strongly that research on low volume roads must add these new dimensions. The technical side is being well cared for as has been clearly demonstrated by the presentations of this conference. But to me, taking a national point of view, the conference's main lesson was that we must broaden our efforts and tackle the other pressing issues which low volume road engineers must face in the years ahead.

SUMMARY ADDRESS: AN INTERNATIONAL VIEW

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Introduction

I wish to express my sincere congratulations to each and every one of the commentators of this conference. The seriousness and professional character of their work are worthy of acknowledgment and demonstrate the existing interest and concern regarding the central theme we are dealing with: Low Volume Roads. I likewise wish to express my sincere thanks to the organizers of this important event for having considered that the point of view of a country like Mexico, whose experience with low volume roads lies within a socioeconomic context different from that of the host country, would be interesting enough to be included in the closing summaries of this conference.

Having listened to most of the papers given during this conference and having carefully read the rest of the works presented, I would like to submit for all the attendees' consideration a synthesis of the points that from the so-called international view I consider to be of major importance, as well as some remarks, a very few, based on Mexican experiences with low volume roads. With this aim, I have considered it appropriate to group the different subjects we are dealing with under the following main headings: Planning, Design and Construction, Maintenance, and Pavements and Soil Mechanics.

Planning

From the keynote speech through most of the papers, it has been clearly stated that there is a significant interest in dealing with the severe restrictions that the worldwide financial crisis imposes on resource allocation for construction and maintenance of roads. This is, therefore, the time to find imaginative solutions for using limited resources inside a multiple objective framework, intelligently expressed by Mr. Owen when he stated that the world need for additional supplies, further requirements for transportation, rural access, and future social needs remain to be satisified. We live in a challenging time full of new opportunities, and this is precisely what has been shown in this conference by analyzing critical issues that must be overcome in the coming years by the road organizations of developed and developing nations.

Praiseworthy indeed are the efforts to deal with the scarcity of financial resources, which will continue to be among the main worries in the coming years, and to search for more economical and lasting materials for the construction and maintenance of low volume roads. In spite of this perplexity, however, I must point out that the human concern has been considered in many papers. For instance, it has been recommended that local transportation patterns strictly associated with tradition and the culture of diverse communites be retained. Riverson, Hine, and Kwakye have stated that the social impact of low volume roads is even more important than production increases. Nevertheless, I have to point out here that it is also important, very important, to open more agricultural areas so that their products can be traded, giving the opportunity to isolated communities to participate in the national marketing process, thus transforming it from an autonomous economy into a community with perspective.

I have listened with particular interest to the development of models which, without any doubt, will become significant planning tools for low volume roads. The efforts to find out how to invest, as well as those related to vehicle operations costs, will certainly form a technical basis for decision making. However, it must be emphasized that the value of these models stems from their use as a part of a major system. This system is the whole decision making process. In addition to the technical point of view provided by these models, one must consider, for instance, social costs, political problems, lack of technical data in many developing countries and the so-called opportunity costs. As a reinforcement to this idea, I will make reference to the vehicle operating costs that were discussed in different sessions. The papers related to this topic are mainly oriented toward reducing vehicle operating costs through improved road surface standards, such as roughness and geometry. I am convinced that a sacrifice of vehicle operating costs can be made on behalf of social costs. Let me give you a further explanation. It is important for some countries to have more roads with medium standards than to have just a few roads with higher standards. The result is that you divert cost from the people who have nothing (the inhabitants of isolated communities) to the people who have (the car owners). This is an experience that has been confirmed by more than 80,000 kilometers of these roads in my country, Mexico.

Many ingenious ideas for solving specific planning problems have been expressed in this conference. Nevertheless, the evaluation of their future use is highly recommended because problems differ from one environment to another depending on diverse characteristics and the development level for each country. For instance, Mr. Mercier's paper has a proposal related to closing a road when there are not enough resources to maintain it, thus avoiding further deterioration. This proposal might seem acceptable from a rich country's point of view. However, for a developing country with a road network in its first stages of formation, this solution might not be so well accepted since many times low volume roads are the only means of transportation.

Design and Construction

The papers presented concerning the general problems represented by the construction of low volume roads are of great importance. The experiences and analytical models on which these papers are based constitute very interesting studies which respond to the restless concern for greater knowledge of the behavior of materials and of the different elements which make up the structure of this type of road.

Sometimes, low volume roads are defined by using the annual average daily traffic of vehicles, in both directions. From the papers presented here on this subject, it seems advisable to emphasize that this single criterion can be confusing because of the large differences that may exist in the specifications and method of construction for low volume roads. Among other factors these differences depend on the degree of economic development of each country; on the policies of maintenance, rehabilitation, and construction; and on the type and composition of the traffic forecast. Concern about these differences has been expressed here by some of the authors. Because of the foregoing, it might be advisable to set up an international classification for low volume roads, with different categories, taking into account more factors, than just the volume of traffic.

Some of the papers presented, referring to construction procedures, acquaint us with the experience of new technologies based on the use of materials not previously taken advantage of on a large scale. Such is the case of rubber asphalt mentioned by Mr. Schnormeier in his qualitative and economic study. The use of this procedure has found interest in Mexico because of satisfactory experiences using it in pavements over clay soils subject to volumetric changes, notably diminishing the cracks in asphaltic surface mixtures.

The studies of stabilization and functioning of the sand bases treated with asphalt and foamed asphalt presented, one by Acott and Myburgh, and the other by Skok, Mathur, Wenck and Ramsey, offer a great possibility for the use of these materials, which have a low acquisition cost, in all countries that have a road network located in desert or coastal zones.

In the Second International Conference on Low Volume Roads Professor Miles S. Kersten mentioned that information for design of low water crossing structures is almost nonexistent.

The paper of Mr. Wen Shen shows, on the basis of inquiries, more important tangible factors, as well as the conditions that were found to be ideal for building low water crossing structures. It is important to consider that the hydraulics studies made for this purpose must include a deep concern about scour.

The physical observation of the constructed works (preferably with observations for more than 5 years), their classification by type of soil, rain precipitation, materials used in their construction, and costs of maintenance could lead to providing more data on the proper selection on this type of construction, as Mr. Eriksson pointed out in his paper.

We cite the experience of Mexico where a great number of low water crossings and bridges have already been built (mainly in the desert zones in the north of the country). There are structures older than 15 years that continue to function correctly with a minimum investment in maintenance.

For countries that are in the road network construction stage, the paper presented by Mr. Baumel on rural bridges and roads built in the United States, will be interesting. These bridges and roads face serious problems because of deterioration since the majority were built before 1940 and are now subject to very different traffic conditions. In developing countries this experience must be taken into account very carefully because traffic volume and vehicle weight may become greater. There is a concern that the constant search for lower costs will lead to a reduction of project standards.

The developing countries confront the problem of rural communication with scarce resources and are searching for the best use of local materials. Thus, they are implementing technologies with intensive labor use. Sometimes this is apparently at a higher cost than the use of imported machinery, but it creates employment and saves foreign exchange.

Maintenance

Significantly important was the observed interest that all countries, more than ever, have shown in maintenance. The proposal of Roberts and Robinson must be taken seriously. Improving management methods, reshaping budgetary policies, legislating vehicular load, and the using adequate technology and labor are realistic alternatives to the traditional strategy of increasing budgets, mainly because maintenance costs have already reached unprecedented levels.

For instance, it has been proposed to divert budgets traditionally assigned to new roads to maintenance thus reversing the common budgetary policy. The reason for this is that maintenance represents a very important contribution to the economic health of a country.

Special mention must be made of those efforts oriented to developing an adequate technology for low volume roads. What I am seeking to point out are the innovative ideas worked out to eliminate the inconvenient practice of giving low volume roads the same technical treatment as highways and freeways. There are papers that provide a technical basis for evaluating deterioration like that realized in Brazil and Idaho. There are also other papers that must be mentioned that are related to this subject, for example the work for Mr. Smith dealing with specific signalization system for low volume roads. However, I must again emphasize the fact that mathematical models must be validated for different conditions. This is especially discussed in the Brazil paper.

Pavements and Soils Mechanics

The papers presented in this conference provide an excellent summary of current problems faced in pavement construction, maintenance, and rehabilitation.

Luhr and McCullough discussed the economic evaluation of pavement design alternatives through several specific examples, using the pavement design and management system (PDMS) program, which optimizes pavement design and rehabilitation strategies on the basis of total overall cost. Perhaps, it would be appropriate to add that the potential users of these valuable techniques should recognize the importance of supplying sound and comprehensive information concerning material properties and costs, seasonal conditions, traffic, and road geometry.

Another paper related to the previous one was presented by Luhr, McCullough, and Pelzner. It described a simplified pavement design procedure for low volume roads that is based on the use of linear elastic-layer theory and performance data from the American Association of State Highway Officials (AASHO) Road Test. The elastic-modulus values used in this design procedure can be determined either by resilient-modulus testing or by either of two empirical correlations. This method is currently used by the U.S. Forest Service, and the information obtained through its implementation will be very useful to other countries. In addition to these experiences, it would be appropriate to validate this method, whose basic algorithm takes into account the environment and pavements tested in Ottawa, Illinois, utilizing studies under different conditions, such as those prevailing in tropical countries.

Coghlan presented a paper where a comparison is made of two models for pavement design: the W.E.S. model for thickness requirements for unsurfaced roads and airfields and the AASHTO model for flexible pavements with a bituminous surface course. Through some conversions the author compares both models using the same parameters as those of the AASHTO model and concludes that the W.E.S. model indicates a required pavement strength 10-50 percent lower than that developed by AASHTO for the same traffic and subgrade strength. The limitations of the W.E.S. model are indicated by the author. It is interesting to observe the large differences between the two procedures.

As Queiroz and Hudson indicated in their paper, the primary objective of their study was to develop models to predict pavement performance and behavior for Brazilian pavements. The models are needed to relate road user costs and road maintenance costs to roadway conditions in order to predict total highway transportation costs. The authors clearly indicate that rutting was found to be light in the study area (average of 2.5 mm) and probably did not act as a trigger to initiate maintenance on the pavements studied; therefore, to extend the results to other conditions, it seems desirable to carry out experimentation on other types of roads, under similar climatic conditions, in order to include information on those cases where permanent deformation becomes a significant factor in the distress mechanism.

Visser, Maree, and Marais presented a very interesting and well documented paper on the implications of light bituminous surface treatments on gravel roads. The use of dust palliatives and surface seals on gravel roads was investigated in order to find a method of upgrading their serviceability that would not require an extensive capital outlay. Regarding this paper, it can be said that the performance and design philosophy of light pavements have a great resemblance to the findings of the long-term research program carried out in Mexico where, in a dry climate, very light structures have satisfactorily endured more than one million standard axle loads over a life span of 14 years. Also, it is considered that the heavy vehicle simulator is a valuable tool for studying pavement performance in the field.

Thurmann-Moe and Ruistven presented an interesting paper on graded gravel seal (otta surfacing). It is felt that the techniques described in the paper may have great appeal in developing countries like Mexico where thin surfacings are widely used.

Scherocman presented a paper covering cold in-place recycling of low volume roads. As indicated before, this procedure has been carried out in developing countries using various types of equipment. The social and economic impact of the use of foreign technology should be analyzed carefully in each case.

Two papers were presented that show construction procedures and long-term performance of low volume roads and streets. The first, by Spelman, discusses problems on rural cold recycling in two eastern national parks; and the second, by Schnormeier, presents the use of asphalt-rubber on low-cost streets in the City of Phoenix.

Various papers were presented on asphalt stabilization. Because of space limitations only three of them will be referred to. Mamlouk and Wood dealt with the use of properties of emulsified asphalt mixtures; Castedo and Wood discussed stabilization with foamed asphalt of commonly used aggregates; finally Tia and Wood presented a paper on the use of asphalt emulsion and foamed asphalt in cold-recycled paving mixtures. It is suggested that the conclusions of this type of study be validated, or broadened, into actual projects that analyze the long-term performance of pavement structures. Most of the findings might also be applicable to higher traffic levels, at least in developing countries.

Stabilized bases could also be useful in low volume road construction. Four papers were presented covering this subject. Shah, George, and Rao showed how poor quality materials can be used when adequate stabilizers are added; bitumen, lime, cement, and even clay have been used. The paper by Ali and Youssef dealt with this aspect as applied to silt stabilization; however, it is not well understood why mechanical stabilization was disregarded. The

article by Ruenkrairergsa presented a cost comparison between bases constituted of soil-cement and of crushed rock. This purely economic aspect is of great interest in countries where very few sources of economically obtainable rock exist. Finally, Usmen, Head, and Moulton presented several cases, with pertinent references, where wastes associated with coal mining have been used in low volume roads and in highways. As the authors claim, economic feasibility is probably the most important consideration that will govern their widespread use. It can be said, as a generalization of this idea, that wastes from the mining industry could also be used in low volume roads. In all cases, the common interest is the best use of available resources during construction.

The interest in predicting or determining the stress-strain characteristics of the different layers of materials of a pavement was well demonstrated by several papers presented to this conference. In the following paragraphs, reference will be made to three articles dealing with this aspect.

Visser, Queiroz, and Hudson showed the results of an interesting research program carried out in Brazil and extended with data collected by a consulting firm. Excellent laboratory work was carried out. The paper presents two models relating the resilient modulus of undisturbed samples, first with Atterberg limits and then with density and California bearing ratio (CBR); deviator stress is also taken into consideration. Unfortunately, no data are presented on the strength of the samples tested, nor is there a discussion of how the results should be applied to a practical design. It would be of interest to see how the use of a resilient modulus is implemented in design methods for pavements of low volume roads in developing countries.

The paper presented by Van Wyk, Yoder, and Wood shows the results of an investigation carried out to determine the structural equivalence factors of recycled layers. The measurements made on an experimental road, 15-km long, during a 250-day period are described. The Bistro program was used to select cross sections that gave the same dynaflect deflection basis. Structural coefficients were calculated using either the subgrade deformation or the tensile strain at the bottom of the recycled layer as the controlling criterion. It is interesting to see that the tensile strain criterion gave the smaller structural coefficients. However, it is unfortunate that the recommended structural coefficient (A_Z) for the recycled layer varies over a wide range. Anyhow, it is well known that structural coefficient values are a function of many factors as well as the failure criteria used, as concluded in this paper.

Clegg showed the application of an impact test to field evaluation of marginal base course materials. He presented interesting correlations between the results of the impact test (CIV), the California bearing ratio and a pseudo elastic model. It is suggested as a procedure for field design; however, it is emphasized that the proposal is in the development stage. The ease with which this type of test can be performed will surely be of great help both during and after construction of roads.

Fingalson and Jackura, and Hannon and Forsyth, presented two papers about the behavior of native earth structures. Here, reference is made to the first paper, where two projects are described for embankment stabilization over unstable, boggy ground with peat thickness up to 12 feet. The use of woven polypropylene filter fabric was successful and resulted in savings over conventional muck excavation. It is unfortunate that no report was made of the actual settlements and of the real volume of fill placed so that comparisons could be made with the volume that would have been placed if no fabric were used. The author reports that compaction in areas where the fabric was used was excellent. Projects like these will be common in several countries, Mexico among them, that are now investing in roads in coastal zones. However, the thicknesses of soft soil may be greater than those reported by the author.

To complement this summary of aspects related to soil mechanics and pavement design, it is appropriate to indicate that a long-term research program on the design, construction, maintenance, rehabilitation, and operation of typical roads is being carried out in Mexico. The roads studied in the program, launched by the Ministry of Communications and Transport in 1962, range from low volume paved roads to heavy traffic highways. The program covers several related areas: (a) investigation of the behavior of specially constructed test roads; (b) study of the behavior of roads representative of the national system; and (c) full-scale laboratory studies using a circular test track, test pits, and dynamic testing equipment. A design method has been developed and validated for pavements with thin surface courses and granular bases and subbases. Performance of pavements at high temperatures is one of the current research programs, as well as the study of local materials and mix design methods related to their actual performance in the field. Information on these studies has been presented to the Permanent International Association of Road Congresses (PIARC) and elsewhere.

Mr. Chairman, ladies and gentlemen. The excellent and exquisite exposition by Professor Owen in the keynote speech showed us clearly the importance of the rural, low volume roads network. It also shows us the role that we, the representatives of the people involved in construction of roads, must play in the very near future in all kinds of world activities in order to improve the living standard in many regions. He contends that local roads are the beginning and the end of a large part of the global traffic in food, minerals, and forest products. He remarked that if rural and low volume roads do not have enough resources, the present situation may find the world without adequate supply lines to the cities and without the necessary rural access rural roads to make possible the provision of food and other resources needed for the economic survival of

both city and country. Professor Owen also called for an international effort of cooperation as a possible way to create a global network of organizations that would focus responsibility for extending and improving the world's transport capabilities. He pointed out that this kind of road means a way to provide benefits for a better education, health, housing, labor, life. He ended by calling to our attention the disease of the mother world: an imbalance in terms of wealth, power, culture, attraction, and hope. But creating new hope for the isolated and forgotten in rural areas all over the world would be a challenging assignment entrusted to this international conference. This philosophical thought is in agreement with the Mexican position expressed by the Minister of Communications and Transport during the Ninth World Meeting of the International Road Federation held in Stockholm. There Mr. Felix stated, "If the future can, at times, be forboding it remains, undoubtedly, full of opportunity and promise." The optimistic spirit with which we all face the future, and the efforts made to shape it, assure us of such fine results. From this framework of hopes and fears we chose the right perspective for our theme. Low volume roads will possess strategic importance in the future. As a consequence, developing nations must take the lead in conceiving and applying those instruments appropriate to their own reality and needs as well as to fulfilling their own requirements.

Finally, three basic elements most certainly shape the framework of our actions to modify and improve human living conditions: liberty, justice, and respect for others. There pertinence and exercise characterize the true sense of progress. Their is no growth without freedom; no humanization without justice; no fraternity without respect. Together they comprise the highest goal of humanity: peace, with freedom, justice, and respect for others. Roads in the future should be roads to harmony. Indeed roads to peace. I do thank you very much.

*CALIBRATING AND STANDARDIZING ROAD ROUGNESS MEASUREMENTS MADE WITH RESPONSE TYPE INSTRUMENTS

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The UK Transport and Road Research Laboratory road roughness calibrating and standardizing beam was developed to provide a calibrating capability for response type road roughness measuring systems (RTRRMS). This development was based on past TRRL experience in the field of roughness measurement in developing countries. The concept of "ride comfort" as adopted in the developed world as a direct measure of the unevenness of a road surface as perceived by the road user was not applicable to the road conditions met in developing countries. In such countries ride comfort and level of service do not have the same importance as in the developed countries, as the greater need is for more roads to provide the basic means of transportation and communication which are operable through the year. Because of shortage of resources for building and maintaining all weather roads, a lower serviceability rating is tolerated by the user. However, the lower quality of the road surface manifests itself in higher vehicle operating costs through greater wear and tear of the mechanical components of the vehicles. Comfort to the vehicle rather than to the rider takes on a greater importance. There is very little evidence to suggest what measure of roughness is most appropriate to relate to the effects of "vehicle comfort." Measures in use have been generally selected on the basis of convenience, simplicity and past experience of investigators, and the most popular measure has been the output of RTRRM's which measure the displacement of the axle relative to the body of the vehicle induced by the roughness of the road it is traversing. The magnitude of these response type measurements varies according to the suspension characteristics of the vehicle used and also with time due to a change in these characteristics through usage. Such measurements are acceptable only if they could be calibrated to a given standard enabling measurements with different vehicles at different periods in time and space to be related to that standard. In spite of these serious drawbacks RTRRMS enjoy a great popularity with practicing engineers and researchers and are in widespread use throughout the world. It has been accepted that this method of measurement will prevail for some years to come and therefore the necessity to provide a viable and readily available calibration system is urgent.

An alternative to the RTRRMS measure of roughness is a profilometry based measure of roughness, and is an obvious candidate for providing a calibration reference for calibrating measurements of RTRRMS. A major requirement of any profilometer based system is that it should have the ability to accurately measure the longitudinal profiles of test sections of road, and also be able to be calibrated independently of other measuring systems. It also requires a method of processing the profile data to yield a single roughness statistic to describe the profile for subsequent correlation with RTRRMS measures.

A successful calibration system based on profilometry for use in developing countries needs to satisfy three important conditions. The calibration system/instrument must be easily transportable particularly from country to country. Appraisal studies undertaken by consultants for developing countries are usually of short duration. This means that unless the instruments can be easily transported to the country and the site, they will not be used by practicing engineers and consultants, however good they may be. Secondly the instrument must be reasonably simple to operate, and data management, analysis and interpretation available immediately after measurement. Manual data processing cannot be undertaken by field staff, therefore the generation of profiles alone in the field and the creation of a large data bank without the capability of instant computation, analysis and presentation of calibrated results is not acceptable as a viable method of calibrating roughness measurements. The last and equally important consideration is