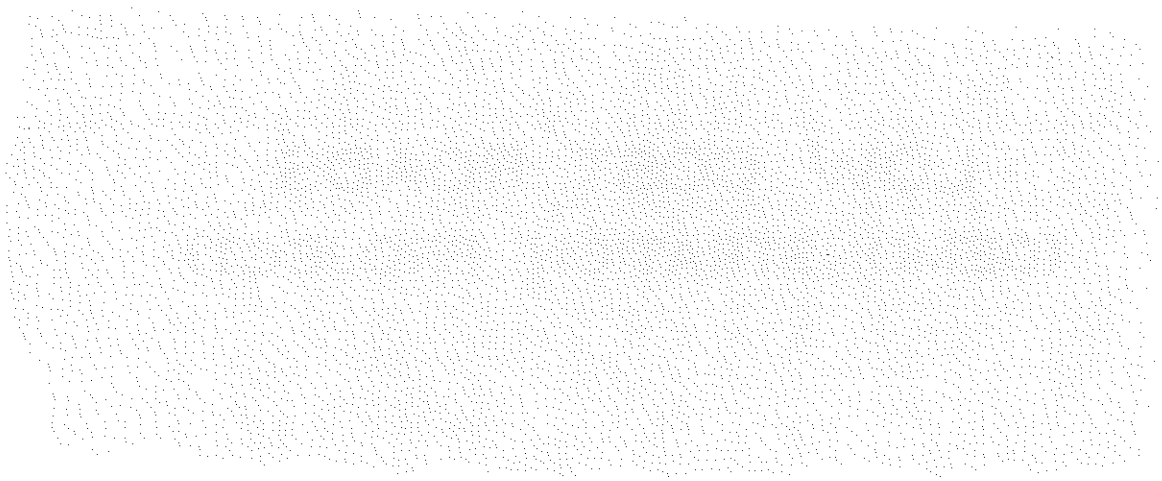
# LOW COST ROADS
## (DEMONSTRATION PROJECT)



NATIONAL TRANSPORT RESEARCH CENTRE

# LOW COST ROADS
# (DEMONSTRATION PROJECT)

NTRC-149

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# EXECUTIVE SUMMARY

## CONSTRUCTION OF LOW COST ROADS

Pakistan has about 130,000 Kms. (1990) of all types of roads giving an average density of 0.16 km per square km of the area which is 1/4th of the generally accepted standard of 0.62 Kms per square Km of the area for developing countries with similar topography and level of economic development. The system deficiency is therefore of the order of 370,000 Kms. The major deficiency is in the case of tertiary rural roads.

The main factors responsible for the slow development of rural roads in the country has been the tendency to demand and adopt much higher road specifications than required for the given traffic load and chronic inadequacy of finances. This combination results in depriving a large segment of population from the benifit of the road access.

The present situation demands that the existing gap in the tertiary rural roads infrastructure should be bridged at the earliest. The objective can be achieved by constructing low cost roads and by adopting the techniques of stage construction for these roads especially in the areas where traffic volumes are low. Such low cost roads are a large part of the network even in modern countries like USA and Sweden where these constitute about 40% and 75% of their road network respectively.

Keeping in view the dire need of meeting the transport requirement of rural population, NTRC has been making sternuous

attempts to evolve low cost road design. The efforts made in this regard were succesful and six roads constructed, in Islamabad and other parts of the country, as demonstration projects fared very well. The salient feature of the projects are as follow:-

**Specifications:-**The specifications adopted for the construction of six experimental roads are:

(i) **Sharifabad-Tarlai Road (District Islamabad)**: Three different designs using brick bats, pitrun gravel of (1") and pitrun gravel of (3/4") were tried on this road.

(ii) **Humak Jawa Road (District Islamabad):** Two different designs using crushed aggregate with khaka material having 5" thickness and 4" thickness were tried on this road having a total length of 2300'.

(iii) **Dheri Mallhu Road (District Attock):** Specification adopted for this road included provision of a 3" thick layer of sand cushion over the existing track before placing, 5" thick, 3/4" down crushed stone with khaka to fill the voids.

(iv) **Dhuni Village Road (District Gujranwala)**: Specifications adopted for this road included compaction of the existing road embankment of 2 & half feet height over which a 3" thick sand cushion was laid. 5" thick, 3/4" down crush stone were provided over the sand layer with sufficient amount of khaka for filling the voids.

(v) **Dorro Village Road (District Islamabad):** 5" thick, 3/4" down crush stones were provided over the existing track with sufficient amount of khaka for filling the voids.

(vi) **Sheikh Qureshian (District Jhelum)**: 5" thick 3/4" down crush stone with sufficient amount of khaka for filling the voids was used as construction material for the construction of this road.

**Construction Technique:** The construction of such type of roads do not require any special skill or equipment. The construction procedure adopted was simple and no equipment was used for compaction of the gravel as the desired objective was achieved by the natural compactive action of the moving traffic loads.

After clearly marking the sections and fixing the pegs to ensure the required thickness of the loose gravel, the crushed

stones of the specified gradation were spreaded with spades/shovels and brought to the proper camber with the help of template. Khaka was then spreaded over the surface of crushed stone to fill the voids and thoroughly watered. After the initial period of 10 days, depression/ruts formed were made-up with the same material.

**Maintenance:** A nominal period of one month was stipulated in the agreement with the contractor during which he had to keep the roads in good condition by properly filling the depressions or ruts if formed after the road was opened to traffic. However, once the roads were handed-over by the contractor, no arrangements were made for even routine maintenance of the roads, but the condition of the roads remained good.

**Cost of Roads:** The cost of these roads except one was less than Rs.100,000 per km as compared with Rs. one million for a compareable black-top road. The actual amount ranged from Rs.63,613/- per km to a maximum value of Rs. 143,043/- per km depending on the lead distance of the crushed stones which had to be hauled from the approved quarry sites.

**Performance:** Performance evaluation of the roads have been carried out using road roughness measurement technique. The

roughness was measured using a vehicle mounted Bump Integrator which gives the surface uneveness in mm/km.

The road roughness measurement of each road was started as soon as it was completed and repeated out during the first week of every month. The road roughness values for the roads are avialable for the period ranging from four months to thirty months. The performance evaluation revealed two important aspects for these roads:

i) **Roughness Vs Age:**

It was found that the roughness of these roads reduced with the passage of time. The road roughness mreasurement just after completion of the roads was found to vary between 6000-7000 mm/km. However, measurements made after a period of 1 year showed a reduction in roughness values to 5000 mm/km or less.

ii) **Roughness Vs Rainfall:**

The other interesting aspect noted was that the measurements taken after rainy periods was lower than those taken during dry spells. Heavy rainfalls did not damage the roads, rather it helped in making the road smoother.

**Traffic:** Prior to the improvement, traffic on these roads was generally less than 100 vehicles/day. However, traffic volume increased considerably in the subsequent period ranging between 100-400 vehicles/day. The pedal cycles which were in some cases almost 100 percent were not taken into account.

**Findings:** The major findings of the demonstration project are as follows:-

(i) The cost of gravel road is nominal i.e 1/8th - 1/10th of the cost of a compareable black-topped road having same width. As a result, construction of such type of roads can provide the benefits of road access to a large segment of population with little investment.

(ii) Although a number of different combinations of the material could be used in the construction of this type of road, a mix made up of crush aggregate with sufficient amount of khaka to fill the voids properly proved to be best suited for the prevailing conditions.

(iii) Roughness of these roads decreases with the passage of time.

(iv) The performance evaluation of these roads during rainy season revealed that rainfall does not damage these roads but rather makes them smoother.

(v) No special road construction machinary is required for construction of these types of roads.

(vi) No special technical know-how is required for the construction of such type of roads.

(vii) These roads provide a very satisfactory all weather access for vehicular and pedestrian traffic.

**Conclusion:**

From the demonstration project, it could be concluded that for the development of rural roads in the country, following strategy should be adopted.

i) All village roads/farm-to-market roads, in the first instance must be constructed as gravel roads as per specifications developed by NTRC.

ii) Improvement to higher specifications must be done in stages, strictly in accordance with the requirement of traffic/soil conditions.

# CHAPTER-I

# I N T R O D U C T I O N

## GENERAL:

An adeauate and dependable network of rural roads is a pre-requisite for accelerating the pace of socio-economic development of rural areas. Without such an innrastructure, no amount of effort and expenditure would yield the desired results. For example, in aggriculture, which is the backbone of the economy, the goal of maximizing crop production cannot be realized without farm mechanisation and ready supply of needed inputs such as seeds, fertilizer and pesticides for which a dependable network of farm-to-market roads is a must. Also, any surplus production of crops in any area would be useless, unless it could be easily transported to consumption centres within the country or abroad. Similarly, the efforts in providing the basic health cover and primary educational facilities to the rural area shall continue to be hampered due to reluctance on the part of doctors and teachers to serve in such isolated areas and without the required amenities. An effective transport system is therefore essential for removing these impediments to social and economic uplift of rural areas. Not surprisingly, the rural roads are termed as the life lines of rural economy.

**Existing Road Network:**

At the end of Sixth Five Year Plan 1988, Pakistan has an about 130,000 kms of all types of roads which includes 6,150 kms of National Highways, 48,700 kms. of Provincial Highways, 65,957 kms of farm-to-market roads and 9,200 kms of Urban roads. This provides a road density of 0.16 kms of roads per square kilometer of the area. As compared to this, West European countries like U.K, France, West Germany and Denmark have a density of 1.5 to 2.0 kilometers of roads and Japan has 2.95 kilometers of roads per square kilometer of area. Details are provided in Table-1. Pakistan thus remains poorly supplied with roads in comparison with European and many regional countries.

TABLE-1

**International Comparison of Road Density**

| Country | Road Density (Length/Km2 of area) |
|---|---|
| U. K | 1.49 |
| France | 1.46 |
| West Germany | 4.95 |
| Netherland | 2.25 |
| Italy | 0.99 |
| Denmark | 1.62 |
| Belgium | 4.20 |
| Turkey | 0.3 |

| | |
|---|---|
| Japan | 2.96 |
| Australia | 0.35 |
| U. S. A | 0.66 |
| India | 0.49 |
| Sri Lanka | 0.48 |
| Korea | 0.55 |

**Requirement of Roads:**

Pakistan has a land area of 796,095 sq.km and population of nearly 100 million. The existing road density in Pakistan is about 0.16 km/sq.km. According to the generally accepted standards, the road density for development should be about 0.62 km per sq.km.

As such, the road requirements on the basis of the distribution of various types of roads in the country should be as follows:-

**Road Requirement**

| Type of Road | (Road Requirement) kms |
|---|---|
| Main Rural | 100,000 |
| Local Rural | 350,000 |
| Urban Street | 50,000 |
| | 500,000 |

Therefore 450,000 kms of rural roads of all kinds are required to serve the socio-economic needs of the country. Out of these, 350,000 kms are the local rural roads i.e village roads, farm-to-market roads and other tertiary roads. The remaining 100,000 kms are the primary (National and main Provincial Highways) and secondary (major district roads) of higher geometrics and quality. Against this, the total availability of roads in the country is around 130,000 kms out of which only 66,000 kms are local rural roads, leaving a net deficit of more than 284,000 kms of roads of such category.

The inadequacy of existing local rural roads in the country can also be judged from the fact that only 16 percent of the villages are situated on all-weather roads and about 30% have an all-weather connection with the markets. The remaining villages are either totally cut off from the rest of the country or are dependent on fair weather connections to the outside world.

The rate of new addition of local rural roads, which are primarily constructed by district councils (the Highway Departments being responsible for Primary and Secondary Roads) during the Sixth Five Year Plan has been approximately 3,000 kms per year. During Seventh Plan period, approximately 11,500 kms of rural roads are to be added, averaging 2,300 kms per year. At this rate, it shall take the local Governments more than 100 years to meet even the basic minimum requirements of local rural

roads. This is an un-acceptably long period and rural population can not be asked to wait that long period. It is, therefore, imperative that the pace of providing transportation infrastructure in the rural areas must be greatly accelerated through a long term programme stretching over many plan periods.

**Factors responsible for low output of Roads:**

Past experience shows that apart from lack of expertise and managerial skills the most critical factors in low output of the roads constructed by the local councils has been mainly due to inadequate finances and the tendency to adopt much higher road specifications than required.

**Finances:**

The allocation for roads in general and the local rural roads in particular have been in the past too low to have any significant impact. The total outlays for Fifth Plan for local rural roads were Rs. 1,200 million against which an expenditure of Rs. 1,600 million incurred. The acceleration in rural roads outlays occurred during last half of the Fifth Five Year Plan and is primarily due to emergence of local governments to the public needs. The local roads being one of the most sought after public facility, the local governments had to respond to demands of their constituents.

During the Sixth Plan period, an amount of Rs. 4100 million was allocated for the construction of rural roads including farm-to-market roads. The total utilization was Rs. 5319 million. Against the target of 10,000 kms of rural roads, 14,957 kms were constructed during the Sixth Plan, showing an increase of 49% which is compatible with the extra allocation in the Sixth Plan.

**Specifications adopted for Rural Roads:**

There is a general tendency, particularly in Sind and Punjab, to construct village roads as black topped, on the plea that the soil conditions in the two provinces are not very good. Farm-to-Market roads are usually less than 10 kilometers long and serve small population with very little initial traffic. As such these roads do not deserve to be constructed as black top from the initial stage. Constructing these roads as black topped right from the beginning results in large amount of ekxpenditure for providing road facility to a small area.

**POSSIBLE MEASURES TO OVER COME THE DEFICIENCY**

Some of the measures that could be used to overcome the inadequacies of rural roads in the country are detailed below:-

a) **Low Cost Roads/Stage Constructions:**

The rural roads especially Fram-to-Market are usually small in length and serve small population with very little initial traffic. These roads must therefore be very low cost facilities. These roads are generally constructed as unpaved even in the most developed countries of the world. Considering that even the most developed countries in the world have not been able to provide black topped local rural roads, it would be realistic for Pakistan to think in those terms. For example, in U.S.A out of a total of 5.8 million kms of rural roads, 1.6 million kms (28%) are unpaved, which include all the farm roads and a substantial portion of even secondary roads. Another 3.2 million kms (56%) have very low grade surface i.e. soil, stabilized slag, gravel or bitumen treated. Similarly, in Sweden which is not only one fo the richest countries in Western Europe, but it also has very severe climatic and soil conditions, 7% of the total rural roads are unpaved.

In view of the above, construction of farm-to-market roads or other village roads as black top is not only un-warranted, being very costly, it can only be done by depriving as large segment of population from the benefit of road access.

Whereas it is absolutely essential that these roads must be constructed with proper specifications for drainage, soil compaction and geometric design, it is not necessary to

provide black topping from the very beginning. It is therefore desirable that all village roads/farm-to-market roads, in the first instance be constructed as low cost gravel roads and improvement to higher specifications must then be done in stages, strictly in accordance with the requirement of traffic/soil conditions.

b) **Canal Roads:**

Pakistan has one of the world's largest Canal Irrigation System which mainly lies in the provinces of Punjab and Sind. These canals have approximately 56,000 kilometers of roads/inspection paths, out of which only 1,100 kilometers are open for public use (mostly in NWFP and Baluchistan). The rest are used primarily for inspection purposes by the Irrigation Department officials. The physical condition of these roads is generally very good, although Irrigation Department does not receive any extra funds for maintenance of these roads. The task is carried out by the labour employed for maintenance of the canal themselves.

Since these roads are ideally situated to serve as Farm-to-Market links, the local farming communities have been constantly demanding to open these roads for public use. However, the proposal could not be implemented due to the apprehension that no additional allocation for

maintenance of these roads would be made. This is genuine fear and has its roots in the past experience of some of roads opened to public. It must be recognized that opening of canal roads to public would entail much greater maintenance effort than at present and far beyond the means of Irrigation Department. It would be absolutely necessary to provide additional funds for this purpose.

The idea of opening of canal roads for public use has also been advocated by a number of expert groups from time to time on the following grounds:

i) It is an important and sizeable national asset, which is not being fully utilized. A poor developing country like Pakistan cannot afford to allow such large resources to be kept in moth ball.

ii) Cost of converting these roads into public facilities would be very low due to saving of land acquisition cost and availability of embankment.

iii) It would double the length of local rural roads in the shortest possible time and at a very low cost.

iv) It would bring about a major change in the socio-economic conditions of the population, hitherto not provided with road connection.

v) They are ideally located for serving the farm-to-market transportation requirements.

vi) The technology of road construction has advanced sufficiently to allow construction and maintenance of roads under adverse soil and moisture conditions generally encountered along canal banks.

vii) Many countries of the world including India, Egypt, USA and some European countries use canal banks for public transportation with considerable advantage.

In view of its far reaching implication to the national economy, the matter be taken up with provincial governments to allow use of canal roads for public transportation provided sufficient are provided for both structural improvements and maintenance.

It is, therefore, proposed that:-

a) All canal roads must be opened to public with immediate effect.

b) Most of these roads serve small pockets of rural areas, the initial traffic is expected to be small. Therefore, the improvement, if any, may be carried out strictly in accordance with traffic demand.

c) Proper maintenance hold the key to the successful utilization of the canal roads for public use. Therefore, allocation of adequate funds for maintenance of these roads when opened to traffic must be ensured.

## CHAPTER-II

## REVIEW ON LOW COST ROADS IN THE COUNTRY

Experimentation is the essence of research work. Demonstration projects are the most economical and quickest method of spreading the benefits of research to a wide area. There is a considerable scope and need for experimentation and demonstration projects in the field of low cost roads.

Prior to the taking up of low cost roads demonstration project by the NTRC, some research work has been carried out in this field in the country by various agencies as briefly outlined below:-

### I. ROAD RESEARCH AND MATERIAL INSTITUTE, LAHORE.

### A. SOIL STABLIZED ROADS:

Road Research and Material Institute, Lahore has worked on the concept of soil stabilized low cost roads. The study was under-taken by the Institute to:-

a) Introduce lime stabilized sub-base and base-courses and assess their suitability under local conditions.

b) Use crushed bricks as a sub-base material after mixing it with local soil and as base course material.

For this purpose, laboratory investigations were first carried out:-

i) To determine the effect of lime stabilization on local soils and

ii) To find characteristics of crushed bricks as sub-base and base materials.

Field experiments were carried out on Daska - Pasrur road, mile 10 by building experimental strips on the basis of specifications evolved as a result of laboratory work.

**Laboratory Testing:**

Soil samples collected from the mile 10 of Daska - Pasrur road were tested for soil gradation, atterburg limits, maximum dry density, CBR and ultimately calculating the thickness of pavement required for medium traffic. Results of these tests showed soil to be silty clay, had approximately 78 to 92 percent passing the 200 sieve and about 28.0 percent finer than 0.002 mm. The soil had a L.L of 26.1 to 29.0 percent and a plasticity Index of 11.1 to 14.30 percent. Standard AASHO density was 123.5 to 124.5 lbs. per cubic foot at optimum moisture content of 12.0 percent. According to Public Roads classification, the soil was classified as A-4 (8) to A-6(10).

The second part of the investigations in the laboratory were to find suitable additives for improving the properties of soil. Two additives one lime and other crushed bricks were selected for stabilization of soil. Soil lime stabilization is more desirable as lime:-

a) is relatively less expensive and available in our country.

b) is effective in reducing the plasticity of clayey soils making them more workable, even at low lime concentration (upto 5 percent).

c) reacts with soil to form cementation components which increase the strength of soil, when properly cured.

d) requires a less stringent construction schedule than many other additives such as cement.

Crushed bricks for stabilization and for use in base course were selected as they:-

a) are relatively inexpensive and available in most parts of the country at very small leads.

b) are effective in reducing the plasticity of soil and the mix acts as a granular material.

c) form a homogeneous mix which gives a sound foundation to the road pavement.

**Results:**

As a result of the laboratory investigations on the lime stabilized soild samples, it was found that soil, when mixed with 3 percent lime and cured for 7 days gave a CBR value of 50.2 percent which was considered to be quite adequate for sub-base and 5 percent gave a CBR value of 71.1 percent which is quite sufficient for base course construction.

**Investigation on Brick Aggregate:**

Brick in crushed form was suggested to replace more expensive stone in base and sub-base, as dry macadam and as coarse component of the soil aggregate granular mixtures. As such tests were performed on crushed bricks. Only the compressive strength tests were conducted on half bricks. Brick aggregate was put to tests generally applicable to road making aggregate.

Strength tests performed on the bricks included:-

1. Los Angles wear Test (AASHO)
2. Aggregate crushing value test (B.S.S)

3. Attribution Value Test (B.S.S)

4. Compressive Strength Test (B.S.S)

5. Weathering tests included:-

(i) Water obsorption (AASHO)

(ii) Sulphate soundness (AASHO)

**Test Results:**

From the laboratory tests, it was found:-

a) Over-burnt bricks have an average Los Angles wear of 30.82 percent and an aggregate crushing value of 27.5 percent which conform well to various standards for sub-bases, bases and even surfaces of roads.

Water obsorption, of course, was high. Soundness loss within limits, however, gives an indication that action of water will not harm too much.

b) Well-burnt bricks have an average Los Angles wear of 40.7 percent and a corresponding aggregate crushing value of 2.0 percent.

## II. COMMUNICATIONS AND WORKS DEPARTMENT, GOVT. OF SIND.

### A. SAND BITUMEN MIX PAVEMENT:

Mr. Sajjad Haider, Director General of Sind Communications and Works Department undertook a scheme sponsored by the Sind Communication and Works Department. The scheme envisaged trial of:-

a) Sand bitumen mix to replace conventional stone metal sub-base and surfacing.

b) Lime stabilized soil to replace stone material sub-base and base.

c) Cement stabilized soil layer to replace stone metal sub-base, and base.

d) Monitoring the results over a period of 3 years.

All the above specifications have since been tried by the C&W Department, Government of Sind. However, details regarding sand bitumen mix tried on a desert track running from Naukot to Mithi is briefly described here.

**SITE AND TERRAIN DESCRIPTION:**

Site selected, for trial of sand bitumen mix was the first mile of a 30 mile long tack in desert area joining Naukot to Mithi Town.

The town of Naukot is 90 k.m to South East of Mirpurkhas; Mithi lies roughly to South East of Naukot at 55 K.M., right in the heart of desert.

The desert begins at 3 miles from Naukot extending upto Great Rann of batch in South and South West. Towards North it extends upto Bahawalpur and in East it joins the great Indian desert belt of Rajhistan.

Geologically this desert, which is commonly known as "Thar" in Sind, is formed of older eolian deposits in the shape of longitudional sand dunes with intervening playa like deposits. The bed rock, about 1000 ft. below is an extension of Kirthar Range: out crops appear at Arevelli - Hills and Nagarparkar.

**DESIGN AND MATERIALS:**

For simple sand bitumen mix such as in the instant case no theorotical or empirical design procedure has yet been standardized. This type of mix using sand of specified grading was first tried during 2nd World War.

However, in the U.S.A the design of sand bitumen mix is being done on the methods used for dense bitumenous

surfacings; the binder content by these methods varies from 5 to 10%.

In the design of sand bitumen mix, Mr. Sajjad Haider also chose Marshal's method for determining binder content that could give acceptable stability value. For the sake of economy, coal tar was first tired as a binder; properties of coat tar used are shown in Table-II (1) below:

**TABLE - II (1)**

**TESTS ON COAL TAR FROM PAK STEEL MILLS KARACHI**

| Test Method | Test Title | Test Result |
|---|---|---|
| ASTM D - 1298 | Specific Gravity @ 77o F. | 1.158 |
| ASTM D - 95 | Water by Dean & Sark Vol.% | 2.2 |
| IP - 47 | Soluble in Carbon Tetrachloride Wt% | 94.85 |

(Testing by Hydro Carbon Development
(Institute of Pakistan, Karachi)

Samples prepared with 3% (by weight) of coal tar gave adequate stability and flow values as would appear from Table-II (2). These samples, however, could not withstand 60oC temperature hence, the idea to use coal tar was given up.

## TABLE - II (2)

## COAL TAR USED IN MIX 3.0% BY WEIGHT OF SAND

| SPECIMEN WT. GRAMS IN AIR | IN H20 | BULK VOLUME | BULK DENSITY | STABILITY LBS | FLOW 1/100" |
|---|---|---|---|---|---|
| 1148.2 | 557.5 | 590.7 | 1.94 | 470.0 | 11.0 |
| 1027.8 | 488.0 | 539.8 | 1.90 | 504.0 | 10.2 |
| 1045.0 | 500.0 | 545.0 | 1.92 | 593.6 | 9.4 |

**SAND SAMPLE:** Mile 3/3 near Naukot Fort. Test specimens with 2% and 2.5% were not stable and, therefore, stability could not be tried.

Testing Done by Soils and Materials Testing Laboratories Karachi.

**BITUMEN-SAND MIX**

Bitumen 80-100% penetration Grade was then tried by Mr. Sajjad. Laboratory results were good with both 4 & 5% by wieght of bitumen; as shown in Tables-II (3) & II (4) below:-

## TABLE-II (3)

## ASPHALT USED IN MIX 4.0% BY WT. OF SAND

| SPECIMEN GRAMS:WT IN AIR | IN H2O | BULK VOLUME | BULK DENSITY | UNIT WT. LBS | STABILITY LBS | FLOW 1/100" |
|---|---|---|---|---|---|---|
| 990.4 | 426.3 | 564.1 | 1.75 | 109.2 | 538 | 13.4 |
| 992.5 | 430.4 | 562.1 | 1.76 | 109.8 | 570 | 13.0 |
| 986.4 | 425.2 | 561.2 | 1.75 | 109.2 | 570 | 12.4 |

## TABLE-II (4)

## ASPHALT USED IN MIX 5% BY WT. OF SAND

| SPECIMEN WT. GRAMS IN AIR | IN H2O | BULK VOLUME | BULK DENSITY | UNIT WT LBS | STABILITY LBS | FLOW 1/100" |
|---|---|---|---|---|---|---|
| 1189.3 | 561.6 | 627.7 | 1.89 | 117.9 | 1602 | 18.8 |
| 1177.5 | 545.5 | 632.0 | 1.86 | 116.1 | 1500 | 12.6 |
| 1177.2 | 544.5 | 632.7 | 1.86 | 116.1 | 1668 | 12.2 |

(Testing done by soils and Materials Testing Laboratories LTD Karachi.)

In the field, however, 4 & 4 1/2% by weight of bitumen could not give adequate coating; the quantity was therefore, increased to 5% by weight of sand, this was found satisfactory and adopted.

The sand used was local, dug after removing about 6" top layer to eliminate foreign matter.

For determining the thickness of pavement, Mr. Sajjad used an equivalency factor of two i.e one inch of sand bitumen mix equivalent to two inches of granular dry bound base was adopted on the analogy of asphaltic concrete. Equivalent thickness in lieu of 9" granular material, which is commonly used, thus worked out to 4 & 1/2 inches and same was adopted.

**SUB GRADE PREPARATION:**

For testing the first specification of sand with 5% bitumen by weight, 50 ft. long 22 ft. wide stretch was selected. This was lightly watered with the idea that sand in moist condition would permit compaction by road roller; the sandy subgrade however could not bear even the lightest roller of 2 & 1/2 T. wt. The subgrade was therefore brought to shape manually by rakers and a tack coat of 80-100 Pen. bitumen was applied at the rate of 15 lbs. per 100 sq.ft.

**SAND-BITUMEN MIX PREPARATION AND LAYING:**

Sand was quarried from area adjoining the site, after removing top six inches layer to eliminate foreign matter, and brought near the mixer.

For mixing, a drum type concrete mixer with heating arrangement was used. First, measured quantity of sand was fed into the drum and heated to about 270oF, the heating time in the drum varied from 1 & 1/2 to 3 min. depending on burner working and sand dampness.

Bitumen separately heated to about 300oF was then poured into the mixer and drum revolved for 1 & 1/2 minutes to achieve complete coating.

Laying was done manually in single layer of 4 & 1/2 inches thickness. (In further construction laying was done in two layers of equal thickness i.e 2 & 1/4 Inches).

The mix-after laying, when atmoshperic temperature was 104oF (40oC) remained in jelly state for 48 hours, it then was hard enough to bear the load of a light car with driver only but with deep tyre imprints. The edges also opened up in 'V' shape on the third day.

To accelerate the hardening time, addition of cement 1% by wt. of sand was tried by Mr. Sajjad on another 50 ft. long stretch. This mix was hard enough to bear car load in 24 hours; opening of edges was also very much reduced.

For further rapid hardening, addition of stone chips (natural bajri) at 3% by wt. of sand together with 1% cement was tried, on another 50 ft. stretch.

This mix was hard enough to bear car load in only six hours and edges did not open up.

All these three types of stretches were then opened to casual light traffic on the fifth day after laying. Mix number one was still being imprinted by vehicle tyres yet rutting was not noticed. Other two mixes were behaving well. On sixth day after laying the test stretches were closed to traffic and the stiffness of mix number one was tested daily by driving a car around noon time and look for tyre impressions. On fifteenth day tyre prints were feable and on twentieth day no impressions were formed. The mix was allowed for another four days to stiffen and then opened to full traffic. The behaviour of all the three mixes was observed for one year to cover all the different seasons. Mix number one softened during summer noons; yet rutting; undue cracking, undulations, corrugations etc. were not noticed. Performance of mixes number '2' and '3' were found to be very good.

**DISCUSSION:**

a) There was an apprehension, since the begining, about the use of 80-100 Pen. grade bitumen in desert area. This very much delayed the stiffening period of the mix. Bitumen 50-60 Pen. would have more suitable but unfortunately grades other than 80-100 Pen. are still not being produced in the country.

b) Mixing device used in the experiment was not very satisfactory; greatest draw-backs were direct heating of bitumen and no temperature control. The best way would be to use asphalt emulsion; this would do away with heating and shall result in further cost reduction. At the time of experiment, emulsions were not produced in the country; now National Petro Carbon Ltd; are ready to produce on order. Same may be used with advantage in future work.

c) Due to abnormally long hardening time the field mix could not be compacted; consequently no relationship between field mix stability and density values and those of laboratory specimen could be determined, to help in quality control. Laboratory testing therefore simply provided the order of stability that is possible for the mix to attain.

The stability value of the field mix was also not determined by core or other tests. Since the pavement had behaved well during past five years it would be reasonable to believe that it's stability is sufficient to bear tyre pressures of 100 psi. For this value of tyre pressure and average flow equal to 12.9 as determined by the laboratory the stability works out to about 1500 lbs.

Thickness of mix adopted is not backed by proper corelation between strength and loads. However, arrangements to evaluate the strength by Core penetration method and relate the same to traffic are underway.

**CONCLUSION:**

From the experiments, Mr. Sajjad Haider concluded that:

i) Mix number '1' i.e native sand with 5% bitumen 80-100 Pen. by weight, despite its softening during Summer hot hours, is quite fit for desert roads carrying about 50 commercial vehicles a day, as has been proved by its five years performance.

ii) Mixes obtained by adding 1% cement by weight of sand and 3% of cement by weight of sand are still better

but cost wise they are 15% - 20% expensive than the Mix number '1'.

iii) Native sand mix with 5% bitumen 80-100 penetration by weight (Mix No. '1') affords 40% saving over conventional design using stone metal sub-base and base; also water and road mixing machinery, except a mixer is needed; even the mixer can be dispensed with if emulsion is used instead of bitumen. This elimination of machinery and water is the biggest advantage in desert areas. Paving with mix number '1' is also very speedy.

iv) Life of mix number '1' in relation to traffic is, however, yet not known, further observations and tests of the pavement are necessary to evaluate it.

## III. ARMY CORPS OF ENGINEERS:

### A) SAND BITUMEN ROADS:

Army engineers had been facing serious problem in providing economical tracks for military vehicles in the operational areas of deserts. During the second World War, some roads using bitumen sand mix material were constructed in the desert areas of Africa by the army peoples for providing economical track for their

military vehicles. This idea has been under consideration since long by the army corps of engineers.

The corps of engineer discussed with Director General, C&W Department, Government of Sind, Mr. Sajjad Haider who had contributed a lot in the design of Naukot-Mithi road about the bitumen sand mix. Based on their own studies and behaviour of above road, the Directorate of Design and Consultancy, E in C's Branch carried out experiments for the construction of such roads. Results of the experiments carried out by the Army corps of engineers using bituminous and cold emulsion are annexed (Annex-I).

The construction technique as recommended by the Army Corps of engineers on the basis of the experiments are outlined below:-

i) Locally available sand should be collected from adjoining site to be used in the construction after removing top six inches layer to eliminate foreign matter. Before heating, the sand should be passed through seive so that any foreign material in the sand is removed.

ii) Sand should be heated to about 270oF (130oC). If crush is used it would also be heated upto 140oC. Heat bitumen separately upto 300oF (140oC) and then mix at a temperature of 325oF (150oC). The mix should not be heated for more than two hours, otherwise the bitumen will loose its property. The bitumen sand mix should be disposed off from Heater/heating plant quickly. Laying temperature should be 10oC less from mixing temperature.

iii) Before laying of bitumen mix the sub grade formation should be levelled/sloped and provided proper camber.

iv) MC-30 should be used as prime coat at the rate of 20 lbs/100 sft or 0.95 kg/sq meter of surface area. Spread the bitumen premix just after prime coat manually using timber screed for finishing.

v) For initial compaction of 4" thick bottom layer, use iron hand tempers. Improvised light phenumatic (Rubber wheeled Trolly with sand bags loaded) should be tried after about 24 to 72 hours.

vi) After laying of bottom coarse, apply tack coat of 80/100 bitumen at a temperature of 150oC (290-350oF) at the rate of 12 lbs/100 sq.ft. Spread and compact the top layer in the same manner as bottom layer.

vii) Road should be opened for traffic after 15 days.

**B. USE OF SAND CUSHION ON CLAYEY SUBGRADE:**

**a) Metalled Roads:**

1. In most of the areas of Punjab and Sind, the road engineers have the problem of clayey subgrades. The roads constructed over such subgrades have failed due to following reasons:

i) The moisture content of sub-base material rises due to capillary action in such soils either due to high water table, surface pondage or due to faulty drainage system thus reducing its strength.

ii) The sub-base material penetrates in fine grained soils, creating cavaties in sub-base and base under the repeated traffic loads.

2. It is therefore necessary to provide a separator between the sub-grade and sub-base and also adopt measures to

break the capillary action. One of the techniques being used in developed countries is to use geotextile as separator.

3. Army has carried out experiment with the provision of 4" to 6" sand cushion on subgrades of fine soils to cope with this problem. With the compaction, sand mixes with the top of the subgrade material making a hard crust with better load bearing characteristics and does not allow subgrade material to seggregate. The sand layer also breaks the capillary action and the sub-base and base behaves much better. The aggregate particles do not penetrate in to the sand layer and the integrity of sub-base is ensured under the traffic loads.

4. In the new cantonment at Pano Aqil where water table was very high and subgrade consisted of fine grained soil, the roads have been designed with above specifications. The roads are behaving very well under the heavy traffic loads.

b) **Shingle Roads:**

Construction of shingle road is very common in army during field exercises. The existing track on soils with poor drainage conditions (mostly fine grained soils) are commonly given shingle cover in problem areas. The shingle roads behave very well under the various types of army traffic both in dry and wet weather. However in areas with heavy rains the shingle

material penetrates in the subgrade soil creating ruts and undulations. In areas where sand cushion between the shingle layers and subgrade was provided such problems were not encountered. The shingle roads were not constructed as part of proper designed plans. In fact these are constructed by army corps of engineers in the operational/exercise area based on Field Engineering Techniques.

**Recommendations:**

a) The existing beaten tracks be selected for converting economical all weather roads with minimum essential modification in its geometric requirements to save the cost of land.

b) The CBR values of subgrade must be established beside other essential subsoils information.

c) Drainage aspects both surface run off and sub soil must be looked into.

d) Sand cushion be provided in areas of fine grained soils having likely moist condition.

e) The shingle roads must have provision for further upgradation i.e provision of hard surface dressing, AC carpeting or additional pavement layers as required when funds position permits. This is only possible if subgrade is properly treated as per minimum design requirements of compaction, provision of sand cushion etc. in the initial construction phase.

## CHAPTER-III

## DEMONSTRATION PROJECT OF NTRC

There is a huge deficiency in the rural road net work in the country. This has been established in the chapter-I of this report. The situation demands that the prevailing deficiency in rural roads should be full-filled at the earliest. The objective could only be achieved by constructing low cost roads and by adopting the technique of stage construction for rural roads especially in the areas where traffic volumes are low.

National Transport Research Centre felt the dire need of spreading the idea of low cost roads over the entire country. The low cost (gravel) roads have been adopted in the modern countries like U.S.A and Sweden where low cost gravel roads constitute about 40% and 75% of their road network respectively.

In early eightees, NTRC started its struggle for the viability of the concept of low cost roads and stage construction techniques. In 1985, Government of Sweden offered an official visit to Pakistani Engineers and Planners to visit Sweden to see the construction and use of gravel roads in their country.

A four member delegation of Pakistani Engineers and Planners visited Sweden and offered some recommendations after returning Pakistan and one of them was the construction of low cost roads as demonstration projects in Pakistan. Since then NTRC

continued its effort in this field for the demonstration of low cost roads.

A study 'Demonstration Project' was started by the National Transport Research Centre to carry out research by demonstrating projects in roads pavement geometrics, pavement thickness and urban traffic management such as exclusive bus lanes, parking meter etc. The '**low cost gravel roads**' was the main demonstration project carried out by the Centre.

As per recommendations of the Pakistani delegation who visited Sweden, the work for the Demonstration Project prepared in NTRC and the constructiuon procedure to be adopted for the execution of the project was chalked out. Research Advisory Committee of NTRC approved the project for the demonstration of low cost roads on 20.1.1986. The cost appraisal committee approved the project at a cost of Rs. 578,000 on 29.4.1986.

**THE "LOW COST ROAD" DEMONSTRATION PROJECT:**

After approval from the Cost Appraisal Committee, preparatory work for the execution of the project was started. It was decided to up-grade some dirt roads in Islamabad Capital Territory being nearer to the Centre as it would enable an early access to roads as regards the maintenance and testing. Administrator, Islamabad Capital Territory was requested to help in selecting the experimental stretches for this purpose.

Two stretches were selected to demonstrate the viability of the concept of low cost roads in consultation with the Deputy Commissioner Islamabad and representatives from M/O Local Government and Rural Development. The following were the stretches selected for up-grading:-

1. Road from Tarlai to Sharifabad
2. Road from Humak to Jawa.

Location Plan and key details are given at Fig.1 & Table-III(1).

**Tarlai-Sharifabad Road:**

Sharifabad is a small village situated nearly 32 km south east of Islamabad and is a part of Tarlai Union Council. It is linked with main Lehtrar Road and that is the only access way for the village. The approach road to Sharifabad consist of three different sections. The initial about 1 & half km portion of the road was black-top surface. The surface of the road was un-even with excessive potholes and revelling. Due to poor drainage, water from the adjoining fields ponds on the road way causing damage to the structure of the road. The next about 1/2 km length was water bound macadam. The surface was very rough with jumps.

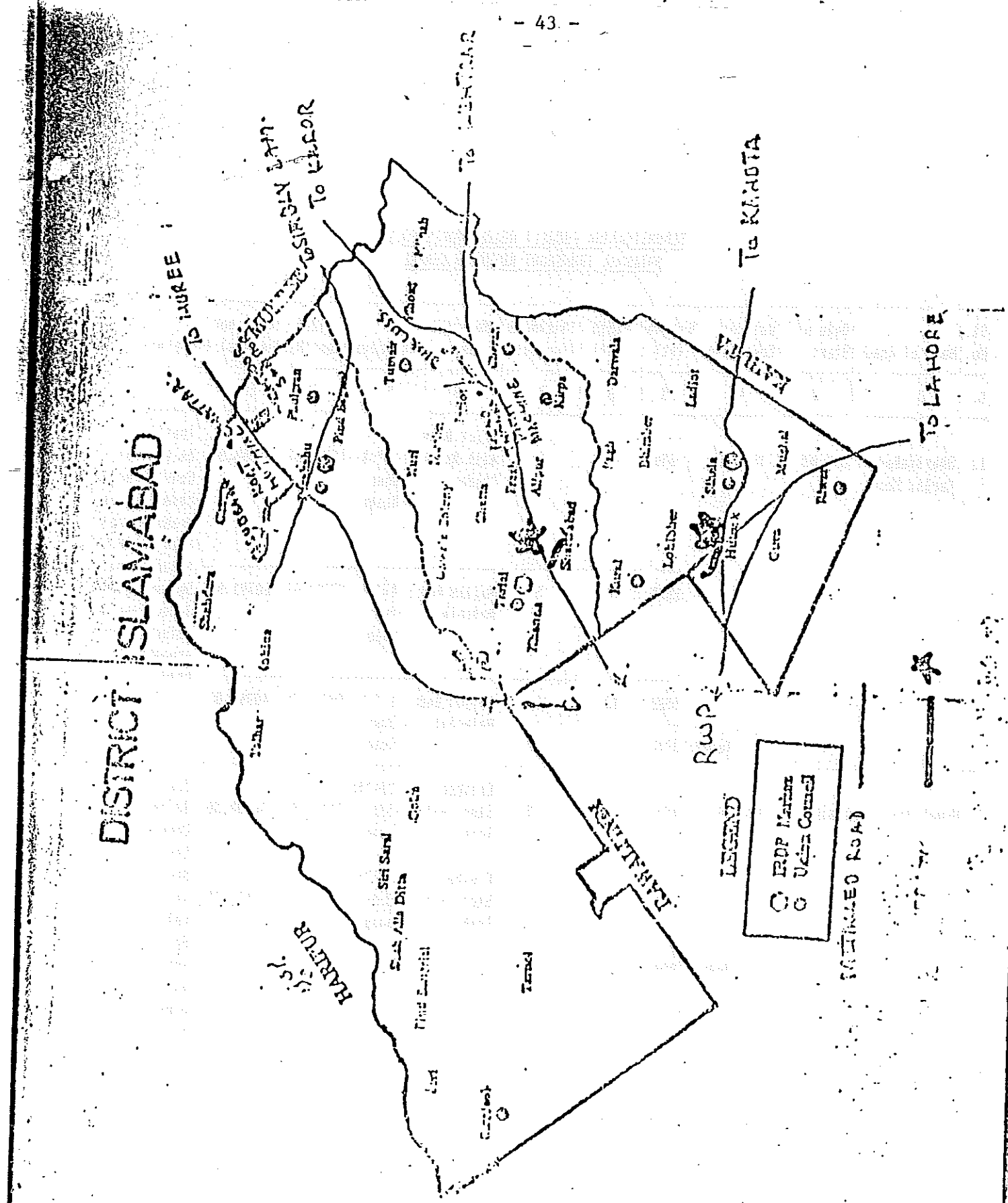

DISTRICT ISLAMABAD
To MURREE
To LAHORE
To KHOTA
To LAHORE
Rawalpindi
HARIPUR
LEGEND
BDP Markaz
Union Council
MURREE ROAD

Fig - 1

## Table-III (1)

DEMONSTRATION PROJECT ROADS COMPLETED BY NATIONAL TRANSPORT RESEARCH CENTRE

| Sl. No. | Name of Road | Date of Start | Date of Completion | Length (ft) | Width (ft) | Thickness (Inches) | Material used | Gradation | Total Cost(Rs) | Cost per km.(Rs) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1. | Sharifabad-Tarlai Road. | 5.1.87 | 18.2.87 | 690 | 12 | 5 | Brick Bats with Brick Powder | 1½" & Down Guage | 15889.63 | 75556.34 | Traffic Vol.= 54 Veh./day Const.Procedure Levelling and dressing upto 6"in depth of natural soil. Spreading of loose Base material over prepared sub-grade. |
| | | | | 1500 | 12 | 5 | Nallah Bed Material | 1½" & Down Guage | 27792.66 | 60791.82 | |
| | | | | 1522 | 12 | 5 | Nallah Bed Material | 1 " & Down Guage | 28200.29 | 60791.82 | |
| | | | Total: | 3712 | | | | | | | |
| 2. | Humak Jawa | 12.4.87 | 21.5.87 | 1200 | 12 | 5 | Crushed Stone with khaka | 3/4"to 3/10" guage | 35100.00 | 36739.50 | Traffic Vol. = 18 Veh./day Const.Procedure. Levelling and dressing upto 6" in depth of natural soil. Spreading of loose Base-material over prepared Sub-grade and provision of 2' wide shoulders. |
| | | | | 1080 | 12 | 4 | Crushed Stone with khaka | 3/4"to 3/16" guage | 25484.64 | 77421.39 | |
| | | | Total: | 2280 | | | | | | | |

Average Cost/km= Rs.85,000/=

Over size stones used in the water bound macadam were protruded above the surface. The last about 1 & 1/4 km of the road was a katcha track. During rainy season, lot of mud and slush formed on the surface and was very difficult for the people as well as traffic of the area to move on the katcha track. Trucks and Suzukis were the main users of the track. The same katcha track has been improved under the Demonstration Project.

**Traffic Volume:**

Traffic Volume was counted at this section for four days from 09:00 Hrs. to 18:00 Hrs. The average daily traffic volume over the stretch was found as 54 vehicles per day. The composition of vehicles in both directions was as under:-

| Sl. No. | Vehicle Type | Veh/day |
|---|---|---|
| 1. | Trucks | 14 |
| 2. | Tractor/Trollies | 12 |
| 3. | Cars/Suzukis/Wagons | 11 |
| 4. | Motorcycles | 17 |
| | Total: | 54 |

**Structural Design and Material:**

The katcha track throughout the whole stretch varied from 10 to 14 ft. in width. The total length of the track

measured was 3712 ft. The track was widened to give a carriage-way width not less than 12 ft. at any section. The entire length of 3712 ft. was divided into three different sections as shown in the Typical Plan and Cross-Section. In the first 690 ft. brick bats broken to 1 and half inch down guage were laid. A loose thickness of 6" was laid to yield a consolidated thickness of 5". In the second 1500 ft, 1 and half inch down guage gravel collected from Nullah bed was laid, 6" thick to give a consolidated thickness of 5". Similarly in the last 1522 ft., gravel, 1" down was laid. The details of the material used in the three sections have been summarised in the table:-

**Table-III (2)**

| Sl. No. | Length Section (ft) | Material Used | Gradation | Pavement Thickness |
|---|---|---|---|---|
| 1. | 690 | Brick bats with Brick Powder or Kilin Wastes. | 1 & half inch down guage | 5" |
| 2. | 1590 | Gravel (Nallah Bed Material) | 1 & half inch down guage | 5" |
| 3. | 1522 | Gravel (Nallah Bed Material) | 1 inch down guage | 5" |

As there are many Brick Kilns and nallahs within the vicinity of the site, therefore, locally available material was used to cut-down the transportation costs.

TARLAI SHARIFABAD ROAD
TYPICAL PLAN AND MATERIALS USED
ROAD WIDTH = 12'

| < 690' > | < 1500' > | < 1522' > |
|---|---|---|
| < TO TARLAI Brick Bats Portion | Shingled Portion | Shingled Portion TO SHARIFABAD > |
| 5" thick consolidated layer of 1-1/2" down-gauge brick bats with brick power as filling material. | 5" thick consolidated layer of 1-1/2" down-Nullah bed (gravel) material. | 5" thick consolidated layer of 1-1/2" Nullah bed Material (gravel). |

TYPICAL X-SECTION

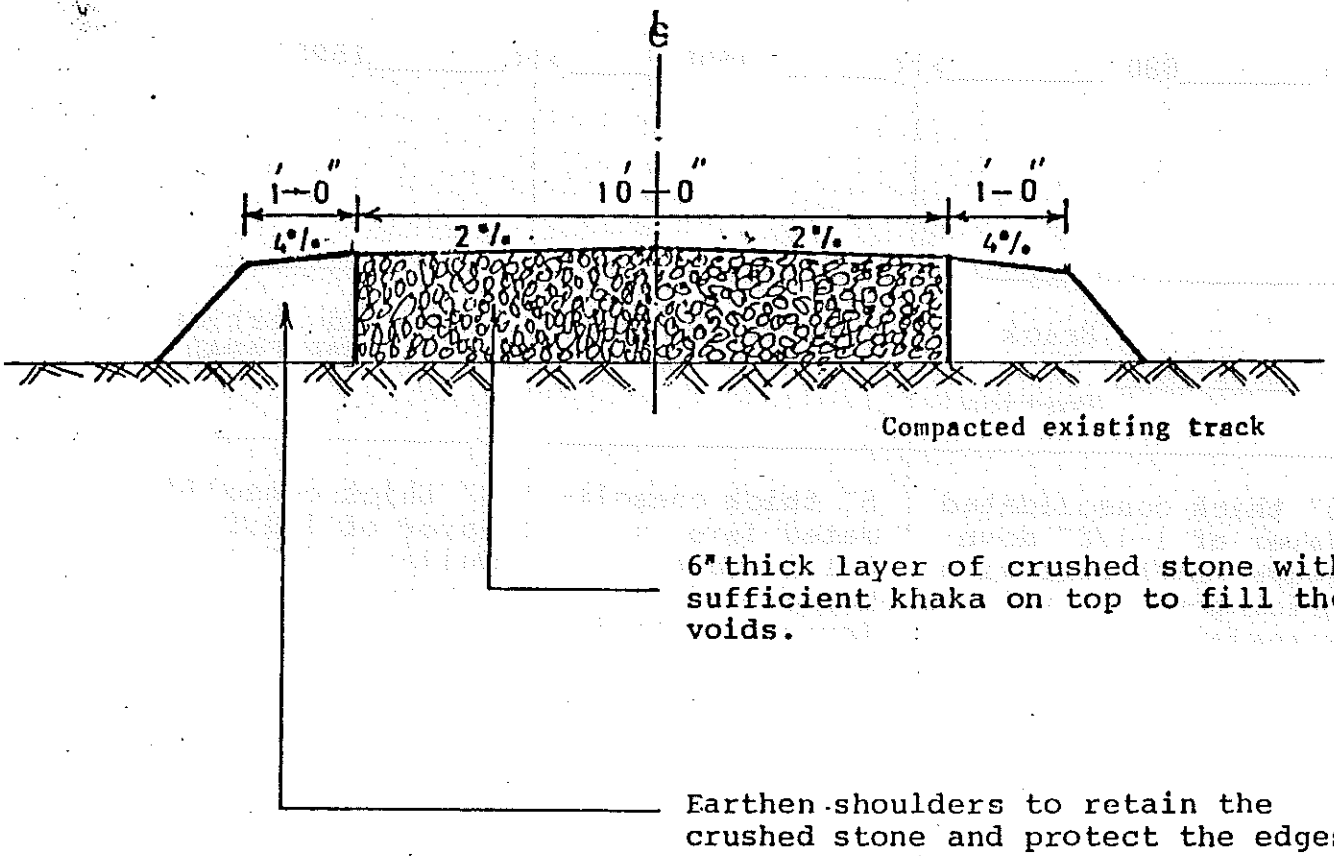



Fig.2

**Cost Estimates:**

After finalization of the geometric and structural parameters of the road, rough cost estimates were prepared for all the three sections of different designs separately within the Centre.

Only the cost of materials and labour was considered in preparation of estimates while supervisory staff was available in the Centre.

**Tendering:**

Tenders were invited from the approved contractors of B&R, CDA, MES and Local Government for the construction of road. M/S Allied Gas Enterprises being the lowest bidder were awarded the work for execution. The work was started on 05.01.1987.

**Construction Procedure:**

The construction procedure adopted for the road was as follows:-

i) **Alignment:** At first instance the alignment of road was straightened so far as possible. The carriageway width was fixed as 12' throughout the whole section of road. Grass and weed growth on shoulders was not disturbed to provide the lateral support.

ii) **Levelling :** As the natural surface of the track was un-even and full of wheel ruts, therefore, the surface was levelled before placement of material. The levelling was carried out with the front blade of tractor and tills. After 3 days of levelling of the surface, the construction material was laid over the levelled surface. The depressions caused by traffic were replaced simultaneously.

iii) **Sieving :** Whole material before placement was sieved. The brick bats to be placed over the first section of the track were sieved from 1 and half inch mesh sieve. Over sized brick bats were broken into small pieces.

Nullah bed material of one and a half inch down guage was used in the second section of the road. The material was sieved therough one and a half inch mesh sieve. The material for the third section was sieved from 1" mesh sieve. After sieving, the three materials were placed in their respective sections. The sieve analysis results of the samples are given at Table-III(2) and Fig.3.

CAPITAL DEVELOPMENT AUTHORITY
(DIRECTORATE GENERAL WORKS)
CENTRAL ENGINEERING LABORATORY
ISLAMABAD

CEL-2 (C)

# GRADATION CURVES

(B.S. STANDARD SIEVES.)

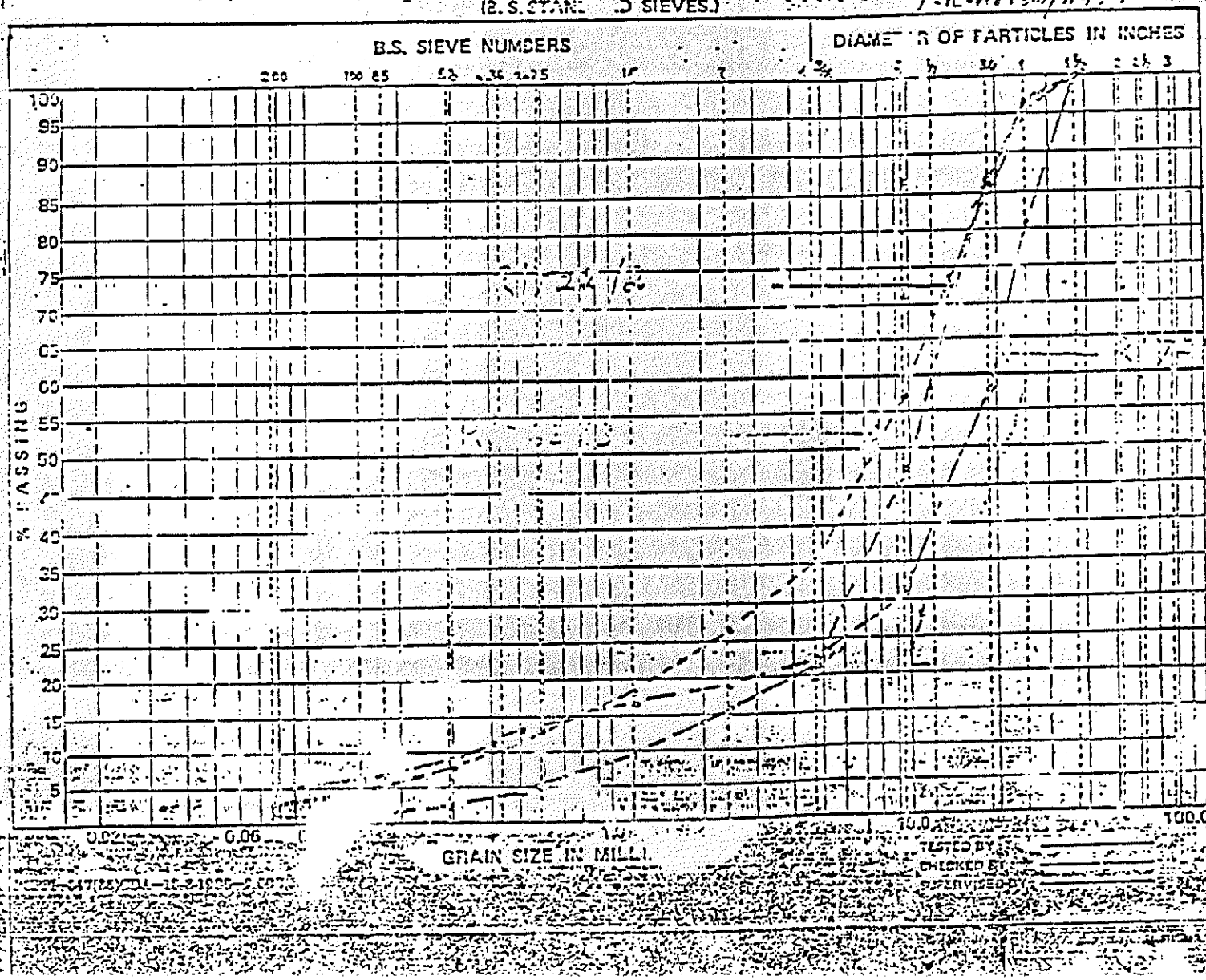
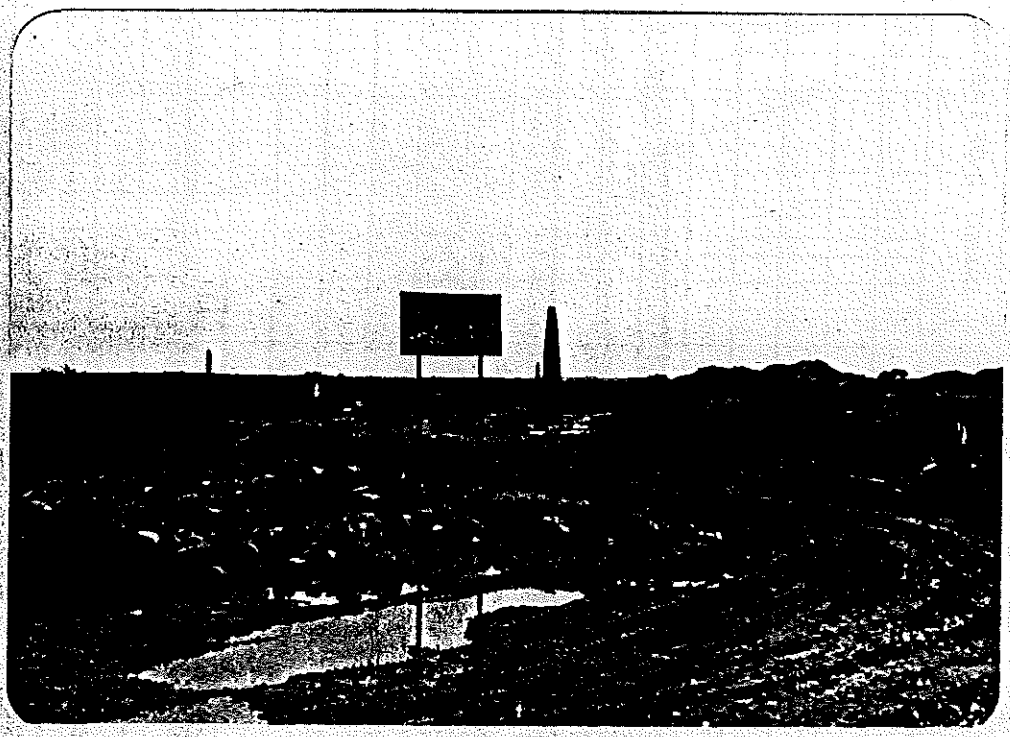
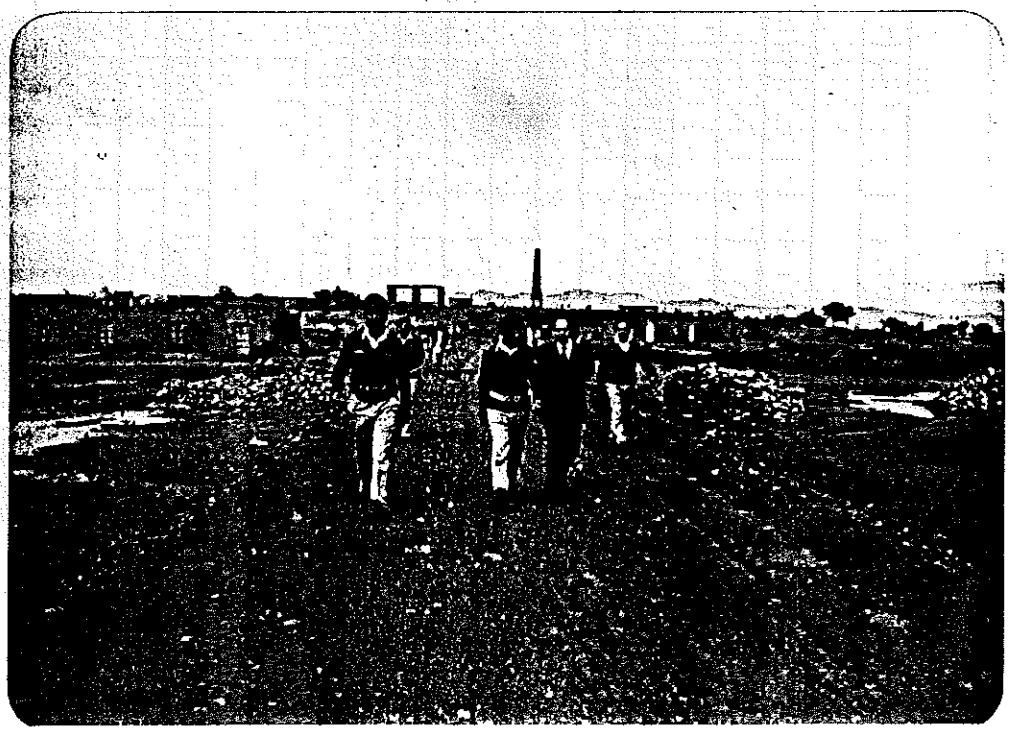



Fig.3

## SHARIFABAD TARLAI



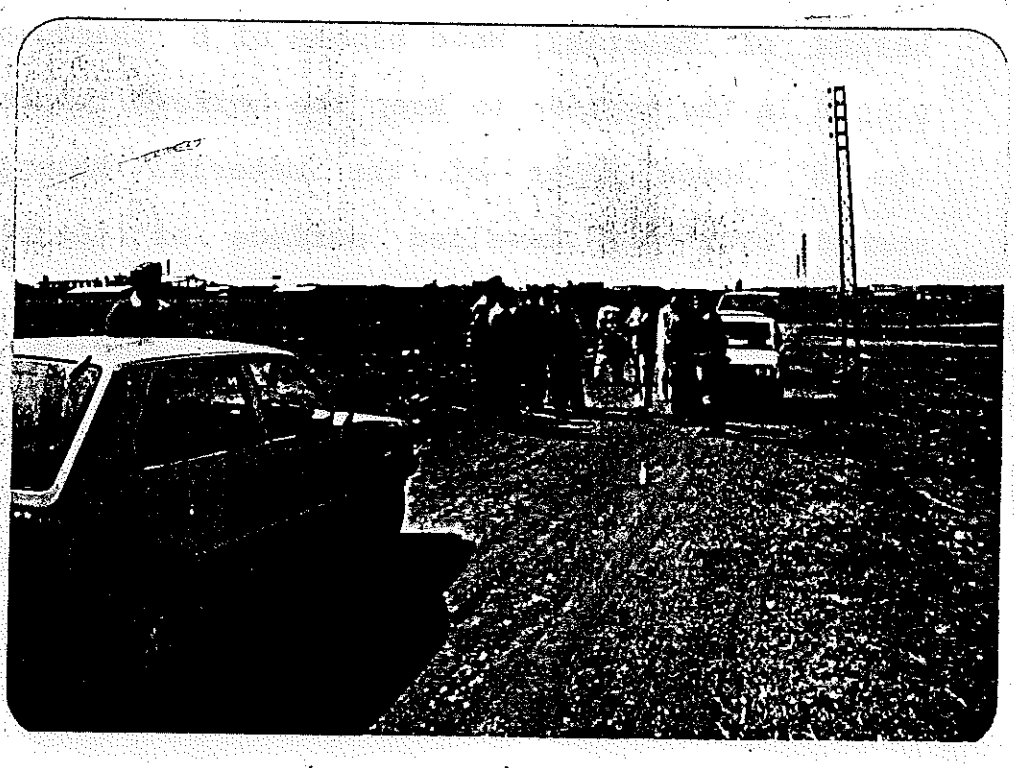
KATCHA TRACK



BRICK BATS AND SURKHI MATERIAL SECTION

Fig.4

## SHARIFABAD TARLAI



SHINGLE (NALLA BED) MATERIAL SECTION

Fig.5

iv) **Laying of Material:** Wood blocks of 6" thickness were placed in the section to keep the uniform thickness of the 6" loose layer of the material. Material was spread over the levelled surface of the track by labourers with the help of spades and shovels. Surkhi was spreaded over the bricks bats to fill the voids. The road was opened to traffic for the consolidation of the material under wheel loads. Depressions and wheel ruts were maintained for 10 days after opening of the traffic. The surface after 10 days of opening was dense crust.

**Completion Period:**

The project was completed on 18.02.1987 and the completion period was 44 days as detailed below:-

| Sl. No. | Length of Section(ft) | Type of Material used in section | Completion period(Days) |
|---|---|---|---|
| 1. | 690 | 1 & half inch down guage Brick Bats with Brick Powder. | 11 |
| 2. | 1500 | 1 & half inch down guage Nallah Bed Material. | 16 |
| 3. | 1522 | 1 inch and down guage Nallah Bed Material. | 17 |

**Total Completion Cost:**

The completion cost of the project was Rs.71,883/- details of which are as under:-

| Sl. No. | Section Length (ft) | Material used | Gradation | Expenditure. | Unit Cost/km |
|---|---|---|---|---|---|
| 1. | 690 | Brick Bats with Brick Powder. | 1&half inch down guage | 15890/- | 75558/- |
| 2. | 1500 | Nallah Bed Material. | 1&half inch down guage | 27793/- | 60792/- |
| 3. | 1522 | Nallah Bed Material | 1&half inch down guage. | 28200/- | 60792/- |

**Humak - Jawa Road:**

Jawa is a small village of nearly 300 dwellings near Islamabad Highway about 22 kms south of Islambad adjacent to CDA Model Town Humak. A small katcha track from Humak Model Town leading to the village Jawa was proposed to be improved under Demonstration Project. There were many stone cruchers within the vicinity of the village and therefore, locally available crushed stone was used.

**Traffic Volume:**

Traffic Volume for the road was counted before construction of road for four days from 09:00 to 18:00 Hrs. The average daily traffic using the track was found to be 18 vehicles per day. Composition of vehicles is as under:-

| Sl. No. | Vehicle Types | Veh/ day |
|---|---|---|
| 1. | Trucks | 2 |
| 2. | Tractor/Trollies | 2 |
| 3. | Cars/Suzukis/Vans | 12 |
| 4. | Motorcycles | 2 |
| | Total: | 18 |

**Geometric Parameters of Katcha Track:**

Width of the katcha track varied from 12 to 15 ft. Katcha track was dusty and un-accessible in rainy season for the pedestrian as well as vehicular traffic due to mud and slush formed. Carriageway width of the road was taken as 12 ft. while shoulders width was kept 2 ft. to retain the material used for road crust. Total length of the track was 2280 ft.

**Structural Parameters:**

The road was decided to be constructed in different thicknesses of road crust unlike Tarlai-Sharifabad road where the pavement thickness was kept uniform for one type of material. Whole stretch of Humak-Jawa road was divided into two sections of 1200 and 1080 ft. The thickness of base material was laid as 5" and 4" in the sections as shown in the construction plan.

**Materials:**

As there were stone crushers near the site, therefore, it was decided to use the local material available as per scope of this project. Crushed stone have been used in this road as the construction material. Details of the material are as under:-

| Sl. No. | Length of Section (ft) | Material used | Gradation | Pavement Thickness |
|---|---|---|---|---|
| 1. | 1200 | Crushed stone with khaka | 3/4" to 3/16" guage. | 5" |
| 2. | 1080 | Crushed stone with khaka | 3/4" to 3/16" guage. | 4" |

Stone dust (khaka) was used as filler material to fill the voids in the pavement.

**Cost Estimates and Tendering:**

Rough cost estimates were prepared in the Centre and tenders were invited from the contractors as previuously on Tarlai-Sharifabad road. M/S Allied Gas Enterprise being the lowest bidder started the work on 12-04-1987.

**Construction Procedure:**

The construction procedure adopted was simple as in practice for construction of granular base and sub-base courses. Compaction was not done and it was aimed to achieve it by the moving traffic loads.

After clearly marking the sections and fixing the pege to achieve the desired thickness in respective sections the crushed stone of specified gradation was spreaded and levelled with spades and shovels. Khaka was spreaded over the surface of crushed stone to fill the voids. Maintenance period for the road was 10 days and depressions/ruts formed were filled with the same material. The road was then opened to traffic to achieve the consolidation under traffic loads.

Ruts resulting by traffic movements were filled with khaka to achieve the smooth riding surface of the track.

**Completion Period:**

The project was completed on 21.05.1987 within 39 days. Details are as under:-

| Sl. No. | Length of section(ft) | Type of Material used | Pavement Thickness | Completion period (days) |
|---|---|---|---|---|
| 1. | 1200 | 3/4" to 3/16"guage crushed stone with khaka. | 5" | 22 |
| 2. | 1080 | " | 4" | 17 |

HUMAK - JAWA

KATCHA TRACK

COMPLETED ROAD

Fig.6

**Project Cost:**

The total project cost was Rs. 60,885/- breakdown of which may be seen in the following table:

| Sl. No. | Length of Section (ft) | Material used | Pavement thickness | Expenditure (Rs) | Unit Cost per Km (Rs) |
|---|---|---|---|---|---|
| 1. | 1200 | 3/4" to 3/16" guage crushed stone with khaka | 5" | 35400/- | 96790/- |
| 2. | 1080 | " | 4" | 25485/- | 77423/- |

**PRELIMINARY EVALUATION OF THE ROADS:**

The preliminary evaluation of the roads was carried-out in terms of the surface roughness measurement of the roads. The surface roughness is a measure of the riding quality of a road surface. The lower is the surface roughness, the better is the riding quality. The increase in surface roughness results in not only increase in wear and tear of the vehicle but also increase in fuel consumption. Therefore, the vehicle operating cost on a rough section of a road would be much higher than on a smooth road surface.

The surface roughness of the roads was measured using a Bump Integrator machine. The instrument is mounted directly over the differential housing on the plateform of a landrover. The unit operates on a 12V power supply, which is usually the vehicle battery.

To measure the surface roughness of a road, the vehicle is driven at a speed of 32 km/hour (20 m.p.h) and the displacements readings are recorded on the counter. The roughness can then be calculated using the formula.

$$\text{Roughness value (mm/km)} = \frac{\text{(Acutuale Count on B.I Counter)}}{\text{(length of Road in kilometers)}} \times 28.4 + 1230$$

The details about the Bump Integrator unit are given at Annexure-II

**ROUGHNESS MEASUREMENTS:**

The roughness measurements of both the roads using B.I machine were recorded at a regular interval after opening of the roads to traffic. The roughness values were recorded separately for the Brick Ballast portion and the shingle portion. The roughness values along with the age of the road are given in Table-III(3) and Table-III (4). The roughness values for the Humak-Jawa road are provided at Table-III(5).

The roughness value of the katcha track for the Sharifabad-Tarlai road was measured and was found to be 13000 mm/km on the section which was later on improved to shingle section. The roughness value just found after completion of this section was 7305 mm/km. The roughness was found reducing with age and after 10 months of service, it was found to reduce to a value less than 5000 mm/km.

Similarly for the brick ballast section, the roughness of the original track was found as 16198 mm/km which was reduced to 13672 mm/km after completion of the brick ballast pavement. The surface roughness further reduced with age and after about ten months of its completion, the surface roughness for the Brick ballast section was recorded as 10832 mm/km.

**Table-III (3)**

TARLAI - SHARIFABAD ROAD

**Brick Ballast Portion**

| Sl. No. | Month | Road Age (Months) | B.I. Value (Unit) | Roughness ( mm/km ) |
|---|---|---|---|---|
| | 1 9 8 7 | | | |
| 1. | January | - | 116 | 16918 |
| 2. | February | 0 | 92 | 13672 |
| 3. | March | 1 | 96 | 14213 |
| 4. | April | 2 | 88 | 13131 |
| 5. | May | 3 | 60 | 9314 |
| 6. | June | 1 | 56 | 8803 |
| 7. | September | 7 | 49 | 7857 |
| 8. | October | 8 | 48 | 7721 |
| 9. | November | 9 | 66 | 10156 |
| 10. | December | 10 | 71 | 10832 |

## Table-III (4)

## TARLAI - SHARIFABAD ROAD

## Shingle Portion

| Sl. No. | Month | Road Age (Months) | B.I. Value (Unit) | Roughness ( mm/km ) |
|---|---|---|---|---|
| | 1 9 8 7 | | | |
| 1. | January | - | 383 | 13040* |
| 2. | February | 0 | 197 | 7305 |
| 3. | March | 1 | 215 | 7860 |
| 4. | April | 2 | 201 | 7428 |
| 5. | May | 3 | 123 | 5023 |
| 6. | June | 4 | 104 | 4437 |
| 7. | August | 6 | 139 | 5516 |
| 8. | September | 7 | 72 | 3450 |
| 9. | October | 8 | 101 | 4344 |
| 10. | November | 9 | 126 | 5115 |
| 11. | December | 10 | 121 | 4961 |

*The reading was taken on katcha track before the construction of the road.

## Table-III (5)

## HUMAK - JAWA ROAD

| Sl. No. | Month | Road Age (Months) | B.I. Value (Unit) | Roughness ( mm/km ) |
|---|---|---|---|---|
| | 1 9 8 7 | | | |
| 1. | January | - | 239 | 12004* |
| 2. | May | 0 | 123 | 6256 |
| 3. | June | 1 | 89 | 4867 |
| 4. | August | 3 | 91 | 4949 |
| 5. | September | 4 | 54 | 3437 |
| 6. | October | 5 | 88 | 4826 |
| 7. | November | 6 | 71 | 4131 |
| 8. | December | 7 | 86 | 4744 |

*The reading was taken on katcha track before the construction of the road.

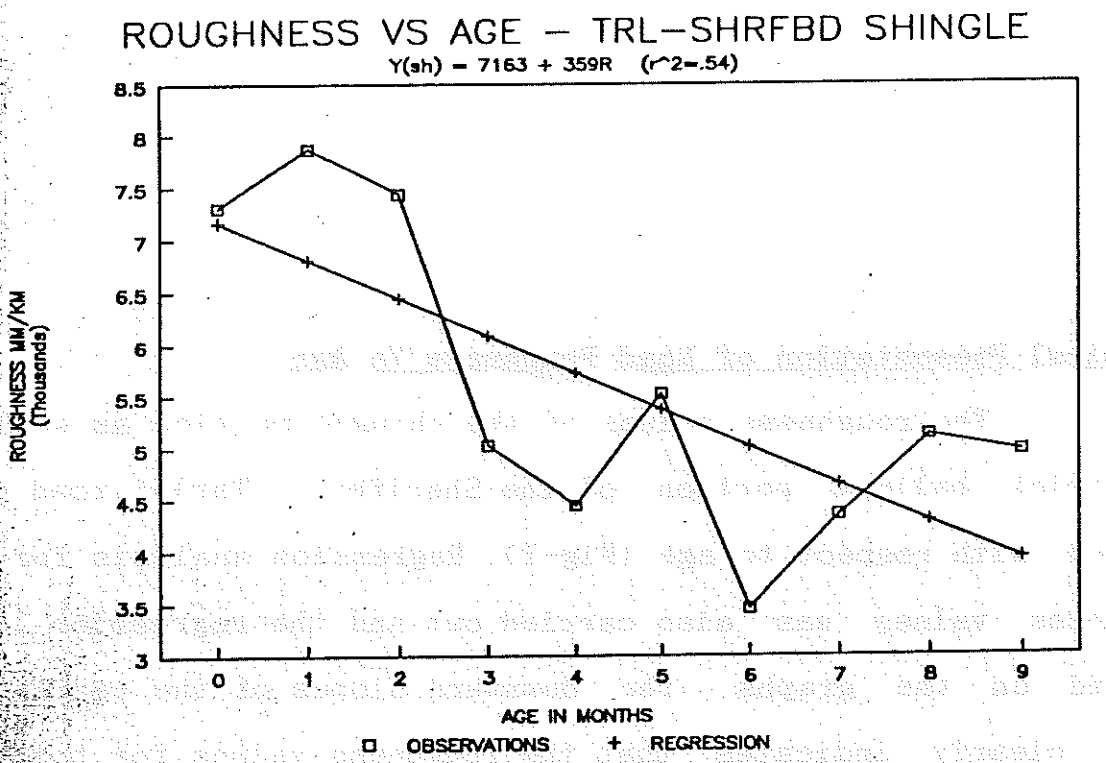
**Graphical Presentation of Road Roughness Vs Age:**

The roughness values of the shingle portion as well as the brick ballast portion of the Sharifbad - Tarlai road were plotted with respect to age (Fig-7). Regression analysis for the roughness values was also carried out and the regression lines plotted on the graphs. The downward slopes of the regression lines clearly indicates that the roughness values for both the brick ballast as well as the shingle portion has the tendency to reduce with the passage of time.

Similarly the roughness values vs age were plotted for the Humak-Jawa road and are shown in Fig.8. The regression analysis of the data was also carried out and regression line plotted on the graph. The downward trend of the regression line clearly demonstrates the fact that the surface roughness of the road is decreasing with the passage of time.

**Effect of Rainfall:**

Water is the biggest enemy of a road. Heavy rainfall generally results in road deterioration. To have the effects of rainfall on the roughness and strength of these roads, rainfall data was also collected after completion of the road. Month-wise rainfall and roughness for the two roads is given in the Table-III(6) and Table-III(7).


ROUGHNESS VS AGE – TRL–SHRFBD SHINGLE
Y(sh) = 7163 + 359R (r^2=.54)
ROUGHNESS MM/KM (Thousands)
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
0 1 2 3 4 5 6 7 8 9
AGE IN MONTHS
OBSERVATIONS + REGRESSION

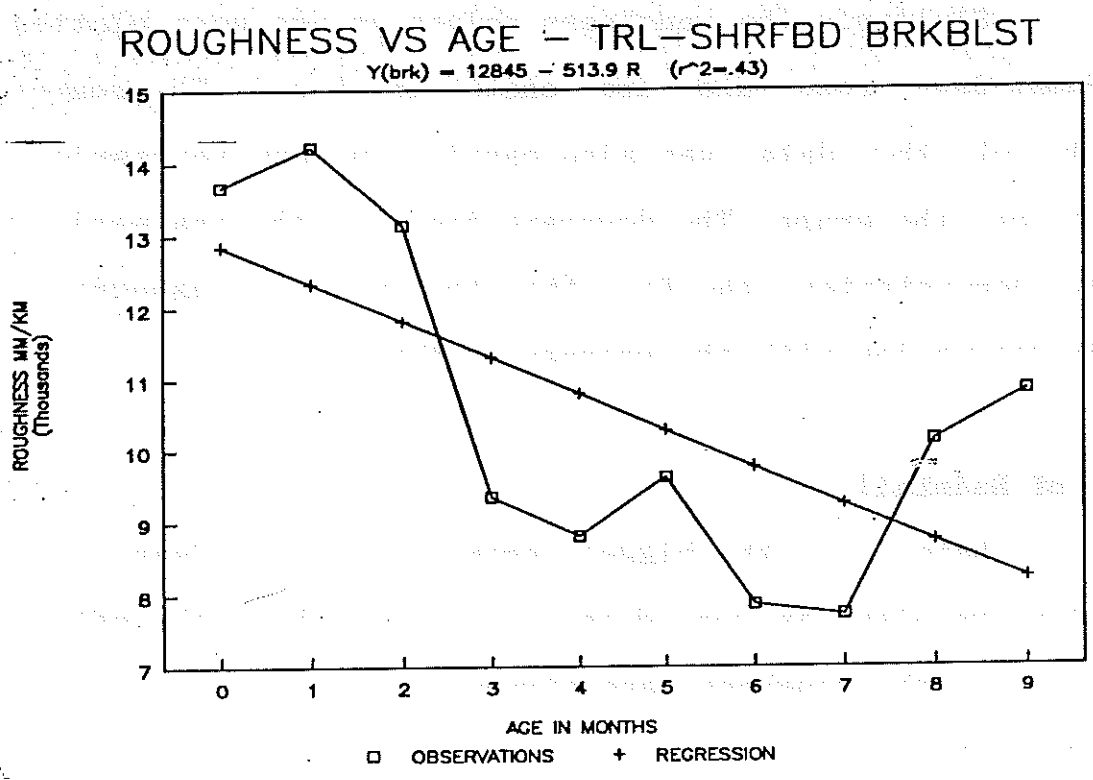

ROUGHNESS VS AGE – TRL–SHRFBD BRKBLST
Y(brk) = 12845 – 513.9 R (r^2=.43)
ROUGHNESS MM/KM (Thousands)
15
14
13
12
11
10
9
8
7
0 1 2 3 4 5 6 7 8 9
AGE IN MONTHS
OBSERVATIONS + REGRESSION

Fig.7

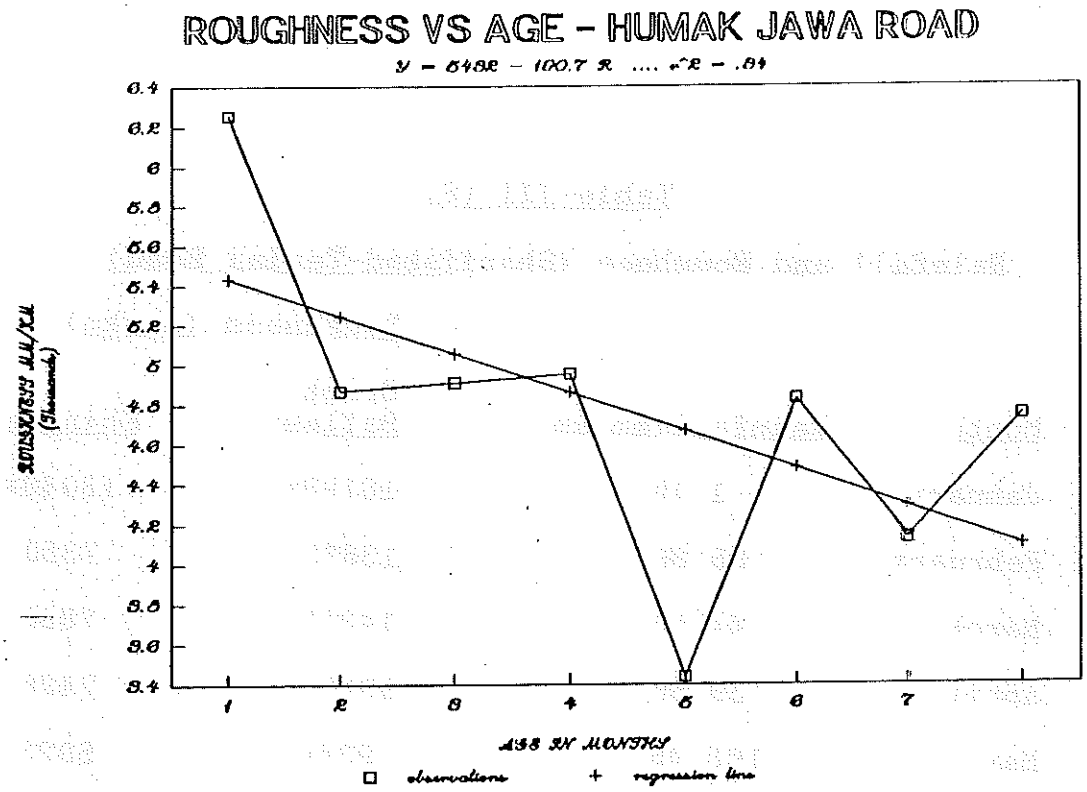

ROUGHNESS VS AGE - HUMAK JAWA ROAD
Y = 5488 - 100.7 R .... r^2 = .84
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
1
2
3
4
5
6
7
AGE IN MONTHS
observations
regression line

Fig.8

## Table-III (6)

## Rainfall and Roughnes (Sharifabad-Tarlai Road)

| Year | Month | Rainfall(mm/km) | Roughness (mm/km) | |
|---|---|---|---|---|
| | | | Brick Ballast | Shingle |
| 1987 | January | 1.10 | 16198* | 13040* |
| | February | 85.80 | 13672 | 7350 |
| | March | 44.50 | 14213 | 7860 |
| | April | 39.50 | 13131 | 7428 |
| | May | 105.40 | 9344 | 5023 |
| | June | 24.80 | 8803 | 4437 |
| | July | 54.80 | - | - |
| | August | 207.50 | 9615 | 5516 |
| | September | 2.4 | 7857 | 3450 |
| | October | 84.00 | 7721 | 4344 |
| | November | - | 10156 | 5115 |
| | December | 7.0 | 10832 | 4961 |
| 1988 | January | 10.0 | - | - |
| | February | 85.8 | - | - |

* Roughness recorded on katcha track.

Table-III (7)

**HUMAK - JAWA ROAD**

| Month | Rainfall(mm/km) | Roughness (mm/km) |
|---|---|---|
| January,87 | 1.10 | 12004* |
| May | 105.40 | 6256 |
| June | 24.80 | 4867 |
| July | 54.8 | - |
| August | 201.3 | 4940 |
| September | 2.4 | 3437 |
| October | 84.0 | 4826 |
| November | - | 4131 |
| December | 7.0 | 4744 |

* Roughness recorded on katcha track.

Source:- Research Wing, Department of Agricultural

It may be seen from the Tables-III(6) and III(7) that heavy rainfall during the month of August, 1987 has not affected the roughness of the road. The roughness remained consistent during the period. It clearly demonstrates that heavy rainfall do not cause any damage to gravel roads, it rather helps in consolidating the material and recuces it roughness .

From the above analysis of the roughness with age and the effect of rainfall on the roads, it was concluded that:

1. The low cost road could be constructed at a nominal cost which is 1/8th of the cost of the black top road.

2. Local construction materials could be easily utilized in the construction of these roads.

3. Construction of such roads does not involve any special or technical knowledge.

4. No special road construction machinery is required. Ordinary tractor with front blad could be used for levelling the surface and aggregates.

5. Low cost roads provide a fairly good link for vehicular and pedestrian traffic during rainy season.

6. Heavy rainfall do not cause any damage to gravel roads, rather it helps in consolidating the material under traffic loads in most conditions.

After the successful demonstration of the roads in Islamabad, it was considered appropriate to construct such type of roads in other parts of the country as well to demonstrate its viability. Four more roads have been constructed since then and are briefly described below:-

## 3. Dheri Mallhu Road (District Attock):

The road is located about 40 kms North West of Islamabad near Taxila. The road takes-off from the Main Taxila-Haripur road at about 16 kms from Taxila. The initial 2 kms is shingle road made on self-help basis by the people of the area. Village Dheri Mallhu is one of those rural areas where traffic volume is low. The access was very difficult to traverse in the rainy days. There are two approaches to the Village Dheri Mallhu. The two katcha approaches providing access to the Village Dheri Mallhu from both sides was envisaged for construction as demonstration project.

### Existing Track Conditions:

The existing track was fairly levelled and passed through plain area with proper drainage on both sides of the track. The width of the track varied from 12 ft to 15 ft.

DHERI MALLHU

UNDER CONSTRUCTION
3" SAND CUSHIONAND 6" CRUSH

COMPLETED ROAD

Fig.9

**Design Adopted:**

The structural design of this road has been constructed keeping in view the actual position of the katcha track. As the existing track was fairly levelled, no earth work was envisaged for the preparation of the subgrade. Due consideration has been given to the drainage of the road. It was decided to lay a 3" thick sand cushion over the prepared natural surface of the ground. A 6" thick layer of well graded crushed stone of size 3/4" to 3/16" with enough khaka to fill the voids of the surface is laid on the sand cushion.

Sand cushion has been provided to fulfill the requirements of drainage and to prevent the rapid loss due to penetration of crushed stone into the soil. Local soils is used to retain the crushed stone in position and is generally known as road shoulders.

**Completion Period:**

The total road length is 4794'. The work of the road was started on 31.5.1988 and completed within one month time.

**Cost of the Project:**

The total cost incurred on the construction of road was Rs. 1,49,268/-. The details are as under:-

| S.No. | I t e m | Unit | Quantity | Rate | Cost |
|---|---|---|---|---|---|
| 1. | 3"thick sand cushion | cft | 11,985 | 3.50 | 41,947/- |
| 2. | Crushed stone of 3/4" to 3/6". | cft | 19,975 | 4.50 | 99,895/- |
| 3. | Earthen shoulders 8" thick 1' wide. | cft | 6,392 | 1.00 | 6,392/- |
| 4. | 5 Nos. of RCC pipes | rft | 60 | 17.57 | 1,054/20 |
| | | | | | 149,268/70 |

## 4. Dhuni Village Road (Tehsil Hafizabad, District Gujranwala.

The low cost road at village Dhuni, Tehsil Hafizabad was taken up for construction after the completion of the road at Village Dheri Mallhu. The road was selected as there already existed an embankment of two and half feet height. However, during rainy season, the embankment used to become fully saturated with water and become practically impossible by the vehicular traffic. The top width of the existing embankment was 27 feet. The condition of the embankment during rainy season may be seen in Fig10.

### Proposed Structural Design:

Soil samples were collected from the existing embankment of the road and was tested from the C.D.A Laboratories. Following tests were performed.

DHUNI ROAD

KATCHA TRACK

COMPLETED ROAD

Fig.10

1. Sieve analysis
2. Atterberg limits
3. Field density test
4. C.B.R test

may be seen in Annexure-II.

According to the test results, the field density of the existing embankment was found to vary between 85% to 90%. It was, therefore decided to first compact the embankment to at least 95% of modified AASHO density. The proposed improvement therefore consisted of the following steps.

i) Levelling and compaction of full width of existing embankment to 95% modified AASHO maximum dry density.

ii) Providing and laying 3" thick sand cushion over the compacted subgrade.

iii) Providing and laying 6" thick layer of crushed stone 1" to 3/16" of approved quantity and grade including sufficient amount of khaka to fill the voids complete.

iv) Providing 8" thick consolidated layer of earth on shoulders to retain the crushed stone.

A 3" sand cushion was added as a precaution against water logging. The initial behaviour of the road, however, shows that it may not be totally necessary to provide a sand cushion.

**Project Cost:**

The total road length is 4300'. The completion of the road costed Rs.187,386 as detailed below:-

| S.No. | I t e m | Unit | Quantity | Rate | Cost |
|---|---|---|---|---|---|
| 1. | Laying of sand | ft3 | 10750 | 3/- | 32,250/- |
| 2. | Laying of crush | ft3 | 17917 | 8/- | 143,336/- |
| 3. | Culverts | Nos | 3 | 2500/- | 7,500/- |
| 4. | Shoulders | ft3 | 5733 | 0.75/- | 4,300/- |
| | | | | | 187,386/- |

5. **Dorro Village Road (District Islamabad)**

The road takes off from about 2 kilometers from the National Highway N-5 on Fateh Jang road. The total length of the proposed track for improvement was 1.7 kms.

**Proposed Design:**

The subgrade condition of the road was generally found good and on most of its length, the subgrade was almost rock. The track passed through fairly levelled area. The depth of water table was very deep. Keeping in view the above subgrade conditions it was decided not to construct any embankment. Also, provision of a layer of sand cushion was not considered necessary

because of water table depth and good subgrade material. It was also considered necessary to provide 6 Nos. of 9" dia pipes for cross drainage purposes.

**Cost Estimates:**

The construction of the road costed Rs.174,350/- as detailed below:-

| S.No. | I t e m | Unit | Quantity | Rate | Cost |
|---|---|---|---|---|---|
| 1. | Levelling & dressing | ft2 | 76400 | 0.07/- | 5,348/- |
| 2. | Laying of Crush | ft3 | 31833 | 5/- | 159,165/- |
| 3. | Earthen Shoulder 1" on either side. | ft3 | 6367 | 1/- | 6,367/- |
| 4. | Katcha drain | rft | 500 | 4/- | 2,000/- |
| 5. | Pipe Culvert | Nos. | 6 | 250/- | 1,500/- |
| | | | | | 174,380/- |

The road was completed on 24th September, 1990. Since then its performance is being measured and it is in good condition.

6. **Sheikh Qureshian Village Road (District Jhelum):**

The road starts from the Village Nasiruddin which is located about 10 kms. from the main National Highway N-5, (8 kms. before Jhelum). The road length completed is 5650 feet.

**Proposed Design:**

The katcha track was very loose. Hence it was felt that before placing the crush over the track, it should be levelled and properly compacted. There are many crushing plants in the vincinity of the site. Hence it was envisaged to improve the katcha track to all weather gravel road by providing 6" loose crush material with sufficient amount of khaka for filling the voids over the compacted track. To retain the crush on either side, 1' wide shoulders were also provided in the Design. Provision of 3 pipe culverts for the cross drainage was also envisaged.

**Completion Cost:**

The project costed Rs. 172,368 as detailed below:-

| S.No. | Item | Unit | Quantity | Rate | Cost |
|---|---|---|---|---|---|
| 1. | Earth work dressing and compaction. | ft2 | 56500 | 0.12 | 6,780/- |
| 2. | Crush Stone | ft3 | 23542 | 6.75 | 158,909/- |
| 3. | Earth work | ft3 | 4708 | 1.1 | 5,179/- |
| 4. | Pipe Culverts | Nos. | 3 | 500 | 1,500/- |
| | | | | | 172,368/- |
| | | | | Cost/km | 100,214/- |

# CHAPTER-IV

# EVALUATION OF ROADS AND CONCLUSIONS

## INTRODUCTION:

It has long been recognized that road surface roughness is directly related to ride comfort and pavement condition, but only recently has it been recognized as a primary factor influencing vehicle operating costs in developing countries.

The concept of 'ride comfort' adopted in the developed world as a direct measure of the uneveness of a road surface as percieved by the road user is not applicable to the road conditions met in the developing countries. In such countries, the greater need is for more roads to provide the basic means of transportation and communication throughout the year and because of limited resources available for building and maintaining all weather roads, a lower servivceability rating is tolerated by the user. However the lower quality of the road surface manifests itself in higher vehicle operating costs through greater wear and tear of the mechanical components of the vehicles. Hence 'comfort' to the vehicle is of greater importance than confort to the rider.

## EVALUATION OF ROADS:

### Roughness Measurements of the Roads:

The evaluation of the roads have been carried out in terms of road roughness. The road roughness has been measured

using a vehicle mounted Bump Integrator. The Bump Integrator unit can be mounted directly over the differential housing on the platform of a passenger car or landrover and unit operates on 12V power supply, which is usually the vehicle battery.

The roughness measurements of the roads were started from the time of their completion and were recorded at regular intervals. The Table-V(1) provides the road roughness values for all the roads for the period during which measurements on these roads were taken. The roughness values of the roads were plotted vs age and are given in Fig-11 to Fig-14.

The roughness of the original katcha tracks were generally found to vary between 13000mm/km to 16000mm/km. However, after the completion of the demonstration projects, the roughness was found to be about 6000 mm/km to 7000 mm/km. The roughness of the roads was generally observed reducing with age and in some cases, the roughness measured after 1 year period was found to reduce to 5000 mm/km or even less then this.

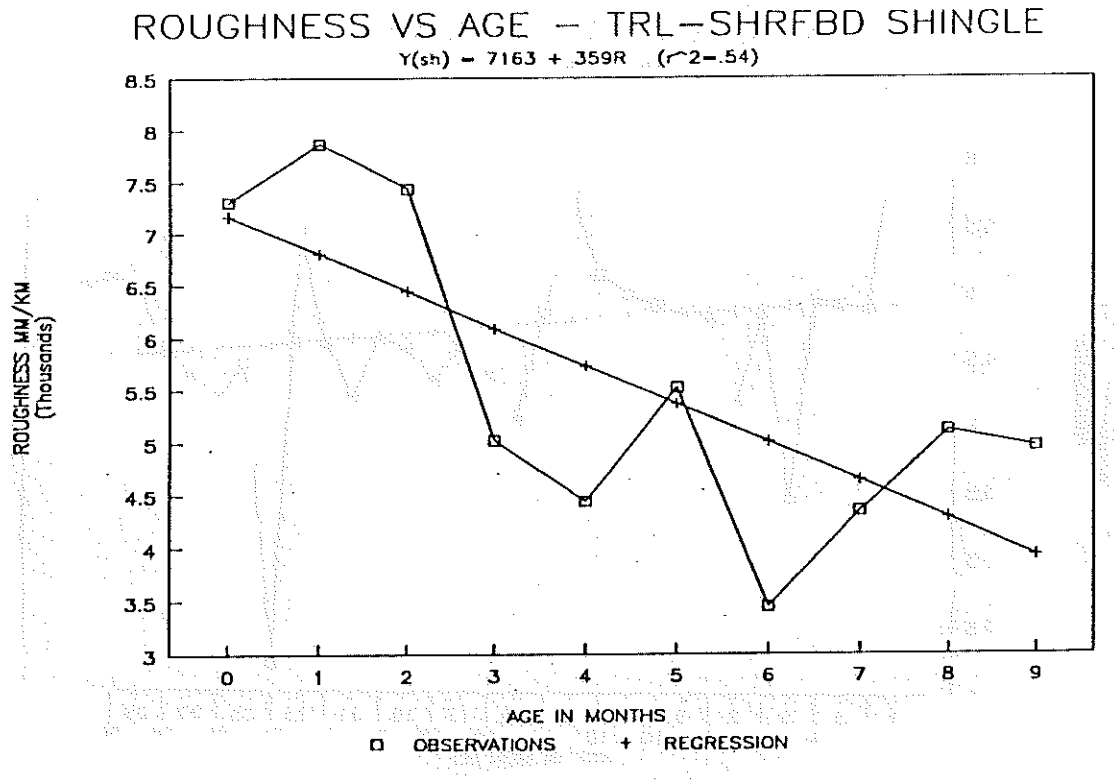
Another interesting aspect noted was that during the dry season the roughness normally used to increase. However, the measurements taken during rainy season was found to be less than those taken during dry spell period. The reason probably was that during the dry weather, with the movement of vehicles on the road surface, the moisture from the surface is evaporated resulting in lack of cohesion between the khaka and the crushed aggregate as a result of which the crushed stones starts dislodging from the surface and removed by the moving tyres causing increase in

TABLE IV(1)

# ROUGHNESS OF LOW COST ROADS ACCORDING TO AGE

| Age | Humak | Dheri Mallhu | | Dhuni | Doro | Tarlai Sharifabad | |
|---|---|---|---|---|---|---|---|
| mnths | Jawa | Kamra | Godo | Vil Rd | Vil Rd | Shingle | Brk/blst |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 0 | 6256 | | | | | 7305 | 13672 |
| 1 | 4867 | 4649 | 4327 | 5630 | 4842 | 7860 | 14213 |
| 2 | | 5508 | 4910 | 5950 | 4194 | 7428 | 13131 |
| 3 | 4949 | 5101 | 4836 | 6169 | | 5023 | 9344 |
| 4 | 3437 | 5427 | 5949 | 4631 | 6058 | 4437 | 8803 |
| 5 | 4826 | 5590 | 5486 | 4414 | | 5516 | 9615 |
| 6 | 4131 | 5549 | 5022 | 4003 | | 3450 | 7857 |
| 7 | 4744 | 5430 | 4938 | 4046 | | 4344 | 7721 |
| 8 | | 4897 | 5182 | 4652 | | 5115 | 10136 |
| 9 | | 5430 | 5064 | 4956 | | 4961 | 10832 |
| 10 | 4967 | | | | | | |
| 11 | 5112 | 5427 | 6118 | | | | |
| 12 | 5725 | 5997 | 6202 | | | | |
| 13 | 4826 | 4204 | 4348 | | | | |
| 14 | 4008 | 4503 | 4306 | | | | |
| 15 | 4335 | 5019 | 5022 | | | | |
| 16 | 4558 | 5142 | 5486 | | | | |
| 17 | 4295 | 5427 | 5949 | | | | |
| 18 | 4540 | | | | | | |
| 19 | 4622 | | | | | | |
| 20 | 4172 | | | | | | |
| 21 | 4581 | | | | | | |
| 22 | 5418 | | | | | | |
| 23 | | | | | | | |
| 24 | 4417 | | | | | | |
| 25 | 4172 | | | | | | |
| 26 | 4317 | | | | | | |
| 27 | 4540 | | | | | | |
| 28 | 4989 | | | | | | |
| 29 | 5070 | | | | | | |
| 30 | 4989 | | | | | | |

| REGRESSION ANALYSIS | | |
|---|---|---|
| Humak Jawa | Y = 4847 – 8.3 R | ... r^2 = .02 |
| Dheri Malhu – Kamra | Y = 5332 – 12.5 R | ... r^2 = .02 |
| – Godo | Y = 4962 + 28.6 R | ... r^2 = .06 |
| Dhuni Village Road | Y = 5894 – 191 R | ... r^2 = .42 |
| Doro Village Road | Y = 3910 + 458 R | ... r^2 = .58 |
| Trl Shrfbd – Shingle | Y = 7163 – 359.8 R | ... r^2 = .54 |
| – Brk Blst | Y = 12845 – 513.9 R | ... r^2 = .43 |


ROUGHNESS VS AGE – TRL–SHRFBD SHINGLE
Y(sh) = 7163 + 359R (r^2=.54)
ROUGHNESS MM/KM (Thousands)
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
0 1 2 3 4 5 6 7 8 9
AGE IN MONTHS
OBSERVATIONS
REGRESSION

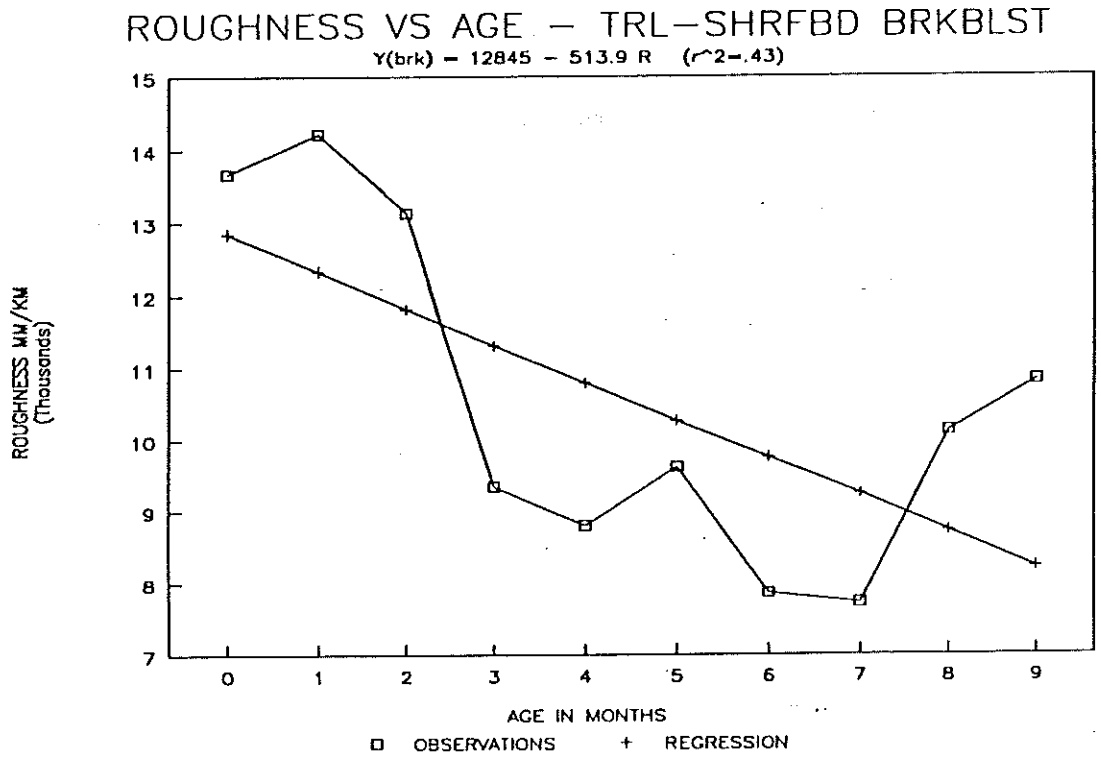

ROUGHNESS VS AGE – TRL–SHRFBD BRKBLST
Y(brk) = 12845 – 513.9 R (r^2=.43)
ROUGHNESS MM/KM (Thousands)
15
14
13
12
11
10
9
8
7
0 1 2 3 4 5 6 7 8 9
AGE IN MONTHS
OBSERVATIONS
REGRESSION

Fig. 11

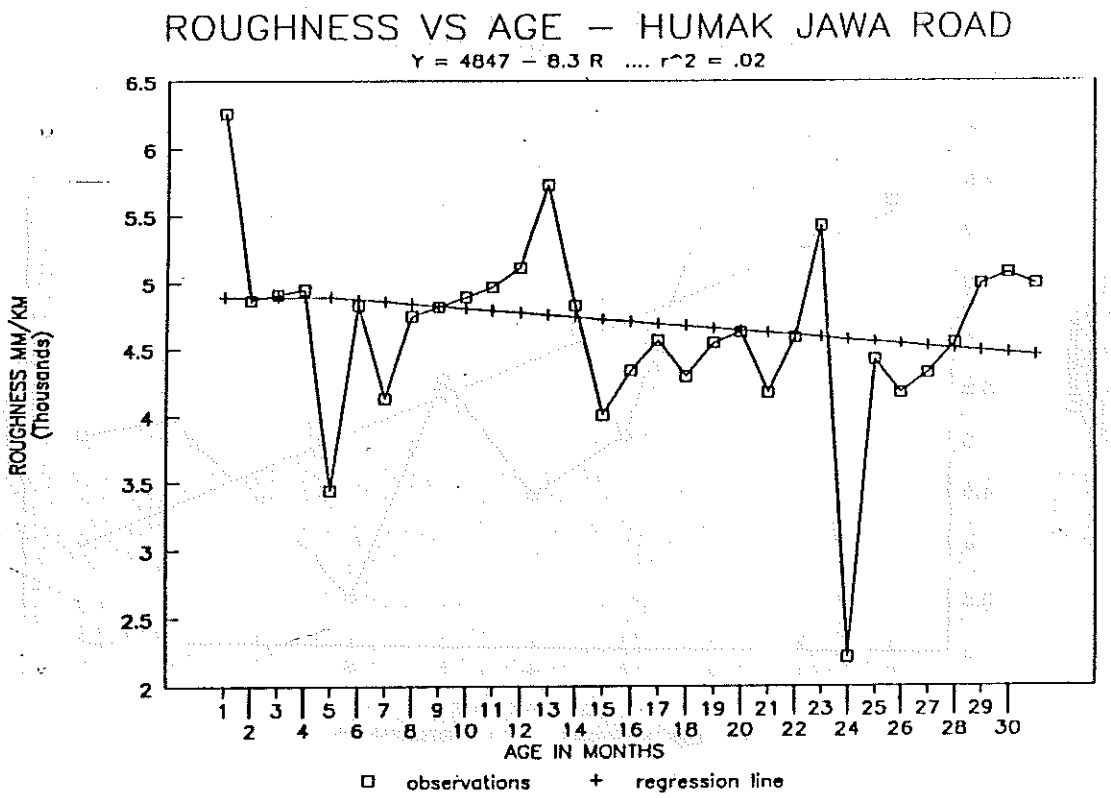
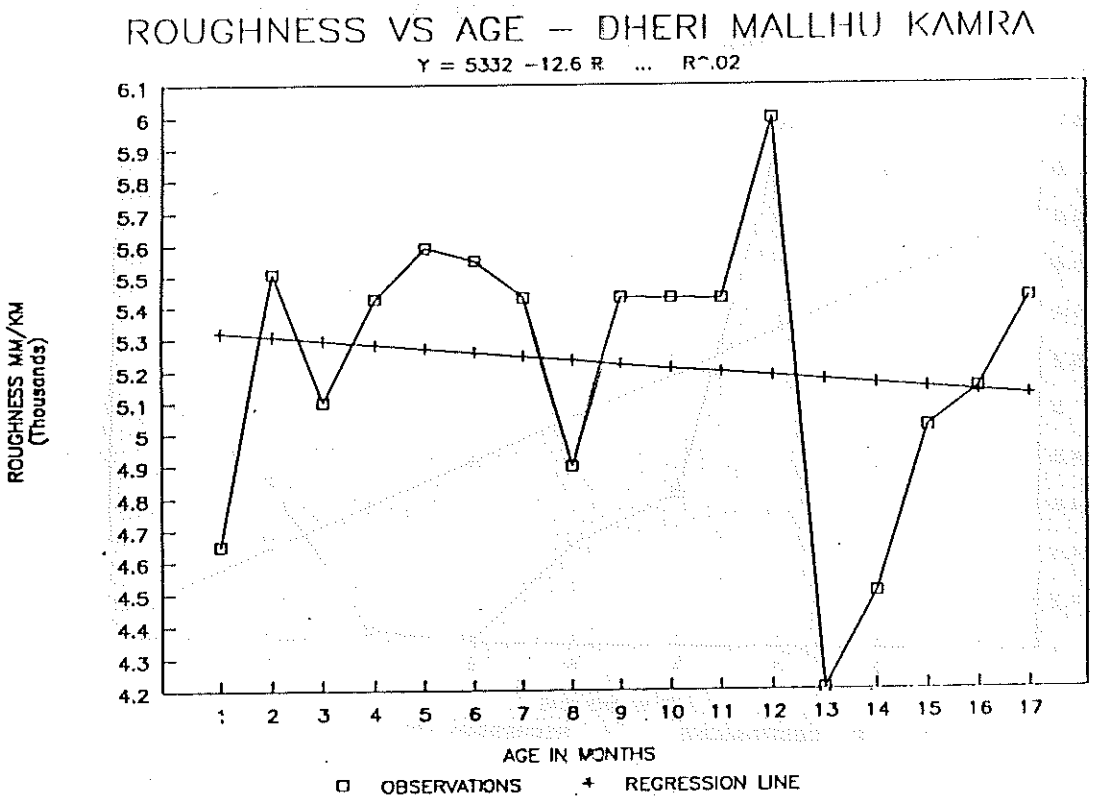

ROUGHNESS VS AGE — HUMAK JAWA ROAD
Y = 4847 − 8.3 R .... r^2 = .02
ROUGHNESS MM/KM (Thousands)
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
AGE IN MONTHS
observations
regression line

Fig. 12


ROUGHNESS VS AGE – DHERI MALLHU KAMRA
Y = 5332 -12.6 R ... R^.02
ROUGHNESS MM/KM (Thousands)
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
AGE IN MONTHS
OBSERVATIONS
REGRESSION LINE

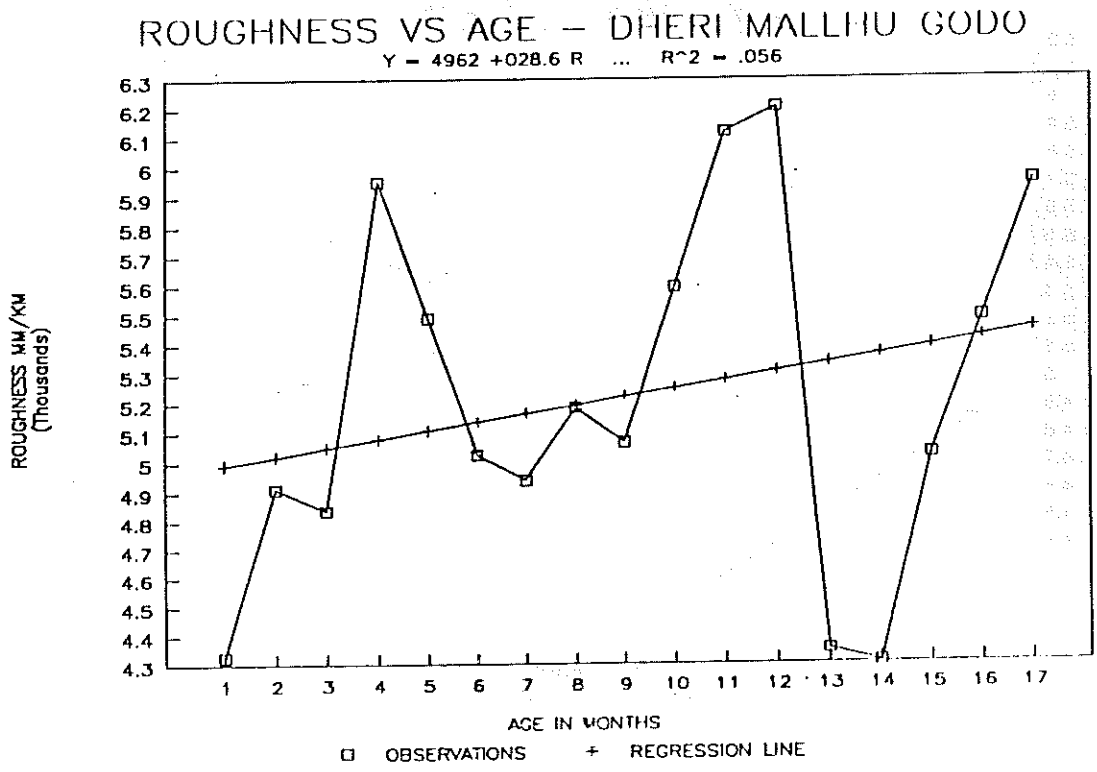
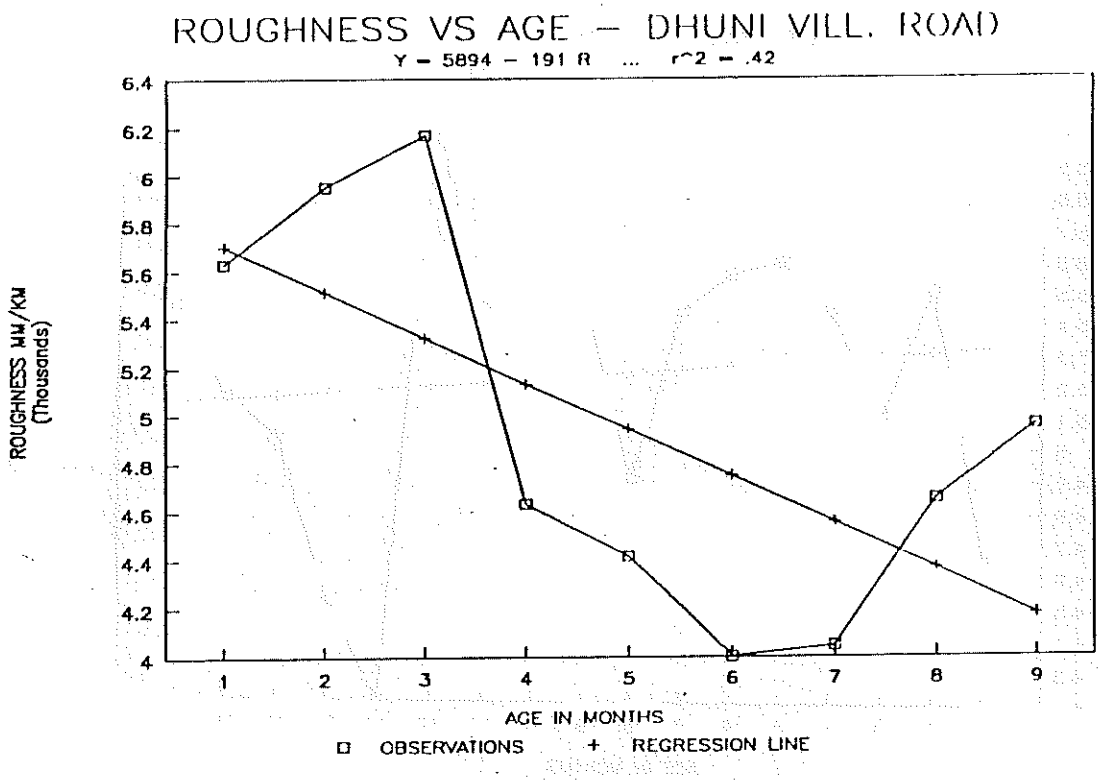

ROUGHNESS VS AGE – DHERI MALLHU GODO
Y = 4962 +028.6 R ... R^2 = .056
ROUGHNESS MM/KM (Thousands)
6.3
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
AGE IN MONTHS
OBSERVATIONS
REGRESSION LINE

Fig. 13


ROUGHNESS VS AGE – DHUNI VILL. ROAD
Y = 5894 – 191 R ... r^2 = .42
ROUGHNESS MM/KM (Thousands)
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
1
2
3
4
5
6
7
8
9
AGE IN MONTHS
OBSERVATIONS
REGRESSION LINE

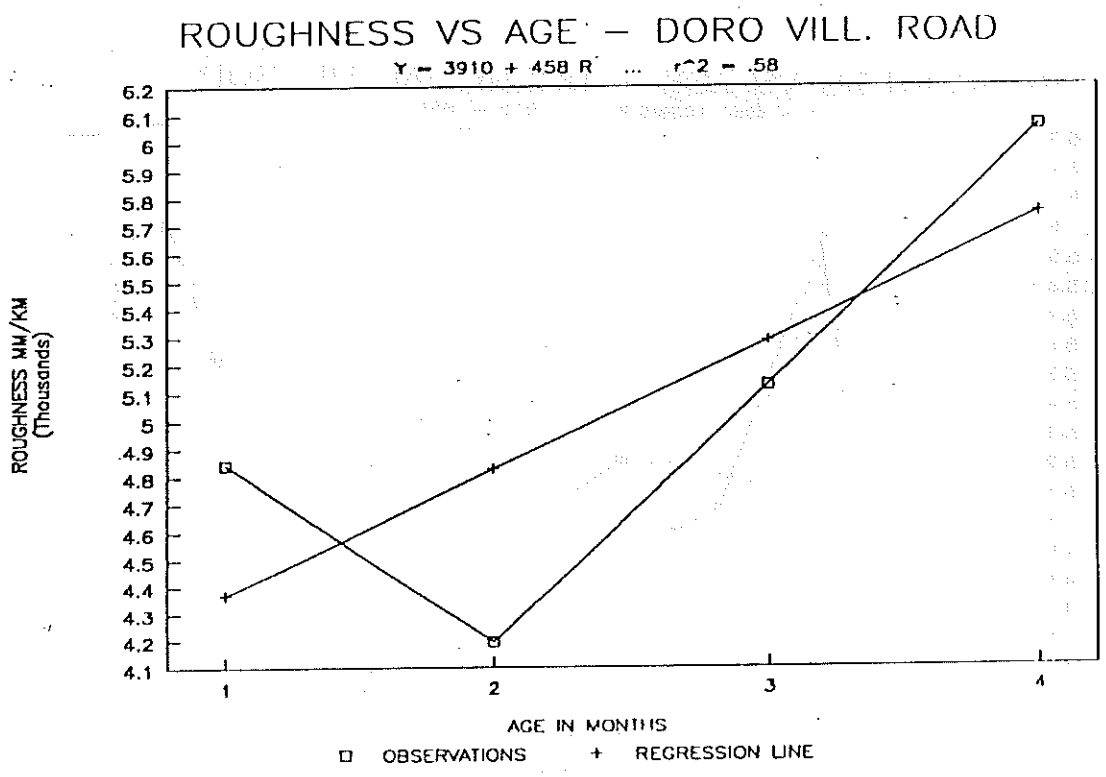

ROUGHNESS VS AGE – DORO VILL. ROAD
Y = 3910 + 458 R ... r^2 = .58
ROUGHNESS MM/KM (Thousands)
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
1
2
3
4
AGE IN MONTHS
OBSERVATIONS
REGRESSION LINE

Fig. 14

roughness. Compared to this, during rainy season, the surface gets moist with rain water which helps in binding the crushed aggregates with the khaka material which in the presence of moisture acts like a cementing material and result in much improved surface. As a result, the roughness measurements taken just after rainy days have shown lower roughness values.

**Subgrade Soils:**

Laboratory tests were conducted on the subgrade soil samples collected from the low cost roads. The samples were tested in the NTRC laboratory. Also the relative compaction of the subgrade was determined for every road after its completion. The Table-IV(2) provides the properties of the subgrade material and the relative compaction on the various low cost roads constructed by NTRC.

**CONCLUSIONS:**

Following conclusion could easily be drawn from the performance evaluation of these roads using the technique of roughness measurements.

i) The cost of the gravel road is nominal i.e about 1/8th to 1/10th of the cost of a compareable black-topped road having same width. As a result, construction of such type of roads can provide the benefits of road access to a large segment of population with little investment.

Table-IV (2)

## SUB-GRADE SOILS RESULTS FOR LOW COST ROADS

| Name of the Road | Type of Soil | Sieve Analysis | Field Moisture | Field Density (lbs/ft3) | Proctor Compaction Test O.M.C | Proctor Compaction Test Maximum Dry Density (lbs/ft) | Relative Compaction | Alterberg Limits L. L. | Alterberg Limits P. L | Alterberg Limits P. I | Specific Gravity | C.B.R % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Humak - Jawa | Redish Brown Sandy Soil | Well Graded Sand=60% Silt&Clay=40% | 5.4% | 110.6 | 8% | 124 | 89.2% | Non Plastic | | | 2.28 | 24 |
| 2. Village Dhuni | Brown Coloured Clayey Soil | Fine Sand=20% Silt&Clay=80% | 9.25% | 118.1 | 16% | 135 | 87.4% | 22% | 19.5% | 2.5% | 1.96 | 2.5 |
| 3. Village Dorro | Light Gray Sand Clayey Silt | Fine Sand=29% Silt&Clay=71% | 8.59% | 112.5 | 12% | 121 | 93% | 23% | 14.07% | 8.93% | 2.25 | 12 |
| 4. Dheri Malihu | Brown Sandy Silt & Clay | Well Graded Sand=22% Silt&Clay=78% | 12.6% | 115.9 | 12% | 123.4 | 93.9% | 34% | 19% | 15% | 2.25 | 14 |
| 5. Sheikh Qureshian | Light Brown Sandy Soil | Sand = 42% Silt&Clay=58% | 7.37% | 117.8 | 11.4% | 129.26 | 98.8% | 22% | Non Plastic Soil | | 2.15 | 7 |

ii) Although a number of different combinations of the materials could be used in the construction of this type of road, a mix made up of crush aggregate with sufficient amount of khaka to fill the voids properly proved to be best suited for constructing such type of low volume low cost roads.

iii) The percormance evaluation of these roads during rainy season revealed that rain fall does not damage these roads but rather makes them smoother. Roughness of these roads decreases with the passage of time.

iv) No special road construction machinary is required for construction of these types of roads.

v) No special technical know-how is required for the construction of such type of roads.

vi) These roads provide a fairly good all weather access for vehicular and pedestrian traffic.

Recommendations for Construction of Low Volume Roads:

On the basis of the performance evaluation of the roads, it could be concluded that for the development of rural roads in the country, following strategy should be adopted.

i) All village roads/farm-to-market roads, in the first instance must be constructed as gravel roads.

ii) Improvement to higher specification must be done in stages, strictly in accordance with the requirement of traffic/soil conditions.

Follwing design specifications are recommended to be adopted for the construction of rural/farm-to-market roads to be constructed under the local rural development programmes.

a) Gradation of existing track to a levelled surface.

b) Compaction of the existing track to at least 95% Modified AASHO density in case of new roads.

c) Placement of 6" thick crushed gravel 3/4" down-grade over the compacted track.

d) Spreading of sufficient amount of khaka over the crush material to fill the voids completely and give a smooth surface.

e) Construction of 1' wide compacted earthen shoulders on either side to retain the crushed gravel.

f) Provision of proper cross and longitudual drainage.

In case of water logged areas, construction of at least three feet high embankment duly compacted and placing of 2 inches sand cushion below the gravel would be desirable.

The above recommended design may be adopted on roads carrying traffic upto 50 vehicles/day. A single layer of bitumen may be applied on roads carrying traffic between 50 vehicles per day to 150 vehicles per day. For roads carrying traffic volume more than 150 vehicles/day, properly designed black topped roads may be adopted.

The minimum road width should be adopted as 10 feet. However, where traffic volume exceeds 50 vehicles/day and the traffic expected to use the facility includes heavy vehicles, 12 feet road width may be used.

roughness. Compared to this, during rainy season, the surface gets moist with rain water which helps in binding the crushed aggregates with the khaka material which in the presence of moisture acts like a cementing material and result in much improved surface. As a result, the roughness measurements taken just after rainy days have shown lower roughness values.

**Subgrade Soils:**

Laboratory tests were conducted on the subgrade soil samples collected from the low cost roads. The samples were tested in the NTRC laboratory. Also the relative compaction of the subgrade was determined for every road after its completion. The Annexure-III provides the properties of the subgrade material and the relative compaction on the various low cost roads constructed by NTRC.

**CONCLUSIONS:**

Following conclusion could easily be drawn from the performance evaluation of these roads using the technique of roughness measurements.

i) The cost of the gravel road is nominal i.e about 1/8th to 1/10th of the cost of a compareable black-topped road having same width. As a result, construction of such type of roads can provide the benefits of road access to a large segment of population with little

iii) The percormance evaluation of these roads during rainy season revealed that rain fall does not damage these roads but rather makes them smoother. Roughness of these roads decreases with the passage of time.

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**ANNEXURE-I**

## CONSTRUCTION OF LOW COST SAND BITUMEN ROADS

**Design Parameters:**

| | | | |
|---|---|---|---|
| a) | Type of soil | = | SP (Fine Sand) |
| b) | O.M.C | = | 11% |
| c) | Liquid limit | = | Nil |
| d) | Plastic limit | = | Nil |
| e) | Design C.B.R (4 days soaked) | = | 5.6% |
| f) | Axle load | = | Loads between 5000-10000 lbs per Axle. |
| g) | Nos. of vehicle per day | = | 100 |
| h) | Total pavement thickness | = | 13 inch |
| i) | Conversion factor into bitumen | = | 2 |
| j) | Pavement thickness of sand bitumen mix | = | 13/2 = 6.5 say 7" |
| k) | Bottom layer | = | 4" thick (Compacted) |
| l) | Top layer | = | 3" thick(Compacted) |

**Recommended Mix:**

1. **Bitumen Grade 60/70**

   a) Top surface 3 inch thick be tried with 5% bitumen & 95% sand by wt.

   b) Bottom layer 4 inch thick be tried with 5% bitumen, 5% crush (1/2" down) & 90% sand.

2. **Bitumen Grade 80/100**

a) Top layer 3" thick be tried with 5% bitumen, 1% cement 94% sand by wt.

b) Bottom layer 4" thick be tried with 5% bitumen, 5% crush (1/2" down) and 90% sand by wt.

3. **Cold Emulsion (Petro Limited Karachi)**

a) Top layer 3" be tried with 10% cold emulsion 1% cement and 89% sand by wt.

b) Bottom layer 4" thick be tried with 10% cold emulsion 5% crush (1/2" down) and 85% sand.

(Summary of mix design attached).

ANNEXURE-II

## NOTES ON THE FITTING AND OPERATION INTEGRATOR OF THE VEHICLE MOUNTED BUMP UNIT

The bump integrator (BI) unit is mounted directly over the differential housing on the platform of an estate car passenger car or landrover.

The flexible cord from the drum of the unit is connected on to the differential housing by a bracket which is fitted on to the differential housing. The cord is hooked on to this bracket when the integrator unit is in use via a 1" diameter hole cut in the floor of the vehicle. This enables the cord to be connected to the differential which ensuring that the cord is vertical and does not rub against the side of the hole. (The use of a rubber grommet is recommended).

The unit is wired up to a recording counter box containing 2 eletromagnetic digital counters which are operated alternately through a two-way toggle switch. The blue and brown colour-coded leads from the integrator unit are connected to the counter through the black cable containing blue and brown leads with spade connectors at one end and a push-on 3 pin plug connector at the other end. The fixed lead for the counter box connects to the 12V power supply, which is usually the vehicle battery. The brown wire from this lead should be connected to the positive terminal and the blue wire to the negative terminal.

**To prepare the integrator unit for use:**

Tension the cord by turning the drum of the integrator anti-clockwise 2 and half times and then winding two turns of the cord in the direction indicated by the arrow marked on the drum before it is drawn down and hooked on to the differential.

**WARNING:**

DO NOT turn the drum of the integrator clock-wise as it will either dislodge or break the internal spring.

**The Operation of the Unit:**

The vehicle is driven at a constant speed of 32 km/h (20 mph) in the gear most suited to maintaining this speed along the section of road to be measured. The counter, having been set to zero, is switched on as the vehicle enters the section and switched off at the end of the section.

The roughness value of road can be measured by the following formula:-

$$\text{Roughness Value (mm/km)} = \frac{\text{(Actual Count on (B.I. Counter)}}{\text{(Length of Section in Kms.)}} \times 28.4 + 1230$$

If it is required to measure consecutive sections of road the twin counters enable alternate readings to be taken during a continuous run. The 2-way switch enables one counter reading to be frozen, noted and then reset to zero while the

other counter is accumulating roughness on the section being traversed.

**On Compaction of the Measurements**: The integrator unit should be detensioned by unwinding the cord from the drum of the unit and allowing the spring to relax SLOWLY. If the drum is released by allowing it to spin violently the spring is liable to dislodge or break making the unit inoperative.

## BUMP INTEGRATOR UNIT -

## NOTES FOR THE OPERATOR AND DRIVER

1. Before tensioning the unit, check that the cord is correctly attached to the differential housing.

2. Tension the unit by rotating the drum 2 & half turns in an ANTI-CLOCK-WISE direction and wrapping the cord twice round the drum. Ensure that the cord is smoothly wrapped round the drum eliminating twists and overlaps.

3. After tensioning the unit, check that the cord will not touch the body of the car when the vehicle is in motion.

4. Plug in the counter box and switch on. The red light will indicate the power supply is on. Bounce the rear of the car to check that the counter is working.

5. Do not drive the car long distances with the integrator unit tensioned when measurements are not being taken. When it is necessary to travel short distances between measurments with the integrator unit tensioned, the vehicle should not be driven at more than 50 km/h.

6. It is recommended that five (5) repeat measurements should be made in each direction and the average of all the readings taken. If an unreasonably high or low reading is recorded an extra run should be made and this measurement substituted for the suspect reading.

**NOTE:** that the first set of measurements will probably be lower than the subsequent ones if the vehicle will not have warmed up and this set of readings should be replaced by an extra run. To avoid this happening it is strongly recommended that the vehicle should be run for about 5 kms immediately before measurements are made.

7. When the integrator unit is not in use, unclip the cord from the bracket on the differential and pull the cord through into the car. This is to avoid having the cord swinging lower under the car and becoming lodged in the pipes adjacent to the differential.

## REFERENCES


1. Sajjad Haider; "Trial of Sand Bitumen Mix Pavement on Naukot-Mithi Road (Sind", Sind Communications and Works Department.

2. Transportation Research Record 702 "Low Volume Roads" Second International Conference, Transportation Research Board, National Academy of Sciences.

3. M. Sadiq Swati, Paper on Rural Roads - Life Line of Economy.

4. Road Transport Research Final Report "Maintenance of Un-paved Roads in Developing Countries".

5. Road Research and Material Testing Institute; "Soil Stablized Low Cost Roads", Highway Department, Government of the Punjab.

6. Tajamal Hussain Qureshi; "Use of Crushed Brick Aggregate in Sub-Base Construction", Road Research Institute, Highway Department, Government of Punjab.

7. Zahuruddin; "Use of Nullah Bed Material as Base Course in Construction of Road Pavements", Communications and Works Department, NWFP.

8. Army Corps of Engineers; "Construction of Low Cost Sand Bitumen Roads", E-in-C branch, G.H.Q, Rawalpindi.

9. Army Corps of Engineers; "Use of Sand Cushion on Clayey Subgrade", E-in-C's branch, G.H.Q, Rawalpindi.