties should be involved when matters affecting low-volume roads are being discussed. Counties should have the opportunity to fully utilize every funding source available. There should also be a reasonable degree of uniformity on how the money can be spent. States and their respective counties have distinguishing features that set them apart from one another which cannot be lumped into one uniform set of laws, regulations, directives and standards and expect it to work out properly. We who have low-volume roads can understand this because we are struggling with the problem. I am certain that I speak for the majority of the counties when I say we stand ready to offer our assistance to the decision makers in helping make the low-volume road system as good and as safe as we possibly can for the motorist of this country.

Thank you.

# Part II

# SUMMARY: DEVELOPING COUNTRY NEEDS FOR INFORMATION ON LOW ROAD TECHNOLOGY

Session 6 of the Second International Conference on Low-Volume Roads was a function of the TRB project on Transportation Technology Support for Developing Countries. Kermit L. Bergstralh, Chairman of the project Steering Committee, was presiding officer for this conference session in which six project correspondents from all parts of the world served as panelists. Each speaker had been invited to discuss information and research needs on one or more aspects of the planning, design, construction, maintenance, and administration of low-volume roads in developing countries.

The first panelist was Mr. L. R. Soares, who has had an active career in the Brazil Highway Institute and the Brazil section of the Institute for Transportation Engineers. He singled out needs for information on compaction methods, low-cost bridges, criteria for surface types, and installation of drainage structures. He reported that compendiums published by the project cover many of these needs, but more compendiums are needed, especially within the state highway departments. He reported that the greatest interest in the TRB project is in 10 of the smaller and less developed of Brazil's 22 states.

Mr. Said Beano, Minister of Public Works in the Republic of Jordan, discussed information needs on six topics:

- Evolution from labor-intensive to mechanized maintenance operations,
- Factors in the performance of hot-mix asphalt overlays,
- Effects of dry compaction that must be used when water is not economically available.
- Surface treatments for dust control,
- Recycling of pavement materials, and
- Utilization of computers in road planning and design.

The third panelist was Mr. Ruslan Diwiryo, Director of City and Regional Planning within the Directorate General of Housing, Building, Planning, and Urban Development for Indonesia. He described the structure and functions of the Indonesian road network (55,000km) in the context of regional development. National development goals for Indonesia include balanced development among regions, and higher national levels of equity, growth, and stability. Problems in local road development include societal reaction to the development, availability of national resources, economic justification, financial capability, road standards and specifications, and operational arrangements among different levels of government.

Research needs in Guyana were presented by Phillip Allsopp, formerly Chief Highway Engineer and now partner in a Guyana consulting firm. His suggestions included research on

- Loss of Fines from untreated road surfaces,
- Width of clearing for roads through tropical forests where there is heavy rainfall and intense sunlight.
- Erosion control in areas comprised of cohesionless sand and having 100 inches of rainfall per year,
- Reduced tire pressures for heavy vehicles on untreated surfaces,
- Safe and economical vehicle speeds in the context of road maintenance.
- Light panel decks for low-cost bridges, and
- Use of coarser grades of laterite soils for concrete.

Mr. Allsopp proposed that bypass test strips for maintenance studies be included whenever a new penetration road is built.

Mr. Pascual A. Caballero is Director of the Bureau of Local Roads in the Philippines Ministry of Public Highways. He stated that the Philippines has about 87,500 kilometers of local (barangay) roads in its total network of 128,000 kilometers. Construction and maintenance of barangay roads is a joint responsibility of the National Government and the smallest political unit, the barangay,

Principal problems in this work arise because of the country's terrain and large number of river crossings. Mr. Caballero stated that the project compendiums have been useful, particularly with regard to drainage structures and river crossings.

The sixth panelist was Mr. Guy E. Otobo, Assistant Director for Federal Highway Construction within the Nigerian Federal Ministry of Works and Housing. Mr. Otobo summarized major points that had been made by the other panelists, particularly with respect to Nigerian concerns. His emphases included the following points.

- Low-volume does not imply low level of importance for roads. There can be societal advantages that are more important than economic justification.
- Consideration should be given to surface treatment as an initial construction strategy. Many low-volume roads carry heavy axle loads that are a great problem in Nigeria.
- Adequate training of construction and maintenance supervisors is essential.
- A major problem is to get adequate data for planning and design.

Mr. Otobo stated that the project compendiums are useful and that many more developing country ministries of works should receive these publications.

A number of significant contributions were made during the open discussion that followed the panel presentations. Excerpts from the audience participation include the following:

"In Sierra Leone we do not have data on axle loads, neither do we have basic data for drainage design." (Mr. Garber)

"There is a basic need in Tanzania for simplified planning procedures. We need better methods for establishing maintenance priorities and for

organizing maintenance units. We need better and simpler techniques for slope stabilization regions. There is a tremendous need for coordinating the problem-solving activities of developing countries." (Mr. Bhandari, project correspondent)

"Socio-economic advantages have been found in Colombia's rural development program that includes pick-and-shovel construction of low-volume roads." (Mr. Gomez)

"More use needs to be made of local engineers and consultants in developing countries. Technical publications should be available in the language of the country, and must be put in the hands of the right people." (Mr. Vera-Barandiaran, International Road Federation.)

"The main problems in Jamaica are to get rid of water and to stabilize the clay soil." (Mr. Williams, project correspondent)

"Sierra Leone is not adverse to labor-intensive methods but believes more can be achieved through mechanized construction. We need to have incentives for local engineers to work for the national ministry. We should join with neighboring African countries to develop our road technology." (Mr. Jones-Dove, project correspondent)

An item regarding this session appears in the Nov.-Dec. 1979 issue of TRB NEWS.

A copy of the complete transcription of the session has been sent to the project correspondents. Single copies may be obtained by writing Dr. Paul E. Irick, Assistant Director for Special Projects, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

# Part III

# SUMMARIES: NATIONAL AND INTERNATIONAL VIEWS

## NATIONAL VIEW

Miles S. Kersten, Professor Emeritus, University of Minnesota

I have been asked to summarize from a national view this conference of some 50 papers and addresses in just a few minutes. Obviously, I can try and emphasize only a few points.

I think we should be especially impressed by the studies being made in other countries to assist them in establishing models to be used in evaluating highway construction and maintenance policies. Four years ago at Boise we heard about the Kenya road transport cost study, with vehicle operating costs related to such items as road surface types and roughness. At this conference, five separate papers have described parts of the 12 million-dollar research in Brazil to determine relationships between vehicle user costs, roadway design standards, and maintenance policies for low-volume roads. This research has included such items as the monitoring of both paved and unpaved sections to measure roughness, gravel loss, and rutting as affected by traffic, alignment, and other items; vehicle operating cost studies for over 1200 vehicles, with road roughness being found a significant factor; and speed studies as affected by surface types, road roughness, and grades. All of these relationships are being incorporated into a computer-based planning model.

Although not as extensive as the Brazil studies, we have had papers concerning planning of highway investment decisions in developing countries, with consideration of a variety of maintenance policies; a study for Egypt in which various maintenance strategies involving thick or thin overlays and three road classes were analyzed; a study of road roughness in Bolivia and its use in planning road grader operations for maintenance; a paper on the effect of simple maintenance, such as a labor-intensive sand sealing, on vehicle operating costs on St. Vincent in the Eastern Caribbean; and a paper of the planning of a road classification system for Gambia, Africa.

What is the significance of papers such as these for engineers in the United States? In this country we seem to be much less concerned with vehicle operating costs and how they are affected by road surface design or maintenance practices. Extensive studies of this nature were made by Winfrey and others here in Iowa about 40 to 50 years ago, and Claffey reported in NCHRP Report 111 in 1971 that road surface conditions do affect fuel and oil consumption, tire wear, and maintenance. However, in the selection of road surfaces and their design by most local road agencies, be they gravel, surface treatment, or more substantial pavement, the possibility of these variations do not seem to have been considered. Perhaps with the range of surfaces which we have these differences are not great, or perhaps we do not really know what they might be. Certainly these extensive measurements which have now been made merit our detailed study, and perhaps we should be making additional studies ourselves.

These countries have attacked such practical questions as "At what average daily traffic on a gravel road is a surfacing such as a light surface treatment economically justified?" Also, measurements of travel losses and needed gravel replacement are being made in the studies. The results should be pertinent to our aggregate surfaced roads.

The Kenya and Brazil projects and research in other countries should be a great help not only in maintenance but also in design of their road surfaces. In the United States, a systems approach for the design of asphalt and aggregate surfaced roads is given in the paper by McCullough, Roberts, and Pelzner of the University of Texas, Austin Research Engineers, and the U.S. Forest Service. This so-called pavement management system utilizes material, traffic, environmental, and economic considerations in the design, as described. However, it does not use vehicle operating costs directly. It uses design patterned on the AASHTO structural design equations for flexible pavements and PSI's. This procedure can be applied, of course, to an extensive system of roadways, and it has now gone through a trial implementation phase by the Forest Service. Such a system is not easy to establish, I am sure. It is interesting to note the considerable effort needed to introduce this system into actual use. Training sessions have been held in several regions, and refresher meetings are being considered. Such face-to-face instruction seems quite essential to make a system work, and several years' time may be required to establish it fully. It certainly would merit study to see if it might be utilized by other agencies. Again, it might not be easy to intoduce its use into a county without some face-to-face instruction

Now, let's note some of the papers of U.S. origin on other subjects. Emphasis in this country seems to be on soils evaluation and on improvements in stabilization methods and economic surfacing or pavement design. It is interesting to note that in Mr. Millard's keynote address he selected three particular aspects of highway engineering to discuss and the first of these was "soil mechanics as applied to highway engineering." As a retired teacher of soils, this is dear to me, even though he did choose to tell us where things have gone wrong. He was really quite rough in stating that those of us who are, or who were, university professors have failed in instructing those who have gone to foreign lands about the nature of soils in the field and the problems encountered. It just reemphasizes that, after learning a few basics, there is no teacher like experience and we must emphasize an inquiring eye and a desire to get one's hands dirty.

I believe this is really what Mr. Millard said in his concluding paragraph. To quote his last sentence, "The real purpose (of education) is to equip us so that our eyes and ears are open and our minds are ready to gain experience of how the world works and to put this experience to good practical use."

I was somewhat surprised by the frequent mention and widespread use of the CBR as an evaluator in several countries. I have no quarrel with this, and am happy to hear of such common use so that comparisons can be made from one country to another. Also AASHTO T-99 or T-180 (that is so-called Proctor or Modified AASHTO) compaction have widespread use. One paper has shown how SCS soil maps and a correlation of soil series names with CBR can assist in preliminary design of thickness. Another paper points out the potential for a soil data bank.

On stabilization or pavement materials, there are two papers on soil-cement, indicating that this process developed almost 50 years ago is still undergoing study, and there are three papers concerning emulsified asphalt-aggregate mixtures, one being a modification with Portland cement. You may recall emulsion-aggregate mixtures were also discussed at Boise. Reduction in use of cut-back asphalts makes the study of such cold mixes more pertinent today. The design procedures for mixes as developed in Illinois and Mississippi and the information on layer coefficients for an emulsion open graded mix should be of immediate use to some agencies. The discussion Monday evening on light bituminous surfaces was in my opinion one of the best learning experiences of this conference. Sessions of a similar nature should be considered for future conferences.

It is interesting to note that at this conference there are two papers on Portland cement concrete for low-volume roads. The utilization of a local aggregate) on an Indian reservation in North Dakota (about 1/3 coarse aggregate and 2/3 fine aggregate) brought the costs of a 5-1/2-inch slab down to $6.00, plus or minus, per sq. yd. And it was also timely to obtain more information on Portland cement overlays on county roads in Iowa, as this state has been a pioneer in trials of such work. The description of the construction procedures for 6-inch slabs over old asphalt pavements, especially to establish and control grade and thickness of the new slab, should be of value to those planning such work.

I am somewhat surprised that there were not more papers or mention of bridge inspection and inventory. Although such work has been required for all spans on the federal-aid systems, recent legislation has extended this to include off-system bridges also. This means that structures on county roads and those under township jurisdiction are included. The paper by Wade and Larsen of the Illinois DOT recounts the experience in that state. Identification of structures and their degrees of obsolescence may be a help in securing funds for necessary rehabilitation. Other agencies may find the Illinois system, or parts of it, useful.

Apparently, design information on low-water crossings of streams, fords with culverts or low-water bridges is almost nonexistent. Thus, the paper by Coghlan and Davis of the Forest Service should be welcome.

I would judge the paper by Glennon on "Highway Safety Requirements for Low-Volume Roads" to be of great value and one which county engineers might put to immediate use. I have found the county engineers reluctantly accept many of the present design standards because there seems to be no good explanation of how they have been derived and many seem to be merely arbitrary. In the Glennon paper, factual information such as accident data and field observations and probability calculations have been used to study and make design recommendations for such items as the need for speed signs, shoulder and total road widths, curve design and warning signs, stop signs, centerline markings, no passing stripes, and possible or needed removal of roadside obstructions. I believe this is the type of information which was stated to be of great need by both Mr. Manning, speaking for the state interest, and Mr. Schwark, for the county interest, at the Plenary Session. Suggestions are also made for studies which would add further to these types of recommendations. A most useful study would be if accident data could be collected along with a traffic volume category and, if possible, some measure of design quality of the road. Another study would be to measure several traffic characteristics, such as hourly volumes, directional split, vehicle types, speed, etc. Such data would be used to verify some of the assumptions which were made in the safety study.

Low-volume roads in our country are designed, built, and maintained by federal agencies, state DOT's, counties, townships, municipalities, and other miscellaneous agencies or organizations. One of our major problems is how to get the best information concerning low-volume roads to this wide divergence of agencies, especially at the county and municipal level. Certainly conferences such as this are one means of making research results known. However, the written reports are not really adequate for many road agencies such as the counties. This point was made very well by Mr. Kimambo of Tanzania in a discussion at Session 6, which was on the needs for information on low-volume road technology by developing countries, when he said, "Don't just send us the compendiums, as they will only be put on the shelves to gather dust."

As was mentioned for the pavement management system which has been developed for the Forest Service training sessions, where the developers discuss the system with the potential users, have been found as the best means of implementing its use. I would like to also call your attention to the procedures which have been developed in Minnesota for assisting the counties and municipalities in utilizing research findings, as described in the paper by Skok and Lukanen. The Minnesota Local Road Research Board has a major research implementation project, and the engineers who have conducted the research go to small groups of municipal, county and state engineers to give detailed instructions. This method has been used to get the agencies to use surface condition rating systems, measurements of ridability, traffic evaluation, and strength measurements. This scheme has been judged to be highly successful in getting our research results into actual use by agencies concerned with low-volume roads.

I would like to finish these remarks with just a few individual statements gleaned from a variety of the papers.

1. "Observation of pavement performance is still and will be for many years to come, one of the most valuable means by which the local practitioner can gain the necessary design skills." (Dunlop)

2. "Road geotechnical engineering is an art which depends for a large measure for its success upon the exercising of sound judgment; and sound judgment comes from long and tried experience, based on acute observation." (Mitchell, Petzer and van der Walt)

3. "The single most important aspect in the design and construction of a low-volume, low-cost road is the variation in material quality." (Strauss and Hugo)

4. I could quote any of several recommendations of the paper by Hicks and Hatch. Just one is: "Improve construction records to better document the history of each project. A documentation process accessible to the designers would allow analysis of new processes and materials."

Certainly if we can learn lessons such as contained in these single statements, our time has been well spent. I am certain I speak for all of us as I express thanks for this conference to the several agencies that organized it, the committee that set up the program, the individuals that have handled the details, and the persons who have authored and presented the papers.

## INTERNATIONAL VIEW

Guy E. Otobo, Federal Ministry of Works and Housing, Nigeria

Mr. Chairman, ladies and gentlemen: I was supposed to speak on the international viewpoint summary from that angle on the conference but the learned Professor, I think, has preempted everything I wanted to say and I am not sure whether there is anything else left to say after such a brilliant summary of what has transpired for the past three days. However, if you will bear with me for a few minutes I will just present one or two aspects that I think should be looked into.

The Second International Conference on Low-Volume Roads, in my view, has been most successful. The conference has highlighted areas in which developing countries need to focus their attention in their desire to maximize development with limited funds. Low-volume roads constitute the bulk of the roads in these countries and they best serve the immediate and daily needs of the people. I would like to touch on a few of the very many excellent papers that were presented at this conference.

### The Use of Local Materials

Many people clearly demonstrated the need to use local materials in the construction of low-volume roads, if minimum costs are to be achieved. One paper dealt with ways and means of turning local soils, either in their natural state or modified by lime, asphalt, or cement into load-bearing bases and subbases. It is recognized that low-volume roads carry heavy axle loads with quite destructive capabilities. Only bases and subbases of high enough strengths can adequately distribute loads to the subgrades. These subgrades are usually, in the case of low-volume roads, prepared with minimum efforts. Two papers dealt with the needs to understand local materials, at first sight, without resorting to complex and costly laboratory tests. The tools to use were soil surveys and geotechnical data banks.

### The Use of Local Labor

Some papers presented at this conference have touched on this subject. I must caution, however, that we must not let ourselves be carried away with the so-called labor-intensive, labor-based methods which reduce the quality of life in the developing world and dehumanize the people. Any so-called appropriate technology that turns human beings into work horses or seeks to perpetrate underdevelopment by embarking on the construction of jungle trails is best forgotten. Only certain aspects of work in the construction of low-volume roads lend themselves to labor-based methods and only these should be encouraged. For instance, protection of embankments through grassing, turfing, and stone pitching; desilting of culverts and cleaning of blocked drains, and routine pavement maintenance operations such as pothole repairs and patching of distressed pavements with hot or cold mixes, are examples that can be executed by local labor. On the other hand, it would be quite futile to attempt soil-cement stabilization by mixing the soil and cement in head pans, spreading by oxen labor and compacting by the stamping of feet.

### New or Improved Methods

Several papers dealt with recent developments in the use of traditional methods, refinements in existing methods and better utilization of local materials. An interesting paper is the one that dealt with the use of sulphur-treated bamboo in reinforcing concrete and in reinforcing earth. The ideas contained in this paper can be extended to reinforcing walls of traditional houses built of clay or mud in developing countries. The need to provide shelter for the population of the developing countries, at least cost, is a matter that is being urgently considered in these countries. In the same category was a paper that dealt with new efforts at making durable pavements with asphalt emulsions, and with the use of lateritic soils in Thailand's Khorat Plateau. New Zealand's experience in the pavement design and the performance of low-volume roads carries a message that can be explored to the advantage of all developing communities.

### Problems of Maintenance

Maintenance, as you all know, is a big problem to many developing countries. Emphasis in development has been on new construction and insufficient funds are allocated for maintenance. Properly organized, equipped, staffed and efficient road maintenance organizations are the exception rather than the rule. It is important, therefore, to always strive to make any construction as durable as possible, and certainly for more than five years of life. Road improvement by new application of surface dressing or the laying of hard asphaltic concrete overlays should be seen as steps in the stages of development of low-volume roads to those of high levels of service and function. When to maintain and what to do were also well illustrated by papers on a program of bridge inventory, inspection, and rating for a local roads system and the evaluation of the structural adequacy of bituminous pavements in Minnesota.

Some interesting papers dealt with the engineering economics of maintaining and paving of low-volume roads. These are useful tools but the immediate needs of developing countries as far as maintenance of low-volume roads is concerned are simple operational manuals that teach basic maintenance procedures.

I would like to comment on the conference session on developing countries' needs for information on low-volume road technology. I was a panelist at that session. What has come out as the prime need from that session is the necessary data for the basic things. Whereas the developed world has computerized data banks, the developing countries are still groping in the dark for such basic data as runoff coefficient for drainage design, rate of asphalt absorption by local aggregates, and, indeed, the required

understanding of the engineering properties, uses and limitations of locally available road building materials. Here I am in complete agreement with the views of Dr. Ray Millard of the World Bank, that engineering training and education should be geared more closely to the practical aspects of the profession and a little less emphasis on the romance of the pure researcher with sophisticated mathematics. What also is needed, at this state, is the knowledge of the basic and practical aspect of building durable bituminous surface dressed pavements. This leads me to some of the new technology we have been introduced to at this conference. I refer to the International Bank for Reconstruction and Development's highway design and maintenance standards model. I believe that it is an excellent research tool. It must be regarded, however, as a means or indeed one of several means available to reach the end. It should not be regarded as the end in itself. I think we should be worried that by plugging a few parameters into a computer we have found the answers to our maintenance problems. One is reminded of the World Bank's transportation planning model. It, too, was a sequential model in that the output from one step became the input to the next step. Final results developed from data inputed by the user nonetheless have been developed without any control by the user of the intermediate steps. The result was that more often than not final recommentations obtained were at odds with the real world. I am informed that this model has now been virtually abandoned and has been replaced by stage planning. What, in effect is seen is that research should be aimed at developing easily understood rule-of-thumb procedures that would enable the average engineer in Lagos, or Indonesia, to perform effectively with perhaps only a slide rule or electronic calculator. I am in fact, therefore, advocating for a practical mind with field experience.

In concluding my summary of the Second International Conference on Low-Volume Roads from international or foreign viewpoints, I want on behalf of my colleagues from Asia, Latin America, The West Indies, and Africa to say how useful this conference has been. It has stimulated our minds and has given us renewed vigor and impetus to develop our countries so as to improve the quality of life of our citizens. This is what development in life is about. BETTER ROADS MEAN BETTER LIVING. I, therefore, want to thank the organizers and sponsors of this conference, the Transportation Research Board, United States Agency for International Development, the Federal Highway Administration, the American Association of State Highway and Transportation officials, the American Road and Transportation Building Association, the National Bank for Reconstruction and Development, the National Association of County Engineers, National Association of County Officials, National Science Foundation, U.S. Army Engineers, U.S. Forest Service, the Iowa State University, the Iowa Department of Transportation, the Iowa Association of County Engineers and the International Road Federation for a job well done.

I do also want to express my deep appreciation to the Secretariat, the University Staff, and the bus drivers who have all helped to make our stay in Iowa a wonderful and pleasant experience.

# Part IV

# IMPLEMENTABLE ITEMS AND RESEARCH NEEDS

## INTRODUCTION

The Second International Conference on Low-Volume Roads was conducted to facilitate a worldwide exchange of information on design, construction, maintenance, operation and management of low-volume road facilities. The primary focus was on practical aspects, particularly the aspect of costs. Current practices and problems were discussed and needed research was identified.

A special task force from the U.S. sector was assigned to review and evaluate the conference proceedings and deliberations as they related to the Federally Coordinated Program of Research and Development Project 5-M, Rehabilitation and maintenance for Low-Volume Roads, and to report their findings at a post-conference meeting. The review concentrated on identifying and recommending for implementation research results deemed suitable for use in the U.S. by states, counties and other local road agencies and on identifying gaps in knowledge that require further research effort at the federal, state and local level. The following two sections summarize the task force's recommendations as supplemented by the suggestion of the Conference Steering Committee.

### Information Suitable for Implementation

1. Low Water Crossings: Flood frequency criteria normally used for bridge-culvert design (50-100 years) in many instances is too high for the low-volume road philosophy. Low water crossings that allow flooding at more frequent intervals have proven adequate and economical. Location and design considerations are available to permit their use under a variety of environmental and terrain conditions (1).

2. In Situ Reduction of Rocks and Boulders: Surface maintenance of unsurfaced roads in rocky soils is difficult. Techniques and equipment have been evaluated for reducing oversized rock in place (2). A successful, though not inexpensive, technique has been developed to reduce rocks up to about 41 cm. (16 in.) in size to the 5 cm. (2 in.) sieve size and smaller.

3. Open Graded Emulsion Pavements: Open graded asphalt emulsion mixes are mixtures of open graded aggregates and emulsified asphalts. A reduction in construction costs and pollution results when these mixes are cold-mixed and cold-laid using conventional paving equipment. Thickness design procedures have been developed and used successfully by several agencies in the Pacific Northwest (3).

4. Soil Cement Stabilization: It has been demonstrated that cement stabilization can improve the engineering properties of materials and has wide application in pavement layers. Procedures for mix design, thickness design and construction are available from past research efforts (4) and realistic field compaction specifications have been developed and tested (5).

5. Portland Cement Concrete Overlays: Portland Cement concrete pavements can contribute to the long-term economical solution of the ever increasing low-volume roads. Demonstration projects have shown that Portland Cement concrete overlays can be successfully constructed over existing asphaltic concrete roads with a minimum of surface preparation (6).

6. Safety Requirements for Low-Volume Rural Roads: The application of national guidelines to the reconstruction of low-volume roads is continually being challenged at a time when local agencies must spend a majority of their limited funds for maintenance. Safety needs on low-volume roads have been reevaluated and revised guidelines suggested. These guidelines should provide more consistent design and traffic control consistent with a rational balance between highway investment, safety and traffic service (7).

7. Design of Dense Emulsion Mixes: Stabilization of granular base materials, particularly substandard aggregates, with emulsified asphalt has increased in recent years. Procedures have been developed for mix and structural design of emulsified asphalt-aggregate bases for low-volume roads (8) as well as mix design criteria for Portland Cement modified asphalt emulsions for stabilization of sands and sand-clay aggregates (9).

8. Multiple Service Level Bridge Railings: There is a need to provide a level of motorist protection at a highway site consistent with the degree of traffic hazard present. Criteria has been developed for selecting bridge railing systems appropriate for the service level required (10). Two systems have been developed and crash tested for certain low-volume road service levels. Demonstration projects should be constructed to validate their economic benefits and field performance.

9. A Model for Highway Design and Maintenance Standards: The World Bank has cooperated with a number of leading research institutions around the world to develop an improved basis for economic analysis of alternative road design and maintenance standards (11, 12, 13). Demonstration projects need to be conducted using the resulting Highway Design and Maintenance Standards Model (HDM) to validate its applicability and feasibility for use on low-volume roads in the United States.

10. Pavement Management Systems: With the significant investment in highway pavement systems and the ever-increasing expenditures required to maintain them has come the realization that modern management methods must be applied to optimize the use of limited available funds. A pavement management system for low-volume roads has been developed and implemented by the U.S. Forest Service (14). This system can be modified for use by other agencies.

11. Evaluation of the Structural Adequacy of Bituminous Pavements: Local engineers must make decisions on when maintenance is needed on a given road and what the most appropriate procedure should be. Flexible pavement evaluation techniques have been developed and demonstrated to be usable by county road agencies in setting up pavement inventory systems (15). The data obtained give the engineer factual information about the road to aid in making maintenance decisions.

12. Geotechnical Data Banks: Large amounts of geotechnical information for transportation projects are accumulated each year by highway departments throughout the United States and abroad. Geotechnical data banks have been developed in a number of geographic locations and these can be accessed to provide valuable information for the design and construction of low-volume roads where funds to generate original data are very limited (16).

13. Alternative to the Design Speed Concept: The AASHO design speed concept for highway alignment design has been generally accepted for a number of years. Recent research in Australia (17) has shown that driver behavior on alignments designed for a high speed range appears to be in accord with the design speed concept. However, for alignments designed for a low speed range the driver speeds vary along the route and are consistently in excess of the design speed. An alternative approach for alignment design of lower speed two-lane rural roads has been developed.

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Research Needs

1. Trade-offs Between Design and Safety: Research should be directed toward developing a means of assessing the trade-offs between road design standards and accident frequency and severity.

2. Trade-offs Between Construction and Maintenance: Research should be directed toward developing a means of assessing the trade-offs between road construction standards and practices and maintenance requirements.

3. Maintenance Management and Practices: Maintenance management and practices procedures suitable for low-volume roads should be developed. Usable information emanating from studies on higher classes of roads need to be evaluated and adapted to low-volume classes.

4. Truck Traffic Data Base: There is a need to develop a truck traffic data base (size, weight, configuration, daily traffic, etc.) for use in design of low-volume roads.

5. Cost Allocation for Maintenance and Rehabilitation: A methodology needs to be developed for allocating road user costs for maintenance and rehabilitation of low-volume roads.

6. Effect of Road Surface Condition on Vehicle Operating Costs and Energy Requirements: Studies should be directed toward determining the effect of road surface conditions on vehicle operating costs and energy requirements.

7. Accident Data Base: Studies should be directed toward developing a data base for the effect of design standards on accident frequency and severity.

8. Rating System for Aggregate Surfaced Roads: There is a need for a rating system for aggregate surfaced roads which includes roughness, looseness and corrugations.

9. Aggregate Loss Prediction: More accurate methods need to be developed for the prediction of aggregate surface loss from low-volume roads.

10. Failure Mechanisms for Aggregate Surfaced Roads: The failure mechanisms for aggregate surfaced roads need to be defined.

11. Implementation of Research Findings: Studies need to be directed toward developing materials and strategies for implementing research findings including useful findings emanating from research and practices for higher class roads and from other appropriate sources.

12. Predicting Future Maintenance Costs: A methodology needs to be developed for predicting probable future maintenance costs for different maintenance strategies.

13. Seasonal Load Restrictions: Information is needed for understanding and predicting the seasonal variation in load carrying capacities of low-volume roads for purposes of establishing load

restrictions and user fees and for design, construction and maintenance considerations.

14. Seasonal Load Volumes: Develop a study to estimate the volume and loads generated by different rural activities (i.e., farming, ranching, logging, mining, etc.).
15. Design for Heavy Vehicles: Research should be directed toward determining the damage brought by single passes of very heavy vehicles.
16. Geotextile Design Standards: Further research is needed to develop engineering design and materials acceptance standards for use of geotextiles in low-volume roads.
17. Loss of Natural Reources: Research is needed to determine the loss of natural resources (i.e., good gravel, stone, etc.) to the nation by current low-volume road maintenance practices.

# Part V
# PARTICIPANTS

Ahlvin, Richard G.
U.S. Army Engineer
P.O. Box 631
Vicksburg, MS
39180

Allsopp, Philip
C. A. Liburd and Associates
61 Hadfield and Cross Streets
Georgetown, Guana
GUANA

Ansell, Earl
The Asphalt Institute
6100 Golden Valley Rd.
Minneapolis, MN
55422

Atkinson, T. A.
Vallentine, Laurie & Davies
10th Fl., Oriental Plaza
Kuala Lumpur, MALAYSIA
MALAYSIA 04-01

Barber, Victor
U.S. Army Engr. Waterways
P.O. Box 631
Vicksburg, MS
39180

Basha, Mohammad
Utah State DOT
757 W. 2nd St.
Salt Lake City, UT
84104

Baughman, Ronald
Weyerhaeuser Co.
P.O. Box 7
Mountain Pine, AR
71956

Beisell, E. B.
Jones County
Box 308
Anamosa, IA
52205

Bergh, A. O.
Machintosh, Bergh and Sturgess
P.O. Box 2723
Pretoria, Transvaal
South Africa 0001

Bergstralh, Kermit L.
Bergstralh Associates, Inc.
4720 Montgomery Lane, Suite 80
Washington, D.C.
20014

Betterton, Ronald
Greene County
Court House
Jefferson, IA
50129

Bhandari, Anil

307 N. Michigan Ave.
Chicago, IL
60601

Blake, Darrell
IA. Corrugated Steel Pipe
22 Happy Hollow Blvd.
Council Bluffs, IA
51501

Blunk, Tedde R.
Madison County
Court House
Winterset, IA
50273

Book, James
Barton Aschman Associates Inc.
Minneapolis
Minneapolis, MN
55454

Bortle, Robert
Iowa DOT
1420 4th St., S. E.
Mason City, IA
50401

Brewer, Kenneth
Civil Engineering Dept.
Iowa State University
Ames, IA
50011

Bronstad, Maurice E.
Southwest Research Institute
P.O. Drawer 28510
San Antonio, TX
78284

Bulman, J. N.
Transport & Road Research Lab.
Crowthorn
Berks,
United Kingdom RG116AU

Al-Abed, Ahmad Atiyeh
Ministry of Public Works
P.O. Box 1220
Amman,
JORDAN

Alvarez, Carlos L.
Roy Jorgensen Associates, Inc.
P.O. Box 575
Gaithersburg, MD
20760

Arnold, Fred
U.S. Forest Service
517 Gold Ave. S.W.
Albuquerque, NM
87102

Atuan, Roberto
Technical Assistance

,
Honduras

Barwell, I. J.
Intermediate Tech. Dev. Group
9, King St.
London,
UNITED KINGDOM

Bauer, Robert
Washington County
210 W. Main
Washington, IA
52353

Beano, Said
Ministry of Public Works
P.O. Box 227
Suweileh,
JORDAN

Bell, J. R.
Oregon State University
Civil Engineering Dept.
Corbvallis , OR
97331

Bergren, Jerry
Iowa DOT
800 Lincolnway
Ames, IA
50010

Berryhill, Robert
USDA - Forest Service
P.O. Box 1628
Juneau, AL
998082

Betz, Mathew
Arizona State University
Administration Bldg. - A.S.U.
Tempe, Arizona
85281

Blackwell, Rex V.
U. S. Forest Service
P.O. Box 490
Sandpoint, ID
83864

Blomdahl, Charles
U.S. Forest Service
633 W. Wisconsin Ave.
Milwaukee, WI
53203

Bocus, Gary
Allied Chemical
Technical Center P.O. Box 6
Solvay, NY
13209

Bortle, Mark
Jones County
Box 308
Anamosa, IA
52205

Brademeyer, Brian D.
Massachusetts Institute of Tec
77 Massachusetts Avenue
Cambridge, MA
02139

Bridwell, Donald F.
AID

Tegucigalpa,
Honduras

Buczyna, Joseph
Armak Co.
8401 W. 47th St.
McCook , IL
60525

Burns, John
Novak, Dempsey & Associates, I
317 W./ Colfax St.
Palatine , IL
60067

Butler, Bertell C., Sr.

2602 Dellana Lane
Austin, TX
78746

Caballero, Pascual A.
Bureau of Barangay Roads
Ministry of Public Highways
Manica,
Philippines

Cabrera, J.C.
University of Leeds

Leeds,
ENGLAND

Carek, Frank
University of Missouri
203 Engineering Research Lab
Rolla, MO
65401

Carlson, Carl
Klamath N. F. Pacific SW Des.
1215 S. Main
Yreka, CA
96097

Chester, Andrew
University of Birmingham
Birmingham B15
Birmingham,
ENGLAND

Clark, Larry D.
Black Hawk County
Engineer's Office, Court House
Waterloo, IA
50703

Clayton, Elmer
Iowa DOT
800 Lincolnway
Ames, IA
50010

Coghlan, Gerald
U.S. Forest Service
633 W. Wisconsin
Milwaukee, WI
53203

Cook, Walter L., Jr.
School of Forest Resources
University of Georgia
Athens, GA
30602

Cowell, Michael J.
Empire Laboratories
214 N. Howes
Ft. Collins, CO
80522

Craus, Joseph
Transportation Res. Board
Technion City
Haifa,
ISRAEL

Cripps, William E.
Government of Saskatchewan
2240 Albert Street
Regina, Saskatchewan
Canada

Cuellar, Enrique
Association Salvadorena de Cam
59th Avenue Norte 314
San Salvador, El Salvador
C.A.

Curfman, Floyd
Forest Service
1755 N. 166 St.
Brookfield, WI
53005

Dankbar, Roman
Federal Highway Administration
18209 Dixie Highway
Homewood, IL
60430

Davis, Neil
Mark Twain National Forest
401 Fairgrounds Roads
Rolla, MO
65401

DeKalb, Vic
USDA Forest Service
P.O. Box 2417
Washington, DC
20013

Diwiryo, Ruslan
Directorate for City Planning
J. L. Pattimura 20
Jakarta,
INDONESIA

Duggan, David A.
Delcanda Intrnational Ltd.
P.O. 8004
Ottawa, Ontario
Canada K1G 3H6

Cabalka, Charles, Jr.
Jasper County Highway Dept.
P.O. Box 714
Newton, IA
50208

Cable, Jim
Iowa DOT
826 Lincoln Way
Ames, IA
50010

Caiser, J. H.
Van Wyk and Louw Incorporated
P.O. Box 905
Pretoria, Transvaal
South Africa 0001

Carcamo, Carlos A. Lopez
Ex. Unit of AID Loans

Honduras

Carufel, Larry
3M Company
320 Shaw Road
San Fransisco, CA
94408

Churka, Bernie
Transportation Agency
1914 Hamilton Street
Regina, Saskatchewan
Canada

Clark, Vaughn
Decatur County
P.O. Box 239
Leon, IA
50144

Clementson, Willard
USDA Forest Service
P.O. Box 2417
Washington, DC
20013

Conrad, Paul
Wilbur Smith & Assoc.
1301 Gervais Street
Columbia, SC
29202

Copas, Thomas
Transportation Research Board
2101 Constitution Avenue
Washington, DC
20418

Cowley, Jorde
Celanese Fibers Marketing Co.
P.O. Box 32414
Charlotte, NC
28232

Crider, Donald
Poweshiek County
P.O. Box 306
Montezuma, IA
50171

Crowther, Lloyd R.
Transportation Research Board
2101 Constitution Ave. N.W.
Washington, DC
20418

Cunningham, Grover
Texas R and D Foundation
2602 Dellana Lane
Austin, TX
78746

Currier, Edward
N.Y.S. Cy. Hwy. Supts'. Assn.
County Office Building
Elizabethtown, NY
12932

Davis, Carl
U.S. Forest Service
1720 Peachtree Rd.
Atlanta, GA
30309

Davison, Warren
Cerro Gordo
Court House
Mason City, IA
50401

Devos, Alois
W. J. Reese & Assoc.
2108 5th Street
Rock Island, IL
61201

Donner, Cindy
Comm. Dev./ Division of Plan.
100 Maryland Avenue, Room 200
Rockville, MD
20852

Dunkley, R. F.
Ministry of Works
140 Maxfield Avenue
Kingston 10,
JAMAICA

Dunlop, R. J.
Ministry of Works & Department
P.O. Box 451
Dunedin, New Zealand
NEW ZEALAND

Dybalski, Jack N.
Armak Company
8401 W. 47th Street
McCook, IL
60525

El-Hawary, Mohamed
Massachusetts Inst. of Tech.
77 Massachusetts Ave.
Cambridge, MA
02139

Everitt, Martin
U.S. Forest Service
11177 West 8th St.
Lakewood, CO
80225

Falk, Gary
Forest Service in Morgantown
180 Canfield St.
Morgantown, WV
26505

Fay, Gordon
Minnesota DOT
Transportation Bldg.
St. Paul, MN
55155

Fiala, William
BIA/Albuquerque Office
P.O. Box 8327
Albuquerque, NM
87198

Fox, Dar
Iowa State University
Building B
Ames, IA
50011

Franklin, B. D.
U.S. Forest Service
1720 Peachtree Rd., N.W.
Atlanta, GA
30309

Fullerton, W. T.
Caddo Parish Police Jury
Caddo Parish Court House
Shreveport, LA
71101

Gadallah, Ahmed Atef
Massachusetts Inst. of Tech.
77 Massachusetts Ave.
Cambridge, MA
02139

Gasser, Donald
University of California
4071 Old Sanoma Road
Napa, CA
94558

George, K. P.
University of Mississippi
Carrier Hall
University , MS
38677

Gheen, William
Inter. Development Bank
808 17th St., N.W.
Washington, DC
20577

Gipple, Kelly
Washington County
210 W. Main
Washington, IA
52353

Gode, O. J.
Johnson County
Box 126
Iowa City, IA
52244

Gomez, J. AleJandro
Fondo Nal De Caminos Vecinales

Bogota,
Colombia

Gregory, Fred
Sierra National Forest USDA
1130 O Street
Fresno, CA
93721

Groskubth, W. A.
Mitchell County
Court House
Osage, IA
50461

Guerra, Jean C.
Asociacion Salvadorena de Cami
59 A.N. #314
San Salvador, El Salvador
C.A.

Dvorak, Philip J.
Grundy County
Court House
Grundy Center, IA
50638

Eder, Bob
Alaska DOT
Box 507
Val Dez, AL
99686

El-Salamawy, Abd-el-Aal
Massachusetts Inst. of Technol
77 Massachusetts Ave.
Cambridge , MA
02139

Faiz, Asif
World Bank
1818 H St., N.W.
Washington, DC
20433

Falk, James, M.
Bay County Road Commission
2521 South Huron Road
Kawkawlin, M, MI
48631

Fernadez, Joaquin
C.M.I. International
P.O. Box 1985
Oklahoma City, OK
73101

Fossberg, Per
WorldBank
1818 H Street, N.W.
Washington, DC
20433

Francis, V. C.
Div. of Nat. Roads
P.O. Box 415
Pretoria, Transvaal
REP. OF SOUTH AFRICA 0001

Franklin, Ray
Federal Highway Administration
400 - 7th St. S.W.
Washington, DC
20590

Furen, Walt
USDA Forest Service
P.O. Box 2417
Washington, DC
20013

Garber, Dr. Nicholas J.
Techsult & Co. Ltd.
26 Percival Street
Freetown, Sierra Leone
United Kingdom

Gatten, Richard
Shoshone County
Courthouse, Box 708
Wallace, ID
83873

Gershowitz, Robert
Frederick R. Harris
453 Amboy Avenue
Woodbridge, NJ
07095

Gillespie, Hugh
International Road Fed.
1023 Washington Building
Washington, DC
20005

Glowach, J. A.
Alberta Dept. of Trans.
161 Trans. Building - 9630 106
Edmonton, Alberta
CANADA T5K2B8

Goetz, W. H.
Purdue University
Civil Engr. Bldg.
W. Lafayette, IN
47907

Grass, George
Saskatchewan Gov. Rural Affair
2240 Albert Street
Regina, Saskatchewan
Canada

Grenke, William C.
Roy Jorgensen Associates, Inc.
P.O. Box 3310
Gaithersburg, MD
20760

Grove, James D.

Courthouse
Nevada, IA
50201

Guinnee, John W.
Transportation Research Board
2101 Constitution Ave., N.W.
Washington, D.C.
20418

Gumbert, Robert
Tama County Highway Dept.
101 S. Main
Toledo, IA
52342

Hamilton, G. W.
Monsanto Company
800 N. Linbergh Blvd.
St. Louis, MO
63141

Hankerd, Marian

10350 Hankerd Road
Pleasant Lake, MI
49272

Hanzlik, George E.
Winneshiek Cy. Sec. Rd. Dept.
P.O. Box 50 - Courthouse
Decorah, IA
52101

Harral, Clell
World Bank
1818 H St., N.W.
Washington, DC
20433

Harris, David
U.S. Forest Service
P.O. Box 1291
Jackson, MS
39205

Hassan, Massood
Saskatchewan Dept. of Hwys.
1855 Victoria Ave.
Regina,
SASKATCHEWAN S4P3V5

Henkle, Roger
Poweshiek Couty
P.O. Box 306
Montezuma, IA
50171

Hettinger, Dale
Jefferson County
401 FiscalCt. Bldg.
Louisville, KY
40202

Hide, H.
Transport and Road Res.
Crowthorne
Berks, United Kingdom
United Kingdom RG116AV

Hollingsworth, Joseph
Sheridan County
P.O. Box 612
Sheridan, WY
82801

Hoover, Jim
Civil Engineering Dept.
101 Buildins B; ISU
Ames, IA
50011

Houden, Benjamin
IL DOT
1000 Plaza Drive
Schaumburg, IL
60196

Huber, Robert G.
Washington County
210 W. Main
Washington, IA
52353

Hugo, Fred
University of Stellenbosch

Stellenbosch, Cape Provine
REP. OF S. AFRICA 7600

Hutcheson, Ellis
IL Dept. of Trans.
126 E. Ash St.
Springfield, IL
62706

Iliff, James
Jackson County
Jackson County Courthouse
Independence, MO
64050

Inglis, John
Waipa County
P.O. Box 12
Te Awamutu, New Zealand
NEW ZEALAND

Ippel, J.
Geustyn Forsyth & Joubert, Inc
P.O. Box 20286
Pretoria, Transvaal
REPUBLIC OF S. AFRICA 0001

Irwin, Lynne H.
Cornell University
P.O. Box 10607
Ithaca, NY
14850

Haddad, George
Ministry of Public Works
P.O. Box 1220
Amman,
JORDAN

Hane, Thomas B.
Department of Transportation
811 E. Randolph Road
Silver Springs, MD
20852

Hansen, M. O.
Poweshiek County
P.O. Box 306
Montezuma,, IA
50171

Hardy, Gene R.
Dallas County
415 River Street
Adel, IA
50003

Harris, D. C.
3M Company
3M Center
St. Paul, MN
55119

Hasan, Ahmad
Sverdrup & Parcel & Assoc.
800 N. 12th Blvd.
St. Louis, MO
63101

Haylock, Robert
Butler County
Court House
Allison, IA
50602

Herbst, Lloyd
Sioux County
207 Central Ave., S.E.
Orange City, IA
51041

Hicks, R. G.
Dept. of Civil Engineering
Oregon State University
Corvallis, Oregon
97331

Hosrefe, Ray
FHWA
Rm. 487, 100 Centenial Mall N.
Lincoln , NE
68502

Holmes, Charles
Jefferson County Sec. Roads
P.O. Box 827, 901 N. 8th St.
Fairfield, IA
52556

Hostler, Daniel J.
Hall County
2900 West 2nd; P.O. Box 1048
Grand Island, NE
68801

Howlett, M. R.
USDA Forest Service
P.O. Box 2417
Washington, DC
20013

Hudson, W. R.
Dept. of Civil Eng.
University of Texas at Austin
Austin, TX
78712

Hunzinger, M.
Stanley Consultants, Inc.
Stanley Building
Muscatine, IA
52761

Hvozdanski, John
B. C. Provincial Highways
940 Blanshard
Victoria, British Columbia
Canada

Ingberg, Richard
Minnesota DOT
Transportation Bldg.
St. Paul, MN
55155

Inouye, Ken
U.S. Forest Service
2245 Morello Drive
Pleasant Hill, CA

Irick, Paul
Transportation Research Board
2101 Constitution Ave., N.W.
Washington, D.C.
20418

Jegaraj, T. A.
Public Works Dept.
Locked Bag No. 95
Kota Kinabalu, Sabah
Malaysia

Jesperseh, Del
Story County
Court House
Nevada, IA
50201

Johnson, Milton
Clayton County
County Office Bldg.
Elkader, IA
52043

Jones, David L.
U.S. Forest Service
444 E. Bonita Avenue
San Dimas, CA
91773

Jonsson, Jon Birgir
Public Roads Administration
Borgartun 7
ReykJavik,
ICELAND

Kamicka, K. L.
Ministry of Works
140 Maxfield Avenue
Kingston 10,
JAMAICA

Kersten, Miles
University of Minnesota
3716 - 47th Ave. S.
Minneapolis, MN
55406

Kizer, John
Arkansas St. Hwy. & Trans. Dep
P.O. Box 2261
Little Rock, AR
72203

Klaus, Ben
Iowa DOT, District 1
1020 S. 4th St.
Ames, IA
50010

Klykylo, Henry
Bay County Road Comm.
2521 South Huron Road
Kawkawlin, MI
48631

Kreiling, Harlan
Mason Co.
Court House
Havana, IL
62644

Kruger, Otto
Bureau of Land Management
P.O. Box 30157
Billings, MT
59107

Kurzman, Harold
Louis Berger Int., Inc.
1730 Rhode Island Ave., N.W.
Washington, D.C.
20854

Lamb, Donald
University of Wyoming
P.O. Box 3226
Laramie, WY
82071

Lamm, Lester
Federal Highway Administration
Washington, D.C.

Lankford, Bill
National Park Service
655 Parfet St.
Denver, CO
80215

Larson, Calvin
Federal Highway Administration
Box 1755
Bismarck, ND
58501

Levy, Dale F.
Phillips Fibers Corporation
8245 Nieman Road
Shawnee Mission, KS
66214

Loetterle, Donald
USFS Rocky Mtn. Region
11177 W. 8th Ave.
Lakewood, CO
80225

Love, G. D. (Jerry)
Federal Highway Administration
Room 218 FHRS
Washington, D.C.
20590

Luciani, Luis E.
Laboratorio Vial, M.T.C.
Sta. Rosa 4 Con;No. 15,Ave.Lib
Caracas, Venzuela
Venzuela

Jesse, Larry
Iowa DOT
503 S. Stone
Creston, IA
50801

Johnson, Tallack
Minnesota DOT
Transportation Bldg.
St. Paul, MN
55155

Jones-Dove, A. S.
Ministry of Works
New England, Freetown Sierra L
Freetown, Sierra Leone
United Kingdom

Jorgenson, Neal
Franklin County
Box 118
Hampton, IA
50441

Kannel, Edward
Civil Engineering Department
380 Town Engr. Bldg. ISU
Ames, IA
50011

Kimambo, I. N.
Ministry of Works
P.O. Box 104
Dares Salaam,
TANZANIA

Klassen, Dwane
USDA - Forest Service
Chugach National Forest
Anchorage, AL
99502

Klockenteger, William L.
Federal Highway Administration
400- 7th Street SW
Washington, DC
20590

Konrad, Paul
Dickinson County
Court House
Spirit Lake, IA
51360

Krodinger, Ralph
Jefferson County
Court House Square
Hillsboro, MO
63020

Kupke, William
Iowa DOT
1420 4th St., S.E.
Mason City, IA
50401

Lafrenz, James
Jenkins, Lafrenz & Walsingham
P.O. Box 1176
Panama City, FL
32401

Lamb, John
U.S. Forest Service
1720 Peachtree Rd., N.W.
Atlanta, GA
30309

Langskov, John
U.S. Forest Service
2245 Morello
Pleasant Hill, CA
94523

Larsen, Melvin
Illinois Dept. of Trans.
2300 S. Dirkson Parkway
Springfield, IL
62767

Larson, Rick E.
W. J. Reese & Assoc.
2108 5th Street
Rock Island, IL
61201

Lieder, Bernard
Polk County
Box 27
Crookston, MN
56716

Long, Peter
World Bank
1818 H St., N.W.
Washington, DC
20433

Lovell, C. William
Purdue University
School of Civil Engineering
W. Lafayette, IN
47906

Luhr, David

University of Texas
Austin, TX
78705

Lukanen, Erland
Minnesota DOT
Transportation Bldg.
St. Paul, MN
55155

Lysne, David
USDA Forest Service
Peavy Hall Oregon State U.
Corvallis, OR
97331

Mandigo, Jim
USDA - Forest Service
Engineering Staff Unit
Washington, DC
20013

Manning, Darrell
Idaho Transportation Dept.
P.O. Box 7129
Boise, ID
83707

McCoy, James
U.S. Forest Service
2245 Morello Drive
Pleasant Hill, CA
94523

McLean, John R.
Australian Road Research Board
500 Burwood Highway
Vermont, Victoria
Australia

McNichols, Kenneth
IA Limestone Producers Assn.,
608 East Locusst St.
Des Moines, IA
50309

Millard, Raymond
World Bank
1818 H St., N.W.
Washington, D.C.
20433

Moavenzadeh, Fred
MA Inst. of Tech.
77 Massachusetts Ave.
Cambridge, MA
02139

Monroe, Roderick
the Asphalt Institute
6901 Dodge St.
Omaha, NE
68132

Morley, Lloyd
Regional Mun. of Ottawa-Carlet
175 Loretta Ave, N.
Ottawa, Ontario
CANADA K2C128

Motheral, Joe
De Leu Cather & Co.
165 W. Wacher Drive
Chicago, IL
60601

Muchlinski,Ray
Redwood County
404 Fallwood Road
Redwood Falls, MN
56283

Nashif, Omar
IL DOT
1000 Plaza Drive
Schaumburg, IL
60196

Nelson, Norman
Portland Cement Association
21390 Edgevale
Elkhorn, NE
68022

Nettleton, Tom
U.S. Forest Service
Bldg. 1 (MEDC)
Ft. Missoula, MT
59801

Nichols, Barbara
Crown Zellerback
1 Bush St.
San Francisco, CA
94104

Novak, Robert
Novak, Dempsey & Associates, I
317 West Colfax Street
Palatine, IL
60067

Ofenstein, C. Michael
DOT
6110 Executive Blvd.
Rockville, MD
20852

Otobo, Guy
Fed. Min. of Works & Housing
Tafawa Balewa Sq., Headquarter
Lagos,
Niseria

Lutenegger, Alan J.
Iowa State University

Ames, IA
50011

Maltby, William
Bureau of Land Management
P.O. Box 2965
Portland, OR
97208

Mandril, George
El Paso County DOT
3120 Century St.
Colorado Springs, CO
80906

Maslin, William
Byrd, Tallamy, MacDonald & Lew
2921 Telestar Ct.
Falls Church, VA
22042

McCullough, B. Frank
University of Texas - Austin
Dept. of Engineering ECJ 6.10
Austin, TX
78741

McNabb, David
Forest Engineering Dept.
1301 Maple Grove Dr.
Medford, OR
97501

Michaelis, Richard
Carrll County
Court House
Carroll, IA
51401

Milner, James
USDA Fores Service
210 Franklin Rd.
Roanoke, VA
24101

Mochel, Rich
IL. Dept. of Trans.
126 E. Ash St.
Springfield, IL
62706

Morin, W. J.
Lyon Associates
7900 Westpark Drive
McLean, VA
22101

Morrow, Ralph
Page County
R.R. 4
Corning, IA
50814

Motucka, D.
State of Nebraska
P.O. Box 94759
Lincoln, NE
68509

Munshi, Neil
Williams & Sheladia, Inc.
3833 34th St.
Mt. Rainier, MD
20822

Nelson, Gus
USDA - Forest Service
P.O. Box 309
Petersburg, AL
99833

Nelson, Thomas E.
Lee County
710 Ave. F
Ft. Madison, IA
52627

Neumann, Ed
USDA Forest Service
P.O. Box 7669, Fed. Bldg.
Missoula, MT
59807

Noonan, M. H.
Muscatine County
1631 Isett Avenue
Muscatine, IA
52761

Odendahl, William
Forest Service
1720 Peachtree Road, N.W.
Atlanta, GA
30309

Oglesby, C. H.
Stanford University
850 Cedro Way
Stanford, CA
94305

Owais, Mohamed
Massachusetts Inst. of Tech.
77 Massachusetts Ave.
Cambridge, MA
02139

ParejO, Rafael E.
Vialidad Agricola

Caracas,
Venzuela

Paulson, Ken
Morrison County
Court House
Little Falls, MN
56345

Pearson, John
DOT
Box 406
Atlantic, IA
50022

Perkins, Dave
Arapahoe County
5334 S. Prince Street
Littleton, CO
80166

Perry, William
Forest Service
Deerlodge N. F., Box 400
Butte, MT
59701

Pestotnik, Thomas
USDA - Forest Service
1311 Dominion Drive
Redding, CA
96001

Petersma, Lewis
Van Baren County

Keosauqua, IA
52560

Pickell, John
Community Development
100 Maryland Ave.
Rockville, MD
20850

Pinsonneault, Mike
Goodhue County
Court House
Red Wing, MN
55006

Porter, Harry
Cass County
Court House
Atlantic, IA
50022

Preble, David
Travis County
P.O. Box 1748
Austin, TX
78767

Raumann, G.
Monsanto
P.O. Box 12274
Res. Tri. Pk., NC
27709

Reed, Gary
W. Virginia Dept. of Hwys.
1900 Washington St.
Charleston, WV
25305

Richardson, Lowell
DOT
800 Lilncolnway
Ames, IA
50010

Ring, George, III
Fed. Highway Administration
400 7thSt. S.W.
Washington , D.C.
20950

Robbins, Guy
Portland Cement Association
5420 Old Orchard Rd.
Skokie, IL
60077

Rogers, Ken
Rogers-Jaques Associates
2183 N.W. 86th St.
Des Moines, IA
50322

Ruenkrairergsa
Materials & Research Division
Department of Highways
Bangkok,
Thailand

Rutherford, Norm
Federal Highway Administration
555 Zang Street
Lakewood, CO
80225

Sargent, H. "Jack"
Elkhart County Highway
600East Jackson Street
Goshen, IN
USA
46526

Pasch, John
Louisa County
R.R. 2, Box 290
Wapello, IA
52653

Peak, Bill
Poweshiek County
Box 306
Montezuma, IA
50171

Pelzner, Adrian
Forest Service, USDA
P. O. Box 2417
Washington, D.C.
20013

Perry, C. C.
Henry County
Box 655
Mt. Pleasant, IA
52641

Perryman, Walt
Williamette N.F., South Engr.
49098 Salmon Creek Road
Oakridge, OR
97463

Petermeier, Gerald D.
Benton County
Courthouse
Vinton, IA
52349

Piche, Larry
USDA Forest Service
633 W. Wisconsin
Milwaukee, WI
53203

Pilkington, George B.
Federal Highway Administration
400- 7th St. SW, Room 3116
Washington, DC
25090

Polus, Abishai
Dept. of Civil Engineering
Israel Institute of Technology
Haifa,
ISRAEL
32 000

Pratt, Robert
Iowa DOT
826 Lincolnway
Ames, IA
50010

Quenoy, John
USDA
7801 Camino Del Rio
Durango, CO
81301

Rawlings, Pearl G.
3M Company- International

St. Paul, MN

Renier, E. J.
Portland Cement Association
6600 S. France Ave.
Minneapolis, MN
55435

Richman, Kenneth
Poweshiek County
P.O. Box 306
Montezuma, IA
50171

Ring, Stanly
Civil Engr./Engr. Ext. Depts.
384 Town Engineering Blds.
Ames, IA
50011

Roberts, Freddy L.
Austin Research Engineer, Inc.

Austin, TX
78747

Ross, Matt
IA Concrete Paving Assoc.
8575 Douglas Suite 38
Des Moines, IA
50322

Russell, George
Jefferson County
Courthouse Square
Hillsboro, MO
63020

Sandy, Bob
Warren County
Box 181
Indianola, IA
50125

Saunders, Neil
Bureau of Land Management
P.O. Box 2965
Portland, OR
97034

Schaeffer, Larry
Dept. of Agriculture
3428 Thresher Drive
Tallahassee, FL
32312

Schiffman, Leonard
World Bank
1818 H Street, N.W.
Washington, DC
20433

Scholen, Douglas
Forest Service
1720 Peachtree Rd.
Atlanta, GA
30308

Schornhorst, Eldo
Shelby County

Harlan, IA
51537

Sears, Norman
U.S. Forest Service
R.R. 4
Watertown, WI
53094

Semmel, Harold
Frederic R. Harris, Inc.
453 Amboy Ave.
Woodbridge, NJ
07095

Senekal, P. J.
Geustyn Forsyth & Joubert, Inc
P.O. Box 20286
Pretoria, Transvaal
REPUBLIC OF S. AFRICA

Shea, Gerald
Louis Berger Int., Inc.
100 Halsted St.
E. Orange, NJ
07019

Shook, James
The Asphalt Institute
Asphalt Institute Building
College Park, MD
20740

Skean, Donald
Gannett Fleming Corddry & Car.
P.O. Box 1963
Harrisburg, PA
17105

Skok, E. L.
St. Paul T.V.I.
441 E. Eldridge Ave.
St. Paul, MN
55117

Smith, Joseph
Forest Service
180 Canfield Rd.
Morgantown , WV
26505

Smith, Wesley D.
Hamilton County
Courthouse
Webster City, IA
50595

Soares, Luiz
Brazilian Road Association
Araucaria, 49
Rio de Janeiro, RJ
BRAZIL
22461

Staffini, Edsardo
World Bank
1818 H St., N.W.
Washington, DC
20433

Stavran, Sig
U.S. Forest Service
Fort Missoula
Missoula, MT
59801

Strauss, P. J.
Bruinette Kruger Stoffberg
P.O. Box 3173
Pretoria, Transvaal
REPUBLIC OF S. AFRICA
0001

Strombom, Robert
USDA Forest Service
P.O. Box 3623
Portland, OR
97208

Sullivan, Edward
Institute of Trans. Studies
111 McLaughlin Hall
Berkeley, CA
94720

Swanson, Charles
Washington County Hwy. Dept.
11660 Myeron Rd. N.
Stillwater, MN
55082

Scheltinga, Drew
Weld Company
P.O. Box 758
Greeley , CO
80631

Schnoor, C. F.
Boone County
Court House
Boone, IA
50036

Schoon, John
Northeastern University
360 Huntington Avenue
Boston, MA
02115

Schwark, Howard
Kankakee County
Kankakee County
Kankakee, IL
60901

Seekins, Larry
USDA, Forest Service
P. O. Box 792
Custer, SD
57730

Semmelink, C. J.
National Inst. for Trans. & Rd
c/o 2555 "M" Street N.W.
Washington, D.C.
20037

Seree, Suebsanguan
Dept. of Highways

Bangkok,
Thailand

Shelquist, Robert
DOT
800 Lincolnway
Ames, IA
50010

Sinclair, H. Raymond, Jr.
USDA Soil Conservation Service

Indianapolis, IN
46224

Skeate, Dennis
Walla Walla County Road Dept.
P.O. Box 813
Walla Walla, WA
99362

Smith, Cleo
Montgomery County Highway Dept
Court House
Red Oak, IA
51566

Smith, North
U.S. Army Cold Regions
P.O. Box 282
Hanover, NH
03755

Snyder, Van
DOT
203 E. 21st St.
Atlantic, IA
50022

Spaine, Larry
Transportation Research Board
2101 ConstitutionAve., N.W.
Washington, D.C.
20418

Stanton, Steven
Walla Walla County Road Depart
P.O. Box 813
Walla Walla, WA
99362

Storley, Dewayne E.
Bureau of Indian Affairs

Aberdeen, SD
57401

Strens, Ronald
B. L. and Management
Fed. Blds, 550 W.Fort, Box 042
Boise, ID
83724

Stuart, Edward, III
U.S. Forest Service
2245 Morello Drive
Pleasant Hill, CA
94523

Sunmark, Darreld E.
H. W. Lochner, Inc.
20 N. Wacker Drive
Chicago, IL
60606

Swarthout, Coburn
USDA Forest Service
P.O. Box 2417
Washington, DC
20013

Taber, Nelson
Henry County Highway Dept.
P.O. Box 25
Cambridge, IL
(309)-937-3346

Taylor, J. A.
Kennametal Inc.
P.O. Box 161
Bedford, PA
15522

Thompson, Austin
U.S. Forest Service
630 Sansome St.
San Francisco, CA
94111

Thorn, Paul
U.S. Agency for Int. Dev.
USAID/JAKARTA Box 4
APO San Francisco, CA
96356

Titus, Lowell D.
Stanly Consultants
Stanly Buildings
Muscatine, IA
52761

Tomopulos, G. G.
Stanley Consultants, Inc.
Stanley Building
Muscatine, IA
52761

Tummarello, Anthony
Agency for Int. Development
AFR/DR/ENGR Room 2485
Washington, DC
20523

Ullburg, Goran
Union Bank of Finland
P.O. Box 868
SF 00101 Helsinki,
FINLAND

Van Der Walt, N.
Div. of Nat. Roads Dept.
P.O. Box 415
Pretoria, Transvaal
REPUBLIC OF S. AFRICA 0001

Van Smaalen, H.
Civ. Eng. Dept. Agri. Universi
Nieuwe Kanal II
Wageningen,
NETHERLAND 6709 PA

Vera-Barandiaran, Luis
International Road Fed.
1023 Washington Bldg.
Washington, DC
20005

Visser, Robert
Jones County
Box 308
Anamosa, IA
52205

Wade, Billy
Bureau of Local Roads, IL DOT
2300 Dirksen Rm. 201
Springfield, IL
62764

Wais, Thomas
Douglas Co. Annex
156rh & Maple
Omaha, NE
68164

Watanatada, Thawat
World Bank
1818 H Street, N.W.
Washington, DC
20433

Welshons, Earl H.
Winona County Highway Dept.
R.R. 20
Winona, MN
55987

Widick, Donald
Bureau of Land Management
18th & C St., N.W.@
Washington, DC
20021

Willard, H. A.
Federal Highway Administration
P.O. Box 627
Ames, IA
50010

Williams, S. G.
Ministry of Works
140 Maxfield Avenue
Kingston 10,
JAMAICA

Wilson, W. G.
Internation Road Fed.
1023 Washington Bldg.
Washington, DC
20005

Tamaklow, E. K. A.
University of Science & Tech.

Kumasi,
Ghana

Teisen, Melrow
Forest Service
R.R. 2
Libby, MT
59923

Thompson, Ronald
USDA, Forest Service
P.O. Box 3623
Portland, OR
97208

Tigner, S. C.
U.S. Federal Highway Admin.
Traffic Systems Division
Washington, DC
20590

Tobey, Vernon
Dept. of Public Works
American Samoa Government
Pago Pago,
AMERICAN SAMOA 96799

Tompkins, Kenneth
Forest Service
633 W. Wisconsin Ave.
Milwaukee, WI
53201

Tweed, Maynard
Webster County
Courthouse
Ft. Dodge, IA
50501

Unruh, Marion
USDA Forest Service
P.O. Box 2417
Washington, DC
20013

Van Gundy, Dick
Polk County
5885 NE 14th Street
Des Moines, IA
50313

Vander Hamm, Lowell B.
Iowa DOT
Box 587
Fairfield, IA
52556

Visser, A. T.
Austin Research Engineers
2602 Dellana Lane
Austin, TX
78746

Voigt, Ruthyn
USDI Bureau of Indian Affairs
500 Gold S.W., P.O. Box 2185
Albuquerque, NM
87103

Wagner, Daniel
USDA -Forest Service Region 2
Box 948
Glenwood Springs, CO
81601

Wasill, Richard G.
Federal Highway Administration
18209 Dixie Highway
Homewood, IL
60430

Weber, Jerry
Calhoun County
Courthouse
Rockwell City, IA
50579

West, Ernest
Tennessee County

Madisonville, TN
37384

Wight, H. Dale
Crawford County
P.O. Box 458
Denison, IA
51442

Williams, Marcus
State of Mississippi
P.O. Box 2451
Jackson, MS
39205

Williamson, Ronald
Forest Service
319 S.W. Pine
Portland, OR
97208

Wisness, Henry
N. Dakota State Highway Dept.
Capital Grounds
Bismark, ND
58501

Witty, Robert
Minnesota DOT
Transportation Bldg.
St. Paul, MN
55155

Woodward, Bill G.
USDA Forest Service
517 Gold Avenue SW
Albuquerque, NM
87102

Yankee, Steve
Stanle Consultants, Inc.
Stanley Building
Muscatine, IA
52761

Yung-Hee, Yoon
Korea Highway Corporation
#293-1 Keum-To Dong
Sung-Nam City, Kyung-Gi-Do
Korea

Zealley, H. E.
Kistchie Nat'l Forest
2500 Shreveport Highway
Pineville , LA
71360

Zimmerman, Gerald
Bureau of Reclamation
P.O. Box 25007
Denver, CO
80225

Woltman, H. L.
3M Company
3M Center
St. Paul, MN
55101

Wyatt, Richard J.
Texas Research Dev. Foundation
2600 Dellana Lane
Austin, TX
78746

Yoder, Eldon
Purdue University
C. E. Building
W. Lafayette, IN
47907

Zaniewski, John
Texas Research & Dev. Found.
2602 Dellana Lane
Austin, TX
78746

Zedalis, John
Office of Engineering
Agency for Inter. Development
Washington, DC
20523

# Part VI

# ERRATA FOR TRANSPORTATION RESEARCH RECORD 702 LOW-VOLUME ROADS: SECOND INTERNATIONAL CONFERENCE

Use the Geotechnical Data Bank! Gary D.Goldberg, C.W.Lovell and R.D.Miles

Substitute Tables 1,2, and 3 on pages 143 & 144

Table 1 Summary of Regression Equations for Prediction of Compression Index ($C_c$) and Compression Ratio ($C_r$). ($p_c$ in kPa)

| Unit | Dependent Variable | $R_a^2$ | Regression Equation | Number of Samples, N |
|---|---|---|---|---|
| All Samples | $C_c$ | 0.856 | $C_c = 0.5684\ (e_o + 0.0033\ w_L - 0.0082\ w_p + 0.000343\ p_c - 0.4322)$ | 96 |
| | | 0.800 | $C_c = 0.5363\ (e_o - 0.4110)$ | |
| | | 0.792 | $C_c = 0.0002\ (w_n^2 - 106.2727)$ | |
| | | 0.783 | $C_c = 0.0129\ (w_n + 0.1015\ w_L - 16.1875$ | |
| | $C_r$ | 0.691 | $C_r = 0.2037\ (e_o - 0.2465)$ | |
| Wabash Lowland | $C_c$ | 0.838 | $C_c = 0.5673\ (e_o - 0.4422)$ | 29 |
| | $\log C_c$ | 0.831 | $\log C_c = 2.7904\ (e_o - 0.3346\ e_o^2 - 0.8449)$ | |
| | $C_r$ | 0.750 | $C_r = 0.221\ (e_o - 0.3074)$ | |
| | | 0.748 | $C_r = 0.0065\ (w_n - 11.6361)$ | |
| | | 0.735 | $C_r = 0.0034((e_o)\ (w_n) + 8.3647)$ | |
| Crawford Upland | $C_c$ | 0.859 | $C_c = 0.0101\ ((e_o)\ (w_L) - 0.5765\ w_L + 12.665)$ | 28 |
| | | 0.833 | $C_c = 0.0114\ (w_n + 0.2491\ w_L - 18.8134)$ | |
| | | 0.788 | $C_c = 0.4941\ (e_o - 0.3507)$ | |
| | | 0.777 | $C_c = 0.0133\ (w_n - 12.1886)$ | |
| | $C_r$ | 0.740 | $C_r = 0.0001\ (w_n^2 + 455.8889)$ | |
| | | 0.736 | $C_r = 0.0033\ ((e_o)\ (w_n) + 12.5168)$ | |
| | | 0.721 | $C_r = 0.1164\ (e_o^2 + 0.3594)$ | |
| Outwash and Alluvial Deposits | $C_c$ | 0.894 | $C_c = 0.6076\ (e_o + 0.003\ w_L - 0.0095\ w_p + 0.000449\ p_c - 0.4186)$ | 63 |
| | | 0.842 | $C_c = 0.5621\ (e_o - 0.4215)$ | |
| | | 0.822 | $C_c = 0.0153\ (w_n + 0.1022\ w_L - 0.3104\ w_p - 11.6123)$ | |
| | $\log C_c$ | 0.772 | $\log C_c = 2.1389\ (e_o - 0.2967\ e_o^2 - 0.9374)$ | |

Table 2 Summary of Regression Equations for Prediction of Unconfined Compressive Strength ($q_u$). ($q_u$ in kPa; $\gamma_d$ in kg/m$^3$)

| Unit | Dependent Variable | $R_a^2$ | Regression Equation | Number of Samples, N |
|---|---|---|---|---|
| Calumet Lacustrine Plain | $q_u$ | 0.756 | $q_u = 0.0003644\ (\gamma_d^2 - 2518883.9)$ | 40 |
| | $\log q_u$ | 0.750 | $\log q_u = 0.3804 \times 10^{-6}\ (\gamma_d^2 + 2.401 \times 10^6)$ | |
| Lacustrine Deposits | $\log q_u$ | 0.699 | $\log q_u = + 0.3804 \times 10^{-6}\ (\gamma_d^2 + 2.570 \times 10^6)$ | 48 |

Table 3 Summary of Regression Equations for Prediction of Standard Proctor Maximum Dry ($\gamma_{d_{max}}$) and Wet ($\gamma_{m_{max}}$) Densities and Optimum Moisture Content ($w_{opt}$). ($\gamma$'s in kg/m$^3$)

| Unit | Dependent Variable | $R^2_a$ | Regression Equation | Number of Samples, N |
|---|---|---|---|---|
| All Samples | $w_{opt}$ | 0.894 | $w_{opt} = -0.03062 (\gamma_{d_{max}} - 2340.3644)$ | 138 |
| Valparaiso Moraínal Area | $\log \gamma_{d_{max}}$ | 0.816 | $\log \gamma_{d_{max}} = -3.683 (1/w_L + 0.127 \log w_L - 1.109)$ | 26 |
| | | 0.785 | $\log \gamma_{d_{max}} = -0.224 (\log w_L - 16.097)$ | |
| | $\gamma_{m_{max}}$ | 0.790 | $\gamma_{m_{max}} = -1848.7498 (\log w_L + 9.962 (1/w_L) - 2.976)$ | |
| | $\log \gamma_{m_{max}}$ | 0.694 | $\log \gamma_{m_{max}} = -0.135 (\log w_L - 26.2080)$ | |
| | $w_{opt}$ | 0.972 | $w_{opt} = 0.0448 (\gamma_{m_{max}} - 1.298 \gamma_{d_{max}} + 604.899)$ | |
| | | 0.870 | $w_{opt} = -0.0260 (\gamma_{d_{max}} - 2432.7118)$ | |
| | | 0.810 | $w_{opt} = 23.0357 + 0.002 (w_L)(w_p) - 285.939 (1/w_L)$ | |
| Residuum of Limestone Bedrock | $\gamma_{d_{max}}$ | 0.772 | $\gamma_{d_{max}} = -1841.0591 (\log w_L + 14.0953 (1/w_L) - 2.906)$ | 22 |
| | $\log w_{opt}$ | 0.781 | $\log w_{opt} = 0.0042 (w_L + 259.0381)$ | |

Effect of Simple Road Improvement Measures on Vehicle Operating Costs in the Eastern Caribbean
H.Hide and D.Keith

Insert Figure 8 on page 276

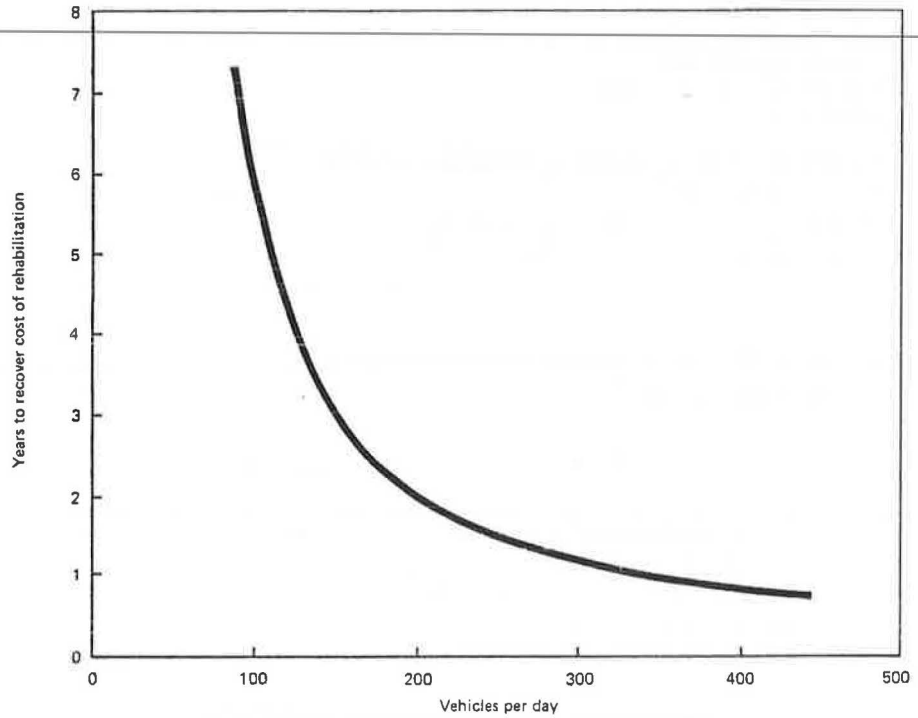


Fig. 8 THE TIME REQUIRED TO RECOVER THE TOTAL COST OF REHABILITATION ON LOW FLOW ROADS