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Indian Roads Congress
Special Publication 26

REPORT CONTAINING RECOMMENDATIONS OF IRC REGIONAL WORKSHOPS ON RURAL ROAD DEVELOPMENT

(With Supplementary Notes)

NEW DELHI 1984

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Contents

FOREWORD

It is well known that a fully developed system of rural roads serving the vast areas of the country is an essential infrastructural facility for rapid socio-economic development of the country. The Governments both at the Centre and in the States have been earmarking sizeable outlays for rural roads in the Five-Year Plans and this is expected to be stepped up further in the future Plans.

For the effective and efficient deployment of large public funds on rural roads, it is necessary that there should be well thought out guidelines on the planning, design, construction and maintenance aspects. For this purpose, the Indian Roads Congress organised Regional Workshops on Rural Road Development in the four regions of the country, at Gandhinagar (Gujarat) in February 1981, at Nainital (U.P.) in July 1981, at Ranchi (Bihar) in May 1982 and at Hyderabad (A.P.) in November 1982. A number of useful recommendations for application by the authorities concerned with rural road development emerged from these Workshops.

This publication contains the consolidated summary of the discussions and recommendations made at the above mentioned Workshops, besides supplementary notes on the different aspects, for better understanding and ready reference for easier application of the recommendations in actual practice.

At its meeting held at New Delhi on 21.3.1983, the Rural Roads Committee agreed that a suitable Special Publication to serve as guidelines relating to rural roads should be brought out incorporating the recommendations of the four Regional Workshops with suitable notes concerning planning, construction, maintenance, quality control, etc. At the said meeting, the Committee also approved a format for the proposed publication.

Initial draft for this publication was prepared by Shri K. Arunachalam, Deputy Secretary, Indian Roads Congress. This was approved by the Rural Roads Committee in their meeting held at New Delhi on the 3rd December, 1983 and as desired by that Committee, it was further reviewed by Dr. Bansilal, Member-Secretary of the Committee under the guidance of Dr. M.P. Dhir, Director, CRRI and processed by Shri Ninan Koshi, Secretary, IRC and Shri P.C. Bhasin, Adviser, Indian Roads Congress for its final printing as a Special Publication of the Indian Roads Congress. The Committee held the view that the existing manual, namely, Manual on 'Route Location, Design, Construction and Maintenance of Rural Roads' (IRC:SP 20-1979) would require to be revised and expanded in the light of the guidelines and recommendations contained in the present publication and that this work should be taken up in due course.

The Indian Roads Congress thanks the Governments of Gujarat, Uttar Pradesh, Bihar and Andhra Pradesh for hosting the Regional Workshops and all the Engineers, Scientists and other experts for their active participation in these Workshops and their contribution besides Shri S. Adaviyappa, Convenor, Rural Roads Committee for ably guiding the deliberations of the Workshops and the Rural Roads Committee which has greatly helped in bringing out this publication.

K.K. Sarin
Director General (Road Development) &
Addl. Secretary to the Govt. of India

New Delhi
June, 1984

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Introduction

1. INTRODUCTION

1.1. For a country with agrarian economy like India, where about 80 per cent of the population lives in 5.76 lakh villages, a system of roads well serving the rural areas is a basic requirement for social justice, national integration, breaking the isolation of the village communities and for the integrated rural development to quicken its pace. Thus rural roads provide one of the basic infrastructure for achieving the objective of integrated rural development. In the hierarchy of road system in the country, rural roads include Other District Roads (ODR's) and Village Roads (VR's) which have the following functions :

(i) **Other District Roads** — These are roads serving the rural areas of production and providing them with outlet to market centres, block development, taluka/tehsil headquarters or main roads.

(ii) **Village Roads** — These are roads connecting villages and group of villages with each other or to the market centres and with the nearest road of a higher category.

1.2. Soon after Independence, the country embarked on development of rural roads, and sizeable road lengths were constructed under programmes like the National Extension Scheme of Community Development. There have also been a number of other schemes like the crash scheme for rural employment, and the various other special funds for rural roads. Having regard to the experience of earlier efforts since 1947, a National Programme of Minimum Needs was introduced during the Fifth Plan (1974-79) envisaging the allocation of larger resources for the social consumption of all areas in the country, the objective being to establish a network of essential services on a coordinated and integrated basis, given certain pre-determined criteria of uniformity and equality. Rural roads had been accorded their due place in the Minimum Needs Programme, the objective being to link all villages with a population of 1,500 and above with all-weather roads by the end of Fifth Plan. In hilly, tribal or coastal areas where population is relatively dispersed, the idea was to go by a cluster of villages of the like size. However, due to paucity of resources, this objective could not be fulfilled.

1.3. According to the national guidelines for the Sixth Plan (1980-85), all villages with a population of 1,500 and above, and 50 per cent of villages with population between 1,000 and 1,500 are to be linked with roads by the year 1990. Fifty per cent of the total number of villages required to be so covered have to be connected by the year 1985. An appraisal by the Rural Roads Working Group of the National Transport Policy Committee showed that by March, 1978, only about 29 per cent of the villages had all-weather road connections while another 16 per cent of the villages had fair-weather access roads. The Group estimated that for giving all-weather access to all the villages, it would require the construction/improvement of 8 lakh km of roads at a cost of Rs 11,000 crores (1978-79 price level).

1.4. The task is stupenduous and requires concerted effort from all concerned, such as policy makers, planners, and design/construction/maintenance engineers. The effort will have to be directed towards achieving the following broad objectives:

(i) Development of an optimum rural road network which will serve the maximum population per unit length and at the same time get integrated with the main road network.

(ii) The roads should be designed not only for immediate requirements but also with a view to providing for future needs within foreseeable future. From this angle, the initial design should make adequate provisions in respect of basic elements like road land width, geometrics, water crossings, drainage, protective works, etc. so that it may be possible to upgrade the roads to a higher specification without involving any appreciable wastage.

(iii) Rural road construction should imbibe the advancements in science and technology, and executed with full knowledge of the properties and behaviour of road building materials with a view to keeping construction costs as low as possible consistent with the requirements of traffic and environment. This includes bringing in all quality consciousness and control measures at each stage of construction so that the roads constructed are durable and offer satisfactory service to the users.

(iv) There should be a constant endeavour in using locally available materials to the maximum extent feasible. This includes the improvement of engineering properties of local soils and other low grade materials through appropriate stabilisation techniques.

(v) Maintenance of these roads to preserve the investments already made on them so as to provide a continued satisfactory level of service.

5. Regional Workshops on Rural Road Development

The Indian Roads Congress organised Regional Workshops on rural road development in the four regions of the country. The main objective of these Workshops was to identify the problems faced and methodologies adopted at the state level by pooling the combined experience in the light of local problems, organizational set-up and financial limitations so as to evolve suitable recommended practices for planning, design, construction and maintenance of rural roads. The Workshops were held at Gandhinagar (Gujarat) in February, 1981, in Nainital in July, 1981, in Ranchi in May, 1982 and in Hyderabad in November, 1982. For pointed attention on individual aspects, discussions at these Workshops were held under four themes, namely, (i) Planning and investment criteria and organizational aspects of rural roads, (ii) Pavement aspects of rural roads and low-cost water crossings, (iii) Construction techniques of rural roads, and (iv) Maintenance of rural roads. These Workshops had been highly useful in understanding the current practices being followed in the various states, the problems faced by them and in finding ways and means for improving the situation and imbibing better technology for optimum benefit. A number of useful recommendations for direct application by the authorities concerned with rural road development in the country emerged from these Workshops. A consolidated summary of the discussions and recommendations made at these Workshops and prepared by the subcommittee under the Convenorship of Shri T.K. Natarajan of CRRI and approved by the main Committee (the personnel given below) in their meeting held on the 21st March 1983 is given in Section 2 of this publication.

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T. K. Natarajan	......*Member-Secretary*
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1.6. Supplementary Notes

For better understanding and ready reference for easier application of the recommendations, supplementary notes on the different aspects have been included in Section 3 of this publication. The information provided reflects the current state-of-art and better engineering practices. These, however, are not static and will require to be reviewed and improved upon from time to time in the light of the information flowing from research and development studies, and feed-back from user organizations. One such study in progress under the auspices of the Indian Roads Congress is the socio-economic study of rural roads in nine districts of the country.

1.7. Fair-Weather and All-Weather Roads

It will be desirable that rural roads are constructed with such surfacings and high level cross-drainage facilities so that these are usable by traffic round the year in all the climatic seasons without any interruption. However, in general, provision of such design features will be too expensive and are neither necessary nor feasible for majority of rural roads which are expected to carry only a low volume of traffic. Interruptions for short period should, therefore, be tolerated and not considered to affect the all-weather characteristics of the road. Overflow of water at the low level cross drainage structures, or the road becoming slushy and impassable because of rains are the major causes interrupting traffic flow on the road. Thus the type of pavement surfacing related to rainfall, and the period of overflow or interruption at the cross drainage structures are the governing characteristics determining whether a road is of all-weather or fair-weather type. From the above considerations, the following attributes are suggested as far as rural roads are concerned :

All-weather roads— At cross drainage structures, the duration of overflow or interruption at one stretch does not exceed 12 hours for ODR's and 24 hours for VR's in hilly terrain, and 3 days in the case of roads in plains. The total period of interruption during the year should not exceed 10 days for ODR's and 15 days for VR's. The pavement should consist of metalling (WBM) or higher type where rainfall is more than 150 cm/year and should atleast be of material better than local soil, such as moorum gravel, kankar, laterite, etc. where the rainfall is less than 150 cm/year.

Fair-weather roads— Roads not satisfying the minimum requirement specified above for all-weather roads. These roads should be taken to be in a stage of development to be improved subsequently for conversion into all-weather type.

1.8. Activities Involved in Rural Road Development

Construction and operation of a rural road involves a number of activities, some running concurrently and others following in close sequence. Important among these are :

(i) Planning - for determining the route, i.e., the villages or points the road has to connect.

(ii) Field surveys - for fixing the alignment in light of topographical features, construction convenience, overall economy etc.

(iii) Investigation - for the availability and suitability of construction materials; hydraulic and foundation investigations for water crossings; investigations for the design of pavement and drainage facilities; etc.

(iv) Design - Geometric design of the road which fixes the horizontal alignment, the vertical profile and the cross-section in line with the geometric design standards; determination of the type and thickness of pavement and the appropriate material/composition of the different pavement courses in light of the locally available materials and needs of traffic/environment; design of side drains (also catch water drains in hilly areas) and disposal of surface water at natural outfalls; design of cross drainage structures; design of retaining/breast walls/pitching and other protection works; etc.

(v) Specifications — Specifications for the construction of the various components of the road. This will generally follow the departmental/IRC specification modified as necessary to suit the local materials, and available equipment and skills. The specification will lay down the limits for material properties, the methods of construction, the equipment to be used and the quality requirements of the final product.

(vi) Construction and quality control—Construction is the process of the translating the designs and drawings on to the ground closely following the specifications and ensuring the achievement of the stipulated quality standards.

(vii) Maintenance — The Maintenance phase starts on the completion of the construction activities and opening the road to traffic. In this phase, the activities are directed towards achievement of the objectives, namely, to make-up the damages to the road in service caused by traffic and environmental factors and to maintain it at a desired level of serviceability, and to preserve the investments already made on the road.

1.9. The guidelines on all the above activities can be had from the IRC Special Publication No. 20, "Manual on Route Location, Design, Construction and Maintenance of Rural Roads". These however, are not static and would require to be reviewed as more and more experience is generated in the coming years. For this purpose, it is suggested that the departments involved in the development of rural roads document their experiences and pass on the information to the Indian Roads Congress so that these guidelines could be improved from time to time in the coming years.

2

Consolidated Summary of Discussions and Recommendations of the Four Regional Workshops on Rural Road Development

2. CONSOLIDATED SUMMARY OF DISCUSSIONS AND RECOMMENDATIONS OF THE FOUR REGIONAL WORKSHOPS ON RURAL ROAD DEVELOPMENT

2.1. Planning and Investment Criteria and Organizational Aspects of Rural Roads

2.1.1. Existing practices

(1) While planning for rural roads, priorities are assigned keeping in view the criteria laid down for these roads under the 'Minimum Needs Programme' by the Planning Commission that viz., all villages with population of 1500 and above and also about 50 per cent of the villages in the population group of 1000-1500 should be connected with all-weather roads. Some of the states like Punjab and Haryana had gone far ahead of these norms and achieved higher levels of accessibility. On the other hand, some of the states of the North Eastern and the Southern regions brought out that it was not possible and certainly not fair to adhere to these norms particularly in hilly areas because of the pecularities of location and the scattered nature of the settlements.

(2) Consideration depending on needs is given by the states for providing road links to tehsils, education centres, railway stations, health care centres, water resources, milk collection centres and other growth centres in order to maximise the socio-economic benefits accruing to these areas.

(3) Special consideration is also given to the provision of road links in tribal areas and in areas inhabited by the weaker sections of the society.

(4) In hill areas of the northern region, the number of villages with population of 1000 and above being comparatively small, states like Himachal Pradesh follow the system of developing major valley roads where bulk of population reside and inter-valley roads covering a number of villages and hamlets enroute. Link roads are then provided from this system to sub-valleys covering production and horticulture belts.

(5) In remote and high altitude areas the possibility of providing aerial cable-ways is also explored as an alternative to link roads, particularly where problems of soil erosion are acute and ecological disturbance can possibly prove deterimental.

(6) The principles of planning laid down in the 20-year road plan (1961-81) has provided major guidance in the past.

(7) Some of the states have formulated Master Plans for rural road development, but the criteria vary somewhat from state to state. While some states adopt an integrated area development approach in planning the road network, others take into account the population size of villages and loçal opinion. The planning horizon varies from 5 to 20 years. Some states take up updating the Master Plans on an yearly basis.

(8) In most of the states, the task of connecting villages with rural roads is very heavy in relation to the plan allocations. Moreover, an equitable share of the National Rural Employment Programme funds is not being made available for rural roads.

(9) On account of resource constraints, many states take up rural road construction in stages, earth formation in the first stage cross-drainage in the second stage, and metalling and black-topping in the third stage. On account of resource constraints, some states do not go in for the third stage of black-topping at all except in special cases of heavy rainfall areas or where funds are provided by International lending agencies.

(10) For funding rural road construction, some states have raised special funds through a cess on agricultural produce.

(11) The present organisational system for the construction and maintenance of rural roads varies from state to state. While some states have exclusive organisations within the P.W.D. itself or under the Panchayati Raj Department for looking after rural roads, some others have multiple agencies. However, agencies like Blocks and Panchayats, in general, do not have adequate equipment, technical know-how and properly trained supervisory staff.

(12) Some states have set up state level and district level committees to take care of coordination and other related aspects for rural roads to ensure planned construction according to proper norms.

2.1.2. **Deficiencies in existing practices**

(1) Inasmuch as the population size of villages constitutes the main criterion in the present planning process, thinly populated areas, like hilly areas, coastal areas and tribal areas despite their economic potential and social needs tend to suffer unduly. This has to be looked at in the context that roads form the only mode of communication in these areas.

(2) For hill areas, the existing norms do not provide for sufficient attention being paid to the requirements of improving accessibility to the villages and hamlets which are situated at different altitudes and are thinly populated and scattered. The need for the provision of jeepable roads, mule paths and foot bridges in remote areas in hill regions also requires recognition and consideration.

(3) Since the road length involved and the related cost of construction are not fully taken into account, small size villages not getting covered under the present norms based on population get neglected even though they may be requiring only short connecting links.

(4) The much needed existing inventories as also perspective developmental plans in the other sectors of the economy for each block/tehsil/taluka are not generally available with the result that it has not been possible to prepare proper Master Plans.

(5) In the absence of proper Master Plans, application of the population criteria has resulted in the development of parallel road systems in a number of cases.

(6) Some of the rural roads have started attracting heavy traffic and are in dire need of improvement. This has however not been possible because of difficulties in acquiring additional land for improving cross-section and geometrics.

(7) Due to the multiplicity of agencies handling programmes of rural road works and the lack of coordination among them, rural road development and maintenance suffer both qualitatively and quantitatively.

(8) Because of the lack of the needed equipment, technical know-how and properly trained supervisory staff with Blocks and Panchayats, the roads constructed or maintained by them are not upto the standards and in some cases have to be abandoned when taken over by State PWDs or REOs. Similarly, roads constructed by PWDs but handed over to Panchayats for maintenance have been found to suffer from want of proper upkeep.

2.1.3. **Recommendations**

(1) Rural roads being one of the key infrastructures for rural development, it is necessary to take a good look at the current planning methodology and priority principles prevailing in the different states in the country for both short-term and long-term periods.

(2) All states should draw up Master Plan for rural roads at the district level covering a time horizon of 15 to 20 years. In the preparation of long term Master Plans for rural roads at district/taluka or block levels, both social and economic needs should be kept in view. In this context, special consideration should be given to the following aspects :

(i) Inter-sectoral development needs,

(ii) Location and dispersal pattern of villages of different population groups,

(iii) Co-ordination of growth centres with other basic minimum social needs like schools, primary health centres, markets, etc.;

(iv) Needs of areas producing perishable goods such as fruits, milk, sea-food, etc.;

(v) Administrative needs.

(3) Some mechanism to ensure citizen participation in the planning should be evolved. Some States have set up District planning committees/councils which include people's representatives in each district. This opproach which will pave the way for effec-

tive implementations of the rural road programme is worth emulating by other states as well.

(4) Roads required for meeting the special needs of a given region such as for hill areas, desert areas, command areas and tribal area, development should be given special emphasis in the planning strategy. Immediate assessment of existing and planned potential of these areas is called for.

(5) In the planning process, while overall national guidelines of providing all-weather access roads to villages with population of 1500 and above and 50 per cent of villages with size 1000-1500 may be kept in view, decisions concerning priority would vary from state to state taking into account the conditions prevailing in each state and the need to reduce regional imbalances. Investment priority criteria such as maximum population per unit length of road, maximum cultivated land area per unit length of road also merit consideration in the context of rural road planning.

(6) Socio-economic impact study of rural roads at district level is in progress in nine districts spread throughout the country with a view to developing mathematical models for planning and prioritisation of rural road network. In the meantime, each state should evolve a priority ranking procedure for connecting of villages with rural roads in a phased manner taking into account weightages for parameters like population, length or density of roads, irrigated area, per capita income, unit cost of construction and financial investments involved in optimal rural road network and existing/planned market centres, school, medical and transport facility. Testing the validity of the priority criteria thus developed is very important so that adjustments, if necessary, could be done in the weightages for various factors. In the meantime, the following broad range of distribution of available outlays for rural roads may be adopted :

	per cent
(a) Linking villages with population of 1500 and above	60—80
(b) Linking villages with population of 1000—1500	10—20
(c) Rural roads in command areas having agricultural/dairy development, for exploitation of mineral resources, and in other backward areas unless these requirements are supplemented by the respective sectors	10—15

(d) Linking villages of population less than 1000, and villages that could be connected through short links at nominal cost 10—15

(7) In order to provide for wider service to rural areas and in view of the energy crisis, black-topping of rural roads should be taken up only selectively and judiciously where traffic, local area needs and climatic conditions so justify.

(8) Provision of stream crossings and foot-bridges in remote areas should receive due priority attention in the planning exercise on a priority basis so that all-weather negotiability is improved.

(9) Where stage construction policy is adopted, it is necessary to ensure timely availability of funds for the subsequent stages as also proper maintenance in the meantime.

(10) Since the requirement of funds to improve the accessibility of villages with roads is very heavy, it will be useful for the state to mobilise additional resources. Creating special schemes by levy on agricultural produce, such as Market Committee Funds and transfer of such funds for use in road construction/maintenance programmes could be considered. Agro industries like sugarcane factories could be encouraged to pool resources to construct their own roads which could be allowed to be maintained by them. This will give a sense of involvement to such intensive road users, and this will also encourage them to maintain the roads in good order for reducing the transportation costs.

(11) In situations where the rural roads are primarily meant to meet the needs of some particular industry/organisation or project, the concerned beneficiaries should bear or contribute towards construction/maintenance of these roads.

(12) While planning for rural roads, their requirements should be considered in an integrated fashion with those of road transport. Animal-drawn vehicles will continue to be an important mode for farm to market movement in many areas. However, it is necessary to undertake a critical study into the kind of rural transport vehicles for both goods and passengers that will meet the requirements anticipated in the different regions of the country.

(13) Roads through the heart of residential areas of villages and towns increase traffic hazards and c ause congestion and delay. Where a serious problem of this nature is feared, it will be advisable to byepass the built-up area staying well clear of the limits upto which the town or village is anticipated to grow in the foreseeable future unless the road in question is to terminate in the concerned village/town.

(14) It is necessary that the requirement of geometrics is given adequate attention at the construction stage itself so that it does not become a problem when the road has to be improved at a later stage. The geometric design standards prescribed should, therefore, be adhered to except in difficult cases such as those in remote and backward areas (where the traffic intensity will be very light of the order of 2-3 veh./day) where some relaxation could be considered. It is also necessary that adequate land widths commensurate with the needs should be procured at the initial stage itself.

(15) While expansion of the rural road network continues, it is advisable to give attention to safety aspects including provision of road signs, well designed speed breakers where they are so justified and reduction in overloading of public vehicles such as tempos, matador vans etc.

(16) The programmes for construction and maintenace of rural roads should be handled by a unified and a technically competent engineering organisation in each state. It is also necessary to create/set up a planning and monitoring cell for the collection of all data and for the co-ordination of programmes with different agencies so that efforts in the rural roads development are duly integrated and a periodical review of achievements and evolving of remedial measures is possible.

(17) At present funds for rural roads are being channelised through different agencies and as such no proper accounting or monitoring is possible for ensuring that investments are being made in creating durable and properly designed assets in the form of rural roads. It would be better if all the funds are controlled in a state by a single agency looking after rural road works.

(18) Necessary arrangements for the systematic training of the staff engaged on rural road works should be made.

(19) The setting up of a Rural Road Commission at the centre as well as Rural Road Commission in each state may be given due consideration as they are intended to co-ordinate and channelise the working of the multiple organisations into purposeful effort. The Planning Commission should give due consideration to this important recommendation.

2.2. Pavement Aspects of Rural Roads and Low Cost Water Crossings

2.2.1. Existing practices

(1) The existing practices for the design of rural road pavements are mostly based on *ad hoc* designs specified for broad subgrade soil types especially for the less important village roads. For the more important rural roads, the CBR method of design is sometimes used, adopting curve 'B' of the pavement design chart recommended by the IRC. Barring the arid zones of Rajasthan, the CBR of subgrade soil is evaluated under 4-day soaked condition, the sample having been compacted to Proctor density in the laboratory even though the density achieved in the field may be far less.

(2) Although there is an increasing awareness of the need for the utilisation of locally available materials like gravels and moorums, the tendency towards specifying hard stone metal in base courses still persists even when other good quality construction materials are available locally.

(3) In the traffic parameter, even if the solid-wheel animal-drawn cart traffic constituted a significant part of the total traffic, it is not taken into consideration for design purposes.

(4) It has been the experience that traffic increases manifold sharply after the road has been built.

(5) In regard to the water crossings, many of rural roads are still fair weather roads since enough funds are not available for providing all the needed cross drainage works. R.C.C. spun

pipes of NP_2 grade are adopted for culverts. Paved dips and cement concrete carriageways are employed for medium size shallow river crossings. Locally available materials like timber, stone slabs, dry stone masonry, stone in cement mortar are also utilised to the extent possible.

2.2.2. **Deficiencies in existing practices**

(1) Although it is generally realised that the use of locally available soils, gravels, moorums and aggregates should be maximised, such materials are not actually being incorporated in the designs for lack of data on the location and properties of these materials, lack of facilities for testing these materials and lack of trained personnel.

(2) Some of the states face the problem of durability of non-bituminised pavements in the context of high rainfall and terrain conditions obtaining in those states since funds available do not permit black topping.

(3) The absence of guidelines and type designs for bringing about the much needed economy in design and for promoting the use of locally available materials for low cost water crossings, are sorely felt.

2.2.3. **Recommendations**

(1) Any *ad hoc* approach in pavement designs for rural roads should be totally discouraged. If at all, it should be restricted to only a few extreme cases where the traffic, both present and projected, is low and cannot be substantiated with any degree of reliability, like in the case of village roads in remote areas interlinking only very small villages and hamlets.

(2) For ODRs and other Village Roads where traffic can be meaningfully anticipated, like the roads connecting big villages to market-centres etc., the pavement crust and composition requirements should be scientifically worked out. These designs should be based on proper material surveys and other field and laboratory pre-investigations. The related infrastructure for such pre-investigations must be provided. There is need to carry out a base line survey of all avilable materials and soils for road building on

a district-wise basis and their properties analysed, so that a form of data bank is available for ready use of highway engineers.

(3) The pavement design procedure evolved by CRRI should be given a fair trial by constructing a few roads designed by the proposed method. A small proportion, say 10 per cent of the rural road length planned to be constructed in the coming year in each of the states, should be set apart for design and construction following the methodology as proposed by CRRI. The performance of roads constructed by such procedures should be monitored by CRRI.

(4) Use of locally available materials and adoption of mechanically stabilised soils should be incorporated in pilot studies and their performance suitably monitored.

(5) All permanent bridges on rural roads may be designed only for IRC class A loading and should mostly be of single lane width (4.25 metre). For pipe culverts, NP_2 R.C.C. pipes should suffice. For all cross-drainage works, the use of lime mortar can be resorted to. As far as possible, masonry arch type of construction should be adopted for cross-drainage structures using lime mortar. The use of economical locally available materials like timber, bamboo and stone slabs etc. should be maximised.

(6) The States should forward to the Indian Roads Congress, information about the various types of low cost water-crossings in use, suggestions for further improvements, etc. so that a comprehensive Publication for the guidance of the Highway Engineers could be brought out.

(7) The terms 'Fair-weather' and 'All-weather roads' should be defined in the context of low cost water-crossings keeping in view the fact that stoppage of traffic for short durations a few times during the rainy season should be tolerated in view of the scarcity of resources for rural roads.

2.3. Construcion Techniques of Rural Roads

2.3.1. Existing practices

(1) Compaction of earthwork for rural roads generally follows two patterns : (a) where the road is built to the first stage of

earth or gravel/moorum surface, compaction is generally done by hand rammers or manually drawn rollers; (b) where the road is provided with metalling or black-topping, it is done by power rollers. Compaction is not receiving proper attention on roads built by agencies other than R.E.Os or State P.W.Ds.

(2) Time of doing the earthwork acquires significance from the view point of availability of water for compaction.

(3) In black cotton soil areas, a capillary cut-off comprising a layer of sand or moorum or any other suitable granular material is provided.

(4) The practice of providing black-topping varies from state to state depending on climatic and terrain conditions, availability of funds, importance of the road and availability of the needed materials and equipment. There is neither uniformity nor laid-down criteria for black-topping these roads.

(5) Rural road works are taken up under various programme by a number of organisations in the same state. Depending upon the technical expertise and equipment available, the standard and techniques of construction vary from totally labour-intensive technology to the use of regular equipment for earthwork and pavement compaction as also laying of bituminous surfacing. In the case of roads constructed by Village Panchayats, Zilla Parishads or Block Development Organisations, no quality control and adequate specifications are being ensured.

(6) Locally available moorum, gravel and aggregates are finding increasing application in pavement construction. Mechanical soil stabilisation is adopted to some extent in some of the states. The works are generally carried out either departmentally, through contractors or cooperative societies.

(7) There is awareness of the need for the provision of catch-water drains and side drains for disposal of surface water, particularly for roads in hills. It is felt that this provision contributes to better serviceability of pavements and stability of foundation.

(8) There is all-round appreciation for bringing in better

quality control measures in construction, since roads constructed now would constitute the main feeder roads of tomorrow and in any case public assets must be made durable.

2.3.2. Deficiencies in existing practices

(1) Compaction of earthwork leaves much to be desired, and as a consequence damages in the form of excessive deformation, shear failure, etc., frequently occur.

(2) Power driven rollers and other equipment are generally not available in adequate numbers. Difficulties are also experienced in transporting such machinery to the dispersed rural road work sites.

(3) Soil stabilisation techniques require trained and qualified personnel who are not readily available in many cases.

(4) Due to lack of testing facilities by way of equipment and trained staff, quality of the construction work suffers.

(5) There is no co-ordination of work between the works undertaken under the National Rural Employment Programme with the normal rural road works taken up under the Minimum Needs Programme or through other state resources by construction agencies.

2 3.3. Recommendations

(1) The Rural road construction programmes should by and large be labour intensive. However, in certain important phases of work, where quality control is of paramount significance, the use of road-making machinery may be resorted to.

(2) There should be a regular system of monitoring in the use of road making machinery so as to maximise their output and utilisation. Also, the requirements of road machinery and spares should be worked out in advance and their procurement arranged in time.

(3) In the case of embankments, the lower layers may be built to a lower level of compaction, say 90 per cent Proctor whereas the top 30 cm of the embankment constituting the subgrade

should invariably be compacted with power roller to 95 per cent Proctor density. However, in difficult and not easily accessible areas where power rollers cannot be made available despite the best efforts, tractor-drawn/animal-drawn/hand-drawn rollers may be used for compaction. In such cases, the lift thickness should be reduced and the number of passes increased to achieve a reasonable level of compaction.

(4) Soil stabilisation technique needs to be encouraged as much as possible so that locally available materials can be utilised to the maximum extent possible.

(5) Where stage construction is followed, it would be desirable to ensure timely availability of funds for subsequent stages of the work as also for the continued and proper maintenance of surface between successive stages of the work.

(6) Quality control is considered to be no less important for rural roads than for other higher categories of roads. There is thus need for framing suitable guidelines suggesting simpler techniques of quality control and investigations relating rural road construction which could be used by field engineers/block level officers.

(7) The staff responsible for the construction and maintenance of rural roads should be given periodic training for ensuring proper construction and maintenance of these roads as well as for ensuring strict quality control during their construction.

2.4. Maintenance of Rural Roads

2.4.1. Existing Practices

(1) Maintenance activities on rural roads are carried out under two heads, as (a) short-term measures like filling of potholes, dressing of berms, routine maintenance of C-D works, sign boards etc., and (b) long-term measures like periodic renewals, upgrading of surface, repairs of C-D works, etc. Strengthening of roads and improvements in structural capacity are not generally taken up out of maintenance funds, except in special situations.

(2) The existing level of maintenance of rural roads, in

general, is very low and is just sufficient to keep the buses and other vehicles somehow ply over them.

(3) In many states, a number of agencies besides the state PWDs are involved in the maintenance of rural roads.

(4) The normal periodicity of renewal is 5 to 6 years for black-topped roads. In the case of gravel/moorum surfaces, renewal coat is laid once in three years or so.

(5) Most of the maintenance grants are utilised towards gangmen and casual labourers leaving very little money for materials to be used for maintenance works. Bulk of the maintenance work is done by unskilled/inexperienced labourers who do not have any special tools or equipment.

2.4.2. **Deficiencies in existing practices**

(1) In the context of the present day hike in the cost of labour and materials, the existing methods of allocation are inappropriate and the actual availability of funds is woefully inadequate. The funds are made available on a kilometre basis, the rate ranging from Rs 2,000 to 4,000 per km which forms only a part of the actual requirements.

(2) Requirements of various maintenance tasks including special repairs and ordinary repairs are not clearly identified. Also there is no criteria laid down for prioritisation of these tasks. As a result of lack of planning for maintenance works, the gangmen and the labourers employed are not fully utilised. Due to lack of proper planning, gangmen do not have enough work throughout the year. Engagement of casual labour also gives rise to certain labour problems.

(3) The recommendation of the Finance Commission are not generally adhered to by the State Finance Departments, and many a time, the maintenance grants are slashed down. As a result of the inadequacy of funds, it has not been possible for states to follow any planned system of maintenance operations.

(4) Involvement of multiple agencies in construction and maintenance results in poor maintenance, due to lack of proper coordination among the various agencies.

(5) Rural roads in hill areas have to face certain special problems like landslides, erosion, etc. during/after rains which consume a major portion of the M & R grants.

2.4.3. **Recommendations**

(1) Rural roads, being productive assets, should receive as much attention if not more towards maintenance as is given towards construction and upgrading. The present level of maintenance of rural roads is quite low. Any neglect in this can prove highly detrimental in the long run. Adequate funds for maintenance should, therefore, be made available on time.

(2) The allocation of funds recommended for maintenance of roads by the Finance Commission should be made available in full and infact enhanced further taking into consideration the need based physical norms recommended by the Technical Committee of the All India State Chief Engineers, increase in prices of materials and wage rates and special requirements of hilly areas, water-logged reaches, flood damage restoration etc. In this regard the states should prepare financial norms for maintenance as applicable to their areas taking into account the traffic needs, the topography, rainfall, cost of materials and labour, etc. and should arrange to have the same updated regularly.

(3) The Eighth Finance Commission will shortly be considering the requirements for maintenance grants. A concrete proposal in this regard supported by factual data should be prepared for the consideration of the Commission so that it is possible to obtain sufficient funds commensurate with the needs.

(4) It should be brought to the notice of the authorities responsible for allotting funds that maintenance should receive due priority vis-a-vis original works so that the assets already created are not allowed to go waste.

(5) Since maintenance is more of a management problem, it is but necessary that a proper management system be followed for the purpose of ensuring the optimum utilisation of available resources. While the level of serviceability may be low for rural roads, items requiring attention should be predetermined depend-

ing upon the nature and the volume of traffic, type of soil conditions, stage construction policy adopted, etc.

(6) A small Manual on maintenance of rural roads should be brought out setting forth guidelines to carry out the various maintenance operations.

(7) Different categories of staff engaged in maintenance should be exposed periodically to training courses.

(8) The efficient drainage of water from the road pavement and embankment sides not only saves the pavement from damage but it also greatly improves the serviceability of roads and as such this aspect calls for suitable control measures to be adopted.

(9) A regular system of programme charts and weekly diaries should be adopted for the maintenance operations, before and after rains, road by road in each sub-division.

(10) Provision of mobile gangs, area-wise should be encouraged to achieve better efficiency and productivity in maintenance operations. It should be ensured that they are provided with necessary mobility and the other needed tools and equipment.

(11) The agency responsible for the maintenance of rural roads should be the same as responsible for the construction of rural roads.

2.5. Planning, Design, Construction and Maintenance of Command Area Roads

2.5.1. Existing Practices

(1) There are twelve on going World Bank aided Irrigation projects, in eight states containing sizable road components, as infrastructural facility in the command areas, costing over Rs 200 crores. Out of 7200 km of project network roads, about 3100 km have been completed. The balance being due to be completed by March 1985. In 1981-82 budgets, provision of about Rs 50 crores has been made for the command area roads. The projected requirement of road length, vital for command areas, may work out to be 4 to 5 times the above indicated figures.

(2) The command area road projects are financed and executed according to the terms and conditions agreed upon between the World Bank, the Government of India, and the State Government concerned. Barring a few variations in individual project, the following practices are generally adopted.

(i) After a thorough reconnaissance survey of the existing communications in the command area, a systematic road network plan is prepared to meet the objective of serving the transportation need of the developments in the area, with minimum road length. A 6 km grid is usually being adopted.

(ii) Detailed plans and estimates are prepared for the network roads to conform to the current Indian Roads Congress (IRC) standards and practices.

(iii) The project costs include 15 per cent physical contingencies over the base costs and allow 7 to 10 per cent price increase per year for the period (4 to 5 years). A shedule of implementation year by year is drawn up so as to complete the road network at least a year before the other irrigation components.

(iv) All construction is required to be carried out according to the IRC specifications, standards and quality control methods and within the prescribed time schedule. For this purpose, the requirement of any additional equipment, such as, road rollers, water tankers, crushers, field and mobile laboratories, workshop facilities etc., is carefully worked out and included in the project estimates.

(v) The cost of essentially needed training of road engineers and the supervising staff forms a part of the project.

(vi) Blacktopping is usually recommended but not insisted upon, depending upon the local circumstances.

(vii) In some projects, practical field research schemes and socio-economic evaluation studies with wide ranging and far reaching applicability have been included.

(viii) The projects are irrigation oriented. However, the planning design and construction is entrusted to the State Road Engineering Organisation (PWD/B&C Dept. etc), in almost all the states, A project planning and monitoring cell with suitable composition is created at the headquarters.

(ix) For contracts above a prescribed financial limit, the tender forms and procedures adopted are as standardised by the Central Water Commission (CWC) in consultation with the World Bank. Inter alia, they include (a) prequalification, (b) prebidding conferences, and (c) escalation and arbitration clauses.

(x) For maintenance of the C.A. roads after construction, the State Government guarantee in the agreement that they would finance and maintain the roads to appropriate serviceability level.

The PWDs of Gujarat and Rajasthan, in their case study reports on command area roads in their respective states, have explained in detail the planning, design, quality control, construction techniques, staff training etc. as adopted on their projects. Land acquisition delays are minimised by Gujarat Officers, through unconventional approach to the problem.

2.5.2. Deficiencies in existing practices

(1) In the irrigation command areas, either out of necessity or convenience, the canal service roads are required to be thrown open to public traffic. There are no precise guidelines and standards for design and construction of such canal service roads.

(2) The existing standards and specifications for construction of roads in waterlogged areas appear to be inadequate.

(3) In the absence of precise method of assessment of rise in water-table due to irrigation, standardising practices of road-design in such area is necessary.

(4) The irrigation drains usually discharge along roadside and there are no proper guidelines for coordination of the road drainage systems and irrigation drains, thus resulting in damages to the road network. This includes also due consideration for adequate and economical cross-drainage works for the roads.

(5) Maintenance of roads in irrigated area pose several difficulties, due to waterlogging, non-availability of land for borrowpits, etc. which are not usually accounted for in the estimates and/budget provisions.

2.5.3. Recommendations

(1) Command area roads are rural roads with a special objective. With the backing of the World Bank Loan, the standard of design, construction, quality control should be maintained at a higher level than normal works. There is need therefore to adopt similar methodology for rural road programmes.

(2) The introduction of clauses for escalation, prebidding conferences and other provisions may be considered for rural road projects as far as possible.

(3) The deficiencies and the problems of design and construction and maintenance of roads in command areas may be examined in depth by the IRC, Union Ministry of Shipping and Transport (Roads Wing) and the State PWDs concerned to evolve suitable practices and standards and incorporate them in the Manual for Rural Roads.

(4) In command areas, the land acquisition problems are felt more acutely as they affect the time schedules, and hence the problems may be taken up with priority at a higher level.

3

Supplementary Notes

3. SUPPLEMENTARY NOTES

3.1. **Planning of Rural Roads**

3.2 **Geometric Design**

3.3. **Pavement Design**

3.4. **Pavement Materials**

3.5. **Cross-Drainage Structures**

3.6. **Construction and Quality Control**

3.7. **Maintenance**

3. SUPPLEMENTARY NOTES

3.1. Planning of Rural Roads

3.1.1. Guidelines of the 20-Year Plan (1961-81)

(1) The principles of planning laid down in the 20-Year Plan (1961-81) had been providing the major guidance in planning of rural roads so far. For planning purposes, the land area of the country was divided into three categories, namely, developed and agricultural area, semi-developed area, and under-developed and uncultivable area. The total length of the road system for the country and the length of individual road categories were calculated by a 'Star and Grid' formula. It was envisaged that the accessibility objectives given in Table 1. would be achieved with the development of such a road network.

TABLE 1. ACCESSIBILITY CRITERIA AS PER THE 20-YEAR PLAN (1961-81)

Description of area	Maximum distance (km) of any place		Length (km) per 100 sq.km. of area
	From a metalled road	From any road	
Developed and agricultural area	6.4	2.4	44
Semi-developed area	12.8	4.8	19
Undeveloped and uncultivable area	19.2	8.0	12

(2) The 20-Year Plan had no doubt given broad indication on the density of roads to be achieved in different types of areas but did not provide guidelines for the physical planning of the road system which should take into account the spatial and locational aspects of human settlements, the growth potential, the connectivity needs and costs, etc.

3.1.2. Guidelines under the minimum needs programme

(1) Rural Road Development was taken up as a part of the Minimum Needs Programme in the Fifth 5-Year Plan (1973-78)

for the first time. According to the national guidelines laid down under this programme, population size of villages constitutes the main consideration of giving road connections to villages. The present objective is to connect all villages having a population of 1,500 and above, and 50 per cent of the villages with population between 1,000 and 1,500 with all-weather roads by the year 1990. The hilly, tribal and coastal areas are to be connected by taking a cluster of villages with matching population.

(2) The population criterion of giving road connections to villages has its own merits but its strict application may lead to certain distortions or deficiencies. Some of these are :

(i) Areas having thinly populated villages, such as tribal areas, hilly areas, etc. may unduly suffer despite their economic potential and social needs. This has to be looked at in the context that roads form the only mode of communication in these areas. Also, this will preclude small villages which could otherwise have been connected with short links at a nomimal cost.

(ii) The application of population criterion may lead to more than one connection to bigger villages while smaller villages are denied of even the basic single connection.

(iii) In the absence of physical planning guidelines, this may lead to development of parallel system of roads not following any hierarchial pattern nor amenable for proper integration with the main road network as also for operating an efficient bus route which is one of the emerging needs in the rural areas.

3.1.3. Physical planning of rural roads

(1) Essentially, a rural area comprises a number of human settlements or villages with supporting agricultural and other production activities, and social services. In these areas, roads help promote the efficient delivery of not only economic goods and services but also social services. For example, faster mobility of students, patients and Doctors and social workers reflects upon the utilisation rate of these facilities.

(2) In the prevailing situation where thousands of villages remain unconnected with roads, provision of a road network satisfying the socio-economic needs of the villages will be possible only in stages over a period of time. So that the work done at the different stages is well integrated and no part of its goes infruc-

tuous in future years, the road system for an area or region expected to be completed in the next 15-20 years should be prepared in the first stage itself in the form of Master Plan. This Master Plan can be conveniently worked out for each Development Block in the first instance which can be integrated to develop District Master Plan for each District. Procedure for preparing Master Plans is discussed in succeeding paragraphs.

(3) In a rural area, the pattern of road network has to match the movement pattern in that area. Movement pattern will depend on the spatial distribution of the various settlements and locational pattern of various economic functions of social amenities in the area. Intensity of movement will depend upon the degree of dependency of the settlement on the others for its socio-economic needs.

(4) It should be understood that in a developing economy it may not be possible to provide for all the functions or amenities to all the settlements. This is for the reason that every function requires some population threshold for its efficient fulfilment and economic justification. This will mean that a large number of small settlements will not be able to have within their own area certain amenities. For example, a secondary school cannot be provided in each village but a large number of villages can share one at a convenient point. In other words, for bringing in small settlements on the mainstream of national development, integrated area planning approach has to be used which integrates a cluster of smaller settlements for providing the various missing facilities and services at a suitable location in the cluster which may be termed local centre or Nodal village. These local centres can be further integrated to form a bigger group of settlements with functions and amenities of middle order being provided at a suitable point which may be termed a Service centre. A service centre may serve an area of 30-80 sq.km. and a population of 20,000 40,000 and provide facilities such as mandi or market, secondary school, primary health centre, places for recreation, etc. Service centres may be further integrated to form a larger group of settlements and higher order functions provided at a suitable location which may be termed Growth Centre. A growth centre will serve an area of 200-300 sq. km. and 1,50,000—2,00,000 population.

These centres would have activities mainly of non-agricultural nature with all centralised amenities and facilities in the field of education, medical, public health, wholesale and retail shopping, civic, cultural and recreational activities, organised industrial estates, etc.

(5) The first step in the planning of roads in the rural areas is the identification of the settlements which have potential or capacity to act as local centre, service centre or growth centre. Important considerations in influencing the choice of these points are the size of population, the area of influence, junction of roads, existance of facilities like Block Development office or other Govt. offices, Post offices, bank, high schools and colleges, hospital or primary health centre, organised market or mandi, veterinary station, bus terminal, railway station, warehouse and collection centres, agro service station, cinema, etc.

(6) Information on the existence of the various facilities can be collected through a base line survey for socio-economic condition of the settlements in the region. This should be supplemented by the development programmes proposed for the area in the different sectors of the economy. Some of the important aspects for which information should be collected are :

(i) The type of area, viz. developed agricultural, semi-developed, or undeveloped/uncultivable area.

(ii) Location of human settlements and population of each settlement.

(iii) Location of marketing centres or mandis, educational centres, hospitals/health centres, places of tourist attraction, etc.

(iv) The existing road network including the main road system.

(v) Location of industrial, mining and commercial activity.

(vi) The investments being made or proposed to be made in the other sectors of the economy.

Once the above information is available, the settlement can be graded for their capacity to act as nodal point by assigning suitable weightages to the various functions. It is expected that the on going socio-economic study of nine districts under the aegis of the Indian Roads Congress will provide guidelines on the weightage scale to be adopted. A balanced framework of nodal points thus developed will ensure a well distributed road network which should be generated by linking every lower order nodal point to the nearby higher order nodal point. The smaller order villages should then be connected to the nearest of these links or nodal points to complete the network.

(7) The network so developed should be superimposed on the existing network and examined in light of the following points for any modification :

(i) Maximum use of the existing road links, whether fair-weather or all-weather.

(ii) Integration with the main road system.

(iii) The proposed links should as far as possible serve maximum population per unit length.

(iv) The links should avoid expensive ridge/stream crossings and low lying areas prone to flooding erosion.

(v) The network should develop a definite hierarchy of roads. The hierarchy of the roads should be tied with the hierarchy of the rural settlements. This will also help in estimation of the relative traffic volumes expected on the various links for design purposes.

(vi) The alignment of the road links should be amenable to maximum use of locally available materials.

(vii) Introduction of public bus service is one of the emerging needs in the rural areas. For economic operation, a bus route should have sufficient catchment area and should be as directional as possible. This aspect should be given due consideration while finalising the network.

(8) As mentioned earlier, a Development Block is a convenient area for starting the planning exercise. A plan of road network developed for a typical Block is shown in Fig. 1. This plan also indicates the possible bus route for the area. Once the network plan for all the Blocks in a District is worked out, these can be superimposed on the District Plan, and further refinements made for compatibility, connectivity at Block interfaces, avoiding expensive bridge/ridge crossings, etc.

(9) While developing a road network at the Block level and finalisation at the District level, there should be a system to ensure public participation. One way in this regard will be to have the Plan examined and processed through District Planning Committees/Councils which have people's representatives in them.

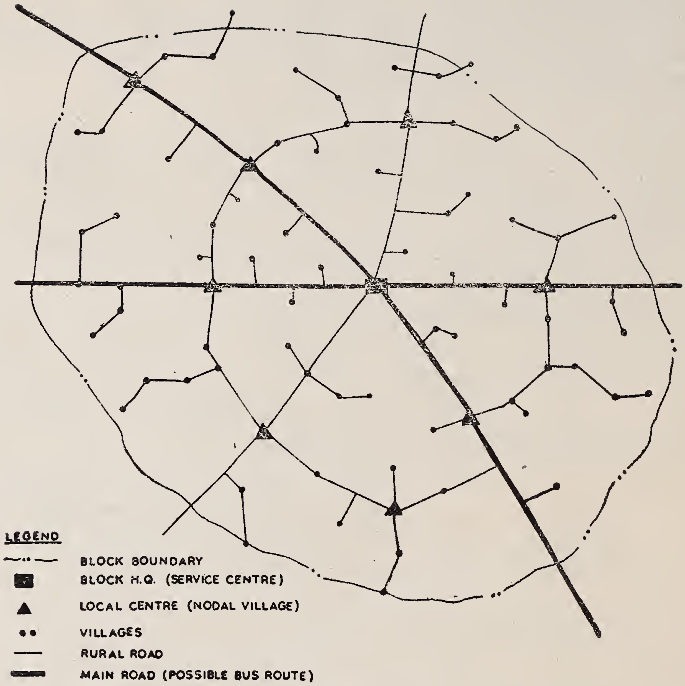

Fig. 1. Road network developed for a typical block

(10) The final rural road Master Plan should show all the villages stratified by population, existing and proposed road network, railway lines, river systems, and existing or planned market centres, educational/health centres, industrial estates, collection centres for diary/agricultural produce, recreational facilities etc. A typical Master Plan for a District is shown in Fig. 2. for illustration. The Plan should be prefaced by a detailed statement covering information on the socio-economic condition of the area, communication facilities etc., a sample of which is given in Table 2.

(11) The Master Plan so prepared should form the basis for the choice of the road links to be constructed during the various Annual/Five-Year Plans. Where more than one agency is involved in the construction of rural roads in a state, it is necessary that the road links chosen by the individual agencies should be

TABLE 2 — DETAILED INFORMATION TO BE FURNISHED WITH DISTRICT MASTER PLAN FOR RURAL ROADS

I. GENERAL INFORMATION

1. Identification
   - Name of State
   - Name of District
   - District headquarters
2. Number of Villages in the District
   - Number with population over 1500
   - Number with population 1000-1500
   - Number with population 500-1000
   - Number with population less than 500
3. Total area of District
4. Total population of District
5. Topography of the District—Plain/Rolling/Hilly
6. Type of Soil
   - Sandy soil
   - Mixed soil
   - Clayey soil
   - Desert sand
7. Type of land area (per cent)
   - Developed and agricultural
   - semi-developed
   - undeveloped and uncultivable
8. Main produce of the district with annual output
   - Food crops
   - Cash crops
   - Milk
   - Fish

   Industrial
   - Mining
   - Others
9. Rainfall
   - Average annual rainfall
   - Rainfall season

10. River system (show on Plan)
11. Location of Tehsil/Taluka HQ
12. Location of Block headquarter
13. Location of organised mandis

II. TRANSPORTATION

1. Railways
   — Existence of railway lines in the district and the proportion of freight and passenger traffic carried.
2. Inland waterways
3. Roads (existing)
   — Length of main roads (other than rural roads)
   — Length of rural roads
   — Density of total road network per 100 sq. km. area
   — Number of villages connected by all-weather roads
   — Number of villages connected by fair-weather roads
   — Number of villages connected by footpath/cart track
4. Roads (proposed in Master Plan)
   — Additional length of rural roads proposed
   — Total length of rural roads
   — Density of total road length per 100 sq.km.
   — Additional number of villages connected hy the proposed network
   — Number of villages yet remaining to be connected by roads.

III. ROAD CONSTRUCTION AND COST ASPECTS

1. Location of stone quarries
2. The type of locally available materials proposed to be used. Can they be used as such or require modification/treatment.
3. Broad specifications proposed for the roads.
4. Unit cost of construction/improvements.
5. Total cost of new construction and improvements.
6. Proposed scheduling of the work.
7. Proposed phasing of expenditure.

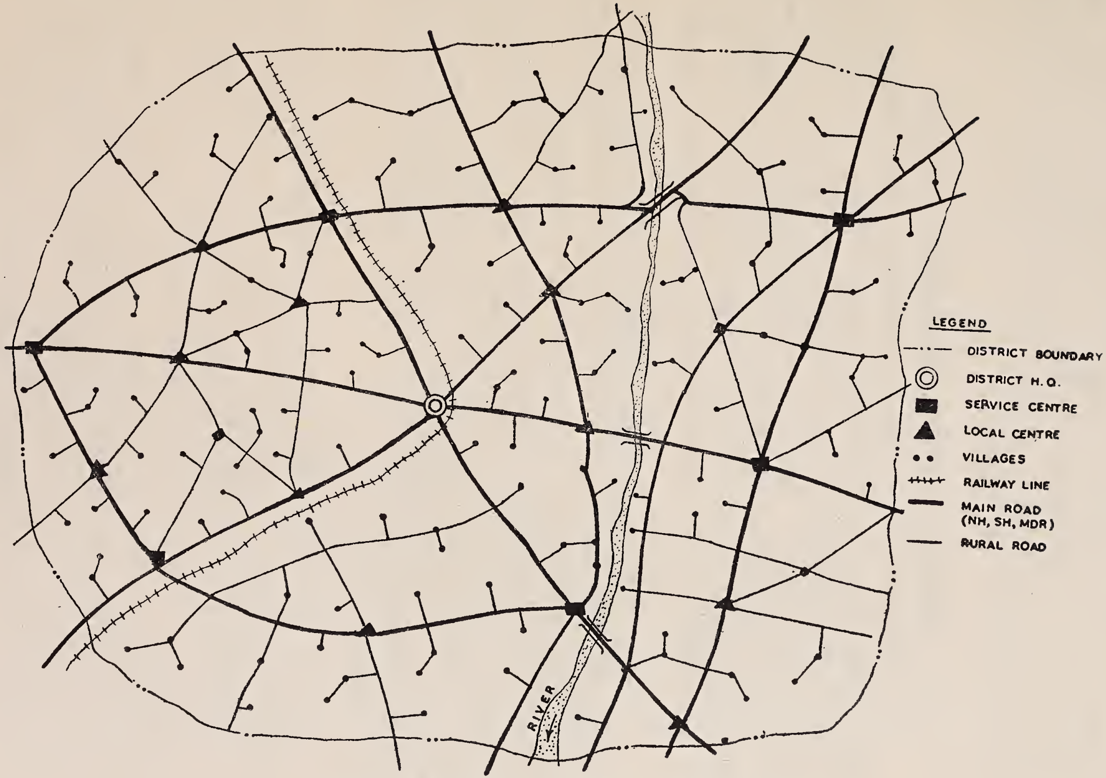

Fig. 2. Sample road master plan for a district

from the Master Plan. The objective is that the road links constructed from year to year form a part of a well thought out and well tied-up road network so that over a period of years, an efficient road communication facility is provided to all the villages in the country and no part of the work taken up in any year becomes infructuous in future years.

3.1.4. **Planning methodology developed by the CRRI***

(1) The Central Road Research Institute have developed a simple methodology for connecting various villages in a rural area once the nodal points are identified and a road network developed to inter-connect these. The method which is helpful in connecting the villages in the interior is based on the concept of "Minimum Spanning Tree" borrowed from the "Graph Theory". The procedure involved is briefly described in the subsequent paragraphs.

(2) The entire road transportation system in a district is divided into four parts, viz., (i) Market centres attracting traffic from various villages; (ii) Main roads inter-connecting the various market centres; (iii) Villages of various population levels generating traffic to and fro the market centre for their marketing, health, education and other facilities; (in) Village roads inter-connecting the various villages and providing connection to the nearest market centre or main road. Such a system in its idealised form is shown in Fig. 3.

(3) The flow of traffic in the road network is considered analogous to the flow of current in a circuit. The market centres are considered as high intensity concentrated electric charges and the main roads as cables with high intensity current flowing through them. The various villages are considered as small concentrated charges. The high charges at market centres and along the main roads attract the smaller charges situated at various villages around them. Village roads are assigned weightages in direct proportion to the attraction force exerted and inversely proportional to the connecting road length which serve as a

* Prof. C.G. Swaminathan, Dr. N.B. Lal and Ashok Kumar "A System Approach to Rural Road Development" Paper No. 346, Journal Indian Roads Congress, Vol. 42-4, December, 1982

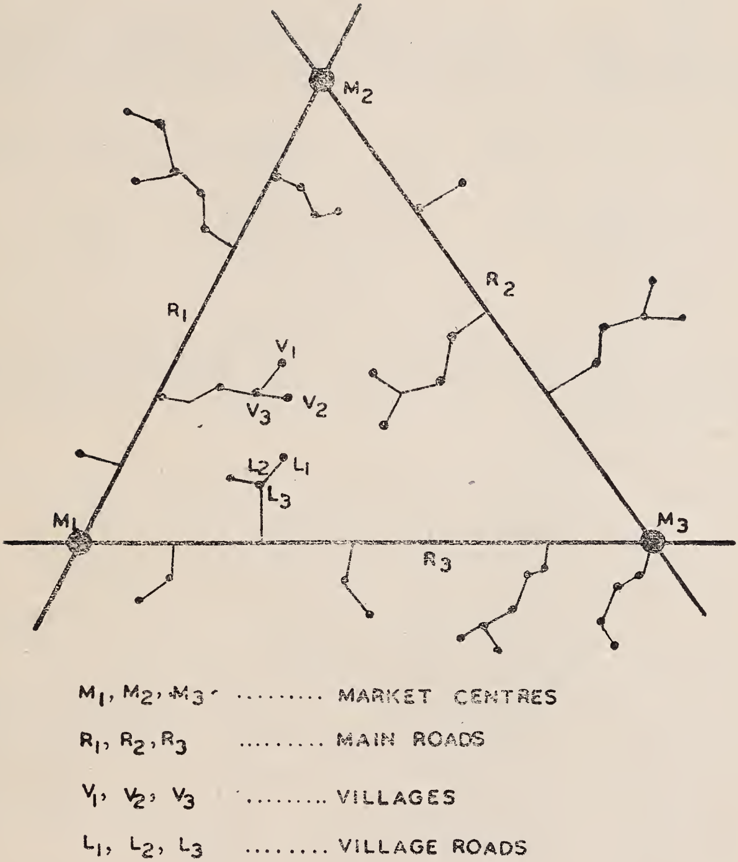

Fig. 3. Idealised system of market centres, main roads villages and village roads

measure of their utility. The final optimised network is then generated by the concept of minimum spanning trees.

(4) The steps involved in the procedure are as follows :

Step-1

Prepare a plan showing the location of various villages, market centres, main roads, etc.

Step-2

The market centres, main roads and villages of various population levels are considered to possess the following magnitudes of electric charge.

(i) Individual village	— Population ÷ 100 units subject to maximum of 100
(ii) Market centres	— 100 units
(iii) Main roads	— 80 units

Step-3

Connect the villages closest to the market centres/main roads and then proceed towards the interior depending on the weight W of the road length. The weight is given by :

$$W = Q/D \qquad \cdots \quad (1)$$

Where—

D = Length of the link option

Q = Total traffic attracting force situated at the market centre/main road/village already connected as the case may be. Q is equal to 100 or 80 if the village is to be directly connected to the market centre or main road respectively. Where a village under consideration is to be connected to a village already conected by rooted tree (such village is termed as attracting village), Q is calculated from the following equation :

$$Q = p + \frac{m}{\sqrt{d}} + \sum_{i=1}^{n} \frac{qi}{\sqrt{ri}} \qquad \cdots \quad (2)$$

Where—

p = Self-charge of the attracting village

m = Charge situated at the tree root (market centre or main road)

d = distance of the attracting village from its tree root.

The procedure is illustrated in Fig. 4.

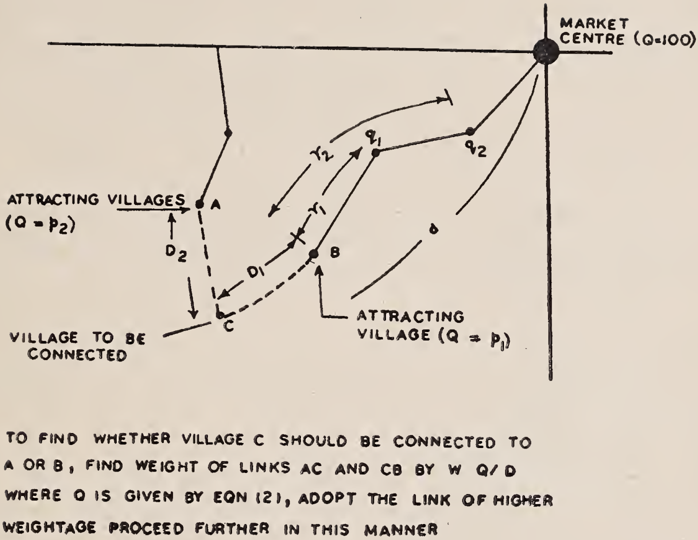

Fig. 4. Procedure for determining the road links

The generation of various rooted minimal spanning trees will start from their roots. For identifying the various tree roots, start connecting the villages which are closest to the market centre/main road by selecting the links of maximum weight (W) calculated by Equation (1). In this way, as many roots as possible are identified. Side by side, the various minimal spanning trees are generated by adding links of maximum weight (W) and connecting village by village starting from the village close to the market centre/main road and then proceeding towards the interior. The procedure is continued till all the villages are connected.

Step-4

The system thus developed will be an idealised one without any regard to the existing rural roads. For making use of the existing road network to the maximum extent possible, the generated network is superimposed on the existing one and modifications made in it as considered necessary and appropriate. One way of carrying out the modifications is to consider the existing road links as of maximum weight (W) and developing the rest of the trees as explained earlier. Another refinement will be required where a proposed road link has to cross a wide water course or ridge involving huge expenditure. For such cases, it will be necessary to examine the proposed links in light of the field conditions and make necessary modifications/adjustments for keeping the cost of the lengths as low as possible. Similar will be the case of the link options having marginal difference in weightage.

3.1.5. **Special consideration for hilly areas.** Hilly areas have certain special characteristics, and these should be taken into consideration while planning rural roads in these areas. First is that in the hills, the villages are generally dispersed located at different elevations and thinly populated with the result that villages forming a cluster within 1 km distance and making up population of 1,000 or more are very few. Second is that because of the difficult topography and the high cost involved in construction, it may not be feasible to connect isolated villages with motorable roads. At the same time, these areas have large potential for horticulture production and tourism, and roads are the only means of communication. In light of these special characteristics, planning of rural roads in hilly areas should keep in view the following considerations in addition to those discussed in para 3.1.3.

(i) Villages located within 1 km radius having difference of elevation not more than 100 m should be considered as a cluster of villages and one suitable village of the cluster should be connected by motorable road.

(ii) All isolated villages for which it is not possible to provide a motorable road connection should be brought within 3 km radius and altitude difference of 300 m from a motorable road. This can be effected by extending the road system upto such points as is economically feasible. Beyond these points upto the isolated villages, mule paths should be provided. Gravity type cableways, where feasible, may also be considered for the transport of produce from such villages to the motorable road head.

3.2. Geometric Design

3.2.1. Design standards

(1) Geometric design deals with the visible elements of a road, i.e., how it is aligned in the horizontal and vertical directions, to what widths the various elements in the cross-section should be provided for, etc. The geometric features of a road except for the

cross-sectional elements do not lend to stage construction. Geometric deficiencies are costly and sometimes impossible to rectify later on due to subsequent roadside developments. It is, therefore, essential that the geometric requirements should be kept in view right from the initial construction stage itself.

(2) Geometric design standards for rural roads (ODR's and VR's) are discussed in detail in the IRC Special Publication 20. Standards for some of the important geometric features which may be required to be consulted at the planning/alignment stage itself are given in Table 3.

(3) Width of land acquired for a road is the most important element affecting its widening in the future. While deciding on the land width, it should be borne in mind that value of the land adjoining the road increases rapidly. Hence, sufficient land width should be acquired at the outset according to the anticipated future development of the road in question. Unless this is done, it may be costly and sometime practically impossible to acquire more land later on for widening or other improvements to the road. Where consolidations of land holding is to take place, advantage should be taken for reserving the necessary land for the road along alignments satisfying the geometric requirements.

3.2.2. **Alignment**

(1) The Master Plan (see para 3.1) would give guidance on the broad route for the roads and the villages to be connected. This will have to be translated on to the ground in the form of properly aligned road links. The main objective in this activity will be that the road system so developed should be efficient in operation and economical in cost. Some of the considerations in this regard are :

(i) Alignment should be as directional as possible so that there is maximum economy in cost of construction, maintenance and vehicle operation.

(ii) The alignment should avoid crossing of large water courses/ridges, low lying and other problematic area needing expensive treatment. It should be amenable to the maximum utilisation of locally available cheaper construction materials. The idea is that for the given standards and the desired level of service, the road should be as economical as possible in initial construction.

TABLE 3.1. STANDARDS FOR SOME OF THE GEOMETRIC DESIGN ELEMENTS OF RURAL ROADS

1. Design Speed (km/h)

Road class	Terrain			
	Plain	Rolling	Mountainous	Steep
ODR				
Ruling	65	50	30	25
Minimum	50	40	25	20
VR				
Ruling	50	40	25	25
Minimum	40	35	20	20

Note : The terrain is classified by the per cent cross-slope of the country which is 0-10 for plain, > 10-25 for rolling, > 25-60 for mountainous and > 60 for steep.

2. Width of Road Land and Roadway (metre)

Items	Plain & rolling terrain		Mountainous & steep terrain	
	Open areas	Built-up	Open areas	Built-up
Land width				
ODR	15	15	15	12
VR	12	10	9	9
Roadway width				
ODR	7.5*		4.75**	
VR	7.5		4.0**	

Notes : (i) The land widths indicated are the minimum. The land width should be suitably increased in high banks or deep cuts or in landslide—prone areas.

(ii) The landwidth should correspond to the higher classification if a road is expected to be upgraded in the foreseeable future.

(iii) * 9.0 m for two-lane roads.

(iv) ** These widths are for single lane roads exclusive of parapet (0.6 m). and side drain (0.6 m). In hard rock stretches, the width may be reduced by 0.4 m. On curves, the roadway width should be increased corresponding to carriageway widening. In general, passing places may be provided at the rate of 2 per km.

3. Width of carriageway (single lane)

ODR	...	3.75 m*
VR	...	3.00 m**

Notes : * 7.0 m for two-lane roads. As an alternative, intermediate width of 5 m may also be used, but the capacity will be less *vis-a-vis* 7 m wide carriageway

** Width more than 3 m may be used judiciously depending on the type and intensity of traffic and other related factors

4. Radius of Horizontal curve and Stopping Sight Distance (metre)

Design speed km/h	Radius of Horizontal Curve			Stopping sight distance
	Plain/Rolling terrain	Hilly terrain		
		Not affected by snow	Snow-bound	
20	—	14	15	20
25	—	20	23	25
30	—	30	33	30
35	45	—	—	40
40	60	—	—	45
50	90	—	—	60
65	155	—	—	90

5. Gradients (per cent)

Terrain	Ruling	Limiting	Exceptional
1. Plain/rolling	3.3	5	6.7
2. Mountainous and steep terrain having elevation more than 3000 m above MSL	5	6	7
3. Steep terrain upto 3000 m elevation	6	7	8

(2) For fixing the alignment on the ground, certain field surface and investigations are required to be conducted. These are :

(i) Route surveys which include the operations of reconnaissance, preliminary survey and final location survey.

(ii) Soil and material surveys and laboratory investigations for the location and suitability of road construction materials, design of pavement and choice of specification for the different pavement layers.

(iii) Studies for drainage and investigations for the location and design of cross drainage structures.

(iv) Miscellaneous such as for the working season, availability of labour/equipment, logistic, etc.

Detailed guidelines on all these aspects are contained in IRC : SP : 20.

3.3. Pavement Design

3.3.1. General considerations

(1) Generally, flexible type of pavement is adopted for rural roads. The objective in the design of such pavements is to provide sufficient cover or pavement crust over the subgrade so as to keep the deformation of the road within tolerable limits so that the road is able to give a reasonable level of service over the design period. The main parameters affecting the design are :

(i) Traffic, its volume and composition.

(ii) The strength of the subgrade to take up the imposed stresses and strains which depends on the type of soil, the moisture content and the variation of moisture from season to season, and the state of compaction.

(iii) Environmental factors like rainfall, water table, freezing conditions, etc.

(2) The parameter of traffic for pavement design purposes is indeed complex as it is generally composed of a number of different vehicle types with widely varying stress intensities imposed on the pavement structure. Solid wheeled bullock-carts have a telling effect on the performance of rural roads, especially when these are in large numbers and follow a channelised path. Even if the wheel loads are lighter, the contact stresses imposed by such

wheels are very high relative to the stresses produced by pneumatic tyred vehicles. To a varying degree, all types of pavements are susceptible to damage by cart traffic, but the problem is comparatively less acute in the case of cement concrete pavement, creteways and bituminous surfacings.

(3) The complexity of the problem being what it is, in the absence of any rational solution to cater for different situations, the pavement design practices for rural roads in the country generally fall under the following two broad heads :

(i) Ad-hoc designs based on the general experience in the area.

(ii) Emperical procedure based on some mechanical tests on the subgrade soil. The CBR method is commonly used in the country.

(4) The CBR method of pavement design is discussed in para 3.3.2. As a slight modification to this method, the CRRI have proposed a design procedure which is discussed in para 3.3.3. Ad-hoc design are brought out in para 3.3.4.

(5) Ad-hoc designs do not take into account the soil strength or traffic loads coming on the pavement and as such may lead to under or over design. These should not, therefore, be adopted except in extreme cases where traffic both present and projected is low and cannot be substantiated with any degree of reliability like the case of village roads in remote areas inter-linking only very small villages and hamlets. Also, no design will be warranted for unsurfaced roads, i.e., earth or moorum roads. For such cases, atleast the top 150 mm thickness of the road should be provided with better granular soils or moorum or any similar locally available materials.

3.3.2. **The CBR method**

(1) The procedure involves the testing of the soil expected to be used in the subgrade portion of the road for CBR estimation of traffic both by volume and composition expected to use the road during the design life and then referring to the design chart for arriving at the pavement thickness.

(2) The density and moisture content of the subgrade soil specimens are the important aspects affecting the CBR value. For

rural roads, it is a requirement that the top 300 mm of the embankment forming the subgrade should invariably be compacted to 95 per cent Proctor density. As such, the density of the specimens to be decided for CBR should be in the range of 95-100 per cent Proctor density.

(3) The choice of moisture `content of the test specimen is not quite so simple. The moisture condition of the subgrade which the test specimen is expected to simulate is governed by local environmental factors such as water table, precipitation, soil premeability, drainage condition and waterproofness of the pavement. With the type of pavement construction practices in the country for rural roads, i.e., with thin pavements made of granular materials which is at best sealed with a thin bituminous surfacing, unsealed shoulders, box type of construction, etc., it is reasonable to assume that in most cases, the subgrade will be in a saturated condition at least for a few months (during the rainy season) in a year. It is, therefore, recommended that as a general practice, the soil specimens should be soaked in water for a period of 4 days prior to testing. Exceptions to this can be areas where the climate is arid throughout the year, i.e., the annual rainfall is of the order of 500 mm or less.

(4) Traffic is considered in terms of commercial vehicles per day in the design year, i.e. trucks, buses, etc. whether laden or unladen. In other words, the method does not take into account the solid wheel bullock-carts which if present in good numbers can cause considerable damage to the pavement. One way to get over this is to choose the design curve corresponding to the next higher traffic intensity.

(5) The CBR design curves for A, B and C traffic categories are given in Fig. 5. For more details of the method, reference may be made to IRC:37-1970 — 'Guidelines for the Design of Flexible Pavements'.

3.3.3. **Design method proposed by the CRRI**

(1) The CBR method requires the testing of subgrade soil specimens after soaking in water for 4 days. This is time consuming, and requires a load frame for conducting the test. Also, this

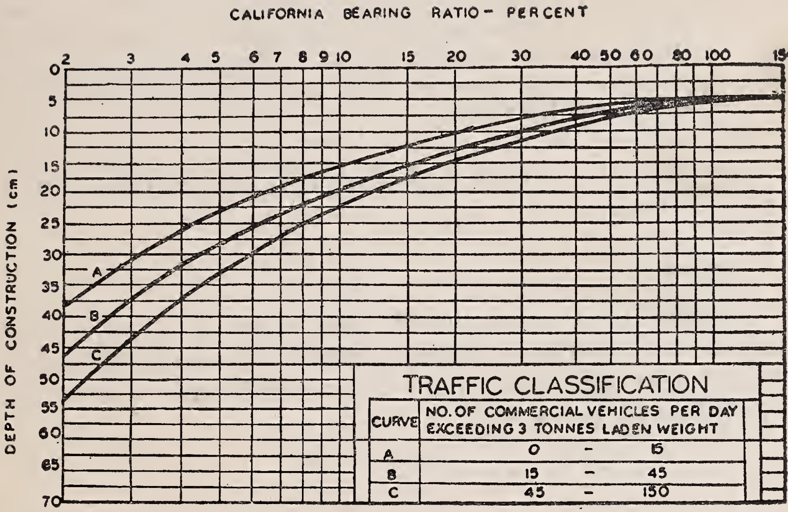

Fig. 5 CBR curves for flexible pavement design (See para 3.3.2)

method does not take into account solid wheeled carts which ply in sizeable numbers* and cause considerable damage to the road. The CRRI method which gets over these defficiencies to certain extent, is based on the following concepts:

(i) The CBR can be correlated with the gradation and other easily determinable properties of the soil without the need for any elaborate laboratory arrangements. The strength value so determined is termed "Strength Index" which in effect is equal to the CBR.

(ii) All vehicles, whether pneumatic tyred, or solid wheeled carts cause damage to roads. The damaging affect of different types of vehicles has been evaluated in terms of that of heavy commercial vehicle. The equivalency factors (in terms of heavy commercial vehicles) are 2 for solid-wheeled cart and 0.4 light pneumatic vehicles. The equivalent annual average daily traffic is computed and termed as "Traffic Index".

(iii) Rural roads can be divided into two categories depending on the expected level of serviceability, categories I and II, the former having better serviceability and accordingly needing thicker pavement than the latter.

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*According to a study by CRRI, solid wheeled carts constituted 47%, 33% and 5% of the total traffic in plain, rolling and hilly terrain respectively.

(iv) Based on a study of a large number of rural roads in the country, pavement design curves have been developed correlating pavement thickness with "Strength Index". Different curves have been proposed for two ranges of traffic index and two categories (categories I and II) of roads.

(2) Application of this method involves the following step by step procedure :

Step-1 :

Estimate the average annual daily traffic in terms of solid wheeled carts (SWC), pneumatic tyred heavy commercial vehicle (CV) and light pneumatic tyred vehicles (OV) and calculate the traffic index (TI) given by :

$$TI = 2 \times SWC + CV + 0.4 \times OV$$

Step-2 :

In this step, the Strength Index (or the CBR) is computed under one of the following two situations as appropriate :

Situation 1 : The ground water table is deep, over 1.5 m below the subgrade. The subgrade is taken to be in a state of equilibrium moisture content which in the absence of factual field data may be assumed to be equal to optimum moisture content.

Situation 2 : The ground water table is shallow, within a depth of 1.5 m below the subgrade. The subgrade is designed for the state of full saturation, i.e. corresponding to 4 days soaking.

After deciding on the subgrade moisture condition for design (Situation 1 or 2), the Strength Index can be computed by using the equations given in Table 4.

Step-3 :

Classify the road into category I or II. Category I will provide better serviceability than category II. Knowing the value of traffic index, strength index and road category, the required thickness of pavement can be directly arrived at by referring to the appropriate design curve given in Fig. 6.

TABLE 4. EQUATIONS FOR CALCULATING STRENGTH INDEX VALUES OF SUBGRADES

(a) For Situation (1)—subgrade at equilibrium moisture conditions

Field dry density (gm/cc)	Equilibrium moisture content (per cent)	Strength Index or CBR
1.40-1.75	12—30	$=3.9\sqrt{d}+8.5\,(1/M)+5.6\,(1/F)-0.6R+1.2$
1.60-1.85	5—12	$=21.8\sqrt{d}+2.2\,(1/M)+1.2\,(1/F)-5R-6.4$
1.86-2.2	5—10	$=37.5\sqrt{d}+4.6\,(1/M)-93.7\,(1/F)-11R+1.3$

(b) For situation 2-subgrade at soaked moisture conditions

Proctor density (gm/cc)	Optimum moisture content (per cent)	Soaked strength Index or CBR
1.40-1.70	15	$=5.5\sqrt{d}+9.4\,(1/M)-2.9\,(1/F)+1.3R-5.4$
1.70-1.85	12-15	$=0.475\sqrt{d}-28\,(1/M)+32\,(1/F)-4.4R+11.2$
1.86-2.2	7—13	$=-6.6\sqrt{d}+246.3\,(1/M)+3.8\,(1/F)+10.3R-1.56$

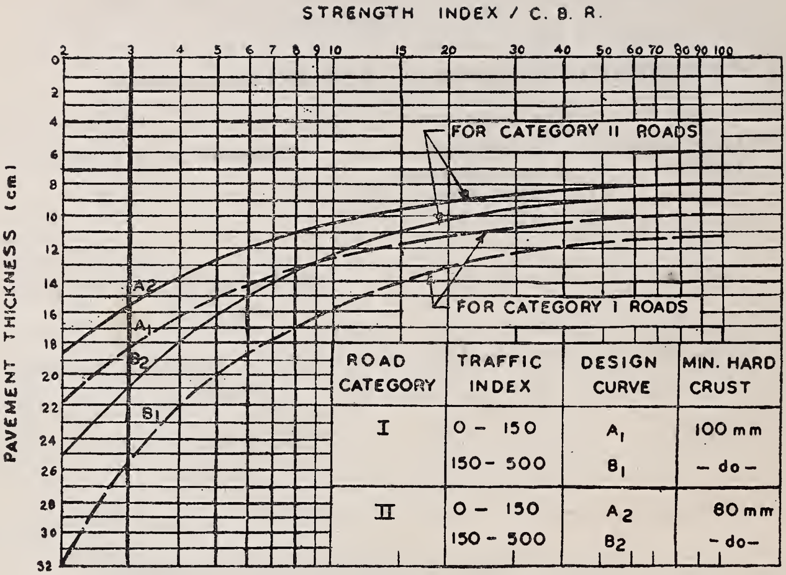
Where :

d=dry density (gm/cc) to which the subgrade will be compacted

M=design moisture content (%) which the subgrade will eventually attain

F=per cent passing 75 micron sieve

R=coarse-grained fraction (less than 1) retained on 75 micron sieve



ROAD CATEGORY	TRAFFIC INDEX	DESIGN CURVE	MIN. HARD CRUST
I	0 – 150	A_1	100 mm
	150 – 500	B_1	– do –
II	0 – 150	A_2	80 mm
	150 – 500	B_2	– do –

Fig. 6. Pavement design curves for rural roads evolved by CRRI
(See para 3.3.3)

3.3.4. **Ad-hoc designs** (Flexible pavements)

Where facilities for determining the soil strength etc. do not exist, ad-hoc flexible pavement designs given in Table 5 may be found useful.

3.3.5. **Drainage**

The performance of a pavement can be seriously affected if adequate precautions to obviate accumulation of moisture in the pavement structure are not taken. Some of the measures in this regard are :

(i) The subgrade should be sufficiently above HFL/ground water table, or the natural ground level, the minimum height being 0.6 m for rural roads.

(ii) The road surface should be provided with reasonable crossfall to facilitate quick runoff of surface water, and suitable side drains

TABLE 5. SUGGESTED AD-HOC FLEXIBLE PAVEMENT DESIGNS FOR TYPICAL SUBGRADE SOILS

Subgrade soil type	Pavement Items	Suggested pavement for	
		O.D.Rs	V.Rs
I. Gravelly soil, hard moorumy soil, laterite or kankar soil. (coarse-grained soils with low to no plasticity)	Total pavement thickness	21 cm	15-16 cm
	Base	15 cm WBM or 7.5-10 cm WBM plus a course of ganular/improved sub-base	7.5-10 cm WBM
	Sub-base	The balance thickness may be made of sub-base which should be distinctly better than the subgrade (WBM with brick soling, stabilised soil, moorum, low-grade aggregate etc.)	The balance thickness may be made up with sub-base as for O.D.Rs
II. Sand and sandy alluvial soils (coarse-grained soils with low to no plasticity)	Total pavement thickness	27-28 cm	22-23 cm
	base	15 cm WBM or 7.5-10 cm WBM plus a course of granular/improved sub-base	7.5-10 cm WBM or 10 cm local soil mechanically stabilised with soft aggregate (stone-grafted)
	Sub-base	The balance thickness may be made up sub-base of stabilised soil, moorum, kankar, brick soling, WBM with brick aggregate or other suitable material	The balance thickness may be made up of sub-base as for O D.Rs.

(*Contd.*)

(*Contd.*)

1	2	3	4
III. Clayey alluvial soils (other than heavy clays)	Total pavement thickness	35 cm	29 cm
	Base	As at II above	As at II above
(L.L. less than 20)	Sub-base	As at II above	As at II above
IV. Black cotton soil and other heavy clays (L.L. more than 50)	Total pavement thickness	50 cm	42-43 cm
	Base	As at II above	As at II above
	Sub-base	As at II above The lowest sub-base layer will be required to act as a blanket course to check the working up of soft subgrade soil and should therefore be selected carefully (graded sand, sandy soil, stabilised soil, moorum, etc.)	As at II above The lowest sub-base layer to be selected as mentioned for O.D.Rs.

Notes :

1. The thicknesses indicated refer to compacted thickness.
2. The above pavement designs are intended for guidance only when the requisite facilities for testing and evaluation are not available.
3. With regard to provision of bituminous surfacing, reference may be made to para 3.4.7.

with outfall should be constructed wherever necessary. The crossfalls recommended are given in Table 6.

(iii) The shoulders should be dressed periodically so that they conform always to the requisite crossfall and are not higher than the level of the carriageway at any time.

TABLE 6. PAVEMENT CROSSFALL CAMBER

Surface type	Crossfall (per cent)
1. Thin BT	2.0—2.5
2. WBM, gravel	2.5—3.0
3. Earth	3.0—4.0

Notes : 1. Use steeper values in table for high rainfall areas and vice-versa.

2. For earth shoulders adopt crossfall 0.5 per cent steeper than that for pavement but not less than 3 per cent.

3. On superelevated sections, the shoulders should normally have the same crossfall as the pavement.

3.4. Pavement Materials

3.4.1. General considerations

(1) The cost of pavement constitutes 25-40 per cent of the total cost of a rural road. Further, it is the pavement which has to carry the traffic plying on the road, and its condition is an important factor affecting the comfort of travel and cost of vehicle operation.

(2) Rural roads are essentially low cost roads, and as such the specification for pavement should be as economical as possible consistent with the traffic likely to use the road, the climatic conditions, etc. From this angle, local materials which are cheaper to extract and involve minimum haulage cost should be made use of to the maximum extent feasible. A variety of local materials can be used which may be grouped under the following categories :

(i) Better granular soil for use in subgrade or as surfacing for earth roads.

(ii) Mechanical stabilisation of local soil, and stabilisation with lime, cement, lime and flyash, as appropriate.

(iii) Naturally occurring softer aggregates like moorum, kankar, gravel, etc.

(iv) Brick and overburnt brick metal.

(v) Stone metal.

Some of the important points in the use of these materials are discussed in subsequent paragraphs.

3.4.2. **Better granular soil** : Well-graded soils with low plasticity have better engineering properties and should be reserved for use in the subgrade portion, or surfacing in the case of earth roads. Such soils can be identified by their high Proctor density and low P.I. values.

3.4.3. **Stabilisation of local soils :** A variety of techniques are available for stabilising local soils for improving their engineering properties, but not all the techniques are applicable to all types of soils. A brief description of the stabilisation mechanism and applicability of the individual techniques are given in Table 7. This may be referred to for choosing the most appropriate technique for stabilising the soil at site. The mix proportions are generally worked out in the laboratory based on soaked CBR.

3.4.4. **Naturally occurring softer aggregates :** Softer aggregates like laterite, kankar, moorum, dhandla, etc. where available within economic leads, should be made use of in pavement construction to the maximum extent feasible. The material may occur in a graded form or as discrete blocks or admixtured with soil. The manner of using these is indicated in Table 8.

3.4.5. **Brick soling :** In alluvial plains where hard stone aggregates are normally not available within economical leads, the general specification adopted for sub-base and base courses is to provide brick soling. Either flat bricks or bricks on edge can be used depending on the thickness requirements. In case of flat bricks, the layers are desirable. The bricks should be of good quality and well burnt. Before laying, it is generally desirable to provide a cushion of sand above the earth subgrade.

3.4.6. **Water bound macadam :** Water Bound Macadam is one of the most common specifications adopted for construction of sub-base, base and surfacing courses. Broken stone, crushed

TABLE 7. MECHANISM AND REQUIREMENTS OF SOIL STABILISATION TECHNIQUES

Sl. No.	Technique	Mechanism	Application
1	2	3	4
1.	Mechanical stabilisation	Blending missing fractions (e.g. clay with sand and sand with clay) so as to produce a mass of maximum possible density with plasticity within limits. A smooth grading similar to that given by Fuller's grading rule** is adopted to work out the proportion of the missing fractions to be blended.	Sands, moorum/gravel having missing fractions and clayey soils can be stabilised by this technique.
2.	Lime stabilisation	Lime in hydrated form reacts with the clay minerals in the soil to cause (i) immediate reduction in plasticity and increase in CBR because of cationic exchange, flocculation and agglomeration which may be reversible under certain conditions, and (ii) long term chemical reaction with the clay minerals to produce cementitious products which bind the soil for increased strength and stability.	Medium and heavy clays having a PI of at least 10 and containing at least 15% of materials finer than 425 micron are suitable. However, some soils though containing clay fractions may not produce the long-term chemical reaction because of the presence of organic matter (>2%), or soluble sulphate/carbonate (>0.2%), etc. For lime stabilisation to be successful, it will be desirable to test the soil for lime reactivity. A soil whose 7-day unconfined compression strength increases by at least 3 kg/cm^2 with lime treatment can be considered lime reactive.

**Fuller's grading rule is given by :

$$\text{per cent passing sieve} = 100 = \left[\frac{\text{aperture size of sieve}}{\text{size of the largest particle}}\right]^{\frac{1}{2}}$$

(*Contd.*)

1	2	3	4
3.	Cement stabilisation	The hydrated products of cement binds the soil particles, the strength developed depending on the concentration of cement and the intimacy with which the soil particles are mixed with cement. A high cement content of the order of 7-10% can produce a hard mass having a 7-day compressive strength of 20 kg/cm^2 or more, and this usually goes by the term soil-cement However, a smaller proportion of 2-3% cement can improve the CBR value to more than 25, and the material going by the term "cement—modified soil" and be advantageously used as sub-base/base for rural roads.	Generally, granular soils free of high concentration of organic matter ($\not>$2%) or deleterious salts (sulphate and carbonate $\not>$0.2%) are suitable. A useful role for soil selections is that the plasticity modulus (product of PI and fraction passing 425 micron sieve) should be less than 250 and that the uniformity coefficient should be greater than 5.
4.	Lime-flyash stabilisation	Lime chemically reacts with the silica and alumina in flyash to form cementitious compounds which binds the soil.	Soils of medium plasticity (PI 5-20) and clayey soils not reactive to lime can be stabilised with lime and flyash.
5.	Bitumen stabilisation	Bitumen binds the soil particles	Clean graded sands can be stabilised by this technique.
6.	Two-stage stabilisation	This generally applies to heavy clays. The clay is treated with lime in the first stage to reduce plasticity and to facilitate pulverisation. In the second stage, the resulting soil is stabilised with cement, bitumen, lime or lime-flyash.	Heavy clays.

TABLE 8. MANNER OF USING SOFT AGGREGATES IN PAVEMENT CONSTRUCTION

Sl. No.	State of occurrence of material	Manner of using in pavement construction	Test/quality requirements
1.	In block or large discrete particles	As water bound macadam without screenings/filler in accordance with IRC: 19, after breaking the material into required sizes	Wet aggregate impact value (IS : 5640) not to exceed 50, 40 and 30 when used in sub-base, base and surfacing respectively
2.	Graded form without appreciable amount of soil	Directly as a granular layer for sub-base/base or surfacing	PI should be 4-9 when used as surfacing and should not exceed 6 when used in lower courses. Evaluated for strength by soaked CBR
3.	As discrete particles mixed with appreciable amount of soil such as soil-gravel mixtures	Directly as soil-gravel mix for sub-base, base of surfacing	The material should be well graded and the PI restricted as for Sl. No. 2. Evaluated by soaked CBR

Notes on improving the engineering properties :

(i) Improving gradation—Sieving out sizes not required and blending with missing fractions

(ii) Reducing plasticity—Stabilisation with lime

(iii) Improving strength—Materials with appreciable soil fraction can be stabilised with lime (where PI is high), lime-flyash or cement.

slag, overburnt brick metal, laterite, or kankar can be used as the coarse aggregate for WBM. For details of the WBM technique, reference may be made to IRC : 19 'Standard Specification and Code of Practice for Water Bound Macadam'.

3.4.7. **Bituminous surfacings**

(1) Bituminous surfacing is a relatively expensive item and its use should be made judiciously. Even where used, the specification will not generally be higher than single/two-coat surface dressing or 2-cm thick open-graded premix carpet.

(2) Thin bituminous surfacing essentially serves the following purposes :

(i) Provides a smooth riding surface.

(ii) Seals the surface thus preventing the entry of water which would otherwise weaken the pavement structure.

(iii) protects the granular base from the disruptive effects of traffic.

From the above considerations, bituminous surfacing would be desirable in the following cases :

(i) Pneumatic tyred fast vehicles disrupt unprotected granular bases and create dust nuisance. Also, the operating cost of such vehicles is highly influenced by the smoothness of the road pavement. Bituminous surfacing will, therefore, be advantageous when the pneumatic tyred faster vehicles ply in large numbers, say, more than 50 per day.

(ii) Pavements in high rainfall areas need to be protected against water infilteration and erosion. From this angle, roads in high rainfall areas (rainfall greater than 150 cm per year) should preferably be provided with bituminous surfacing.

3.5. Cross-Drainage Structures

3.5.1. **General :** Cross-drainage structures which are intended for crossing of water barriers along the road alignment constitute the most important component affecting the all-weather character of the road. These crossings are generally one of the costly items (forming roughly 25-30 per cent of total construction cost) in road projects. On rural roads, these structures should be built as economical as possible to be in consonance with the low-cost concept of the road and at the same time be consistent with the technical and functional requirements.

3.5.2. Choice of the type of water crossing

(1) A variety of water crossings are possible. These can be considered under two broad groups, namely :

(i) Crossings that are submersible, such as fords, paved dips, causeways, etc.

(ii) Crossings that are not submersible, such as culverts, bridges and ferries.

Each type of crossing has an appropriate place for use. Generally, high level bridges across major water courses are not envisaged for rural roads, and this aspect must be paid due attention at the road planning stage itself.

(2) The considerations in the proper choice of the type of crossing are :

(a) **Functional**

(i) Number of vehicles delayed

(ii) Length of time of each delay

(iii) Number of times per year these delays occur.

(b) **Technical**

(i) Nature and width of stream, and flood flows whether flashy or sustained

(ii) Velocity of flow and bed slope

(iii) Maximum and minimum depth of flow

(iv) Presence of floating debris, boulder movement on the bed, etc.

(v) Local materials and skills available.

(c) **Economical**

(i) Cost of initial construction

(ii) Cost of maintenance or reconstruction

(iii) Cost of delays to vehicles (in the case of submersible crossings).

Normally, experience and local practice will be highly helpful in the choice of the appropriate crossing thus obviating the need for detailed calculations. However, there can be overlapping cases suggesting more than one alternative. In such cases where doubt exists, it would be worthwhile to evaluate the alternatives taking all the above mentioned aspects into account. For the quick selection of promising alternatives, the guidelines given in Table 9 will be helpful.

TABLE 9. GUIDELINE SFOR THE CHOICE OF CROSS DRAINAGE STRUCTURE FOR RURAL ROADS

Sl. No.	Type of Structure	Locations where the structure will be found suitable
1.	Ford	Shallow non-perennial stream where maximum depth of flow does not exceed 1.6 m and the period of interruption at one stretch does not exceed 12 hours for ODRs and 24 hours for VRs in hilly terrain, and 3 days in the case of roads in plains. Also, the total period of interruption should not exceed 10 days for ODRs and 15 days for VRs. Suitable for roads in arid or isolated areas carrying very low traffic. Also for roads in a network where alternate route is available during the rainy season. Low in initial cost, and ideal for crossing of men on foot and cattle.
2.	Paved dip (or bed causeway)	Same as for Sl. No. 1 except that the traffic on the road may be somewhat higher.
3.	Vented causeway	Shallow streams having permanent dry weather flow exceeding 0.6 m in depth. The same criterion indicated for Sl.No. 1 as regards interruption equally apply to this case also.
4.	Submersible bridge	In cases where high level bridge is too expensive to construct.
5.	Culvert	This is a high level structure having total span up to 6 m. Suitable for narrow streams.
6.	High level bridge	Ordinarily high level bridges designed to cater for the maximum possible flood discharge should not be considered for rural roads. However, situations warranting such bridges are crossing of deep narrow streams or ravines in hilly terrain.
7.	Ferry and pontoon/ boat bridge	In case of large streams where it is not economical to provide a bridge, ferry service or pontoon/boat bridge may be appropriate.

3.5.3. Design standards

(1) Design loading

Road bridges, culverts and vents for causeways should be designed for the categories of loadings as described in IRC: 6-1966 "Standard Specifications and Code of Practice for Road Bridges, Section II-Loads and Stresses", reproduced below :

IRC Class A Loading : This loading is to be normally adopted for all roads on which permanent bridges and culverts are constructed.

IRC Class B Loading : This loading is to be normally adopted for temporary structures and for bridges in specified areas. Structures with timber spans are to be regarded as temporary structures for the purpose.

(2) Roadway width

Culverts (upto 6m span) : In plain and rolling terrain, the roadway width on culverts (measured from outside to outside of the parapet walls) both for ODRs and VRs should equal the normal roadway width given in Table 3. In mountainous and steep terrain, the clear roadway width available on the culverts (measured from inside to inside of parapet walls or kerbs) should be as below :

ODRs	—	Same as given in Table 3
VRs		
Minimum	—	As given in Table 3
Desirable	—	4.25 m

Bridges (greater than 6 m span) : At bridges constructed for road traffic, clear width of roadway (between kerbs) should be as under :

Desirable	—	7.5 m
Where 7.5 m width cannot be provided	—	5.75 m
Exceptional	—	4.25 m

Where a footpath or footbridge is provided for the use of pedestrians, its width should not be less than 1.5 m.

Causeways and submersible bridges : Roadway width at causeways and submersible bridges should be normally adequate for two lanes of traffic, i.e. 7.5 m wide, unless it is specially reduced by the competent authority.

(3) Gradient

The Gradient on the low-level crossings (*e.g.* paved dip) and their approaches shall not exceed 1 in 12. Suitable vertical curves designed for safe stopping sight distance should be provided at breaks in the grade line subject to a minimum length of 15 m.

3.5.4. Details of submersible type of cross-drainage structures

(1) Ford

Location for the ford is chosen at a place where the stream runs in shallow channel. A trench about 1 m wide and 1 to 1.2 m deep is dug on the bed of the stream along the downstream edge of the road. The trench is then filled with stones in wire crates upto the level of the road. As an alternative, a masonry (stone or brick in cement mortar 1:4) wall could be built along the downstream edge to retain the road in position. The road surface is formed by levelling the stream bed with gravel. After one or two seasons, fines transported by the stream will fill in the voids in the gravel surface, leaving a satisfactory stream crossing. Details of a typical ford are illustrated in Fig. 7.

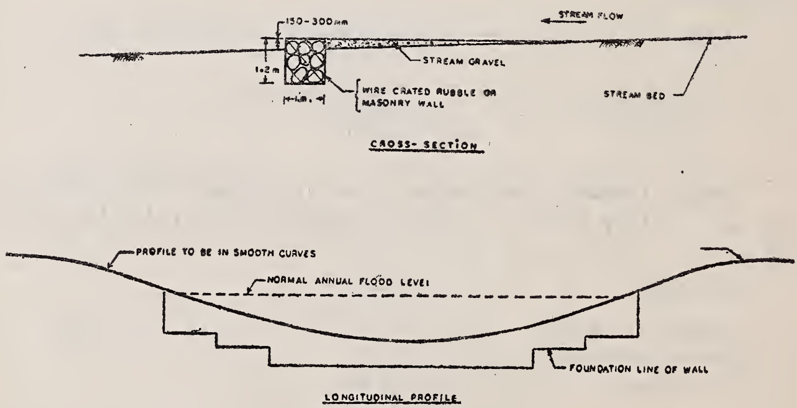


Fig. 7. Typical ford

(2) Paved dip

This is similar to a ford constructed flush with the stream bed except for the provision of permanent riding surface protected by cut-off walls both on the upstream and downstream sides. Fig. 8. illustrates the details of a paved dip.

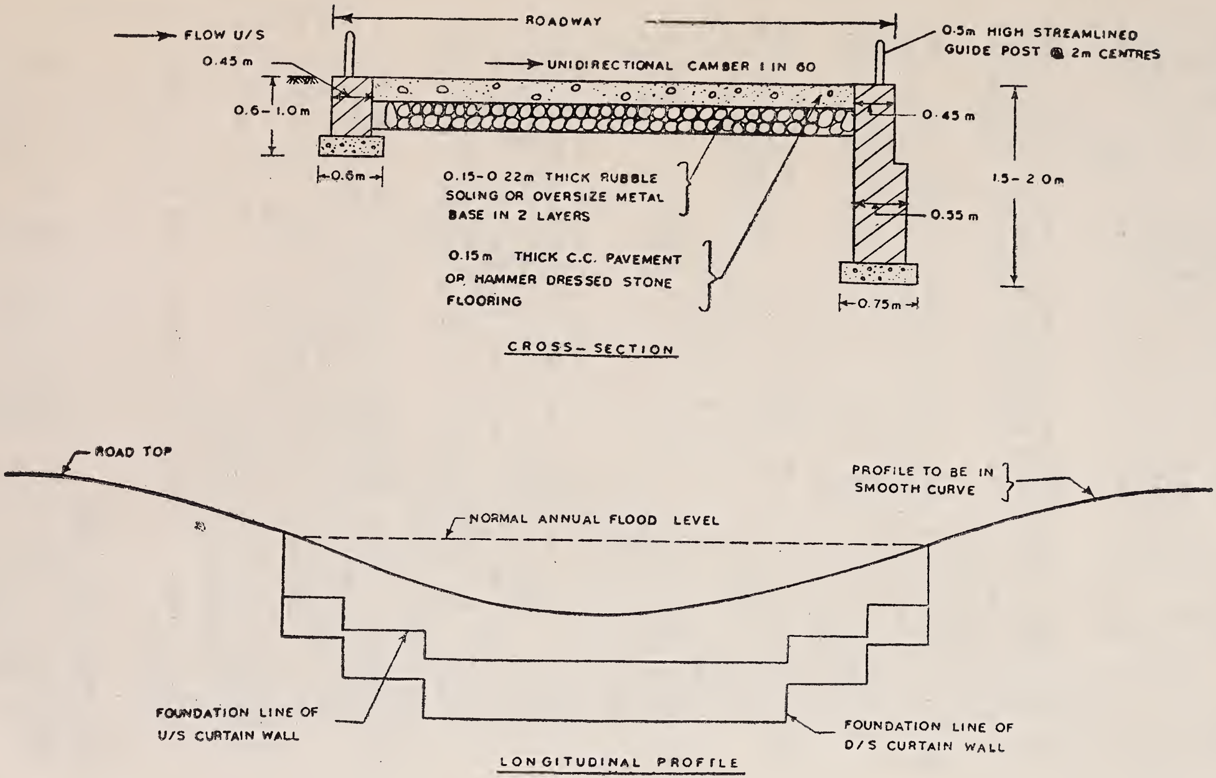


Fig. 8. Typical paved dip

(3) Vented Causeway

Vented causeways have the double function of passing normal discharge through the vents and below the roadway and the flood discharge both through the vents and over the roadway itself. Some of the important considerations in the design of this type of structure are :

(i) The vents should be sufficient to pass the normal water flow without overtopping. This should be checked for the maximum annual flood to ensure that the interruption criteria given in Table 9. are not transgressed.

(ii) The vents should be distributed throughout the length of the causeway. All entry faces should be bell-mouthed to reduce hydraulic losses, and thereby the afflux. The vents may consist of pipes, reinforced concrete slabs, arches or stone slabs depending on the availability of materials and local conditions.

(iii) The roadway should preferably be given one way crossfall towards the downstream side. This will have the advantage of reduced afflux and avoid the chance of a standing wave (consequence—turbulance and serious erosion) being formed.

(iv) Other measures for reducing the hydraulic resistance are rounding/bevelling the upstream edge of the causeway, and provision of streamlined guard stones.

(v) The final road levels (grade line on the causeway) should be kept as low as possible consistent however with satisfying the interruption criteria. It should be clearly understood that the flood levels will increase (because of afflux) on the upstream side after the construction of the structure depending on the extent of obstruction. Any checking for the interruption criteria should be with reference to the affluxed flood level.

(vi) Suitable cut-off walls should be provided at both the upstream and downstream sides. Unless rock is met with at higher levels, these walls should go down to at least 1m and 2m respectively on the upstream and downstream sides respectively. These walls should be protected by means of apron comprising rubble stone or cement concrete block to a width of 2m and 5m on the upstream and downstream sides respectively.

Fig. 9. shows a typical vented causeway using R.C.C. pipes for the vents.

(4) Submersible bridge

Submersible bridges are functionally superior to vented causeways, and are provided where it will be very expensive to construct high level bridges. Normally, the ventway and deck

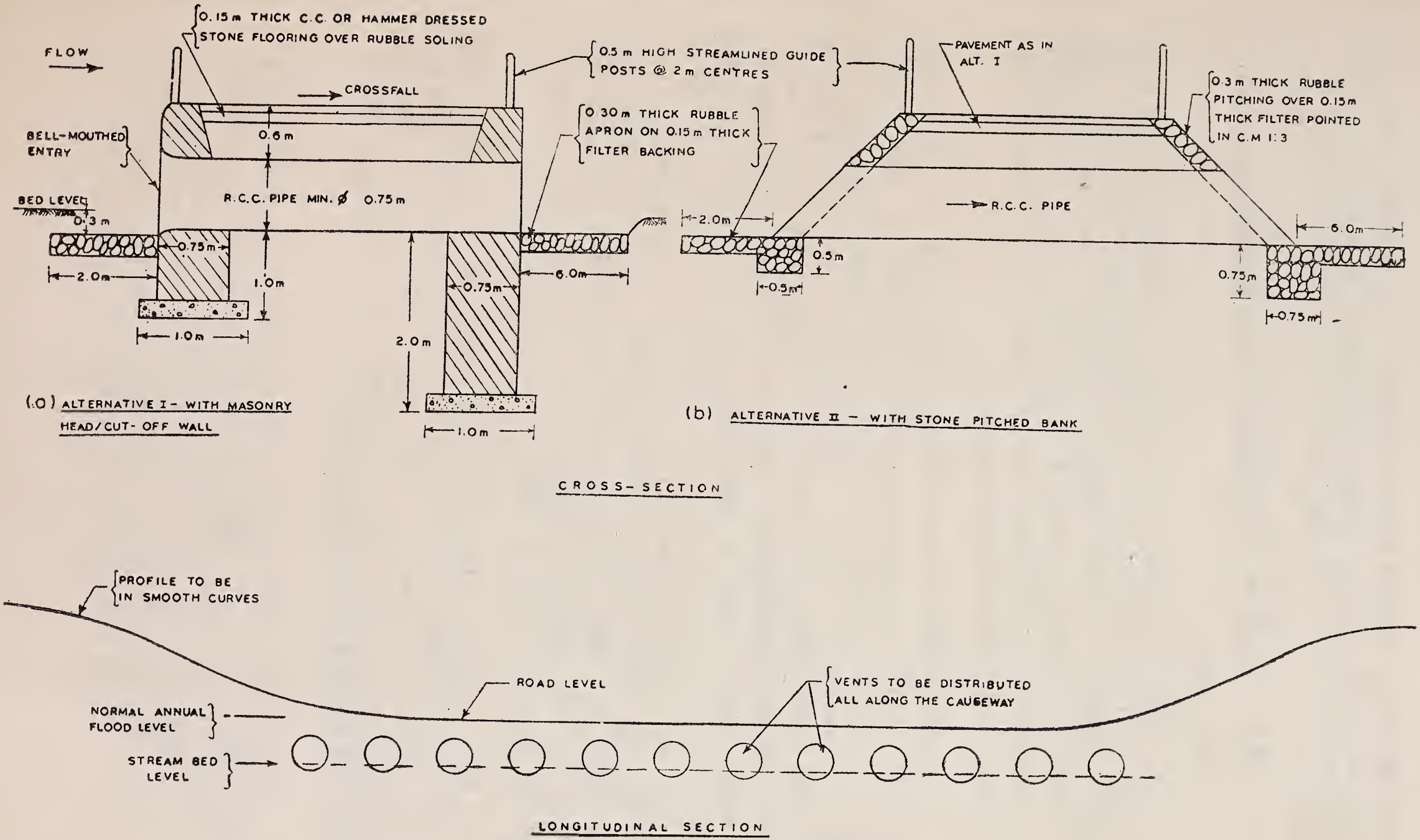


Fig. 9. Vented causeway with R.C.C. pipes for vents

level should be so fixed that it is possible to pass below the roadway the flood of 5 to 10 year frequency. In the design of such bridges, the impact of floating debris should be taken care of.

3.5.5. Details of non-submersible cross-drainage structure

(1) Culverts

A culvert is defined as a bridge structure having a gross length of 6 m or less between faces of abutments or extreme ventage boundaries. Culverts may be of different types, namely, pipe culvert, R.C.C. slab culvert, R.C.C. box culvert stone slab culvert or masonry arch culvert, but their choice will depend on the relative cost and construction convenience.

Pipe culverts are versatile and will be found to be economical and easy to construct in most of the situations where a difference in level of at least 1.25 m between the stream level and road level is available. R.C.C. pipes should be of NP-2 grade to IS : 458 and shall have a minimum diameter of 0.75 m to ensure easy cleaning. The minimum cushion over the pipe shall be 0.6 m. It is important to place the pipes on an even bedding of granular soil or sand shaped to fit the lower portion of pipe to a height of at least one-fourth the diameter of the pipe. Longitudinal slope of the pipe should be 1 in 1000 minimum. It will be preferable to extend the pipes beyond the roadway till they meet the earth slopes so that expensive headwalls are avoided. The entrance should be bell-mouthed to improve hydraulic efficiency.

R.C.C. slab or stone slab culverts may be used where the available difference in level between the stream bed and road top is not sufficient to introduce a pipe. Stone slab culverts may be advantageous in areas where suitable stone is easily available. They can be used for spans upto about 1.5 m.

In isolated areas, where the crossing is generally used by men, cattle or a few light vehicles, empty bitumen or oil drums with their ends removed could be used as a temporary crossing. The drums are placed one after the other in a line, with earth cushion to a depth of at least 0.6 m on the top. These may, however, require to be replaced once every 2-3 years.

(2) **Foot bridges**

In isolated areas, in locations where provision of a motorable bridge may not be economically feasible and where a crossing is required only for people and cattle, provision of foot bridges will be an expedient solution. Foot bridges may vary in shape and details of construction depending on the local materials available. A variety of materials, like tree trunks, wooden sections, R.S.Js or used rails can be used for the main beams over which wooden deck could be constructed. In areas where bamboo is available in plenty, two to four pieces of bamboo can be clamped or fixed together to act as a single beam for span upto 3 m.

For foot bridges, the minimum width of deck shall be 1.5 m. Where the crossing stream is deep, or the water current is fast, hand railings should be provided.

(3) **Timber bridges**

In areas where timber is locally available, it can be used both for the foundations and the superstructure of a bridge. Timber bridges should be considered as temporary structures having a life span of 10-20 years.

The foundations may consist of timber piles or trestles depending on local conditions. Pile type supports should be used when site conditions are affected by deep water or swift current causing scour, low capacity soil overlying rock, or unconsolidated soil with low bearing capacity. Typical timber trestle pier and pile pier are illustrated in Fig. 10. For spans greater than 5 m, a double row of piles/trestles should be used for the pier.

Timber for the piles and other structural members of the bridge should be creosoted sal wood or any other wood of similar quality.

The cap or timber which rests directly on the piles/trestles should consist of creosoted wood 200 mm × 300 mm in size and long enough to bear all the supports. The cap is generally fastened to the supports by means of drift pins which consist of iron rod pieces of about 0.6 m long sharpened at one end. A hole

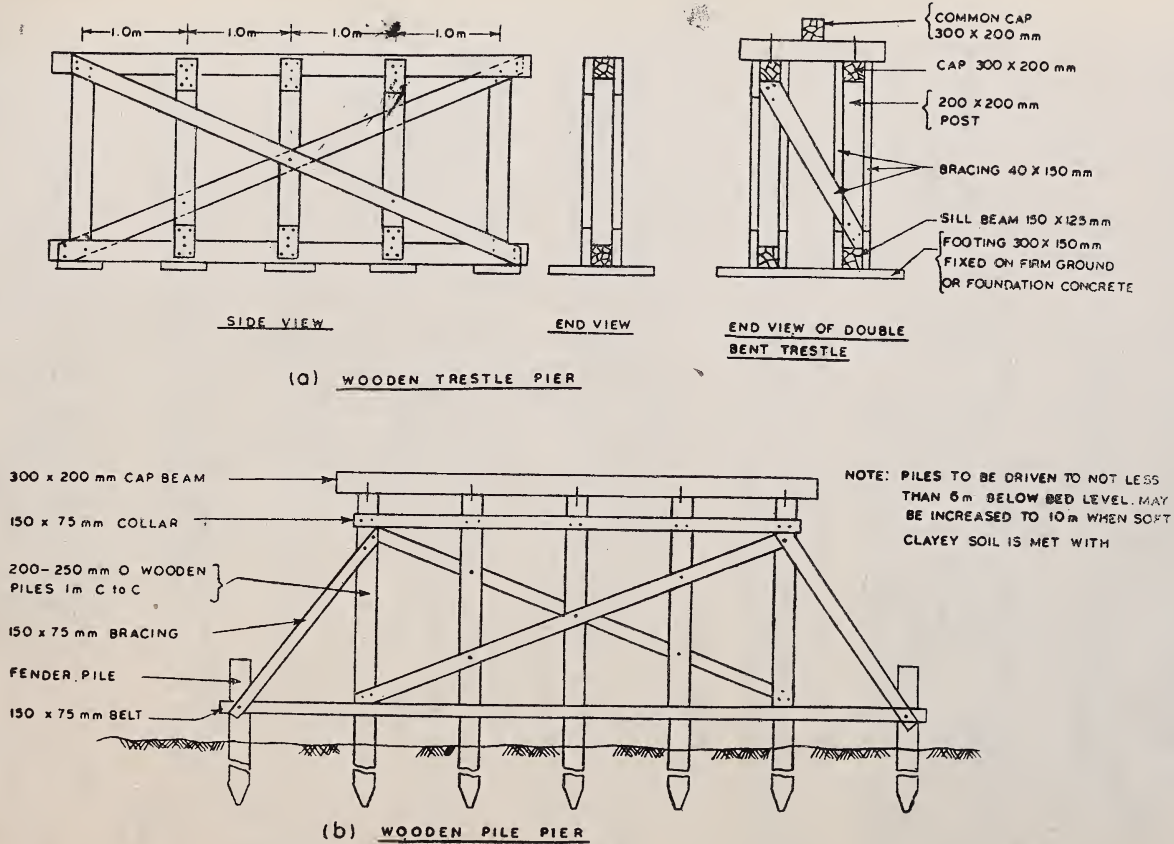


Fig. 10. Wooden trestle/pile pier

slightly smaller than the size of the drift pin is bored down vertically through the cap just over the centre of each support, and the pin dipped in hot bitumen driven with a heavy hammer down through the cap and into the support. Stringers or longitudinal beams may be of rectangular or circular wooden sections for spans upto about 6 m. Beyond this span, rolled steel joists (RSJ) should be used.

All stringers should be at the same level at the top so that floor planks will bear evenly on every stringer in a panel. If one stringer is slightly higher than the rest, turn it over and trim it a little at the ends where it rests on the cap. Cutting of the timber sections all along the length for achieving the desired level should be avoided.

Decking planks 100 mm thick should be laid with each plank nailed to one next to it so that a solid slab of wood 100 mm thick is obtained. The floor should also be creosoted.

(4) Masonry arches for culverts and bridges

Masonry arches for culverts and small bridges will be found suitable where there is sufficient difference in the level between the stream bed and the road, and necessary skilled labour is available.

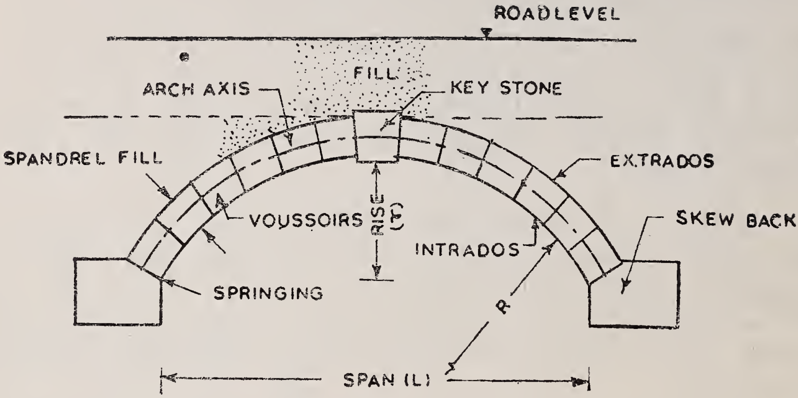
The masonry arches may be either of cement concrete blocks 1:3:6 or dressed stones or bricks in cement mortar 1:3. Details of masonry arches for spans upto 6 m are given in Fig. 11.

(5) Scupper

Scupper is an opening below the roadway formed by stone corbelling for cross drainage purposes. This can be advantageously used in hilly areas where stones are generally available in abundance. The scuppers should be built in such a manner that flow along the bed of natural water course is not obstructed. Minimum cushion over the scuppers should be 40 cm. Scuppers and culverts on hill roads should be provided with catch pits.

(6) Other types of bridges

Among the other types, suspension bridges will be found convenient for crossing deep gorges in mountainous and



Notes: 1. Rise $\gamma = \frac{L}{4}$

2. Thickness of Arch $T = \frac{4+\gamma}{10}$ metre

3. Fill over crown of arch to be not less than 0.5 m and not more than 1.0 m

4. The arch may be in 1st class dressed stone masonry or c.c. Block masonry or 1st class brick masonry in cement mortar 1:3 lime mortar 1:2 mix may also be used as an alternative.

Fig. 11. Details of masonry arch

sbu-mountainous areas where provision of intermediate supports will be not feasible. Another type which is used by the armed forces and for emergency crossings is the Bailey bridge which is formed by joining pre-fabricated panels and members.

(7) Boat ferries

Ferry is a floating device that operates between two terminal points of a road network interrupted by a water barrier. Ferry should normally be considered only where the draft is adequate for plying of boats, there is not much seasonal fluctuations in water level or widths, and where the river current is within manageable limits. The site of crossings should allow the economical construction of terminal facilities sush as ramps, loading/unloading platforms, etc. In adverse weather and high spate conditions of the river, the ferry will not be safe and the operation should be suspended. For passenger traffic, country boats having capacity of 15-20 passengers can be operated economically. For transport of vehicles like lorries and passengers/cattle in larger numbers, large-sized boats or two boats joined together may be warranted.

(8) Pontoon bridges

Pontoon bridges are temporary means of crossing the water barriers. These may be employed at locations where ferry is not economically or technically feasible and at locations with difficult bottom conditions to make fixed bridging uneconomical.

3.5.6. **Signs and guide systems for water crossings :** Generally, a majority of the low cost water crossings of rural roads will have some deficiency or the other as compared to permanent high-level structures on main roads. These may be with regard to submergence during the monsoon season, or limitation on load carrying capacity or roadway width.

All submersible crossings must be provided with flood gauges to indicate the depth of flow over the roadway for warning the road users. Type design for flood gauge is given in IRC : 67. Also, guide posts (circular or streamlined in shape) should be provided at two-metre centres on either edge of the roadway. These posts should be about 0.5 m high, and should be painted white.

For all crossings deficient in load capacity or roadway width, the restrictive/warning signs should be posted sufficiently in advance on either side for advance notification to motorists. Details of these signs are given in IRC : 67-1977.

3.6. Construction and Quality Control

3.6.1. General

(1) Construction is the phase of operation where the design and drawings are translated on to the ground to form the road, closely following the laid-down specifications. Quality control is the phase which runs concurrently with the construction phase to ensure that the road has been built in accordance with the design/ drawings and that the specification requirements have been fulfilled

so that one can be sure of the performance expected of the road.

(2) The construction method will depend on the type of specification and the complement of tools and plant available for the project. Compaction of subgrade to say 100 per cent Proctor density will be possible only with power rollers. Surface dressing will require at least a hand operated sprayer, and premix carpet will call for mechanical mixing equipment. In other words, the necessary equipment must be made available if these specifications are to be constructible. It is, therefore, necessary that while choosing the specification and laying down the acceptance limits for the work, the requirement of the equipment needed must be worked out and arrangements made for their availability in working condition at site.

3.6.2. Earthwork

(1) Earthwork constitutes a major component in the cost of any road project, and on the overall basis, the cost of earthwork may amount to 40-70 per cent of the cost of a rural road. Careful site planning and efficient operation of the activities involved are therefore necessary for economising road construction cost.

(2) Earthwork may be for forming the whole road cross-section upto the surfacing as in the case of earth roads, or upto the subgrade level for roads provided with pavement courses. In either case, the main activities involved in earthwork operations are :

(i) Identification of the sources for the embankment material; and

(ii) The earthwork process.

(3) Generally, the soil used for embankment construction should be the same as the one available in the road side borrow areas or from nearby roadway/drainage excavation. Import of soil from long distances should not ordinarily be considered for rural roads. Guidelines for the location of roadside borrowpits (see IRC: 10 for more details) are given in Table 10. Among the available soil, the one with better engineering properties (better soil has higher Proctor density and lower plasticity index) should be reserved for the top 300 mm height of the embankment.

TABLE 10. GUIDELINES FOR THE LOCATION OF ROADSIDE BORROWPITS

1. **Location and Shape**

Borrowpits should be rectangular in shape with one side parallel to the centre line of the road. If on road land, they should be dug as near the road boundary as possible. In any case, no borrowpits should be dug within 5 m of the toe of the final section of the road embankment, after making due allowance for future development.

Borrowpits should not be dug continuously. Ridges of not less than 8 m width should be left at intervals not exceeding 300 m. Small drains should be cut through the ridges to facilitate drainage.

2. **Depth**

The depth of borrowpits should be so regulated that :

(a) The bottom of the pits do not cut an imaginary line having a slope of 1 : 4 projected from the edge of the final section of the road embankment;

(b) The bed level of the pits should slope down progressively towards the nearest cross drain, if any, and should not be lower than the bed of the cross drain;

(c) Where the pits are on temporarily acquired cultivable land, the depth should not exceed 450 mm. The top soil to a depth of 150 mm should be stripped and stacked aside. Thereafter soil may be dug to a further depth not exceeding 300 mm. The top soil should then be spread back on the land.

3. **Special Cases**

(a) In waterlogged areas the borrowpits should take the form of deep narrow continuous ditches, connected with natural drainage, so as to conserve as much land as possible.

(b) Borrowpits should not be dug within 800 m of towns or villages. If unavoidable, they should not exceed 300 mm in depth and should be drained.

(c) Where the road embankment is used as flood bank, as far as possible, earth should be borrowed only from the river side. The inner edge of any borrowpit should not be less than 15 m from the toe of the bank. Where borrowing earth from the landside cannot be avoided, a berm at least 25 m wide should be left between the borrowpit and toe of the bank.

The toe of the bank on the rear side should have a cover of 750 mm to 1.25 m over the saturation line drawn at a slope of 1 in 6 from the high flood level on the river side.

A quick estimation of plasticity index can be had by the Uppal's Syringe method. The method consists of making a paste of soil passing 425 micron sieve by adding sufficient quantity of water so as to bring it close to the plastic limit state. The paste is put in the syringe and pushed through the holes. If the thread coming out of the holes is unbroken and shiny, the PI can be considered to be more than 10. The threads do not come out of the syringe for soils having PI less than 5. For soils with PI between 5 and 10, the texture of the threads is not smooth.

(4) The earthwork process involves the following activities :

(i) **Excavation**—This is for winning soil for the embankment which may be from the roadside borrow areas, or from nearby roadway/drainage excavation. Excavation in hard soils can be facilitated by prewetting, or pre-ripping with a plough.

(ii) **Hauling and depositing**—This includes the hauling of the excavated material and depositing the same in layers at the embankment site directly. The activities of excavation, hauling and depositing should be combined into single task so that double handling of the material is avoided.

(iii) **Breaking clods**—Clods of earth which contain clay, exceeding 150 mm in size should be broken either at the excavation site or at the embankment. If left in position, the clods with unslaked clay in them will not only permit proper compaction but also create problems of unequal expansion in the presence of water.

(iv) **Adjustment for moisture**—For a constant compactive effort, the maximum density will be achieved at a particular moisture content which is termed the optimum moisture content (OMC). The OMC will depend on the type of soil and the intensity of compactive effort. For the same soil, OMC will be lower for higher compactive effort than for smaller compactive effort. For the type of soil used in the embankment, the OMC should be determined corresponding to the proposed compactive effort which is normally Proctor compaction. In actual working, the moisture content is maintained within a tolerance of $\pm$ 1.5 per cent of OMC. However, for highly expansive clays, it is preferable to compact these at about 2 to 4 per cent on the higher side of OMC. This is for the reason that such clays compacted at lower moisture content imbibe considerable water subsequently

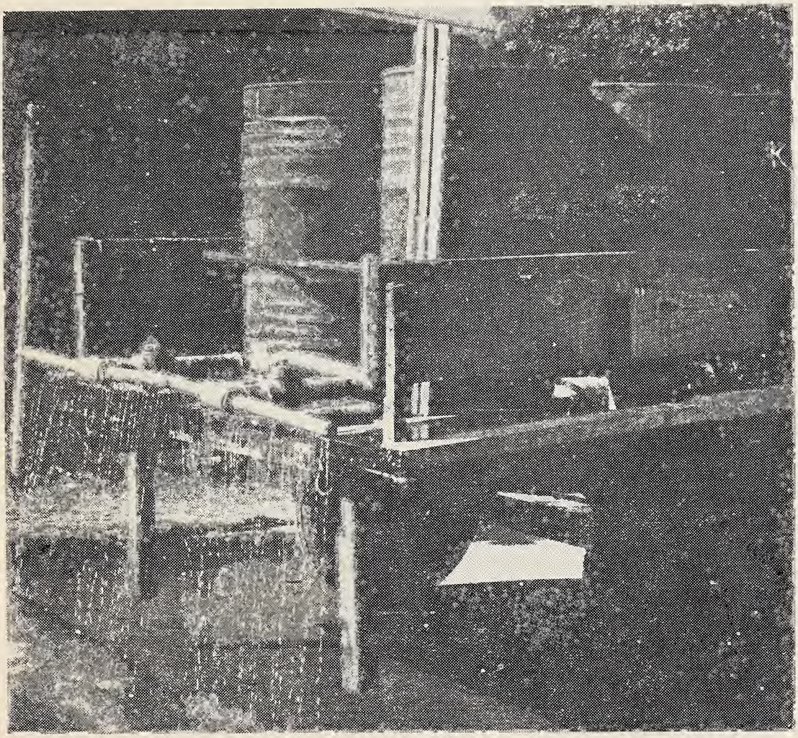


Photo 1. Cart-mounted water browser fabricated from empty oil drums.

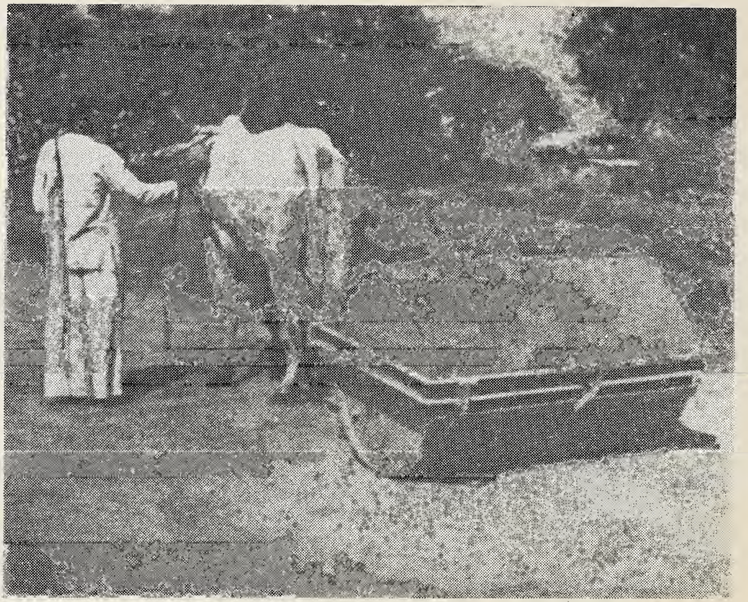


Photo 2. Animal-drawn roller (weight 1100 kg, 600 mm dia. and 600 mm long)

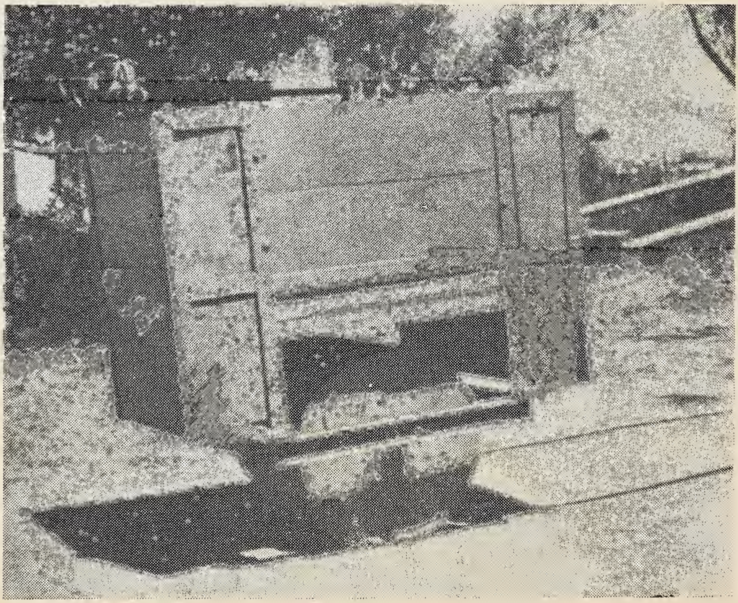


Photo 3. Ballasted animal-drawn roller (ballasted weight 1100 kg)

in service and lose strength besides showing signs of unequal expansion.

Moisture may be adjusted either at the borrow area or after the soil has been delivered at the embankment site. Addition of water may be conveniently arranged by an improvised water browser carried on a bullock-cart. It can be conveniently fabricated from empty oil drums interconnected at the bottom and finally leading to a perforated pipe at the end serving as the browser. Photo 1 illustrates the design.

(v) **Spreading in layers**—The compaction plant can exert its effective compactive effort only upto a certain depth. It is, therefore, necessary that the material for compaction is spread in layers not exceeding this critical depth. For 8-10 tonne 3-wheeled rollers normally used in the country, the thickness of loose layer should not exceed 225 mm. For lighter rollers, the layer thickness will have to be lower than this figure.

(vi) **Compaction**—This is the most important phase of embankment construction. The type of compaction equipment appropriate for the job will depend on the type of soil to be compacted. However, three-wheeled power rollers will be found suitable for most soils, though sheepfoot roller will be more appropriate for clayey soils.

Three-wheeled power rollers are also required for compacting the pavement courses. It is, therefore, necessary that all efforts should be made to procure this piece of equipment which has the most crucial role to play in the construction of rural roads. The level of compaction should not be allowed to go below the following :

Top 300 mm of embankment forming subgrade	95 per cent Proctor density
Body of embankment	90 per cent Proctor density

There may, however, be isolated areas where limited rural road works may have to be done but no power roller can be made available. In such cases, tractor-drawn/animal-drawn/hand-drawn rollers may be used. The layer thickness may, however, be reduced and the number of passes increased to achieve a reasonable level of compaction. Two designs of animal-drawn rollers are illustrated in Photos 2 and 3. These are capable of compaction upto about 90 per cent Proctor density.

3.6.3. Pavement courses

(1) As discussed in para 3.4, a variety of materials are possible for in use in pavement courses depending on availability and suitability. The effort should be towards maximising utilisation of the following materials/techniques in pavement construction :

(i) Locally available softer aggregates in whatever form they occur, either in virgin state or after treatment, see Table 8 for the manner of their use.

(ii) Stabilisation of local soil for improving the engineering properties—see Table 7 for the choice of appropriate stabilisation technique.

(2) In soil stabilisation, the important operations are pulverisation of the soil, uniform mixing of the stabiliser with the soil and compaction of the mixed material with power roller to a density not less than 95 per cent Proctor. Pulverisation is difficult in clayey soils and it would be advantageous to use some sort of equipment. Most versatile equipment in this regard is the agricultural tractor to which mould-board plough, disc-harrow and off-set harrow could be hitched for processing the soil. After achieving the required degree of pulverisation (100 per cent passing 25 mm sieve and 60 per cent passing 4.75 mm sieve), the soil is levelled, moisture content adjusted, and the stabiliser spread over it manually. The off-set harrow is then used for 4-6 passes for mixing. After levelling, the layer is compacted with power roller. For heavy clays, pre-treatment with lime may be adopted for aiding pulverisation.

(3) In the purely manual method, the soil is cut several times with hoe/spade for pulverising it. The stack of the cut soil is then made, moisture adjusted and stabiliser spread on it. The whole stack is then turned over 4-6 times till uniformity to mixing is achieved.

(4) In soil stabilisation works, the amount of stabiliser should be determined in advance in the laboratory for satisfying

the specified strength criteria. It will be advantageous to add about 1/2 per cent extra stabiliser to cover possible loss during spreading and non-uniform mixing in the field. When lime is the stabiliser, its quantity should be regulated in terms of available calcium oxide content.

(5) Water bound macadam construction depends for its strength on complete rolling to interlocking of the coarse aggregates. It will, therefore, not be advisable to start on this type of construction unless suitable power rollers in working order are available at site. Also, this type of construction will require a lot of water for driving in the screening/filler material. Adjustments in the working season are also, therefore, called for.

(6) For rural roads where bituminous surfacing is to be provided, the choice may fall on either surface dressing or open-graded thin premix surfacing. Surface dressing (single or two-coat) is simple to lay from the angle of tools and plant, but the surface should receive reasonable amount of pneumatic traffic so that the binder can work up to embedded chips properly. Where sufficient pneumatic traffic is not expected, surface dressing with pre-coated chippings can be adopted with advantage.

(7) Premix carpet construction will warrant suitable mixer, atleast an improvised one. It will be advantageous to heat the aggregate separately prior to mixing with bitumen for ensuring better coating.

3.6.4. **Quality control**

(1) The road work may be executed departmentally or let out on contract, but in either case the basis of construction will be the drawings and the specifications. It will be incumbent on the Engineer-in-Charge to ensure that the materials incorporated and the work executed are in accordance with the specification requirements.

(2) For ascertaining whether the material or work conforms to specification requirements, objective testing will be required. The whole operation of controlling the quality of the materials and the work with the help of objective tests performed at predetermined frequency generally goes by the term "quality control".

(3) For small works, quality control can be performed by the construction staff itself, but for large works, *e.g.*, construction of a large number of rural roads in a single area, it will be advantageous to have separate quality control unit independent of the construction staff.

(4) The construction specification normally adopted in the country are tailored to a combination of both procedural control and end point control. For example, in the case of earthwork, the specifications not only stipulate the control on moisture content at the time of compaction and layer thickness (which are controls on the process) but also on the final compacted density (end point control). Control at all stages of construction is therefore, necessary to achieve the desired characteristics of the completed work.

(5) Among the quality control tests, some are crucial, *i.e.* those relating to the properties which have a telling effect on the performance. Such crucial tests are listed in Table 11 for pointed attention with recommended frequency of testing. This does not mean that tests to control other properties are not warranted.

(6) Achievement of good quality work can be helped to a great extent through care and attention at the material survey and investigation stage itself. It is at this stage that properties of the available soils and other materials are tested to choose the most appropriate material with identified source. Considerable testing work at the quality control stage could be obviated if it is ensured that the material delivered at site is from the same pre-identified source. For example, repetitive testing of aggregates for aggregate impact value could be obviated (except perhaps where the quality changes or is in doubt) if it is made sure that the aggregates are delivered from a pre-tested quarry.

(7) Quality control operations for rural road construction will require a variety of laboratory equipment. A list of the minimum equipment required for a rural road project is given in Table 12. It will be advantageous if these equipment are carried in a mobile laboratory so that a good coverage of a large area can be had quickly and effectively.

TABLE 11. IMPORTANT QUALITY CONTROL TESTS FOR RURAL ROAD CONSTRUCTION

Type of test	Frequency
1. **Earthwork**	
(i) Moisture content prior to compaction	One test per 250 m^2 subject to minimum of 4 tests/day
(ii) Thickness of layer	Regularly
(iii) Degree of compaction	One test per 500 m^2 subject to minimum of 5 tests/day
2. **Granular sub-base/base surfacing (other than WBM)**	
(i) Gradation	One test per 200 m^3 subject to a minimum of two tests per day for material from each source
(ii) Atterberg limits	-do-
(iii) Moisture content prior to compaction, thickness of layer and degree of compaction	Same as for (1) above
3. **Lime/Cement stabilisation**	
(i) Purity of lime (for lime stabilisation)	One test for each consignment subject to minimum of one test per 5 tonnes of lime
(ii) Degree of pulverisation	Periodically
(iii) Lime/cement content	Regularly, through procedural checks
(iv) Moisture content prior to compaction, thickness of layer and degree of compaction	Same as for (1) above
4. **Water Bound Macadam**	
(i) Aggregate Impact Value, Flakiness Index and grading	One test for each source of supply and subsequently when warranted by changes in quality of aggregate
(ii) P.I. of filler material	One test per 25 m^3 of material
5. **Thin Bituminous Surfacing**	
(i) Quality of aggregate such as A.I.V., Flakiness Index and grading	Same as for 4 (1) above
(ii) Binder temperature at application	At regular close intervals
(iii) Rate of spread of binder, binder content in mix and rate of spread of aggregate/mix	Regular procedural control

TABLE 12. LIST OF ESSENTIAL EQUIPMENT FOR QUALITY CONTROL IN RURAL ROAD CONSTRUCTION WORKS

Sl. No.	Equipment	Number required
1.	Post hole auger (with extensions)	One set
2.	Digging tools like pick-axe, shovel, etc.	One set
3.	Uppal's syringe apparatus	One No.
4.	Indian Standard sieve 40 mm, 20 mm, 12.5 mm, 10 mm, 4.75 mm, 2.36 mm, 425 micron and 75 micron with lid and pan	One set
5.	Standard Proctor's compaction test apparatus with rammer, etc.	One set
6.	Aggregate impact value testing machine	One set
7.	Liquid limit testing apparatus complete	One No.
8,	Physical balance with weight box (capacity 100 gm)	One set
9.	Pan Balance, Capacity 5 kg with weight box	One set
10.	Sand bath with primus stove	One No.
11.	Enamelled trays	4 Nos.
12.	Miscellaneous items like measuring tape, spatula, pestle mortar, gunny bags, plastic bags, laboratory glassware, porcelain dish, chemicals, etc.	
13.	Dry bulk density test apparatus (sand puring cylinder, tray, can, etc.) complete	One set
14.	Core cutter apparatus 10 cm dia, 10 cm/15 cm height, complete with dolly, rammer, etc.	6 Nos.
15.	Speedy moisture meter complete with chemicals	One No.

(8) Most of the quality control tests are standard tests of the ISI. Outlines of some of the commonly used tests are given in Table 13.

TABLE 13. BROAD OUTLINE OF SOME OF THE COMMON TESTS ON MATERIALS AND WORK

1. **Determination of Moisture Content of Soils (IS: 2720, Pt. II)**

Where facilities are available, the method consists of drying a sample of the soil in the oven at 105-110°C for a period (normally not more than 24 hours) till the dry weight of the soil becomes constant.

In the field, the alcohol method, though less accurate, can be used as a quick test. It consists of taking the soil specimen in a evaporating dish, pouring over it methylated spirit at the rate of about one millilitre for each gram of soil, mixing the two materials and igniting the spirit. After burning away of the spirit, the dish is cooled and weighed.

2. **Liquid Limit and Plastic Limit (IS: 2720, Pt. V)**

The liquid limit test is conducted on the standard instrument with soil specimens at various moisture contents. The liquid limit is taken as that moisture content where the standard groove will close under an impact of 25 blows.

The plastic limit is the water content at which the soil will begin to crumble when rolled into a thread of 3 mm in diameter. The Plasticity Index is taken as the difference between liquid limit and plastic limit.

3. **Moisture-Density Relationship (IS: 2720, Parts VII & VIII)**

Two degrees of compaction, light compaction (IS: 2720, Part VII) and heavy compaction (IS: 2720, Part VIII) are usually specified. The former compaction also goes by the term Proctor compaction.

In light compaction, the wet soil is compacted in three equal layers by the rammer of weight 2.6 kg and free fall 31 cm with 25 evenly distributed blows on each layer. In heavy compaction, rammer weighs 4.89 kg and the free fall is 45 cm. Compaction is done in 5 equal layers, each being given 25 blows.

The procedure is to compact the soil with different moisture contents and drawing a moisture-density curve to find out the maximum dry density and the corresponding moisture content (OMC).

4. **In-situ Density by Sand Replacement Method (IS: 2720, Pt. XXVIII)**

The principle of the method is to find the volume of a hole cut in the layer to be tested by filling it up with sand of known density. Moisture content of the soil sample is determined to work out the dry density.

A hole roughly 10 cm dia. and 15 cm deep is made and the excavated soil is carefully collected and weighed. Sand pouring cylinder is placed on the hole and the sand allowed to run to fill up the hole.

5. **Core Cutter Method (IS: 2720, Part XXIX)**

In this method, a metallic ring of known dimensions is pushed or driven by a hammer into the compacted soil layer and the compacted soil after trimming both the faces flush with the ring, is weighed and the dry density determined. The application of this method is rather limited to fine grained cohesive soils.

(Contd.)

6. **Aggregate Impact Value (IS: 2386, Part IV)**

The apparatus consists of a metal base and a cylindrical steel cup of internal dia. 10.2 cm and depth 5 cm in which the aggregate specimen is placed. Metal hammer 13.5-14.0 kg weight having a free fall from a height 38 cm is arranged to drop through vertical guides. Aggregate sample passing 12.5 mm sieve and retained on 10 mm sieve is filled in the steel cup in three layers by tamping each layer with 25 blows. After subjecting the test specimen to 15 blows, the crushed aggregate is sieved through 2.36 mm sieve. The Aggregate Impact Value is expressed as the percentage of fines formed in terms of the total weight of the sample.

7. **Tray Test for Control of Rate of Spread of Binder (IRC SP: 11)**

Light metal trays of about 20 cm × 20 cm and 3 cm deep, previously weighed and numbered are placed at intervals along the road in the path ofthe binder distributor. After passing of the distributor the trays are removed to find out the rate of spread of binder. Tests with such trays at a number of locations can also indicate the uniformity of distribution.

8. **Determination of Calcium Hydroxide content in Lime Sample by Iodine Method**

Preparation of Standard Solutions

(i) **Iodine Solution :** First dissolve 90 gm of Potassium Iodide (A.R.) and then 45.27 gm of Iodine (A.R.) in distilled water (using minimum quantity of water) and dilute to one litre.

(ii) **Thiosulphate Solution :** Dissolve 44.24 gm of sodium thiosulphate (A.R.) in water and dilute to one litre.

(iii) **Starch Solution :** Dissolve 0.5 gm of starch in 200 ml of boiling distilled water.

Step-wise Procedure

(i) Determine the percentage of lime sample passing through ISS 425 micron.

(ii) Add 1 gm of lime passing through 425 micron sieve to 50 ml of distilled water, boil and then cool.

(iii) Add excess of iodine solution to this slowly with constant stirring. The excess of iodine solution is indicated by persistence of iodine colour.

(iv) Titrate back the excess of iodine solution with sodium thiosulphate solution using starch indicator. Null point is indicated by the appearance of white milky colour.

(v) Calculate the calcium hydroxide content using the formula

$$Ca\,(OH)\text{ per cent} = \frac{V_1 - \frac{V_2}{2}\, 0.0132\, Z}{100}$$

Where V_1 = Volume of iodine solution added

V_2 = Volume of sodium thiosulphate solution used for titration

Z = Percentage of lime sample passing ISS 425 micron

3.7. Maintenance

3.7.1. **General :** Road maintenance is an operation of keeping the facility as nearly as possible in its original condition as constructed, or as subsequently improved to provide satisfactory level of service for movement of goods and passengers. Safeguarding the investments already made, extending the life of the road, better facility of travel and creating a good image of the Government in public eyes are some of the advantages of good maintenance. Maintenance of rural roads which are spread throughout the country is somewhat complex because of the low cost specification adopted, differences in prevailing construction practices, terrain, soil type, climate, types of locally available materials, resources both organisational and financial, and quite often there is a tendency to ignore their importance because of their lower ranking in the heirarchy of road system. A conscious effort is, therefore, needed to understand the inter-play of several factors in developing optimum maintenance management systems under different situations.

3.7.2. Quantum of maintenance effort

(1) A Committee of Chief Engineers had quantified the effort needed in the maintenance of lower-order roads like MDR, ODR and VR in the year 1978. A summary of the recommendations of this Committee is given in Table 14. The norms recommended by the Committee are by and large physical norms which can be quantified in terms of money from time to time and from place to place depending on the prevailing cost of materials and wage rates.

(2) Though the recommendations of the Committee have been there since some years, the general experience has been that maintenance funds commensurating with the needs are not being made available. It is, therefore, necessary that the available resources are put to best possible use. From this angle, action in the following directions will be helpful :

(i) Close inspection of the road prior to, during and after rains in identification and correction of defects. In this country rain is the major source of damage to the roads. Close inspection of the road prior to rains and appropriate corrective measures can ward off major damage that might happen had no action been taken.

TABLE 14. SUMMARY OF MAINTENANCE NORMS FOR THE LOWER CATEGORY ROADS (i.e. MDB, ODR AND VR) RECOMMENDED BY THE TECHNICAL COMMITTEE OF CHIEF ENGINEERS, (1978)

Sl. No.	Particulars	Earth roads	WBM roads	Black-topped roads
1.	Ordinary repairs			
	(a) Road gang (person/km)	1/2	2/5	3/10
	(b) Mate (person/km)	1/20	1/20	1/20
	(c) Road Supervisor (person/km)	1/48	1/48	1/48
	(d) Patch repairs (per/km)	—	—	5 cu.m of grit and 0.6 tonne of bitumen
	(e) Heavy berm repairs (per/km)	—	Rs 400	Rs 400
	(f) Arboriculture and landscaping (per km)	Rs 220	Rs 220	Rs 220
	(g) Original works treated as repairs (per km)	Rs 250	Rs 250	Rs 250
	(h) Structures (per km)	Rs 275	Rs 275	Rs 275
	(i) Roadside drainage and roads signs (per km)	Rs 165	Rs 165	Rs 165
	(j) Maintenance of inspection bungalows, rest houses and godowns (per km)	Rs 250	Rs 250	Rs 250
	(k) Watch and ward of roadside stockyards and godowns (per km)	Rs 100	Rs 100	Rs 100

(Contd.)

Sl. No.	Particulars	Earth roads	WBM roads	Black-topped roads
2.	Periodic renewals	One layer of moorum or gritty earth in thickness 150 mm (loose) every third year	One layer, 75 mm thick every third year	**
3.	Special provisions (extra) as per location (on actual length of section involved) per km			
	(a) High rainfall areas (rainfall more than 3000 mm/year)	Rs 770	Rs 770	Rs 770
	(b) Hilly areas	Rs 1000	Rs 1000	Rs 1000
	(c) Snow-bound areas (elevation greater than 2150 m above MSL and snowfall more than 400 mm/year)	Rs 300	Rs 300	Rs 300
	(d) Urban links	Rs 2000	Rs 2000	Rs 2000
4.	Special repairs	5 per cent of the total		
5.	Rain damages	10 per cent of the total		
6.	Small tools and plants	1 per cent of the total		
7.	Extra for double-lane roads	60 per cent of renewal cost, or 25 per cent of the total cost		

** *Roads in plains* : Ronewal by surface dressing once in 4 years, using 120 kg bitumen and 1.067 cu.m of 10 mm grit per 100 sq.m area. Add 10 per cent of the cost of renewal for levelling course. For roads carrying heavy traffic, premix carpet may be used for 6-year cycle.

Hill roads : Premix carpet on 6-year cycle

For example, a choaked drain can cause rise in water level which might overtop and wash out the road. Simple action to clear out the drains of debris could have warded off such a danger. Important points to be looked for during the inspection are listed in Table 15 for guidance.

(ii) Maintenance activities may run into several numbers and types. While some generally crop up only in a particular season and which will have to be attended to urgently, some others are of routine type and can be attended to in any time during the year. For optimum utilisation of the available resources, it is necessary that the maintenance activities are listed out and prioritised. Based on this priority list, a calendar of activities could be drawn up for the day-to-day working of the maintenance gangs.

3.7.3. Maintenance operations

(1) The various maintenance operations can be broadly classified into three categories :

(i) Routine maintenance, comprising patch repairs; heavy berm repairs; arboriculture and landscaping; maintenance of and repairs to road-side drains, road signs, inspection bungalows, rest houses, and godowns; and

(ii) collection of data such as traffic data, which are required to be carried out by the maintenance staff once or twice every year.

(iii) Periodic maintenance, which consists of work items such as renewal of the wearing surface that are to be carried out periodically every few years.

(iv) Special repairs, and flood and rain damage repairs, which consist of repairs to the embankment, pavement, culverts, road furniture, etc., necessitated by landslides, earthquakes, cyclones, heavy rains/cloud bursts, floods, etc. the nature and extent of such repair works could not be foreseen or predicted.

(2) The details of these maintenance activities are indicated in the following paras. Before starting with the work, it should be ensured that adequate arrangements (which include the erection of barriers, signs, and red flags/lights/reflectors) are made for the safety of the traffic, workmen, pedestrians, cattle, etc; and wherever possible, the work should be confined to half the pavement width at a time leaving the other half for the traffic, and if that is not possible and if short alternative routes are not available, diversion roads may have to be provided for the traffic.

Table 15. Points to be Looked for During Inspection and Action to be Taken Prior to/During/After Rains

Prior to rains	During rains	After rains
Cleaning/clearing all drains, catch pits etc.	Have close watch on flood levels, any tendency for overtopping, and blockage of drains/culverts, etc.	Assess the damage, give top priority for repairing breaches and removing blockages
Repairing damages to all protection works like pitching, etc.	Repair potholes and keep road trafficworthy	Watch for water oozing out of shoulders/slopes. If so, cut out to release and remove the locked up water.
Filling scour holes at abutment/pier of C—D works	In case of any breach, cordon off the affected stretch by barriers, arrange for traffic diversion, notify the public of the diversion and take immediate action in making up the breach.	Repair potholes/cracks etc.
Storing and protecting road construction materials safe from floods		Study stretches showing recurring damage to ascertain causes and to evolve remedial measures.
Repaving/sealing pavement cracks, potholes etc.		
Dressing berms so that these easily shed off water.		

Patch repairs

These are carried out to rectify local distresses in the pavement. The distress may be manifested in the form of loss of material from the pavement crust resulting in pothole, or uneven surfaces due to localised ruts, settlement/consolidation, etc. The need for patching is usually the first indication of major distress to the pavement. More often, the principal cause for the distress happens to be the lack of proper drainage. Each location requiring patching should be examined carefully to identify the causes of the distress, so that suitable maintenance measures can be taken not only to rectify the damage but also to prevent or delay its recurrence.

Regular and frequent dragging can be done on earth and gravel roads for filling-in ruts and potholes as soon as these defects appear and dressing the road to proper camber. This can be accomplished by a mechanical power grader if available, or by a wooden drag consisting of two halves of a log of wood 2.6 to 3 m long and about 250 mm dia., framed together to be approximately 2 m apart. Dragging cannot be very effective on a dry or too soft a surface and hence it shall preferably be done after a shower when the surface is just moist. The number of passes needed with the drag will depend on the length of the drag and the width of the road.

In the case of roads having WBM as the wearing course, patch repairs to rectify localised potholes, ruts, corrugations, ravelling damaged edges, etc., should be done by cutting the road to regular shape upto the affected depth, and then laying fresh material and compacting.

For bituminous surfaces, the rectification of potholes consists of squaring the edges of the hole and cutting the hole to solid material with vertical edges before filling up the hole with fresh gravel, WBM and/or bituminous materials, depending upon the depth of the hole. Before applying bituminous patch material, a tack coat at the rate of 7.5 kg per 10 sq.m. area shall be applied on all the surfaces of the hole that would come in contact with the bituminous patch material. The bituminous patch material shall be a prepared premix conforming to clause 5.6 ‘Premix open-graded patching' of IRC : 82-1982. For rectifying unevenness, the uneven area is first defined by a string line and marked; the area upto atleast 0.3 m beyond the marked area on all sides is thoroughly cleaned, and on the uneven area, a tack coat followed by premixed bituminous patch material is applied as per clause 5.6 of IRC : 82-1982.

For treatment of other types of defects in bituminous surfaces, the procedures indicated in IRC : 82-1982 should be followed.

Berm repairs

Heavy repairs to the berms may be necessitated because of loss of material or settlement, due to the action of the traffic (passing/overtaking vehicles) and environment (rains, wind, etc.).

Berms may be restored to their proper longitudinal and transverse profiles by applying the drag. The drag would not be effective if the berm surface is dry or too soft, and hence dragging may be resorted to after a shower when the surface is just moist.

It should be ensured that berms upto a width of 30 to 50 cm from the edge of the pavement are maintained properly so that lateral support to the pavement is assured. In the case of grass shoulders, a careful watch should be kept to ensure that the grass does not trap the material washed off the road by rains, thus raising of the level of the shoulder adjacent to the pavement with the result that the water stagnates at the edge of the pavement.

Arboriculture and landscaping

The road might have grass on the berms, side slopes of the embankment and side ditches; or other plants/shrubs including trees along the road to prevent soil erosion/shifting sand-dunes from affecting the road, or for providing shade, etc. Also tree-guards/fences might also have been provided. These will require proper maintenance by way of mowing, pruning, lopping, and felling in the case of grass/trees and repairs/painting for the tree-guards and fences. Further, wherever the trees get uprooted during the storms, etc., they are to be cleared speedily.

Roadside drainage

It is essential that the roadside drainage system is maintained properly to avoid serious damages to the pavement and the shoulder. Maintenance measures in this regard are of two parts—the maintenance of side drains/catch water drains and the maintenance of cross-drainage structures like culverts, causeways and bridges, retaining walls, breast walls, etc.

The maintenance of the side drains includes the removal of accumulated silt, debris, leaves, etc., from the drains, repairing the linings if provided, and restoring the profile of the whole drain. These operations are done atleast twice in the rainy season and a careful watch kept to ensure that the drains do not get chocked up by accidental slips of side earth. The bottom of the side drain should be maintained atleast 1 m below the formation level of the road. The silt, etc., removed from the side drain shall be disposed off suitably; if conditions permit, these may be thrown at least 2 m from the side drain on the side away from the road; where possible, leaves etc., can be disposed off by burning them. Under no circumstances should the silt, etc., removed from the side drains be utilised for repairing the road surface. Where silting of the side drains occur frequently, realigning of the side drains may be considered for increasing the velocity of flow.

Cross drainage structures, retaining walls and breast walls should be periodically inspected and necessary repairs carried out. In the case of cross drainage structures, it should be ensured that they never remain clogged due to silting, debris, etc. They should also be protected against erosion/scouring and structural damage. It may be emphasized here that a clogged drain or cross drainage structure may prove more dangerous to a rural road than the provision of no drains at all, as the defective drain increases the chances of waterlogging and water gaining access to sub-base and base courses.

Where the culverts are too small for a man to get inside for observation and clearance work, suitable long-handled shovels or shovels attached to rods can be used to probe and clear silt, vegetation, and debris. Trees or branches obstructing culvert entrances might require to be sawn into smaller pieces to help their removal. Culverts which frequently get clogged by debris should preferably be provided with grills on the upstream entrance.

Erosion/scouring and structural damage should also be rectified by filling with gravel and compacting it, and recurrence be prevented by taking suitable measures such as protecting it with riprap, concrete, stone gabions, or mattresses on the downstream side of the outlet, if necessary, the discharge velocity may be reduced by increasing the area of cross-section of the culvert and/or reducing its gradient, or masonary/concrete fan discharge or drop outlets may be provided.

Road signs

The road signs/traffic aid devices are provided to give proper guidance to the traffic and to ensure road safety. As such the maintenance of these is an important part of the overall maintenance activity. Missing signs and direction posts shall be replaced promptly. Painting of road signs, guard/parapet rails, kilometre stones and boundary stones, and numbering of cross drainage structures should be done wherever required and cleaning of these to remove dust, vegetation, etc., should be carried out atleast twice a year so that the signs etc., would be visible to the traffic.

Periodic maintenance

Whatever be the type of the pavement, it needs periodic renewal of the wearing surface to maintain it in a traffic worthy condition. The type and periodicity of the renewal depend upon the type and quality of materials used in the existing pavement, the climate, terrain, and traffic volume and intensity.

In the case of earth roads, it is necessary to lay one layer of moorum or gritty earth for 15 cm thickness once in 3 years followed by rolling. For WBM surfaces, after scarifying and loosening the existing surface and reshaping, fresh stone metal for an additional thickness of 7.5 cm thickness needs to be laid once in 3 years, and adequately compacted with a road roller to at least 95 per cent Proctor density. In the case of bituminous surfaces the following practice is recommended : for roads in plain terrain, a renewal coat of surface dressing as per IRC : 17-1965 shall be provided once in 4 years after bringing the road to the correct gradient and camber by necessary patch work; where the traffic intensity is high or on special locations on these rural roads in plains, premix carpet as per IRC : 14-1977 may be laid once in 6 years. For roads in hilly terrain, surface dressing is not recommended because there are likely to be many curves where the grit flies off under the action of pneumatic tyres; and hence premix carpet according to IRC : 14-1977 should be provided as the renewal coat once in 6 years, after bringing the road to the correct gradient and camber by necessary patchwork.

Special repairs, and flood and rain damage repairs

Any damage to the pavement/shoulder, side drains or cross-drainage structures, embankments, retaining walls, breast walls, etc. due to natural calamities like landslides, earthquakes, cyclones or heavy rains, cloud bursts, and floods should be immediately repaired or the facility reconstructed to restore it to the proper condition.

3.7.4. **Maintenance management**

(1) **General :** The objectives of Maintenance Management are to plan and programme the maintenance activities making optimal use of the resources of men, materials, machinery and money so that the planned works are performed to a traffic-worthy condition. The steps to achieve these objectives are discussed below.

(2) **Road data banks :** A proper management decision could be taken only when sufficient data are available on the problem. Hence it is of vital necessity to collect and compile all relevant data about the road and its environment and the resources available to maintain the road network. These data should also be updated regularly. It is recommended that the following data may be made available in the road data banks.

(i) Road cross-section including pavement, composition (type and thickness) shoulders, height of embankment, side slope, etc.

(ii) Geometrics of the alignment.

(iii) Details of various structures along the road *viz.*, cross drainage structures, roadside drains, breast walls, retaining walls, kilometre stone, traffic signs, inspection bungalows, rest houses, godowns, etc.

(iv) Condition of the road—pavement surface condition (rutting, potholes, etc.), condition of shoulder, and side drains.

(v) The maintenance history of the road—the date and type of maintenance put in, and its subsequent performance.

(vi) Traffic volumes and the quarterly rate and type of accidents.

(vii) Data regarding the funds made available, men, materials and equipment and also their achievements/performance in the previous years; changes in available resources and possible improvements in them; spare-parts inventory, etc.

Each state should possess a suitable machinery to collect, analyse and compile these data, update them regularly, and appropriately utilise them.

(3) **Standards of maintenance :** The next step in maintenance management will be to evolve reference standards to help the maintenance staff to take the right decisions. In a systems concept, there are three distinct types of reference standards :

(i) Quality standards which define the level of quality below which the various components of the road should not fall, so that the road users are given a satisfactory level of service from the technical and economic points of view. These standards are the basis for determining when and what type of maintenance activities are to be provided to the road network. Cracking, rutting, potholing, etc. are the parameters used to assess the quality level.

(ii) Quantity standards, which indicate the resources required to achieve the necessary level of service; and

(iii) Operational standards, which specify the working method and crew requirement consistent with a reasonable level of productivity for each maintenance activity possible. These standards be revised and improved based on the achieved possible output in the field.

(4) **Operational management :** For proper management of the resources allocated for maintenance, the objectives to be aimed at should be reduction in costs for a defined quality of work, better work performance within the same cost and proper deployment of men and machinery to ensure an optimal utilisation of the available resources. For this, it is necessary to identify the basic maintenance activities, quantum of work needed in relation to quality standards and the resources needed to fulfil these tasks in terms of materials, machinery and man-hours. Having done this, it would be easy to prepare a work schedule for weekly, monthly, quarterly and yearly operations. In this way, it will be possible to move from a purely financial accounting system to a rational process of analytical management.

Modernisation of maintenance management may involve radical changes in traditional working methods. Mobile system of gangs in the place of the time-honoured labour groups, who are practically immobile and have little or no equipment will go a long way in streamlining the routine maintenance work. The maintenance personnel should also be given periodic training.