

runs were prepared in new number order, old number order, bin order, and manufacturer number order, and all new PMIS catalogs were supplied.

Since the old system was not up to date with the inventory balances, 100 percent audits were made of the quantities on hand. The new system supplies the report used for auditing in bin number order. This report actually reduces the physical count time from about 7 h with the old procedures to 3 h with the new.

The ASHTD Internal Audit Section completed a review of PMIS design documentation and operational procedures. The final report indicated that audit-ability and control are adequate.

The two pilot districts have conducted periodic inventories of a percentage of their stock as prescribed by ASHTD policy. These partial inventories yielded the least variance ever achieved between actual and book figures in those districts. The pilot districts balanced their year-end inventory within a day of the end of the fiscal year whereas all other districts required about four weeks.

Authorization to proceed with statewide implementation of PMIS has been requested. That decision is being delayed pending legislative action on additional highway funding.

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Abridgment

Routine Maintenance of Highways in Member Countries of PIARC

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The techniques currently used for routine road maintenance are described on the basis of data from the member countries of the Permanent International Association of Road Congresses (PIARC). The planning and control of these works are examined. Details are given regarding the established administrative structure (maintenance districts and maintenance centers) and personnel training. Finally, the financial management of road maintenance is dealt with from the point of view of maintenance costs and analytic accounting. The following areas of needed improvement are noted: greater cost-effectiveness of specific maintenance techniques, the development of more durable materials, the necessity of an overall maintenance strategy, and the continued improvement of analytic accounting.

In member countries of the Permanent International Association of Road Congresses (PIARC), as a result of advances in vehicle ownership and the development of road network equipment, the problems presented by road maintenance have required a total reorganization of the methods used. In Great Britain, the Marshall committee, taking this reorganization as a basis, studied organization and maintenance standards. In France, efforts were for a long time aimed at strengthening strategies for the national road network, while at the same time the Federal Republic of Germany achieved the highly mechanized organization of its motorway maintenance centers.

Nevertheless, it has been felt necessary to adopt a systematic and rational approach to the formulation of overall maintenance strategies. Although maintenance budgets have traditionally been drawn up on the basis of the budget for preceding years, it has now been confirmed that the establishment of these budgets with respect to levels to be achieved is desirable. Currently, the procedure used in most countries combines both approaches.

TECHNIQUES

As a result of the increase in traffic and the degree to which roads are equipped, it has proved to be necessary to work out maintenance techniques that are both more suitable and more economical. The improvements made in these techniques have to do chiefly with the increasing mechanization of works, which in turn is the result of more efficient plant better adapted to maintenance tasks and the use of improved materials.

Patching is in most countries the largest item in day-to-day pavement maintenance. Patching may be used to remedy local deficiencies of a pavement in good condition and also to maintain minimum service levels over a short period on a damaged pavement for which major repairs have been scheduled. Ways of mechanizing the process to the greatest extent possible are currently being studied.

The patching of flexible pavements consists of making emergency repairs of defects such as pot-holes, local depressions and cracks, or incipient peeling, by the following methods:

1. The means involved in temporary patching are very limited: cleaning with a brush, spreading with a shovel, and tamping with a rammer.
2. Permanent patching consists of removing the unstable material by cutting with a saw, filling the cut with a bituminous material, and completing the operation by laying a bituminous surfacing mix. Special bituminous mixes are being tested in the Federal Republic of Germany and in Finland.
3. The sealing of surface cracks is done with a coat or with a thin layer of hot-laid sheet asphalt.

As for the patching of rigid pavements, a current practice in a number of countries is the use of thin concrete layers for the repair of scaled and peeled surfaces.

The purpose of sealing the joints in cement concrete pavements is to prevent the infiltration of water into subjacent layers and to prevent aggregate from entering the joint. A distinction is made between (a) local repair, which is often carried out by government agencies and consists in cleaning the joint and applying a warm sealant, and (b) general repair, which is often executed by a specialized firm and consists of stripping the sealant out of the groove, cleaning the groove, and applying new sealant.

For sealing, three main types of materials are used: (a) hot-injected sealing compounds (most commonly used), (b) cold-injected mastics (used only for local maintenance), and (c) rubber (neoprene) compressible strips (used in new construction).

Pavements with base courses that have been treated with hydraulic or pozzolanic binders, paved with a thin or average layer of bituminous material, will after a period of time show reflection cracks. Routine maintenance calls for the sealing of these cracks with fluidified, possibly modified, bitumen. The most striking positive aspects of crack sealing are an improvement of imperviousness and, consequently, an improvement in the bearing capacity of the wearing course and in its resistance to freeze-thaw cycles and to deterioration as well as the relatively low cost of the repair. Drawbacks worth noting are an appearance and evenness that often leave much to be desired, a relatively short life-span (generally less than a year), and the low productivity entailed in the sealing process.

A major effort has been made in the past few years to achieve a greater uniformity of horizontal markings on national road networks. Various countries have thus been induced to introduce a preliminary approval procedure for marking products. As a result, the quality of horizontal road markings has significantly improved.

Road marking is most often done with road paints and hot coatings; cold coatings and glued strips are also used but less frequently.

Painted markings usually have to be restored every one or two years depending on the intensity of the traffic. The restoration of markings made with hot coatings usually becomes necessary two to six years after their application. In countries where studded tires are widely used, hot coatings usually last three to four times longer than paints. The use of cold coatings and glued strips is restricted to urban areas.

Illuminated road-sign equipment is maintained by the awarding authorities, and the works are carried out by subcontracting firms (who are often the constructors themselves) or, in some large towns, by the municipal engineering services. Maintenance work for nonilluminated signs consists of the cleaning, repair, and replacement of signals as well as cutting back vegetation in order to improve visibility.

The maintenance of green areas is closely related to local relief, climate, the density of traffic on the road, and the status of the road. Because of this diversity, there are no exact standards for the various types of maintenance required, except in some countries where the frequency of maintenance is stipulated. The mowing of embankments at least once a year is more or less systematic except on certain extremely secondary roads. In France, it is thought that grass should not exceed 20-40 cm in height, which means that mowing is required two or three times a year. The use of growth inhibitors in spring has generally been held up by ecological considerations, except in a few countries. Mowing is most often mechanized; the traction units used may be either agricultural tractors or, less frequently, cross-country vehicles.

Cutting tools are also often of the agricultural type (cutting bars with blades, circular cutters, or disks), the productivity of which is well known. Drums with mobile arms and cylindrical rotors onto which knives are fitted are increasingly used. These machines are known as brush clearers.

Road-cleaning operations cover the trafficked areas and the gutters as well as the edges of the road and rest areas. The equipment used usually consists of sweepers and gully emptiers.

WORK PLANNING AND CONTROL

For the work organization, the choice of the type of operation, as well as the required plant, is settled

in different ways from one country to another. Urgent maintenance operations are usually carried out by bodies controlled by the road authorities, whereas many other activities that are not so urgent and that require the use of construction plant are more often entrusted to private firms.

The system of individual maintenance was progressively replaced by a team system equipped with suitable vehicles and plant. Since then the team system has been modified so that each task is performed by increasingly flexible groups, consisting of one to four men and equipped with the vehicles and equipment required.

Work is usually planned on the basis of an analysis of pavement condition. This is carried out--at least for the national road network--by means of systematic visual inspection as well as by high-yield measuring equipment.

The parameters measured are skid resistance, bearing capacity, rutting, and evenness. The measurements are then correlated to surface defects determined either by photographic inspection or by systematic visual inspection, which remains the most common basic element in the determination of maintenance requirements. Apart from the visually determined data, these data are increasingly entered into road data banks and used for planning maintenance.

In all PIARC member countries, the road network to be maintained is divided into districts. The size of these districts varies considerably according to the structure of the network of which the road is a part, its topography, and the density of the traffic. The maintenance of motorways is not separated from the maintenance of other roads except in countries that have large motorway networks. For motorways, a district usually covers 50-60 km, though where networks are extremely dense a district may comprise as much as 120 km. For other roads, the size of the district varies enormously, from less than 100 km to more than 400 km. This depends on the structure of the network--more precisely, on the time required to reach all points on the network, the optimum being between 1 and 1.5 h.

Maintenance centers managed by the road authorities are generally entrusted with the following tasks: the supervision of the condition of the road and its ancillary equipment, work preparation, emergency services, certain specific tasks (such as maintenance of appurtenances), acting as principal contractor for work performed by private enterprise, and often patching and winter maintenance.

Radio communications are increasingly used. In theory, a base radio station is found in each maintenance center. This means of communication is very useful, allowing all maintenance vehicles to be in constant contact with the road maintenance center.

The number of personnel employed permanently on road maintenance depends on local conditions. In most countries, one man for each 6-7 km of maintained road is employed, not including administrative and management staff. These figures may vary considerably, however, and in some cases ratios may be as low as one workman per 25 km. On the other hand, 25 men may be required for the maintenance of 50 km of motorway because operating requirements are far stricter.

FINANCIAL MANAGEMENT

One of the critical elements in maintenance management lies in the financial control and analysis of expenditure, which should make it possible to determine the order of priority of the maintenance budget. Nevertheless, despite the fact that this expenditure represents a considerable portion of

national spending, people are generally very badly informed on maintenance costs.

Any comparison of maintenance costs at an international level appears to be impossible. This is because of the diversity of administrative structures, the differences in the significance of budget items, and the variety in the applied standards and budget controls.

The application of an analytic accounting system, more or less at maintenance-center level, seems to be spreading. This is necessary if all expenses are to be related to each type of road involved and to each type of task. In Switzerland, the Federal Road Service has developed an analytic accounting system for motorway maintenance centers. Operating expenses are accounted for by type of task and by section of motorway. The processing of data on small office computers allows a thorough analysis of operating results.

CONCLUSIONS

1. This paper has noted the progressive introduction of specialized low-cost maintenance techniques, which are the result of productive equipment more suited to maintenance tasks, and the introduction of materials with improved properties. However, an effort must still be made to improve the cost-effectiveness of certain techniques such as the patching of flexible pavements and of cement concrete. More durable materials for patching flexible pavements, for repairing cracked semirigid pavements, and for sealing joints in cement concrete

pavements are currently being studied.

2. The use of rational methods for formulating an overall maintenance strategy based on target levels is increasing, and the scanning of national road networks is becoming more widespread. However, problems regarding the analysis and interpretation of visual and photographic inspections remain to be solved. Various countries use the data stored in a data bank for planning maintenance, sometimes in conjunction with the data contained in a technical guide to maintenance.

3. In the majority of countries, maintenance centers have been set up that are run by the road authorities and are entrusted with the task of carrying out road maintenance operations at regular intervals. Major improvements have been made in their operation, largely as a result of the installation of radio communications.

4. One of the critical elements in maintenance management is the analysis of expenditure, but to date people are still very badly informed about maintenance costs. However, the continuing introduction of analytic accounting systems should provide greater insight into maintenance expenditures.

5. Advances in road maintenance must be assimilated and actually applied by the personnel involved. A major effort is under way to introduce local staff to new techniques and to train new personnel.

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