GOVERNMENT OF PAKISTAN
PLANNING COMMISSION
NATIONAL TRANSPORT RESEARCH CENTRE

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QUALITY CONTROL IN ROAD CONSTRUCTION
(Phase-II)

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EXECUTIVE SUMMARY

Excercising a proper quality control over for the construction of highways, roads and streets is the foremost responsibility of highway agencies throughout the world. Lack of such control results in serious deterioration of the pavement conditions in no time, giving rise to poor riding quality of the road network, functional and/or structural failures to the pavements and discomfort to the road users.

A study "Quality Control in Road Construction in Pakistan - Phase-I" based on several visual observations of 52 roads in the NWFP, Punjab provinces including the capital city concluded that with the exception of a very few cases, almost no quality control for the construction of highways is practiced in our road construction. The study pointed out that coupled with total absence of quality control, other variables e.g. under-design pavements and heavy axle loads, etc. contribute disproportionately towards the deterioration of the pavements. World Bank and Japan International Cooperation Agency (JICA) in their recent reports indicated that the main problem in the road construction industry in Pakistan is the lack of quality control practice.

National Transport Research Centre (NTRC) after establishing a full-scale materials testing laboratories at the Centre conducted the second phase of the same study analysing road sections at 21 different locations based on performing actual field and laboratory tests on the pavement materials. Various field and laboratory tests were carried out on the subgrade, base and surface course materials obtained from the locations in question. These tests were performed strictly in accordance with the standard specifications setforth in the American Society for Testing Materials (ASTM) Manuals. The brief summary of the results is as follow:

a) Almost 85 percent of the subgrade materials sampled from 13 different locations were found to be of low specification i.e. poor gradation and high percentage of finer materials.

b) At all locations the CBR value obtained were far below the minimum required as specified by the National Highway Authority.

c) Poor gradation and high percentage of finer materials indicates that the existing subgrade materials at these locations have a greater tendency to deform quite easily under dynamic load application causing distress to the pavement.

d) Results of the tests on base course materials shows that although the materials used at these places were sound in strength as indicated by the L.A. Abrasion test results, these were not graded properly. Poorly graded materials causes seggregation and ultimately end up with surface rutting corrugation, stripping and cracks on the pavements.

e) Surface courses materials when tested did not meet the minimum specified requirement of the standard specification. Low core density and high air voids and bitumen content were found almost at all locations that were included in the test samples. This shows that poor mix design formula were used without taking into account the factors for evaluating the mix properties which has a significant effect on the desired pavement life.

The preceding analysis has confirmed the finding of the visual observations made under earlier study i.e. Phase-I. It is obvious that any road pavement constructed with the above mentioned deficiencies is not likely to withstand the designed traffic load. To expect otherwise would be un-realistic.

This study is not intended as an indicement of any particular agencies. The main objective is to evaluate the quality of construction and its related problems of material inspection, in-place performance, sampling and testing and bring them into the notice of the concerned authority to enable them to take remedial measures.

I. INTRODUCTION

a) General:

The quality and durability of our highways, roads and streets has always been a major concern to the users. The quality of work can primarily be attained through the skills and experience of the individual engineers and the highway craftsman. When the proper combination of these skills is applied, satisfactory and sometimes outstanding, highway quality can be obtained.

The materials used and the quality control in the construction of highways are of prime interest to the highway engineers. This requires not only a thorough understanding of the properties of pavement materials which affect pavement stability and durability, but also need to put emphasis on the implementation of standards and specifications.

The quality of road construction in this country is generally substandard in many ways. Very little work has been done in the past in this area to determine the principle causes of the problems and recommend remedial measures. However as we are all aware today, there are a number of changing factors which make this highway system subject to breakdown. Some of these factors are the diminishing numbers of experienced personnel, the increasing speed of cosntruction, and the volume of the materials that must be handled. Also engineering activities and often duties that are time demanding have increased to the extent that experienced engineers now delegate many activities to persons whose skills and experience are often inadequate for on-the-spot decisions.

The overall management of the highway industry can be improved by developing and implementing a modern Quality Assurance (QA) programme, which is, in fact, using new management techniques to achieve standards of higher quality.

A modern quality assurance programme could be defined as the overall process whereby the joint efforts of highway industry, provincial and federal agencies are combined to develop or establish performance - relating quality criteria, excercise systematic process controls, establish attainable specification criteria that recognize product variability, and develop unbiased sampling and testing procedures. To put this in the most simplistic terms, modern quality assurance for highway construction is a management tool or process for assuring product acceptance, product sampling and testing and systematic feedback and evaluation. Quality assurance is basically a management tool that represents management concern for quality and the efforts to assure quality. The recommended quality assurance programme is an effort toward better management of our highway projects, and better - managed projects will ultimately result in facilities of higher quality.

b) <u>Brief Summary of Phase-I Study:</u>

The Study "Quality Control in Road Construction in Pakistan" was approved in early 1985. The main objective of the study was to evaluate the quality of road construction in Pakistan and to determine the basic cause of the problems and suggest remedial measures. The scope of the study included in the proposal covered complete examination of the whole problem encountered from planning, design and construction aspects; observation and noting of deficiencies and discrepancies, if any; finding out difficulties and problems in adopting proper standards and specifications; and suggesting measures to overcome such problems.

An intensive data collection was made by filling out detailed questionnaires based on the visual observations at various stages of road construction namely sub-grade, sub-base, base, surface and drainage. The supervision system followed by the executing agencies was also examined. A total number of 52 roads were visually observed at various stages of construction. The conclusion was that almost no quality control is being excercised in our road construction which results in poor quality of road network in this country and deterioration of the system that may cause functional and/or structural failures to the network[(1)]. The report emphasised on strict implementation of quality control during construction that will not only improve the quality of the pavement but will also have a significant reduction in road user cost.

The study did not involve field and/or laboratory testing of the road materials being used and was based on surprise inspections of the on-going construction site. The Phase-I study was already completed in May, 1990.

c) Objective of Phase-II Study:

The Phase-II of the Study is intended to evaluate the quality control of highway and road construction by actual field and laboratory tests which were carried out on the roads selected from the list of roads considered in Phase-I study. The objective is to elaborate the quality of construction and its related problems of material inspection, in-place performance, sampling and testing and bringing them to the notice of the concerned authorities to enable them to take remedial measures.

d) Scope of The Phase-II Study:

The study covered 18 roads sections and involved in the following steps:

- Survey of the roads selected in Phase-I Study regarding the inforamtion on construction progress.
- A thorough review of the construction specifications to find the required standards of field and laboratory tests of the material.

- Pavement Core under wheel track were drilled and laboratory test samples were collected.
- Field and laboratory tests were done in order to check the conformity of the construction materials.
- Analyses of the field and laboratory test data.

e) Sample Size Considered in Phase-II Study:

The sample size consisted of 18 road sections to which three road sections were added on the request of Chief Secretary, Government of NWFP, increasing the sample size to 21. The list of roads appears in table 1 at the end.

II. TESTING PROCEDURES

a) Field Sampling:

Samples of road materials of various layers i.e. of subgrade, sub-base, base and surface courses were obtained from the roads that were included in the sample size and mentioned in Table 1. Where the roads were already surfaced, an electrically driven coring rig with a graphite drill bit was used to cut a core sample and collect other materials.

The samples once obtained were secured in sample containers and plastic bags which allowed maintenance original moisture condition for laboratory tests. The pavement material samples were first processed before carrying out any tests on them in accordance with the standards setforth in the manuals of the American Society for Testing Materials[3,4]. All soil samples were prepared for testing by passing them through a No.4 mesh sieve after sufficient air-dry[6].

b) Field Testing:

Series of field density tests were conducted in accordance with the standard methods at selected locations on the sample roads which at the time of test were not paved or the surface course was not laid down. Simultaneously depth of various layers were also measured to see if the materials during the construction were placed in accordnace with the specification prepared for that very project.

An average of three field density tests using sand replacement methods were carried out at each location.

c) Laboratory Testing:

The following standard tests for the control of quality based on the methods described in ASTM Standard Specifications[3,4] were conducted on the subgrade, base, and surface course materials sampled from selected roads in Table 1.

i) Determination of moisture content of soil as per ASTM D2216-80 of Vol. 04.08 (Fig. 1).

ii) Sieve analyses of fine and course aggregates as per ASTM C136-84 of Vol. 04.02 and D1140-54 of Vol. 04.08 (Fig. 2).

iii) Liquid limit, plastic limit and plasticity index of soils as per ASTM D4318-84 of Vol. 04.08 (Fig. 3).

iv) Moisture-density relations of soils and soil-aggregate as per ASTM D698-78 of Vol. 04.08 (Fig. 4).

v) California Bearing Ratio of laboratory compacted soils as per ASTM D1883-87 of Vol. 04.08 (Fig. 5).

vi) Resistance to degradation of course aggregates by abrasion and impact in the Los Angeles Machine as per ASTM C535-89 of Vol. 04.03 (Fig. 6).

vii) Bulk specific gravity and density determination of compacted bituminous mixture using situated surface dry specimens as per ASTM D2726-89 of Vol. 04.03 Fig. 7).

viii) Quantitative extraction of bitumen from bituminous paving mixtures as per ASTM D2172-88 of Vol. 04.03 (Fig. 8).

III. ANALYSIS OF TEST RESULTS

a) Test Results

Test results shown in Table 2 were obtained after conducting various property tests on the road materials obtained from subgrade. The following tests were conducted on the subgrade soil:

- Gradation
- Atterberg Limits
- Specific Gravity
- Moisture-Density Relationship
- Laboratory CBR (@ 4 days soak)
- Field Density.

The tests that were conducted in base and surface course materials are listed below. The results of tests are presented in Table 3 to 4 respectively.

- Gradation
- Los Angeles Abrasion Test.
- Moisture-Density Relationship (Modified)
- Core Density
- Air Voids
- Extraction of Bitumen Content

b) Discussion on Test Results

Test results on subgrade soil from eleven different locations does show variability in the engineering properties. Except at three locations i.e. Bajrana-Chakri, Dehri-Paryal and Jatta Hathyal-Nakrali, all other soil samples show that particles finer than number 200 sieve lies between 80-96 percent which indicates that soil particle have a tendency to deform easily with small amount of water as soils with particles passing # 200 sieve on the heavier side must be either silty clay or clayey silt.

Plasticity index value of 20 at Keller Syedan-Dangalli shows high plastic soil that is considered to be an expansive soil which may cause damage to the pavement as it has the tendency to swell. This type of weaker soil with a CBR value of 4.5 needs to be treated before laying any structure on it. This type of soil with high PI can also be called as sodium-saturated clay. The factor that affect plasticity index is the amount or nature of the exchangeable cation. In this case sodium-saturated clay can be treated with either lime or cement to exchange sodium ions by calcium and that will make the soil more workable and friable. The percent compaction of the first six inches layers of the subgrade at eight out of eleven locations were found to be in accordance with the minimum specified by the standards. However density at three locations i.e. Bajrani-Chakri, Jatta Hathyal-Nakrali and Beval-Choha-Khalsa does not meet the requirements of the specifications.

Poorly graded soil normally does not behave very well when CBR test is conducted on them. Except Bajrana-Chakri and Dehri-Paryal, the materials obtained from all other location have CBR below 10, whereas National Highway Authority in their recent publication (5) specify that the subgrade material when compacted shall attain a laboratory 4-day soaked CBR not less than 20%.

None of the test result show a CBR value which is greater than 20% as specified.

Gradation test conducted on base course materials reveals that poorly graded materials were used at all locations (Figs. 9&10). The gradation obtained does not meet the requirement of the specifications. However base course materials when subjected to Los Angeles Abrasion tests indicate that the materials used do meet the specifications required at all locations except at Quaid-e-Azam Avenue where the loss comes to be more than 40% i.e. the minimum specified losses.

Surface course materials when tested found to be totally out of specification (Fig. 11). Core density at locations except at Faizabad-Dhokri Chowk and Kashmir Highway are less than the minimum specified. At almost all locations air void and bitumen content in the asphaltic mixture are much more than the maximum required values. High bitumen content causes the problem of flow, surface ruts and ultimately functional and/or structural failures (Figs. 12&13).

More air void in the asphaltic concrete mixture will give rise to seggregation due to the vibrating effect caused by the vehicle in motion. This in turn will create depression at places with the appearance of surface cracks.

IV. CONCLUSION

It is generally believed that no quality control in road construction is excercised in the country. The Phase-I of this Study (NTRC-133) supported this belief and confirmed lack of quality control earlier reported by World Bank and Japan International Cooperation Agency (JICA).

The Phase-I of the Study also investigated availability and performance of material testing laboratories at the construction site and found that maintaining a highway materials testing laboratory at the site is very uncommon. It was observed that almost in all cases no laboratory personnel were present at site at the time of construction despite the fact that all the government agencies involved in road construction have full scale laboratory staff. The overall performance in this respect was found to be very poor.

This report covering Phase-II of the Study, presents the results of the field and laboratory tests conducted on materials obtained from 18 road sections. Details are shown in Tables 2, 3 & 4 respectively at the end. It is evident from these tables, that results do not comply with the requirements. Materials from each layer at equal interval need to be controlled through different specified tests that should be carried out by an experienced technician at various stages of construction. Materials that do not meet the specifications should be rejected. Special consideration should be given to the subgrade soil as this is the most important part of the whole set up. High plastic clayey soil should be treated with either lime or cement or with any other pozzolm in order to bring down the plasticity index to a lower limit where the soil can behave as a plastic material instead of elastic material.

It is apparent from the results that no proper asphaltic concrete has been used in almost all cases. High bitumen content, over heating and improper gradation deteriorates the whole structure of the roadway. Properly designed mix formula need to be evaluated for the mix properties as well that should include determination of the following:

i) Resilient Modulus

ii) Diametral Modulus.

It is quite evident that improving the quality of road construction through laboratory control is not very difficult now a days. The NTRC and many other agencies as well as private sector maintains full scale laboratory and can be utilized in a better way to build a better road network.

V. FUTURE RESEARCH AND STUDIES

The data generated by this study and a research carried out by B.L. Swami, et.al (2), indicate that properties of the materials used for the construction of roads and highways do vary from place to place and it is difficult to ascertain the behaviour of the pavement materials under variable conditions. Thus we see the need for added research studies where at least one major highway from each province should be selected and materials from more than ten places from each test location should be obtained and laboratory tests carried out on them in order to investigate the possible variations in the properties of the pavement materials, their factors and to develop better procedures for material characterization based on statistical analysis.

REFERENCES

1. Tahir Sharif, "Quality Control in Road Construction, Phase-I" National Transport Research Centre Publication No.133, May 1990.

2. B.L. Swami, Dr. A.K. Gupta, Dr. S.S.Jain, "Characterization of Pavement Component Materials Incorporation Variability on Selected National Highways", Indian Highways, Vol.19 No.3, March 1991.

3. "Road & Paving Materials; Pavement Management Technologies", Annual Book of ASTM Standards, Volume 4.03.

4. "Soil and Rock; Dimension Store; Geosynthetics", Annual Book of ASTM Standards, Volume 4.08.

5. "General Specifications", National Highway Authority, March,1991.

6. Yoder and Witzak, "Material Characterization", Principle of Pavement Design.

Table 1

List of the Roads Sampled & Tested for Phase-II Study

A) Punjab Provincial Roads

1. Bajrana to Chukri
2. Dheri to Paryal
3. 17-Miles to Angori
4. Faizabad to Dhokri Chowk
5. Kaller Syedan to Dhangali
6. Beval to Chooha Khalisa
7. Dhamial to Kalyal
8. Jhattha hathyal to Nakerali
9. Dhokri Chowk to Islamabad Turning

B) Capital Development Authority(CDA) Roads:

10. Sector G-11 Road
11. Sector H-8 Road
12. Quaid-e-Azam Avenue
13. Kashmir Highway Peshawar More to Zeropoint
14. VR-I, VR-II roads in Sector H-8

C) Abbottabad Development Authority (ADA) Roads:

15. Piffer Chowk to Supply Bazar
16. Jeb Bridge to Supply Bazar
17. Shahrah-e-Karakurram

D) NWFP Provincial Roads:

18. Havelian to Kalabagh
19*. Behrain - Kalam Road
20*. Peshawar - Charsada Road
21*. Jehangira - Swabi Road

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* These roads were also included in the study and analysed for quality control check on the request of Chief Secretary, Government of NWFP.

Table 2

Physical Properties of Subgrade Soil

Sl. No.	Sampling Location	Gradation - % smaller than No.4	No.10	No.40	No.200	Test Constant LL (%)	PI (%)	Spg	Max dry density (pcf)	Opt mos. %	Field Densty. pcf	% compaction	CBR at 14 days soak. %
1.	Bajrana to Chakri	100	100	98	47	27	0	2.54	123	12.2	102	82.9	10.0
2.	Dheri to Paryal	100	99	97	41	0	0	2.76	119	11.7	117	98.3	16.0
3.	Kallar Syedan to Dangalli.	100	100	99	95	35	20	2.41	111	17.3	105	94.5	4.5
4.	Jatta Hathyal to Nakrali.	75	65	57	48	35	13	2.06	135	8.4	124	91.8	6.5
5.	Dhamial to Kalyal.	100	100	99	96	29	11	2.40	112	14.5	112	100.0	4.5
6.	Beval to Choha Khalsa.	100	100	98	92	32	13	2.07	113	14.0	105	92.9	4.6
7.	Shahr-e-Karakurm	100	98	90	80	38	15	2.45	122	17.0	117	95.9	7.5
8.	Sector G-11 Road.	100	97	94	84	25	0	2.10	119.5	11.5	114	95.4	6.5
9.	Main Sector H-8 Rd.	100	99	92	87	22	3	2.04	116.3	16.3	113	97.2	6.0
10.	Quaid-e-Azam Ave.	100	98	96	90	32	12	2.10	112.0	16.0	107	95.5	6.5
11.	VR-I/VR-II Road H-8	100	97	95	93	33	9	2.08	111.0	18.0	106	95.5	6.0
12.	Jehangira-Swabi Road	90	83	73	58	27	10	2.01	123.0	10.2	-	-	7.0
13.	Peshawar-Charsada Rd.	100	61	50	39	22	NP	2.54	129.0	8.6	-	-	7.5

Table 3

Physical Properties of Base Course Materials

S.No.	Sampling Location	Gradation 3"	2"	1-1/2"	3/4"	3/8"	L.A.Abrasion % Loss	Max. Dry Density(pcf)	Opt. Moisture Content (%)
1.	Rajrana to Chakri	100	61	43	39	34	34	125.0	5.9
2.	Dheri to Faryal	95	93	61	37	18	37	139.0	7.5
3.	Kallar Syedan to Dangalli.	100	70	46	29	21	36	141.0	6.7
4.	Jatta Hathyal to Nakrali.	100	89	69	50	46	27	160.0	7.7
5.	Shahr-e-Karakurm	100	75	54	29	12	23	142.0	6.5
6.	Sector G-11 Road.	100	95	85	63	45	26	141.5	6.0
7.	Main Sector H-8 Rd.	100	75	55	31	15	25	142.0	6.5
8.	Quaid-e-Azam Ave.	100	97	86	60	47	27	146.5	5.3
9.	VR-I/VR-II Road H-8	100	75	54	29	12	29	140.0	6.8
10.	Jehangira-Swabi Road	100	75	35	0	0	33	143.5	5.4
11.	Peshawar-Charsada Rd.	100	100	85	56	27	25	137.0	8.2

Table 4

Physical Properties Surface Course Materials

S.No.	Sampling Location	Specific Gravity	Core Density (pcf)	Air Voids(%)	% of Bitumen
1.	17 Mile to Angori	2.15	134.4	10.3	12.6
2.	Faizabad to Dhokri Chowk.	2.31	144.3	3.7	14.8
3.	Dhokri Chowk to Islamabad Turn.	2.16	135.1	9.7	14.5
4.	Kashmir Highway	2.36	147.3	2.0	14.3
5.	Havellian to Kalabagh	2.13	133.2	11.0	5.3
6.	Supply Bazar to Piffer Chowk	2.17	135.5	9.5	8.9
7.	Piffer Chowk to Jeb Bridge	2.18	136.4	8.8	9.3
8.	Peshawar-Charsada Road	1.68	105.0	30.0	8.1
9.	Behrain-Kalam Road	2.09	134.3	13.0	6.8

Fig. 1: Determination of Moisture Content

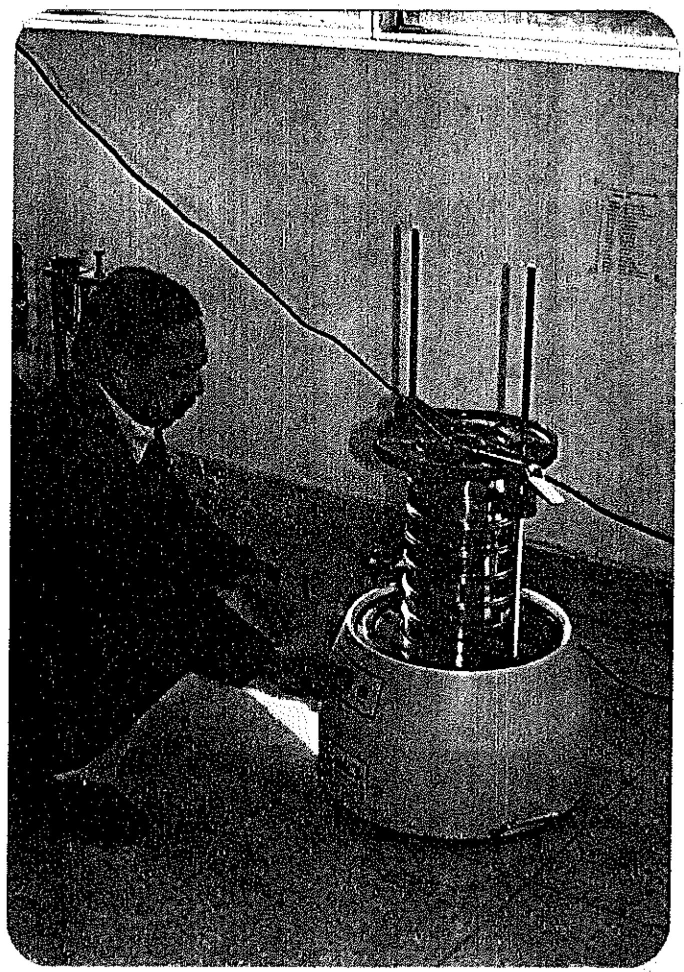


Fig. 2: Sieve Analysis (Gradation Test)

Fig. 3: Atterberg Limits Test

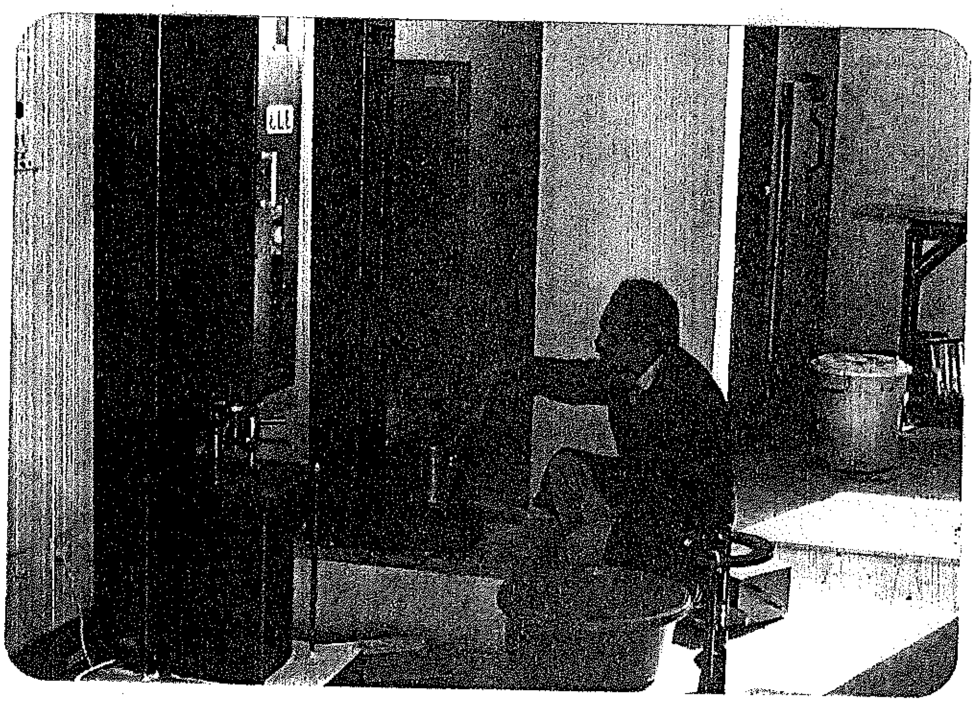


Fig. 4: Determination of Moisture-Density Relation

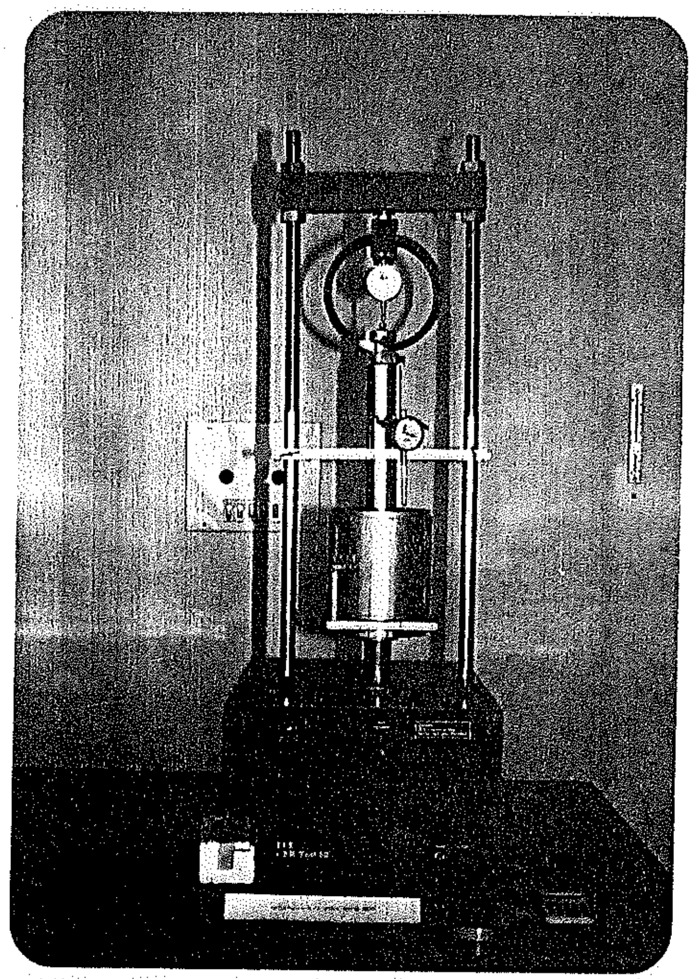


Fig.5: Determination of CBR Value of Laboratory Compacted Soils.

Fig. 6: Determination of Resistance to Degradation

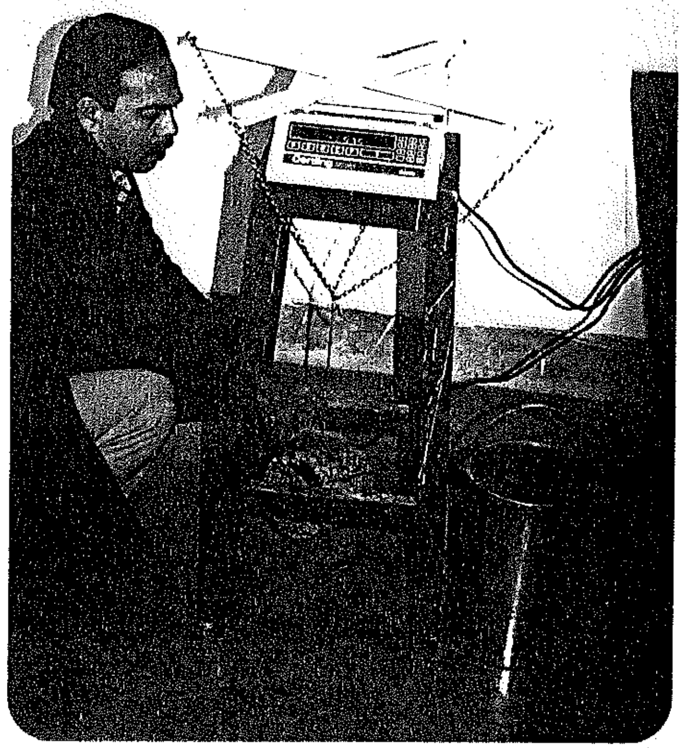


Fig. 7: Bulk Specific Gravity and Density Determination of Compacted Bituminous Mixture.

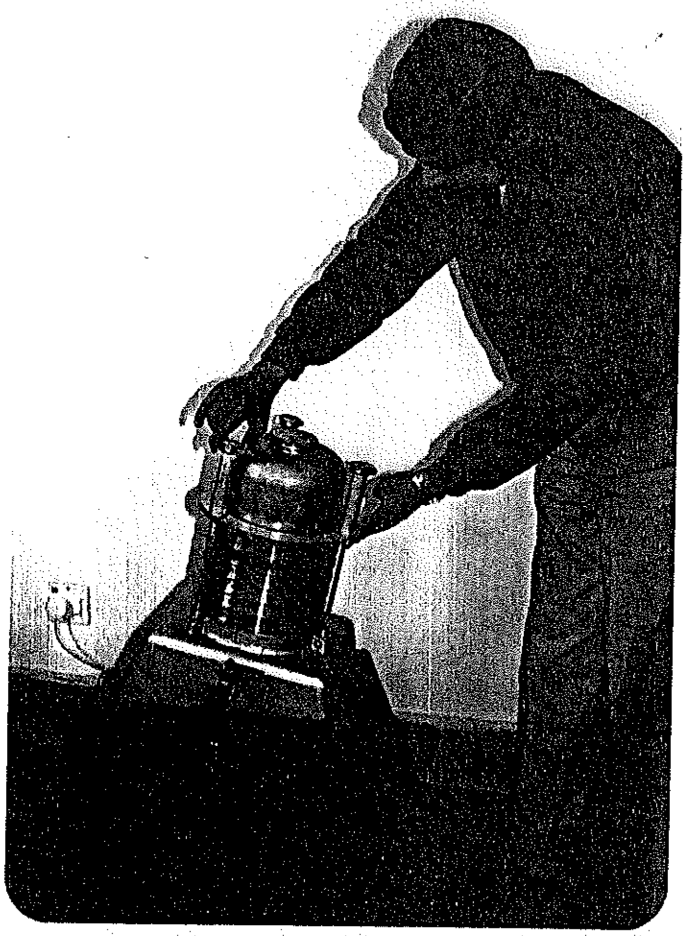


Fig. 8: Extraction and Gradation of Asphalt Mix

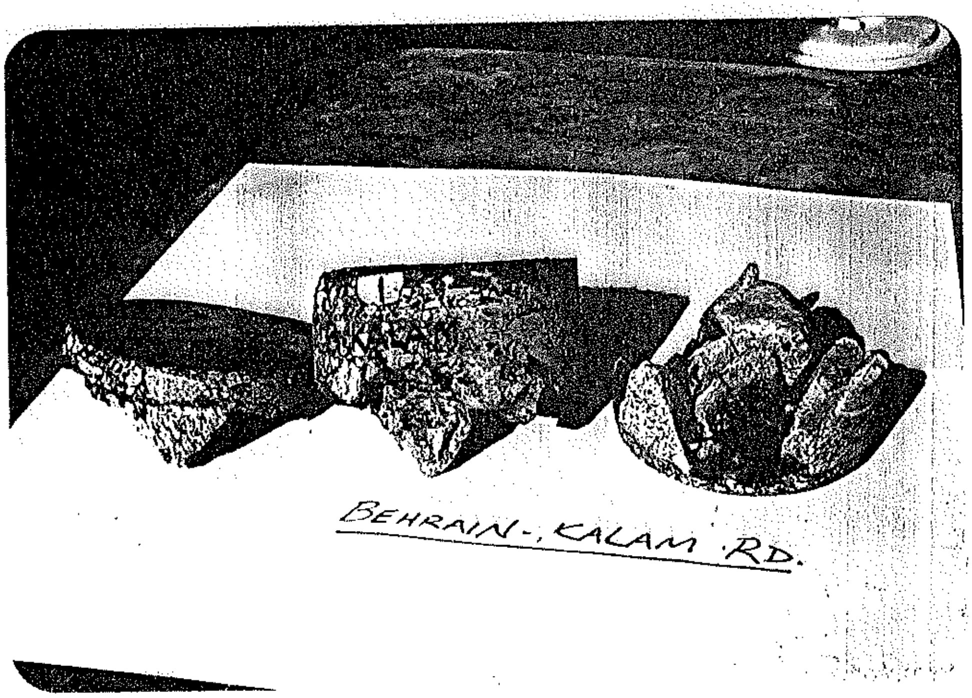
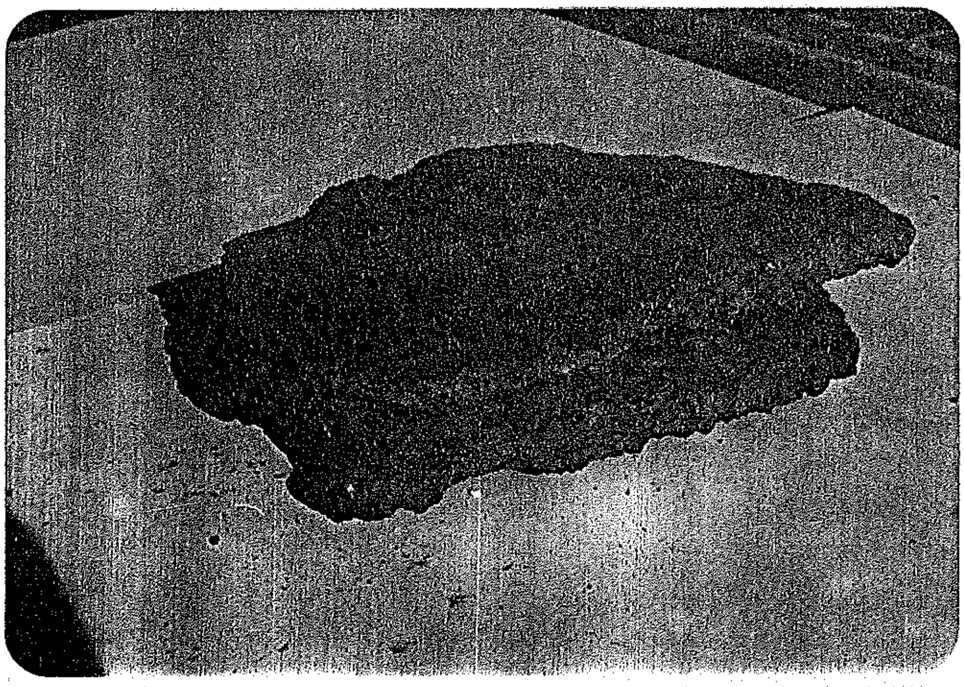


Fig. 9&10: Over-sized Base Course Material

Fig. 11: Lack of Binder Between Base and Surface Course.



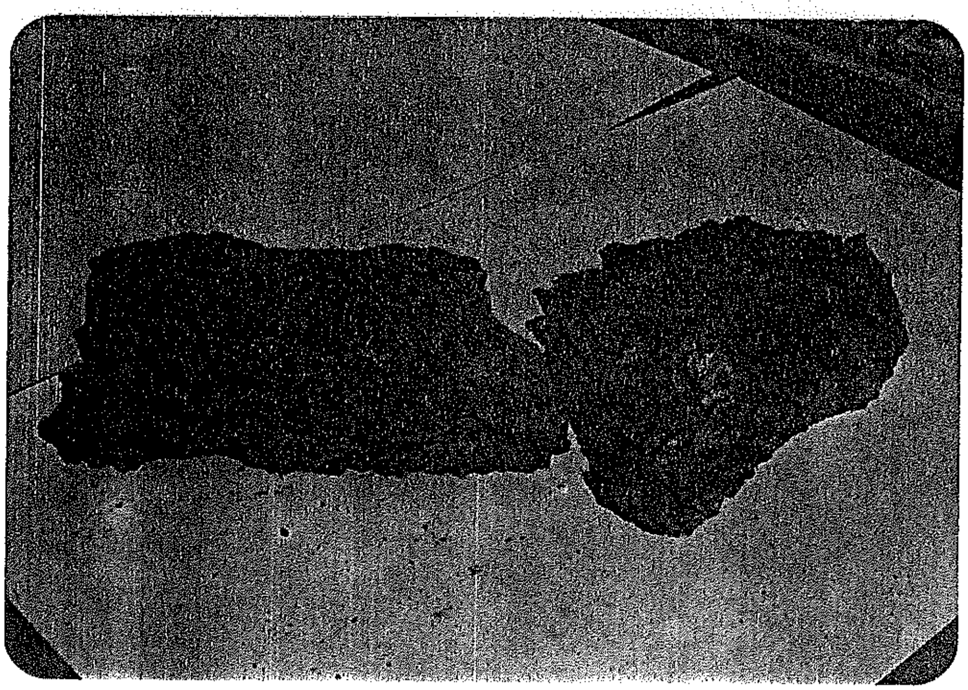


Fig. 12&13: Use of Non-Standard Materials at Jehangira-Swabi Road.