# QUALITY CONTROL OF ROADS CONSTRUCTION IN BANGLADESH

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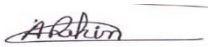
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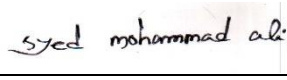
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# DECLARATION

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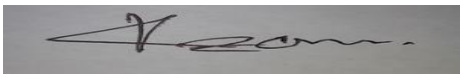
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*to*

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# ABSTRACT

Quality Control of Roads Construction in Bangladesh, is a prime performance issue for any organization. The Roads and Highways Department, RHD and The Local Government Engineering Department, LGED Bangladesh is facing problems with quality. The citizens of the country are not satisfied with the current road network of the country. But RHD and LGED have quality Assurance plan and the road network is constructed following it. Despite following the standards RHD and LGED is having quality problems. It is seen that quality problems are not mainly arising from construction but from the lack of proper support activities like management, human resource development, planning, value adding procurement and audit/review. It is rather a total quality issue. Quality Management is a new concept and widely used in private sector. The concept is not familiar in public sector but it is the solution that situation demands now in public sector. So, the problems of RHD and LGED can be overcome by imparting Quality Management.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background and Motivation

Quality is how well the design matches the original specifications. It is the ability of a product or service to satisfy stated or implied needs. It should be achieved by conformingto established requirements within an organization. From Roads and Highways Department, RHD and Local Government of Engineering Department, LGED perspective quality is to construct sustainable, serviceable and safe national highway, regional highway and zila road for the road users. Quality in road construction and Quality Control can be incorporated in any phase of the procurement cycle for road construction using public money. Quality Control of Roads construction of Bangladesh issues starts from the defining the need extends to design, sourcing, construction, contract management and maintenance.

## 1.2 Research Objectives and Overview

The research objectives are to know

1. Total Quality Management (TQM) in road construction.
2. Evaluation of the Procurement Process for Quality Control.
3. Major Government Department Responsible for Quality Control of Road Network Construction in Bangladesh.
4. Soil compaction process by roller for Quality Control.
5. The Process of Measuring Field CBR value for bearing capacity and level of compaction determination of road subgrade against standard for Quality Control.

## 1.3 Organization of the thesis

The organization of the thesis is the time constrain; the time available to conduct the research not enough. The Data used are the internal data of Roads and Highway Department (RHD) and Local Government of Engineering Department (LGED) of the Government of Bangladesh and no other data source is available.

## Chapter 1: Introduction and Objective

Bangladesh has characteristics of high population density, high productivity of land, intensive cultivation, small-scale farming and marketing of its petty production and diversified employment of rural under-employed in farms and non-farm activities. All these together generate intensive trading of goods and services in the rural areas and a high level of demand for movement of goods and people, which results the level of traffic in the rural areas of Bangladesh comparatively high.

## Chapter 2: Literature Review

The Roads and Highways Department (RHD) and the Local Government Engineering Department (LGED) share responsibilities for the entire road network of the country. While the former is to manage the National, Regional and zila Road, the latter is to focus on the Upazila Road, Union Road and Village Road. Quality control is an essential part of any production process and Quality control in road and highway construction is no exception. Due to significant increases in traffic intensities in recent times, the need for quality control on these specifications has increased considerably

## Chapter 3: Quality Control Road in RHD and LGED

Quality control is an essential part of any production process and Quality control in road and highway construction is no exception. Due to significant increases in traffic intensities in recent times, the need for quality control on these specifications has increased considerably. By improving the level of service of roads and highways results in considerable savings in operating costs of vehicles and in favorable road user reactions and opinions of the public.

## Chapter 4: Challenges and Scope for Improvement

The audit and review system is weak in RHD and LGED. For quality in construction third party auditis important. BRRL was nominated by CE as the quality control auditor of RHD. But no fund is available for quality control audit. Without the third party audit quality in construction cannot be imparted. Review is necessary for future improvement. Monitoring circle of Planning and Maintenance wing has evaluation division to evaluate the works executed. But their activity is one off just after the project. Long term evaluation is necessary. Mainly the quality control field labs are now not sufficient to carry out field tests. There are some tests which are easy to conduct and frequently conducted these tests facilities should be established in the field divisions. Complex tests should be performed at the field labs.

## Chapter 5: Conclusions and Future Work.

Some problems for quality degradation are identified in the study. For some problem the suggestions are given. But there are some problems which need further study as these issues have wide domain. But if the suggestion of the study is implemented properly the Roads & Highway Department and Local Government of Engineering Department will be able to provide safe, service able and cost effective road for the nation. The proper use of public money in road construction will help Bangladesh to become a medium income country of the world.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Past literature exactly about the selected topic is not available. Before going detail on the topic the available literatures related to quality. The evaluation and improvements of quality control is also discussed in this chapter. Idea about the latest quality control philosophy like Total Quality Management is also given here. At last an overview of Roads and Highways Department and Local Government of Engineering Department is given.

## 2.2 Literature Review Overview

Quality control in road and highway construction used for obtaining an improved and uniform standard of road construction. Quality control of construction materials and the product is an essential requirement.

Quality control is an essential part of any production process and Quality control in road and highway construction is no exception. Due to significant increases in traffic intensities in recent times, the need for quality control on these specifications has increased considerably. By improving the level of service of roads and highways results in considerable savings in operating costs of vehicles and in favorable road user reactions and opinions of the public.

## 2.3 Content

Basically, road construction specifications and estimates provide basis for effective quality control. In addition, organizations set up quality management systems, adequately trained staff and good monitoring system for implementing quality control.

A number of lab and field tests are conducted on the materials used and the finished product on road construction projects. A few important ones are briefly explained below. The lab tests should be carried out by approved/certified labs and the field test should be conducted by the responsible supervising staff by the client or client's representatives. The frequency and extent of tests should be adhered to the standard criteria.

## 2.4 Total Quality Management, TQM

Total Quality Management, TQM is a new concept. It is being widely used in private sector organizations. Public sector organizations have not yet considered it in their operations. Total Quality Management, TQM is to impart quality in every value adding point in an organization. For imparting TQM in RHD and LGED the main causes of problem are identified and showed in cause effect diagram below

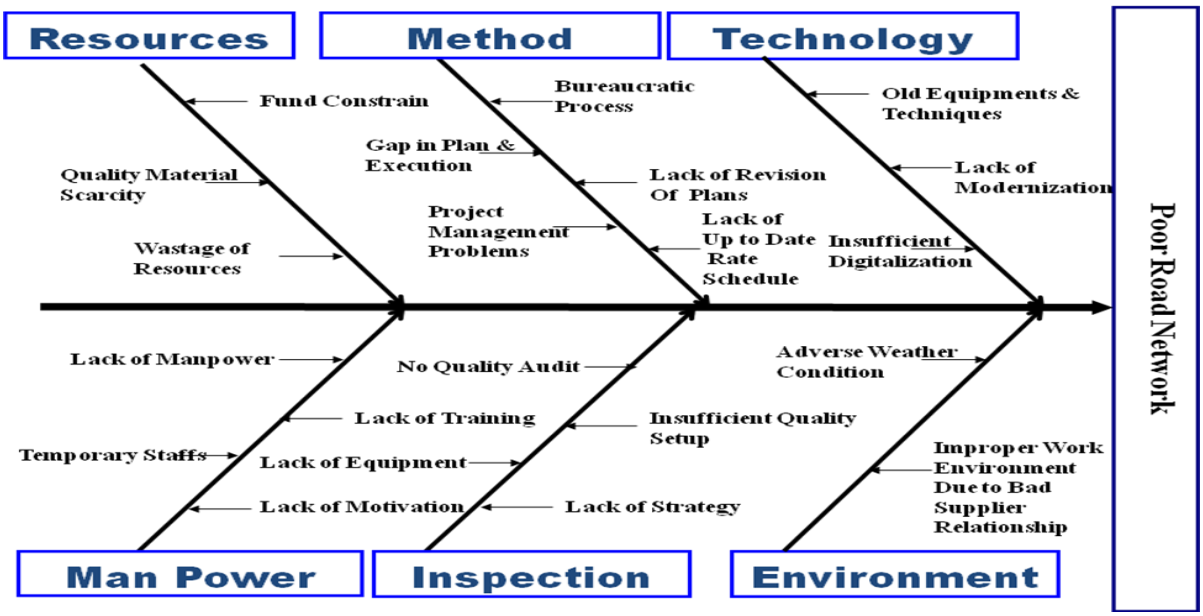



**Figure 2-1: Cause Effect Diagram for Poor Road Network**

- Material (Includes Raw Material, Consumables and Information.).
- Method (process).
- Machine (technology).
- Man Power (physical work)/Mind Power (brain work).
- Measurement (Inspection).
- Management/Money Power Nature (Environment).

The original 6Ms used by the Toyota Production System have been expanded by some to include the following and are referred to as the 8Ms. However, this is not globally recognized. It has been suggested to return to the roots of the tools and to keep the teaching simple while recognizing the original intent; most programs do not address the 8Ms.

## 2.5 Evaluation of the Procurement Process Quality Control

Quality should be imparted in every step of the sourcing process, as the quality failure cost is much higher than the quality control cost. The procurement cycle is shown in figure 2-1 Quality can be incorporated in every step of the procurement process.

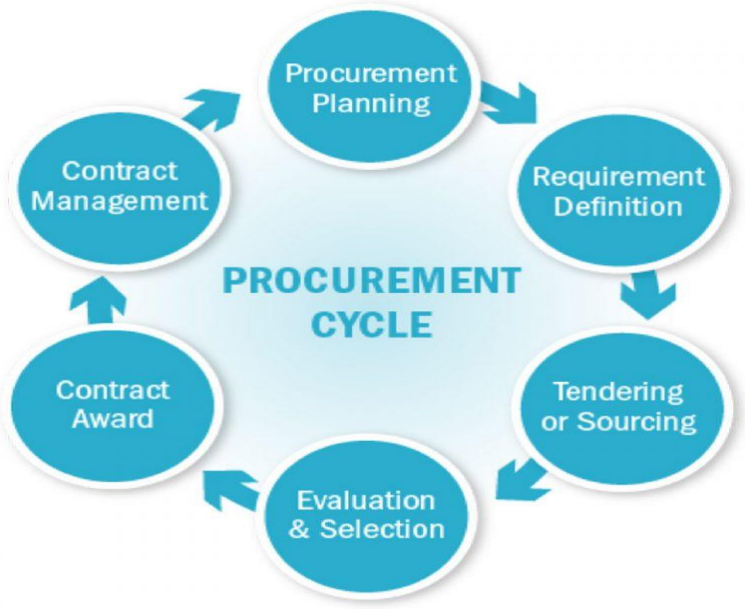



**Figure 2-2: The Procurement Cycle**

(https://dwfoh96rza0z7.cloudfront.net/wp/wp-content/uploads/2019/05/02204424/procurement.cycle_.psf_.800.jpg

Better quality service or product can be provided to the consumers/users if quality is taken in to account in defining the need (planning), design, sourcing, supplier selection, project management or project review.

The evaluation stage comprises the following steps: establishing the group of people to be interviewed; value stream maps, general and detailed; project surveys; review of performance indicators; analysis of nonconformity reports; cause – effect analysis regarding delays, costs, Time cycles and others. The supply group is the one that shows most frequent problems, followed by the stages of the procurement process. Periodic reports with processed information could greatly help managers to prevent and reduce problems that can affect the procurement process.

(https://www.researchgate.net/publication/228380047_Evaluation_and_improvement_of_the_Procurement_Process_in_Construction_Projects

### 2.5.1 Quality Control

The old concept of quality control is to inspect for quality after production. In this old erathe focus of quality control shifted from inspection to statistical sampling, then statistical sampling to organizational quality focus. After 1980s the quality control was totally customer driven. From that period and now on the organizations are imparting quality in every possible step of the process. Figure 2-2 shows the evaluation of quality control.




**Figure 2-3: Evaluation of Quality Control.**

https://slidetodoc.com/presentation_image_h2/3c7ba89d3c9dffca4b5d2c5501bdacd7/image-40.jpg

### 2.5.2 Quality Assurance:

Quality Assurance (QA) is a way of preventing mistakes or defects in manufactured products and avoiding problems when delivering solutions or services to customers. ISO 9000 defines quality assurance as "A part of quality management focused on providing confidence that quality requirements will be fulfilled". It thus differs subtly from quality control. QA is applied to physical products in pre-production to verify what will be made meets specifications and requirements, and during manufacturing production runs by validating lot samples meet specified quality controls.

Quality Assurance refers to administrative and procedural activities implemented in a quality system so that requirements and goals for a product, service or activity will be fulfilled. Suitable quality is determined by product users, clients or customers, not by society in general.

It is not related to cost, and adjectives or descriptors such as "high" and "poor" are not applicable.

- a clear specification of road agency requirements for Quality Assurance (QA)
- a targeted, risk based approach to independent monitoring and reporting on the performance of a contractor's QA process
- a resource that can be used for training across the industry.
- Systematic and effective quality control by a road construction contractor, and reliable auditable evidence of that control, provides a win-win outcome for both contractors and road agency clients.

## 2.6 International Standards

International Standardization is the way of quality. To achieve the international standard organizations improve its overall procedures. When such standard is achieved to maintainit the organizations do their best. The best international standard for quality ISO 14000 is discussed below.

**ISO 14000 Standards**

The need for standardization of quality created an impetus for the development of other standards. In 1996 the International Standards Organization introduced standards for evaluating a company's environmental responsibility. These standards, termed **ISO 14000,** focus on three major areas.

**Management systems** standards measure systems development and integration of environmental responsibility into the overall business.

**Operations** standards include the measurement of consumption of natural resources and energy.

**Environmental systems** standards measure emissions, effluents, and other waste systems with greater interest in green manufacturing and more awareness of environmental concerns, ISO 14000 may become an important set of standards for promoting environmental responsibility.

## 2.7 Organizational Aspects of Quality

An organization consists of Hard aspects i.e. structure, strategy and system, on the other hand the organization have soft aspects i.e. shared values, style, skills and staff. In the Subsequent sub section the hard and soft aspects is discussed. Various types‟ organizational structure is discussed broadly as the all the hard aspects are taken into consideration designing the organizational structure.

An organizational structure defines how activities such as task allocation, coordination and supervision are directed towards the achievement of organizational aims. An organization can be structured in many different ways, depending on their objectives. The structure of an organization will determine the modes in which it operates and performs.

### 2.7.1 Strategy

Strategy is important because the resources available to achieve these goals are usually limited. Strategy generally involves setting goals, determining actions to achieve the goals, and mobilizing resources to execute the actions. A strategy describes how the ends (goals) will be achieved by the means (resources). The senior leadership of an organization is generally tasked with determining strategy. Strategy can be intended or can emerge as a pattern of activity as the organization adapts to its environment or competes. It involves activities such as strategic planning and strategic thinking. In developing countries like Bangladesh strategic GAP analysis is important.

Gap analysis identifies gaps between the optimized allocation and integration of the inputs (resources), and the current allocation level. Gap analysis naturally flowsfrom benchmarking and other assessments. Once the general expectation of performance in the industry is understood, it is possible to compare that expectation with the company's current level of performance. This comparison becomes the gap analysis. Suchanalysis can be performed at the strategic or operational level of an organization. Figure below gives idea about GAP analysis.

### 2.7.2 The Soft Aspects

The soft aspects are related to the Human Resource Management. Skills, Shared values, staff and styles are developed by the Human resource management of an organization.This includes the job design, job description, recruitment process, training etc.

### 2.7.3 Quality Assessment Tools

Assessing the state of quality of the process, performance or anything of an organization is very important for applying quality control. There are many quality assessment tools available. The Project Management Institute references Seven Basic. The Seven Basic Tools stand in contrast to more advanced statistical methods such as survey sampling, acceptance sampling, statistical hypothesis testing, design of experiments, multivariate analysis, and various methods developed in the field of operations research. Some of the quality assessment tools will be used to evaluate the quality position of RHD and LGED, for this reason seven basic tools for quality are discussed in following sections.

### 2.7.4 Cause-and-Effect Diagrams

Cause-and-effect diagrams (also called Ishikawa diagrams, fishbone diagrams, herringbone diagrams are causal diagrams created by Kaoru Ishikawa (1968) that show the causes of a specific event. Ishikawa diagrams were popularized by Kaoru Ishikawa, who pioneered quality management processes in the Kawasaki shipyards, and in the process became one of the founding fathers of modern management. Each cause or reason for imperfection is a source of variation. Causes are usually grouped into major categories to identify these sources of variation. The categories typically include.

2.8.4.1 People: Anyone involved with the process.

2.8.4.2 Methods: How the process is performed and the specific requirements for doing it, such as policies, procedures, rules, regulations and laws.

2.8.4.3 Machines: Any equipment, computers, tools, etc. required to accomplish the job.

2.8.4.4 Materials: Raw materials, part 6s, pens, paper, etc. used to produce the final product.

2.8.4.5 Measurements: Data generated from the process that are used to evaluate itsquality.

2.8.4.6 Environment: The conditions, such as location, time, temperature, and culture inwhich the process operates.

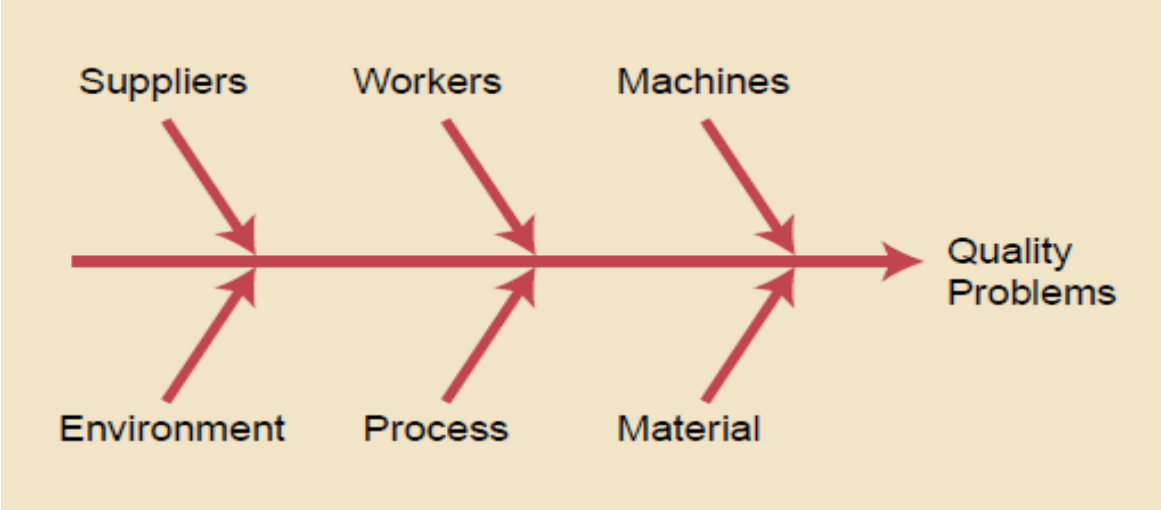



**Figure 2-4: Sample Cause Effect Diagram**

### 2.7.5 Check Sheet

The check sheet is a form (document) used to collect data in real time at the location where the data is generated. The data it captures can be quantitative or qualitative. When the information is quantitative, the check sheet is sometimes called a tally sheet. The defining characteristic of a check sheet is that data are recorded by making marks ("checks") on it. A typical check sheet is divided into regions, and marks made indifferent regions have different significance. Data are read by observing the location and number of marks on the sheet Check sheets typically employ a heading that answers the Five Ways.

2.8.5.1 Who filled out the check sheet?

2.8.5.2 What was collected (what each check represents, an identifying batch or lot number).

2.8.5.3 Where the collection took place (facility, room, apparatus).

2.8.5.4 When the collection took place (hour, shift, day of the week).

2.8.5.5 Why the data were collected.

### 2.7.6 Control Charts

Control charts, also known as Stewart charts (after Walter A. Stewart) or process- behavior charts, in statistical process control are tools used to determine if a manufacturing or business process is in a state of statistical control. The control chart is one of the seven basic tools of quality control. Typically control charts are used for time- series data, though they can be used for data that have logical comparability (i.e. you want to compare samples that were taken all at the same time, or the performance of different individuals), however the type of chart used to do this requires consideration.

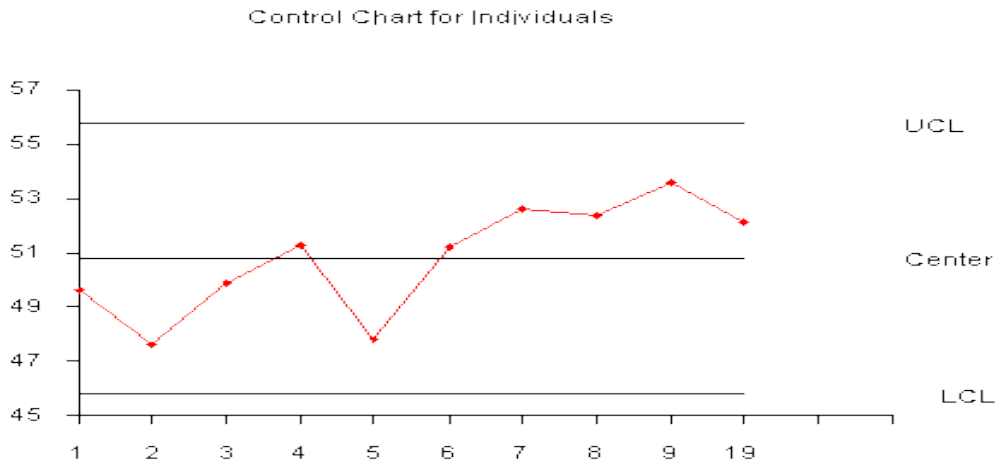



**Figure 2-5: A Sample Control Chart**

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### 2.7.7 A Sample Pareto Chart

A Pareto chart, named after Wilfredo Pareto, is a type of chart that contains both bars and a line graph, where individual values are represented in descending order by bars, and thecumulative total is represented by the line. The left vertical axis is the frequency of occurrence, but it can alternatively represent cost or another important unit of measure.

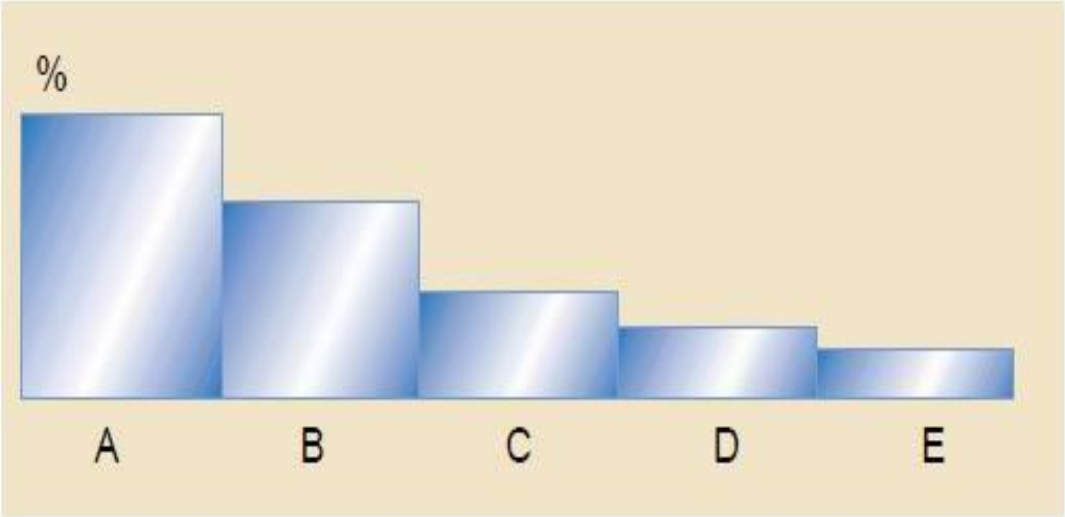



**Figure 2-6: A Sample Pareto Chart**

Because the reasons are in decreasing order, the cumulative function is a concave function. To take the example above, in order to lower the amount of late arrivals by 78%, it is sufficient to solve the first three Issues. These charts can be generated by simple spreadsheet programs, such As Open Office. Organization Calculation and Microsoft Excel and specialized statistical software tools as well as online quality charts generators.

### 2.7.8 Scatter Diagrams

Scatter diagrams are graphs that show how two variables are related to one another. They are particularly useful in detecting the amount of correlation, or the degree of linear relationship, between two variables. For example, increased production speed and number of defects could be correlated positively; as production speed increases, so does the number of defects. Two variables could also be correlated negatively, so that an increase in one of the variables is associated with a decrease in the other.

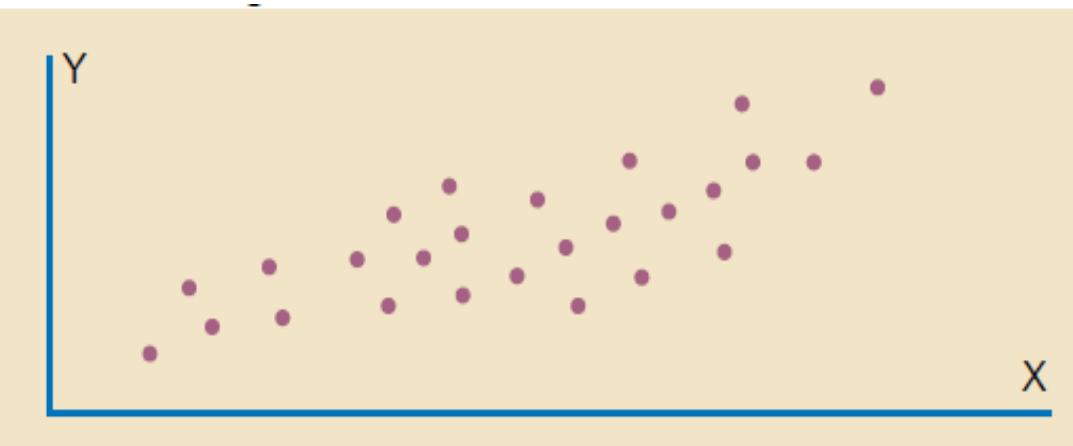



**Figure 2-7: A Sample Scatter Diagram**

### 2.7.9 Flow charts

A flowchart is a schematic diagram of the sequence of steps involved in an operation or process. It provides a visual tool that is easy to use and understand. By seeing the steps involved in an operation or process, everyone develops a clear picture of how the operation works and where problems could arise.

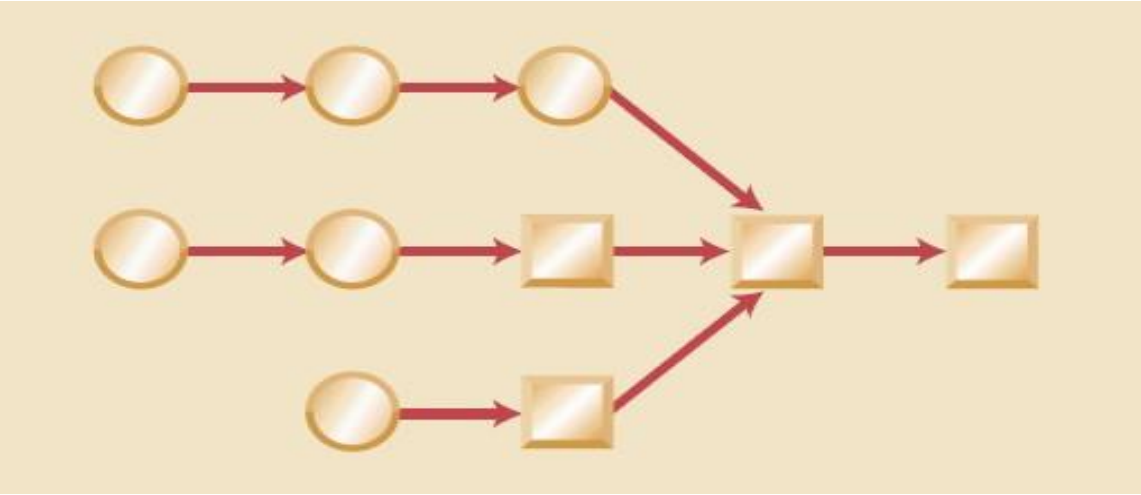


**Figure 2-8: A Sample Flow Chart.**

## 2.8 Quality Control Related tests are listed below

1. Penetration Test on Bitumen.
2. Softening Point Test on Bitumen.
3. Viscosity of Bitumen.
4. Moisture Condition Value (MCV) Test.
5. Los Angle Abrasion Value Test.
6. Flakiness Index Test.
7. Elongation Index Test.
8. Sulphate Soundness Test.
9. Ten Percent Fine Value (TFV).
10. Percentage Refusal Density.
11. Polished Stone Value (PSV).
12. Sand Patch Test.

### 2.8.1 Penetration Test on Bitumen

Its basic principle is to determine the depth to which a needle penetrated as asphalt sample under specified conditions of load, time and temperature.

The test is conducted under following conditions:

Load = 100g

Temperature = 25C

Time = 5 Sec

The depth of penetration is measured in units of 0.1 mm and reported in penetration units (e.g.if the needle penetrates 8 mm, the asphalt penetration number is 80). Penetration grading is based on penetration test. (*Link-2)*

### 2.8.2 Softening Point Test on Bitumen

The softening point is defined as the temperature at which a bitumen sample can no longer support the weight of a 3.5-g steel ball. Ball & Ring apparatus is used. Water is used for bitumen with a softening point of 80C or below. The temperature is raised at the rate of 5C per minute.

### 2.8.3 Viscosity of Bitumen

Shear stress is applied to a film of bitumen sandwiched between 2 flat plates and the rate of strain is measured. The viscosity in Pascal second is given by shear stress divided by the rate of strain.

### 2.8.4 Moisture Condition Value (MCV) Test

There is a relationship between compacting effort, moisture content and density. The MCV test involves testing a soil at fixed moisture content and by increasing the number of blows of a rammer determining the compaction effort beyond which no further increase in density occurs. As a general guide MCV of 8.5 is recommended as the lower limit of acceptability of a soil for compaction at its natural moisture content and difficulties in earth working can be expected when MCV drops significantly below this value. (*Link-2)*

### 2.8.5 Los Angles Abrasion Value Test

The Los Angle Abrasion value test is to indicate the resistance to abrasion. Percentage of fines passing through the 1.7mm sieve is measure of Los Angle Abrasion Value. If its value is over 40% then the material is quite soft. If it is 25% then the material is hard. (*Link-2)*

### 2.8.6 Flakiness Index Test

This test eliminates aggregates unsuitable for bituminous spray and chip seal.

Flakiness Index is the percentage by weight of particles, whose least dimension is less than three-fifth of its mean dimension. Max Flakiness Index is 25%. It should not be greater than 35%.

### 2.8.7 Elongation Index Test

Elongation Index is the percentage by weight of particles whose largest dimension (i.e. length) is greater than one and four-fifths times its mean dimension. . (*Link-2)*

### 2.8.8 Sulphate Soundness Test

This test is for checking resistance to disintegration after immersion in a 20% solution of sodium Sulphate. This test is used for assessing weather susceptibility. (*Link-2)*

### 2.8.9 Ten Percent Fine Value (TFV)

A test specimen is compacted in a standardized manner into a steel cylinder fitted with a freely moving plunger. The specimen is then subjected to a load applied through the plunger. This action crushes the aggregate to a degree, which is dependent on the crushing resistance of the material. The degree of crushing is assessed by a sieving test on the crushed specimen. The procedure is repeated with various loads to determine the maximum force which generates a given sieve analysis. This force is taken as the ten percent fines value. TFV should not less than 180KN (dry).

### 2.8.10 Percentage Refusal Density:

This is a measure of relative state of compaction of a site sample of laid DBM or asphalt Concrete To that of a similar sample compacted to refusal (i.e. It will not compact further even though it may still contain void) lab conditions. (*Link 2)*

### 2.8.11 Polished Stone Value (PSV):

Micro texture is quantified by the PSV. The test assesses whether an aggregate will polish under traffic, as this will be major determinant of the pavement skid resistance. It involves polishing aggregate specimen with a pneumatic type coated with an abrasive paste. (*Link 2)*

### 2.8.12 Sand Patch Test

Macro texture is measured by Sand Patch test. It is a measure of resistance to aqua planning. A specific volume (25 ml) complying with specific grading of sand is spread over the surface with use of the wooden disc with its face kept flat, in a circular motion so that the sand is spread into a circular patch with the surface depression filled to the level of the peaks. Measure either the radii of the dividers on the sand patch or practically the diameters at every 45° and calculate the mean of the 4 individual diameters (d) to nearest 1 mm. (*link-2)*

### 2.8.13 Sideway Coefficient Routine Investigation Machine (SCRIM)

The skid resistance of finished surface of road is checked by SCRIM.

It operates by dragging a wheel at an angle to its direction of travel. Though the wheel is free to rotate the angular difference leads to a side way force, which is measured, and which gives a coefficient of friction. The test is carried out on a wet road surface since the presence of water leads to minimum skid resistance. (*Link 2*)

## 2.9 A Few Important Requirements for Ensuring Quality in Road Construction

- The design mix proportion arrived at the laboratory shall be based on representative samples available at the site.
- Prime coat where necessary shall be applied over the prepared base at the specified rate before laying the bituminous surfacing.

- The temperature of binder at the time of missing shall be in the range of 150 $^0$C-177 $^0$C and aggregates in the range of 155 $^0$C-163 $^0$C. Care should be taken that the difference of temperatures between the aggregates and binder doesn't exceed 140 $^0$C
- Mixing time should be shortest possible to obtain uniform distribution of the binder and a homogenous mix.
- A variation in binder content of +0.3 percent by weight of total mix shall, however, be permissible.
- The mix shall be carried to the site by tipper trucks and spread and compacted to obtain a carpet of required thickness. The temperature of the mix at the time of laying shall be in the range of 121$^0$C-165$^0$C.
- Soon after laying of mix, rolling shall be started with 8-10 tones vibratory rollers at a speed not more than 5 Km per hour. The final rolling shall continue till the mix is fully compacted and no roller marks are left on the surface. The density shall not be less than 95 percent of lab density. During the rolling, the roller wheels shall be kept moist to prevent the mix from adhering to the roller wheels and being picked up.
- Traffic shall be allowed on the surface only, when the carpet after final rolling has cooled down to the ambient temperature.
- The finish surface shall be checked in-process quality control for line, grade and regularity. ( *link 2)*

# CHAPTER 3
# QUALITY CONTROL RHD AND LGED ROAD CONSTRUCTION

## 3.1 Introduction

Present state of quality control in RHD & LGED is discussed in this chapter. Chapter includes sections like organizational supports for quality, strategies for quality, quality in sourcing, quality in construction management and at last audit. Present state of each of these points is evaluated in the following sections to find out the present of quality control.

## 3.2 Organizational Support for Quality Control

RHD and LGED is a Government Organization under the Road Transport and Highways Division, RTHD of the Ministry of Road Transport and Bridges. Being a government organization the processes of the organization is bureaucratic in nature. For any approval or order of the government bureaucratic process is followed. RHD is headed by the Chief Engineer; he is the Chief Executive Officer of the organization. RHD is divided into 10 operational zones and five wings, which are headed by Additional Chief Engineers ACEs. The operational zones in the field are Dhaka, Chittagong, Comilla, Sylhet, Rajshahi, Rangpur, Khulna, Barisal, Mymensingh and Gopalganj zone and Wings are Planning and Maintenance, Bridge Management, Technical Services, Management Services and Mechanical Wing. At the top zones and wings are functional type divisionsDesign supports are given by road or bridge design divisions. For quality related testing and audit RHD has a central laboratory, Bangladesh Road Research Laboratory, BRRL. There are nine field labs in Mymensing, Comilla, Sylhet, Rangpur, Rajshahi, Jessore, Chittagong, Barisal and Rangamati for quality testing in field level. For the training of the officers and staff RHD have Training Center.

## 3.3 Quality Assurance Program

The BAIDP Quality Assurance Program is a key part of the US and Bangladesh Government Agreement. All aspects of the BAIDP program are being implemented by LGED and their staff using well established tender processes. LGED will contract with a local construction Contractor who will implement the work. LGED will utilize their staff to monitor quality, safety and environmental aspects of the work. LGED has the organizational structure in place to execute construction work in the various Districts and Upazilas throughout

Bangladesh. In the case of the BAIDP effort, all work must be certified by US Government personnel. USAID has reached an agreement with the US Army Corps of Engineers (USACE) to provide this certification. This adds a new layer of monitoring and communication that requires careful planning prior to field implementation. Because LGED will have contractual arrangements with local contractors that require payment, any miscommunication in the required quality process will have significant impact. This Quality Assurance Plan for Roads has been prepared to define the process for implementing quality under the BAIDP program, BAIDP Quality Program Process and Interfaces, provides a summary of the process.

### 3.3.1 Quality Control Strategy

RHD and LGED have both long and short term strategy for the development of the road network of the country. These strategies are important of the quality control of the processes involved in road construction and maintenance. Strategies are discussed here so that their impact and lickings of them can be identified. Also to see weather poor quality is rising from poor strategy formulation or not.

## 3.4 Overview of RHD

The Roads and Highways Department (RHD) was created in 1962 when the old 'Construction & Building (C and B) organization was split into 2 separate bodies (the other being Public Works Department). RHD is responsible for the construction and the maintenance of the major road and bridge network of Bangladesh. Since the Department was established the size of the major road network in Bangladesh has grown from 2,500 km to the present network of 22,362.821 The RHD is headed by a Chief Engineer who is supported by a number of Additional Chief Engineers. The RHD is responsible for construction and maintenance of the major road network of Bangladesh.

### 3.4.1 RHD Road Network

The Roads and Highways Department (RHD) in Bangladesh is responsible for over 22,362.821 km of roads which are classified in Table 2-1. Not all the roads, particularly in the Zila category, are yet paved. As Table 2-1 shows 13,541.50 km of the total Zila roads are paved, or just under 72% of the total. Map 2.1 shows the current RHD network.

| Road Class) | Definition | Length (km) |
|---|---|---|
| National Highways | Highways connecting National capital with Divisional HQ‟s or sea ports or land ports or Asian Highway. | 3,979.80 Km |
| Regional Highways | Highways connecting District HQ‟s or main river or land ports or with each other not connected by National Highways. | 4,897.70 Km |
| Zila Roads | Roads connecting Districts HQ‟s with UpazillaHQ‟s or connecting one Upazilla HQ to another Upazilla HQ by a single main connection with National/Regional Highway, through shortest distance/route. | 13,541.50 km |
| **Total** | | **22,362.821** |

**Table 3-1: Roads and Highways road network definition and lengths (BangladeshGazette, 6 November 2003 and Planning Commission, 2007) (R-4)**

https://oldweb.lged.gov.bd/UploadedDocument/UnitPublication/4/14/2004_Road%20Design%20Standards.pdf

### 3.4.2 Activities of RHD

The Roads and Highways Department (RHD) was created in 1962 when the old 'Construction & Building (C&B) organization was split into 2 separate bodies (the other being Public Works Department). RHD is responsible for the construction and the maintenance of the major road and bridge network of Bangladesh.

RHD is responsible for the construction and maintenance of total Road Length 22,419.00 Km of its road network. The works for maintenance and rehabilitation is given new road construction includes the sequential construction of the various layers of the road. The layers are the sub grade (soil), improved sub grade (compacted sand), sub base (aggregate, sand), base (aggregate/stone, sand), surface course (asphalt concrete).

This is a 40 mm thick manual overlay used in lowtrafficked roads in place of dense bituminous overlay. Life expectancy has been taken as 2 to 4 years.

RHD currently employs 19,903 staff. However, only 7 per cent of these are Class 1 and 2 degree and diploma level staff. Over half RHD’s staff are work charged or master roll casual laborers. The current workforce is not therefore of the right size or profile to manage a modern organization. There is a need for more skilled trained personnel.

### 3.4.3 RHD Road Network Map




**Figure 3-1: RHD Road Network**

**https://4.bp.blogspot.com/-TC-lzLrCVRc/TqHr0nsSdUI/AAAAAAAAANo/msdrto1o958/s1600/Road%2BNetwork.jpg**

## 3.5 Over view LGED

Local Government Engineering Department (LGED) is one the largest engineering agencies of the country. LGED was finally given the shape of a full-fledged department remaining it as Local Government Engineering Department (LGED) in 1992. It began its journey in 60s as Rural Works Program and with the passage of time its activities expanded from remotest corner of the country up to the cities.

Role of LGED in strengthening of rural economy development of rural transportation and improvement of rural markets and growth centers are visible across the country.

Contribution of these infrastructures are enormous in achieving the ever-increasing national growth. People living in rural areas now have the access to metaled roads within two kilometers while the rural infrastructures play pivotal role in the improvement of lifestyle and reducing poverty. (R-5)

### 3.5.1 The LGED Road network

With a view to developing an efficient road network in the country, it is essential to prepare a Road Master Plan. The Plan should address the long term objectives for the Bangladesh road network, and comprise a physical plan of the network required to meet the country's economic and social needs. Following are the criteria for road investment as considered in the Rural Road Master Plan:

- Traffic and transport need;
- Improvement of accessibility to the poorer sectors of society;
- Contribution to strategic economic growth targets
- Projects should provide links with the paved network;
- Roads should be implemented able over a reasonable time period so as to bring benefits quickly (6 years maximum);
- Phased projects should provide staged benefits;
- Connections to the paved road network for growth Centre's and Union Parishads. (R-5)

### 3.5.2 LGED Road Network

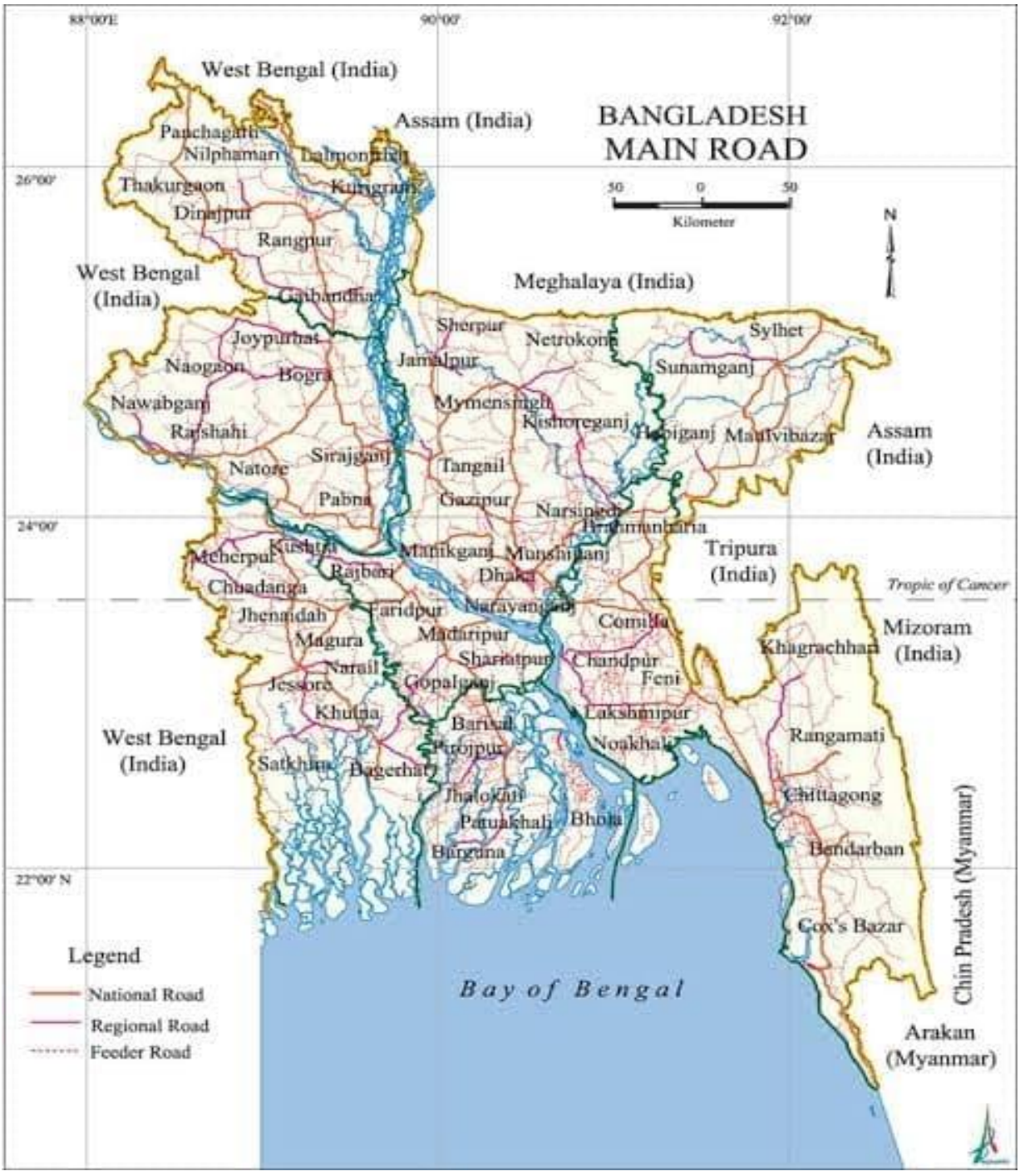



**Figure 3-2: LGED Road Network**

https://en.banglapedia.org/images/thumb/9/9d/RoadNetworkNationalRegional.jpg/40px-RoadNetworkNationalRegional.jpg

## 3.6 National Road Classification

National Road Classification Higher Road System and Rural Road are two broad classifications for which agencies responsible are RHD and LGED/LGI respectively.

LGED and LGI both belong to the Local Government Division under the Ministry of Local Government, Rural Development and Cooperatives (LGRD and C). LGED's one of the mandate is to provide technical support to the LGIs. LGED takes the responsibility to construct/re-construct, rehabilitate and maintain roads in conjunction with LGIs under the purview of Local Government Division.

| Sl. No. | Type | Definition | Ownership and Responsibility |
|---|---|---|---|
| 01. | National Highways | Highways connecting National Capital with Divisional HQ/s or seaports or land ports or Asian Highways. | RHD* |
| 02. | Regional Highways | Highways connecting District HQ/s or main river or land ports or with each other not connected by National Highways. | RHD |
| 03. | Zila Road | Roads connecting District HQ/s with Upazila HQ/s or connecting one Upazila HQ to another Upazila HQ by a single main connection with National/Regional Highway, through shortest distance/route. | RHD |
| 04. | Upazila Road | Roads connecting Upazila HQ/s with Growth Center/s with another Growth Center by a single main connection or connecting Growth | LGED*/LGI* |

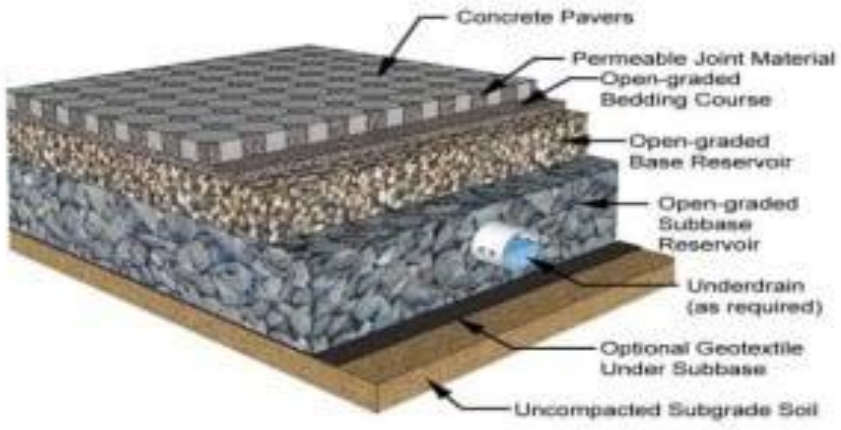
| | | | |
|---|---|---|---|
| | | Center to Higher Road System**, through shortest distance / route. | |
| 05. | Union Road | Roads connecting Union HQ/s with Upazila HQ/s, Growth Centers or Local Markets or with each other. | LGED*/LGI* |
| 06. | Village Road | Roads connecting Villages with Union HQ/s, local markets, farms and ghats or with each other. Roads within a Village. | LGED*/LGI* |
| * | The above road types do not include the roads belonging to the Pourashavas and the City Corporations. The responsibility for development and maintenance of such roads will lie with the respective Pourashavas and the City Corporations. | | |
| * | RHD-Roads and Highways Department, LGED - Local Government Engineering Department, LGI - Local Government Institutions. | | |
| ** | Higher Road System - National Highway, Regional Highway and Zila Road. | | |

**Table 3-2: Description of the Types Definitions and Agencies Responsible for various Roads of the Country (2003). (***Link-5)*

https://oldweb.lged.gov.bd/UploadedDocument/ProjectLibraryGallery/384/2005_Road%20Design%20Standards_Rural%20Roads_Final%20(1)

## 3.7 Pavement Design in Road Construction

Pavement design is the major component in the road construction. Nearly one-third or one-half of the total cost of construction, so careful consideration should be taken in design of pavement. Type of pavements.




- Flexible pavement
- Rigid pavement
- Semi-rigid pavement
- Factors which affect the selection of these pavements
- Initial cost
- Availability of good materials
- Cost of maintenance
- Environmental conditions
- Availability of industrial wastes
- Traffic intensity

### 3.7.1 Design parameters

Criteria for determining the pavement (flexible)

Thickness is vertical compressive strain comes to the subgrade due to the standard axle laden of magnitude 8.17 KN (8170 kg) , if more than this causes permanent deformation in form of rutting. The maximum rutting can be accepted in village road as 50 mm before maintenance and the analytical evaluation can be done for rigid and semi-rigid pavement tensile stress is taken as the design criteria. (*Link-5)*

### 3.7.2 Design life

The no. of years to be taken until the major reconstruction. Design life depend upon the environmental conditions, materials used maintenance etc. For rural roads design life of 10 years is considered. In low volume roads for the thin bituminous surfacing design life of 5 years is considered. (Link-5)

### 3.7.3 Computation of design traffic

**a= p (1+r) ^ (n + x)**

Where,

**a**=no. of commercial vehicles/day for design

**p**=no. of commercial vehicles/day at last count

**r**=annual growth rate of commercial traffic

**n**=no. of years between last count and year of completion of construction

**x**=design life in years.

## 3.8 Quality Control in Road and Highway Construction

Quality control in road and highway construction used for obtaining an improved and uniform standard of road construction. Quality control of Construction materials and the product is an essential requirement.

Quality control is an essential part of any production process and Quality control in road and highway construction is no exception. Due to significant increases in traffic intensities in recent times, the need for quality control on these specifications has increased considerably




**Figure 3-3: Quality control check**

The extra cost of exercising quality control being only a minute cost i.e. 1-2 percent of the total construction cost and hence result in more benefits. And direct and indirect economic return from quality control could be 5 to 10 of the total construction cost. (*Link-7*)

### 3.8.1 Requirement of Road Construction Quality Control

Mainly Road Construction estimates and Specifications provide the basis for effective quality control. Plus organizations set up quality management systems, adequately trained staff, and proper monitoring agencies for exercising quality control. For effecting possible improvements and implementation in quality control and the construction techniques the periodic appraisal of quality control data is necessary. (*Link-7*)

### 3.8.2 Process Quality control

The designer makes decisions regarding the type of procedure of construction, equipment, and the amount of work required to obtain the desired result. (*Link-7*)

### 3.8.3 End Quality Control

In the end result of Quality control in Road and Highway Construction, the construction agency may be contractor, have a free hand in the selection of road construction methods and equipment to achieve the desired end product. In End result type specification, the quality engineer carries out tests on finished work at regular intervals to evaluate whether it meets the required specifications or not. (*Link-7*)

### 3.8.4 Frequency & Extent of Site Testing

The frequency and extent of testing for normal conditions are the minimum necessary consideration. And for abnormal conditions where excessive variations are found to carry out additional testing. (*Link-7*)

### 3.8.5 Criteria for Site Acceptance

For different items of work, acceptance criteria may be based on minimum values or the statistical analysis as it is considered wise. For effective road construction quality control of material and work. (*Link-7*)

### 3.8.6 Training on Quality Control

To bring awareness to the officers of the department and to update their knowledge method of testing, a regular workshop on quality control should be held.

In order to make awareness in participants of basic necessities like required test acceptance criteria, specifications, frequency of testing, and methodology of tests for understanding the quality control system and operation of regional and field laboratories. (*Link-7*)

### 3.8.7 Project Site Training Facilities

There are central, regional, and field levels testing facilities normally. The Regional labs are at circle level and headed by Quality Engineer in addition, they shall provide all facilities for training of all Quality Control Staff in the region.

### 3.8.8 Critical Parameters in Quality Control for Road Construction

- The following points for construction in-process quality control shall be attended to
- The mix design proportions arrived in the lab shall be based on representative samples of material actually available at the site.
- Combined aggregate gradation and binder content shall satisfy the design criteria of the relevant BRTA specifications.
- At necessary places apply a prime coat over the prepared base at the specified rate before laying the bitumen surface
- The adequate capacity of mixing plant to field a mixture of proper and uniform quality.
- Quantities of various sizes of aggregate shall be fed in such proportions that the resulting combination follows the job-mix formula.
- To obtain a uniform distribution of the binder and the homogenous mix mixing time is should be the shortest possible.
- A variation of +0.3 % in binder content by weight of the total mix shall be permissible.
- The tipper truck carried the mix to the site and spread and compacted to obtain a carpet of the required thickness. Self-propelled mechanical pavers do spreading provided with screeds for spreading tamping and finishing the mix True to grade, cross-section, and line.
- Quickly after laying the mix, rolling shall be started with 8-10 tons vibratory rollers at the speed, not more than 5 km/hr. the final rolling shall continue till the mix is fully compacted and on the surface, there are no roller marks are left. The density of the mix is not less than 90 percent of the laboratory density. During rolling the roller wheel should be kept moist to prevent the mix from adhering to the roller wheels and being picked up.
- Traffic is allowed only when the carpet after final rolling has cool down to ambient temperature.

- The finished surface shall be checked in-process quality control for line, regularity, and grade. (*Link-7*)

## 3.9 Soil compaction process by roller for Quality Control

A vibratory roller is a compactor having a drum used to density soil, asphalt or other materials through the application of combined static and dynamic forces to increase the load-bearing Capacity of the surface. Vibratory rollers can fully cover the area underneath the wheel. It's more efficient compared to other road roller types when it comes to compacting. The vibration of the roller can arrange the particles and exerts direct pressure on the specific layer. When the vibratory roller is in reverse, the vibration is briefly turned off to avoid disturbing the compacted area. This roller is best used to reduce air voids and for density granular soil.




**Figure3-4: Sub-grade compaction**




**Figure 3-5: Soil compaction**




**Figure 3-6 Soil compaction process by roller for Quality Control**




**Figure 3-7: Soil compaction by Roller**

### 3.9.1 Design of the Works

The designs of the new works are done following the international standards. For the structural design of concrete structure American Concrete Institute ACI standards are followed. For the road design purpose ASTHO standards are followed.

For routine or minor maintenance works RHD and LGED standard designs have been prepared and these should be adopted. Although minor in nature it is essential that these works are carried out to the required standards to avoid premature failure.

RHD and LGED standard designs should be adopted according to the type of road and volume of traffic using it. Where fullreconstruction is required, and for all new road construction road pavements must be designed, with the design calculations being checked and approved by the Engineer and subsequently filed by him as part of the document control system. In particular, the new road pavements must be designed to be above the relevant Highest Flood Level (HFL) as defined in the RHD Pavement Design Guide. For all road contract where a new surface is to be laid a design must be undertaken for the required new Carriageway markings and traffic signs. These must be designed in accordance with the BRTA Traffic Signs Manual.

### 3.9.2 Drawings

Divisions have limited capacity for the production of engineering drawings. For this reason RHD Standard Drawings have been prepared, and these should be referred to and be included as part of every road Contract the Divisions have available to them GIS mapping on request from HDM Circle. These maps should be used to create a location drawing for each contract showing, where surface water drainage is required (see RHD Design Advice Notes) and is to be included in a works contract, a longitudinal plan showing the gradients and outfalls must be included within the contract documents. This can be in diagrammatic form but must show the relevant information required by the Contractor for the drainage to be constructed by him Where special minor structures are to be included in road contractsfor which standard drawings are not available (e.g. large retaining walls) then design drawings approved by the Engineer must be included within the contract documents.

### 3.9.3 Quality in Construction

The Quality Assurance Plan of RHD and LGED covers the major issues that affect the quality of works achieved within RHD and LGED contracts, namely the preparation of contract documents and quality control during the works. Responsibility for checking and

approving all designs, tender documents and quality control tests on site rests with the Engineer for the contract andthrough him the Engineer's Representative.

## During Works Contracts:

- The Contractor is required to perform quality control tests on all materials and workmanship of the type and frequency called for under his Contract
- These are to be undertaken in accordance with the RHD and LGED Standard Test Procedures,such tests being witnessed and countersigned by an RHD and LGED representative.
- Off-site laboratory tests are to be undertaken by the Contractor on site samples where appropriate testing equipment is not available at his on-site laboratory (e.g. bitumen extraction, Marshall tests, etc).
- Site samples are to be tested in an independent off-site laboratory to confirm (or otherwise) tests undertaken by the Contractor.
- The Contractor may only proceed with successive road pavement layers subject to authorization by the Engineer following satisfactory and certified quality control tests on the underlying layer
- Interim Payment Applications from the Contractor must be supported by relevantquality control test reports certified correct by the Engineer's Representative.
- Road contracts will be subject to post construction tests on a sampling basis to check compliance with the specification and Contract Documents.

This QA Plan defines the roles and responsibilities of the key RHD and LGED staff involved in road contracts, and outline the procedures that should be adopted by them to achieve the required quality control in these contracts.



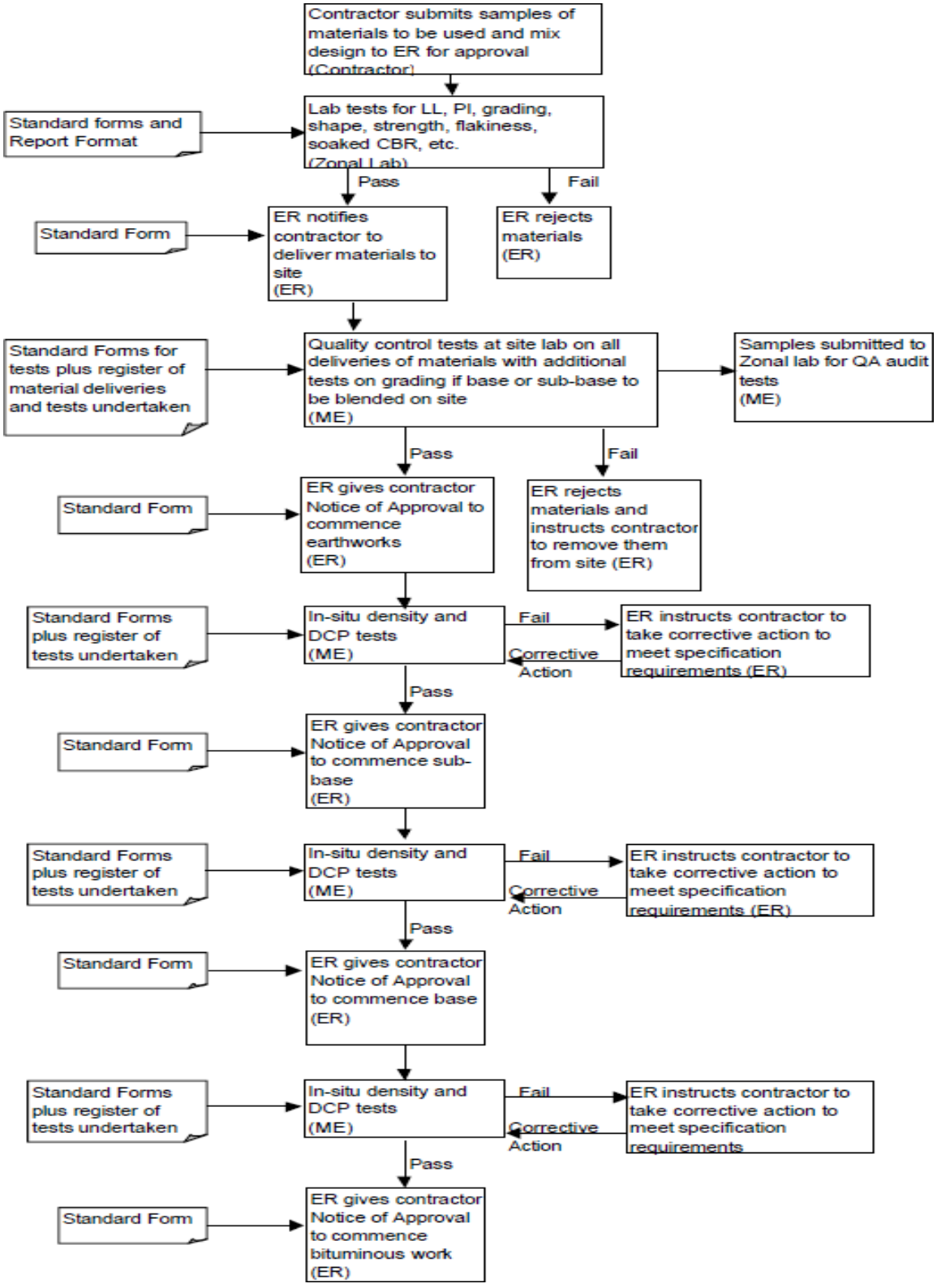
**Figure 3-8: Construction area**

### 3.9.4 Construction Management

Construction management is a complex task. Constructions of new roads and bridges have to follow certain procedures to maintain quality. The quality Assurance plan of the RHD has given the flow charts to maintain quality. These flow charts are given in figure 3-7, 3-8 and 3-9. Despites the project team of RHD also uses project management tools to allocate time, resources, manpower. It also does the complex task of adjusting the time and resources to timely completion of work.




**Figure 3-9: Site visit**




. **Figure 3-10: Flowchart for Earthwork, Sub-base and Base**

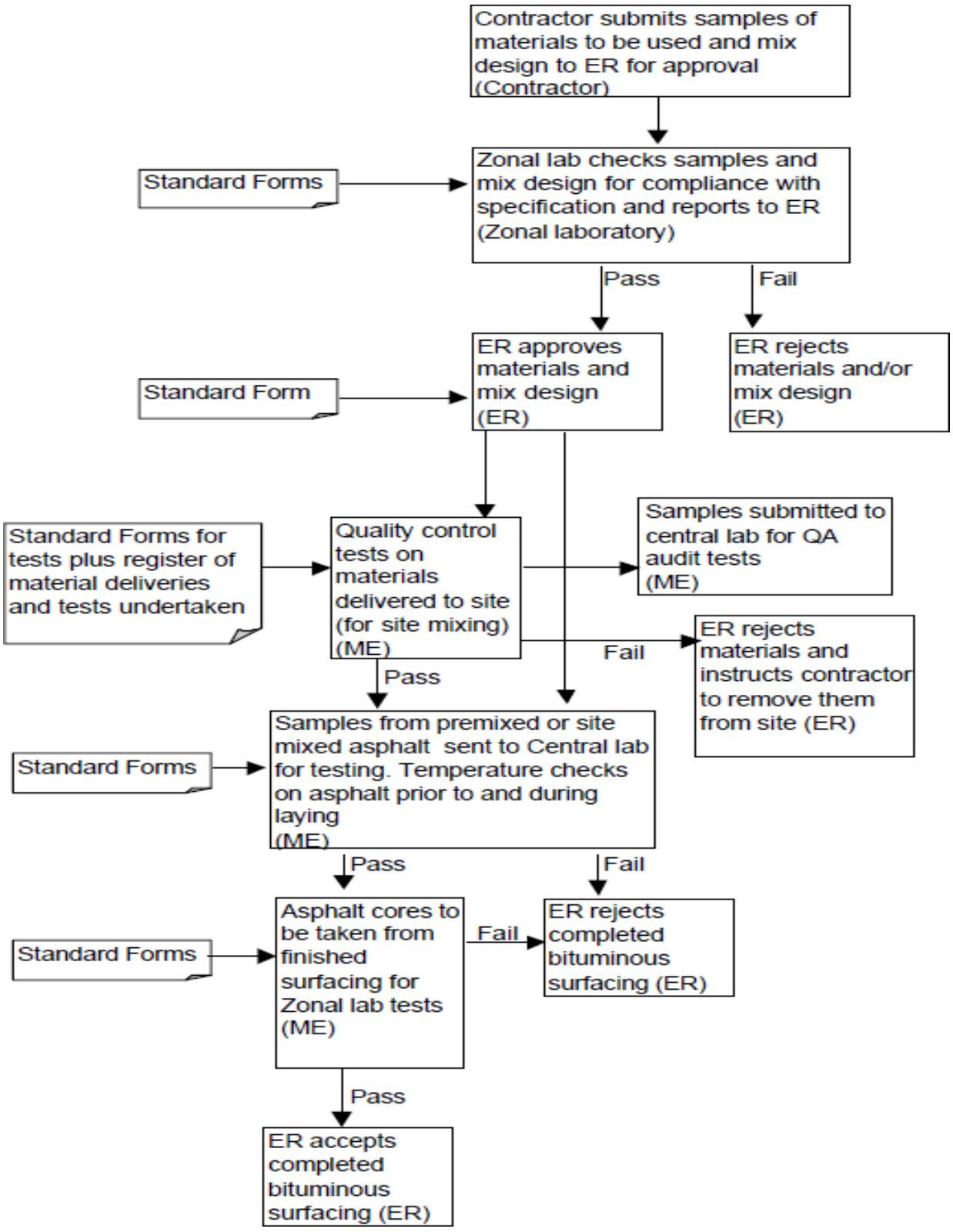



**Figure 3-11: Flowchart for Bituminous Surfacing**

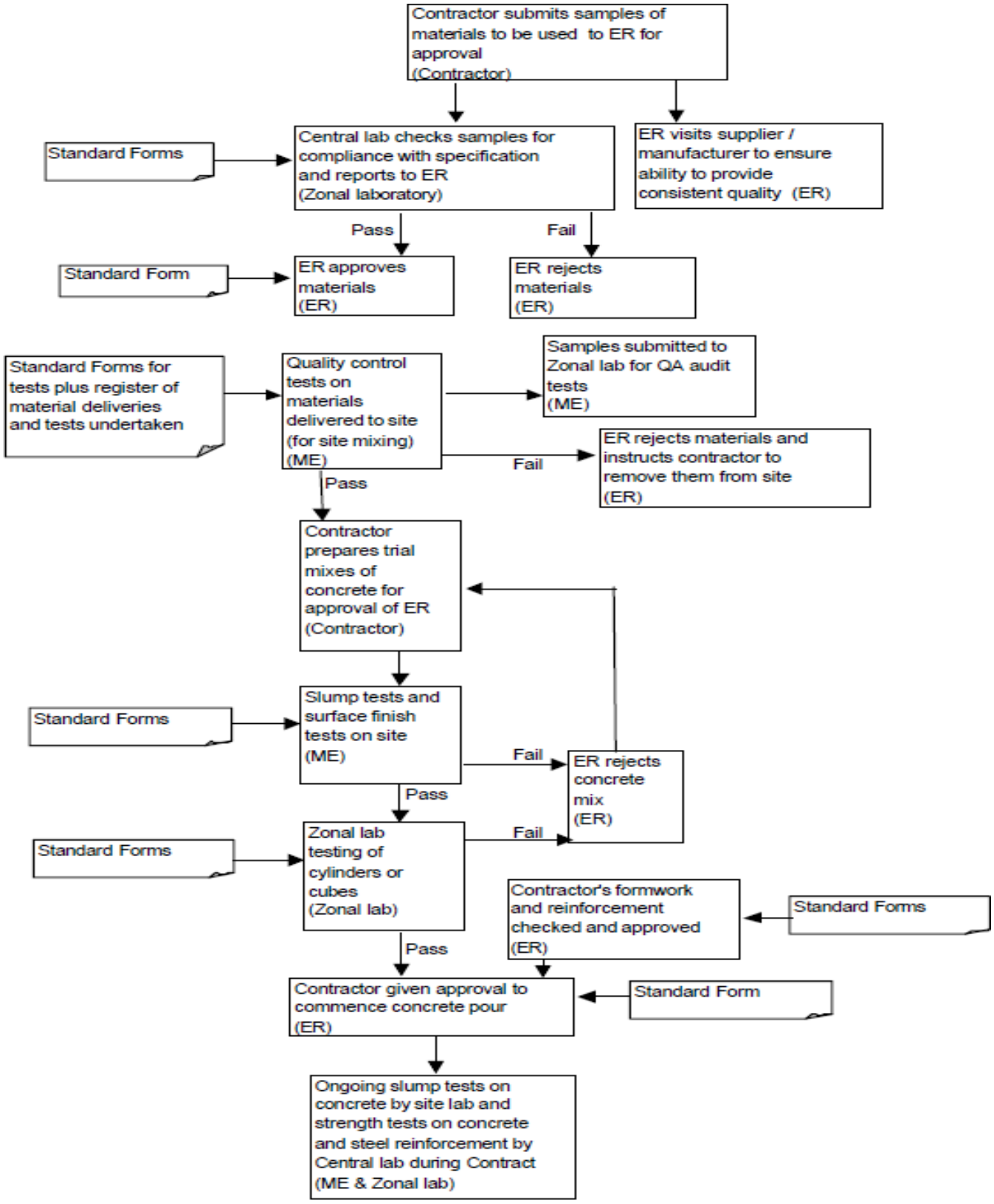



**Figure 3-12: Flowchart for Structure**

## 3.10 RHD Pavement Design

This RHD Pavement Design Guide has been prepared based on two internationally recognized design standards, namely the AASHTO Pavement Design Manual and the TRL Overseas Road Note 31, with a view to making the design of road pavements as straight forward as possible and to ensure that the same standards are adopted for all RHD roads.

For roads that are intended to carry only low volumes of traffic standard pavement designs have been included, together with an easy to follow design procedure to identify the required thickness of the various pavement layers for other more heavily trafficked roads. In this respect, throughout this Guide the following descriptions have been adopted for these pavement layers:

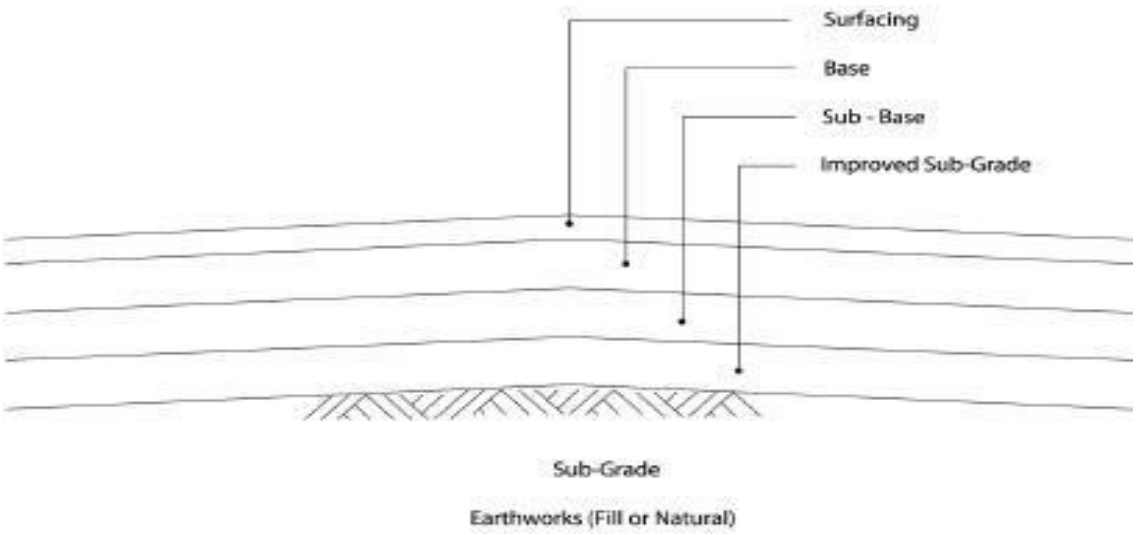



**Figure 3-13: Pavement Design Manual** *(link-8)*

- **Surfacing** is the riding surface of the road and varies from light bitumen spray with stone chippings (bitumen surface treatment) to one or more layers of dense bitumen surfacing.
- **Base** is the main load-spreading layer of the road pavement. It must be constructed of high quality brick or stone aggregate.
- **Sub-base** is the secondary load-spreading layer of the pavement. It is usually either crushed stone, broken brick aggregate (frequently mixed with sand) locally available gravel.
- **Sub-grade** is the soil immediately beneath the road structure. It is a layer of natural locally available material that meets the requirements of RHD Technical Specifications. *(Link-8).*





## 3.11 Principles of Design

Natural ground, including earth embankments, cannot support the wheel loads of vehicles - particularly when wet. The purpose of a road pavement is to distribute and spread wheel loads through to the underlying ground (i.e. the sub- grade) via pavement layers of the required thickness and strength such that each layer can support the load transmitted from the layer immediately above it without deformation. The strength of each layer is expressed in terms of the California Bearing Ratio (CBR) and it is essential that the materials used, and compaction obtained, for each layer achieves the required CBR for that layer. If the underlying layers do not have the required CBR then the upper layers of a road pavement will fail even if they have been correctly constructed.

The CBR requirements for the various pavement layers are contained in the RHD Specification and are summarized as follows:

| **Pavement Layer** | | **CBR** | **RHD Specification Clause** |
|---|---|---|---|
| Aggregate Base | Type I | >= 80% | 3.3.2 |
| | Type II | >= 50% | 3.3.2 |
| Sub-base | | >= 25% | 3.2.2 |
| Improved Sub-grade | | >= 8% | 2.8.2 |
| Sub-grade | | >= 5% | 2.7.2 |
| Embankment fill/natural ground | | >= 3% | 2.6.2 |

**Table 3-3: Required CBR for Pavement Layers, (link-8)**

Reference should be made to the RHD specification for the ma trials, workmanship andtesting procedures that should be adopted to achieve the above CBR values.

Standard pavement designs for 3.7m and 5.5m roads are shown at Appendix A. All other road pavements require to be designed with the thickness of the various pavement layers, including the bituminous surfacing, being determined by estimating the cumulative number of Equivalent Standard Axles (ESAs) that the road will be subjected to over its design life, and then reading off the required thickness for each layer from the design chart included at Table 5. An example of a pavement design based on this method is included at Appendix B. *(website 8)*




**Figure3-14: Sub-grade compaction**

## 3.11.1 Site Laboratory

Under all RHD & LGED contracts a site laboratory is to be established by the Contractor who is responsible for carrying out quality control tests on his materials and workmanship to demonstrate compliance with the specifications for the Contract. This laboratory should be established before the Works commence and within the limits of the Works area. Subject to the approval of the Engineer some of the tests may be carried out at an alternative laboratory containing more advanced testing equipment.

All tests must be witnessed by the ER or someone appointed by him for the purpose (the „Materials Engineer"). The tests required and their frequency is contained in Appendix 2. Appropriate test forms must be used and both these and the test result forms at Appendix

3 must be signed by the person carrying out the test and representatives of both the Contractor and the Engineer. The ER must check on a weekly basis that the required tests on all materials delivered to site and the Contractor's workmanship have been carried out and that the results of such testing are correctly recorded and filed within the site laboratory.

### 3.11.2 Quality Control Tests

The quality control tests listed in Quality Assurance plan, are the tests required by the RHD General Specification. Where works are to be undertaken that are not covered bythe RHD General Specification then the Contract must include a Particular Specification for such works, including the tests, frequencies and required results for those tests, both for the materials and workmanship for these works. In addition to these tests, where the Contract requires particular materials to be used but the specification does not require tests to be carried out on those materials, then it will be the responsibility of the Engineer (through his support staff) to ensure that the Contractor provides those materials to the requirements of the specification. For example, where the Contract requires thermoplasticpaint to be used the contractor must use a proprietary brand of thermoplastic paint and not simply road paint.

Quality control tests fall into three categories:

- Tests on materials prior to and during construction
- Tests on the quality of workmanship during construction.
- Tests on the finished works after construction

In the event that the quality control tests demonstrate that the materials or workmanship do not meet the requirements of the specification, the Engineer's Representative has no alternative but to reject them and instruct the Contractor to replace them at his own cost. All quality control tests must be carried out at the earliest opportunity both to avoid delays to the Contractor and to minimize any abortive works.

### 3.11.3 Quality control tests on material samples

Prior to the commencement of the Works, tests must be carried out by the Zonal laboratory on material samples (or mix designs) submitted to the Engineer for his approval by the Contractor in advance of them being taken on to the site. Given that the Zonal laboratory may be testing samples from a number of different contracts at the sametime, it follows

that within the laboratory itself there must be a management system to ensure that samples are correctly registered, tagged, tested and recorded for the separate contracts. Similar tests must be carried out by the Contractor on all such materialssubsequently delivered to site in the site laboratory (supervised by the Materials Engineer) with additional tests on those materials carried out on a sampling basis at the Zonal laboratory as a quality control check.



**Figure 3-15: material samples**

### 3.11.4 Quality Control Tests on Workmanship

To a large extent these tests are required to ensure that the approved construction materials are correctly mixed, placed and compacted during the works. With respect to road pavements, it is essential that each layer is tested and approved before the Contractor is allowed to place the next layer, since failure of an underlying layer will inevitably result in failure of the layers above it.

Accordingly, the Contractor may only be permitted to commence work on a particular layer when the underlying layer has been approved in writing by the Engineer's Representative.



**Figure 3-15: Rod Binding**

### 3.11.5 Mixing of Materials

Where on-site mixing is employed by the Contractor, the grading and proportioning of the materials must be strictly controlled so that at all times the final mix complies with the design mix that has been approved by the Engineer. To this end careful batching ofthe materials must be employed by the Contractor prior to placing them in the mixer. Under no circumstances should the proportioning of mixes be undertaken by laborers taking materials from stockpiles on a random basis.

Where granular materials are mixed on site to form sub-base or base material, and priorto the addition of bitumen or cement to granular mixes to form bituminous surfacing or concrete, samples of the granular mix should be taken in the presence of the ER‟s support staff for grading and other tests in the site laboratory.

### 3.11.6 Placing and Compacting of Materials

Premature failure of the works will occur unless the materials are correctly placed and compacted (where appropriate) in accordance with the specifications. In the case of road widening work, premature failure will also occur if required cross drainage structures or drainage layers are not provided. With respect to road pavements, this essentially means the compaction of each layer to the required density (typically 98% of MDD) to achieve the necessary CBR to support the next layer. In the case of Dense Bituminous Surfacing or carpeting the required degree of compaction can only be achieved when rolling takes place while the material is still hot and within the specified temperature range forcompaction. Accordingly the ER must ensure that field density measurements are taken by the Contractor at the appropriate times to demonstrate that the underlying layers are properly compacted (or corrective measures taken if not), and that rolling of the bituminous surfacing is undertaken within the correct temperature range.

### 3.11.7 Quality and Testing Equipment

Our goal is to execute projects and provide services in accordance with customer requirements, optimizing prices, meeting deadlines and fulfilling legal requirements and regulations with the highest profitability. We aim to be known as market leaders due to the high level of satisfaction of our customers, employees and shareholders. With this in mind we keep ourselves up-to date with the latest quality and testing equipment and labs.

| **Name and Description** | **Type of Testing** |
|---|---|
| Oven - Electrically Operated, Thermostatically Controlled From 0°C to 250°C (Sensitivity 1°C) (Internal Size: 600 x 600 x 600) | Bitumen Test Temp. Controlled, Aggregate Moisture Test & Soil Moisture Test |
| Electronic Balance 35 kg | Sample Weight |
| Sand Pouring Cylinder, 150mm dia. as per BS Specifications | Site FDD Test (As per 2720 part 28) |

| Name and Description | Type of Testing |
|---|---|
| Liquid Limit Device Casagrande Apparatus (LL, PL, PI) | Atterberg Limit - Liquid Limit & Plastic Limit (As per IS 2720 Part 4) |
| Aggregate Impact Tester with Blow Counter | Aggregate Impact Value Test |
| CBR Test Machine | CBR Test (As per 2720 part 16) |
| Core Cutting Machine | DBM, BC, PQC Core Cutting |
| Centrifuge Extractor, Electrically Operated. Capacity 1500g | Bitumen Extraction Test (As per AASHTO T-164) |
| Marshall Stability Machine | Marshall Test - BM, DBM, BC, SDBC (As per AASHHT0:245,ASTM T 1559-62) |
| Water Bath | Marshall Could Water Temp. Maintain |
| Ductility Machine | Bitumen Ductility |
| Ring & Ball Apparatus (as per 1205-1978) | Bitumen Softening Point Test (As per IS 1205) |
| Compressive Strength Testing | Concrete Cube Test, Paver Block Test, |

| Name and Description | Type of Testing |
|---|---|
| Machine (2000 KN Capacity) | Brick Test (As per IS 516) |
| Thin Film Oven | Bitumen Test |
| Tar Viscometer | Bitumen Test |

**Table 3-4: Type of Testing Name**

### 3.11.8 Quality in Audit and Review

Audit and review is important. The RHD & LGED General Specification requires cores to be taken from completed bituminous surfacing work and for laboratory tests to be undertaken on these samples to determine whether or not they comply with the requirements of the specification. Amongst other things these tests will include Marshall Stability, determination of bitumen content and the grading of aggregates in each sample. In addition to this the laboratory will measure the compacted thickness of the bituminous layer for compliance .The taking of cores is to be undertaken by the Contractor and all tests on those cores are to beundertaken by an off-site laboratory approved by the Engineer, with all costs associated with this testing being borne by the Contractor. Road pavements Dynamic Cone Penetration (DCP) tests are to be undertaken for the underlying layers through to the sub-grade to determine both the thickness of these layersand their respective CBR values. In the event that the DCP tests show that the underlying pavement layers do not have the required thickness or CBR or if the bituminous cores do not meet the requirements of the specification or thickness required by the Contract, the Engineer will immediately notify RHD & LGED requesting that an inquiry be held to determine what course of action should be taken.

# CHAPTER 4
# CHALLENGES AND SCOPE FOR IMPROVEMENT

## 4.11 Introduction

There are many challenges in the way of quality control. The challenges come both from inside and outside of the organization. Some problems like the limitation of resources are national problems. There are also scopes of improvement in some cases. These issues are discussed in the following sections.

## 4.12 Organizational Aspects

Most of quality related issues arise within the organization. For this reason, the organization should be analyzed in various aspects to determine the quality relatedproblems. The main aspects to be considered are human recourse, culture of the organization's current position.

## 4.13 Human Resource Development

Human resource is the main resource of an organization. The government of Bangladesh Recruits the workforce and provides the required facilities. The facilities are in some cases not sufficient but as it is a government decision, this issue will not be discussed here. Recruitment is also a government issue. The first class officers of RHD are recruited by Bangladesh Public Service Commission BPSC. The recruitment is done for the entry first class post of Assistant Engineer. BPSC also recruits second class officers Sub Assistant Engineers. The first and second class officer recruited following rules and regulation of the government and they are the main workforce of RHD for implementing the construction and maintenance work. The higher posts are filled by promotion. The second class officers also get promotion to first class post, 33% of Assistant Engineerpost is filled by promotion. Third and Fourth class employees are for support and recruited by the government. The hierarchy of Roads & Highways Department Training is important for Human Resource Development (HRD). RHD and LGED has a training center. It is providing training on various financial and management issues. RHD and LGED Training Center is giving training on various topics but quality related training is absent. There is also scope of training for staffs in home and abroad. But the training is not uniformly distributed among the staffs. Another problem is 3rd and 4th class employee get less or no training.

### 4.13.1 Organizational Structure and Culture.

As mentioned earlier RHD is a government organization under the Road Transport and Highways Division, RTHD of the Ministry of Road Transport and Bridges. Being a Government Organization the processes of the organization is bureaucratic in nature. For any approval or order of the government bureaucratic process is followed. RHD is headedby the Chief Engineer; he is the Chief Executive Officer of the organization. RHD is divided into ten operational zones and five wings, which are headed by Additional Chief Engineers ACEs. The operational zones in the field are Dhaka, Chittagong, Comilla, Sylhet, Rajshahi, Rangpur, Khulna, Barisal, Mymensingh and Gopalganj zone and Wings are planning and Maintenance, Bridge Management, Technical Services, Management Services and Mechanical Wing The organizational culture in any department of Bangladesh is bureaucratic in nature. The organizational culture cannot be changed overnight. The technical decision making power is delegated at different level of the organization. It helps to maintain proper acceleration of the works. But in case of planning and approval of major projects the process is lengthy.

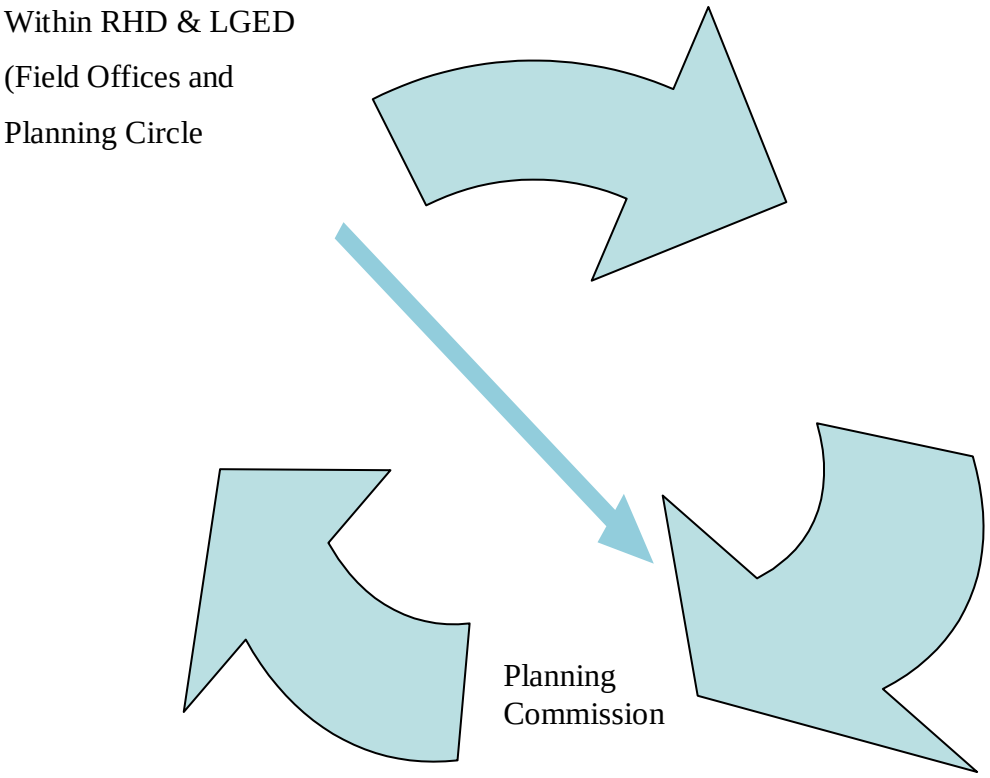



**Figure 4-1: Departments Involved in Planning**

The planning of projects involves every field level office and planning circle of RHD and LGED. It is a long process if ministry steps are avoided then the process will be easy and less time consuming. The organizational structure can be expanded for better project planning. The offices of RHD & LGED like Planning, Maintenance, HDM, BRRL, Training Center, PPP Cell, Procurement, and Design should be restructured

### 4.13.2 Organizational Position

Organization position can be determined by SWOT (Strength, Weakness, Opportunity and Threat) analysis. To develop safe, cost effective and well maintained road network RHD & LGED should overcome the weaknesses and work with integrity to minimize threats. From analysis above it can be seen that it has the ability to perform its mission.

### 4.13.3 Long Term Planning

Road master plan is a quality long term plan for quality road construction. It has identified and given solution to many of the problems. Road master plan was for 20 years, after five years from the initial projects taken are not completed. The road master plan suggested many priorities, which still remains as problem. These things should be considered immediately. Following are the prioritization fixed in the Master Plan.

4.13.3.1 Recurrent (maintenance) expenditure should have the first priority, and full needs should be planned for on an annual basis;

4.13.3.2 The rehabilitation of National Highways, Regional Roads and Zila Roads must be considered a priority, as delay will increase the costs of recovery;

4.13.3.3 Road and bridge projects that are related to traffic growth should be programmed according to dates that they are needed;

4.13.3.4 Bridge replacement and repair programmers are a priority, but have to be phased inorder to respect human capacity constraints in RHD and LGED; and

4.13.3.5 Axle load control is of the utmost priority.

## 4.14 Short Term Planning

The short term planning like project planning consumes time due to the bureaucratic nature of the processes. It cannot be avoided as many part of the government LGED, ministry and planning commission are involved in planning. Cross functional team work is needed to improve the efficiency. But the planning and design are done maintaining international standards.

The maintenance planning as said earlier is not given the top most priority.

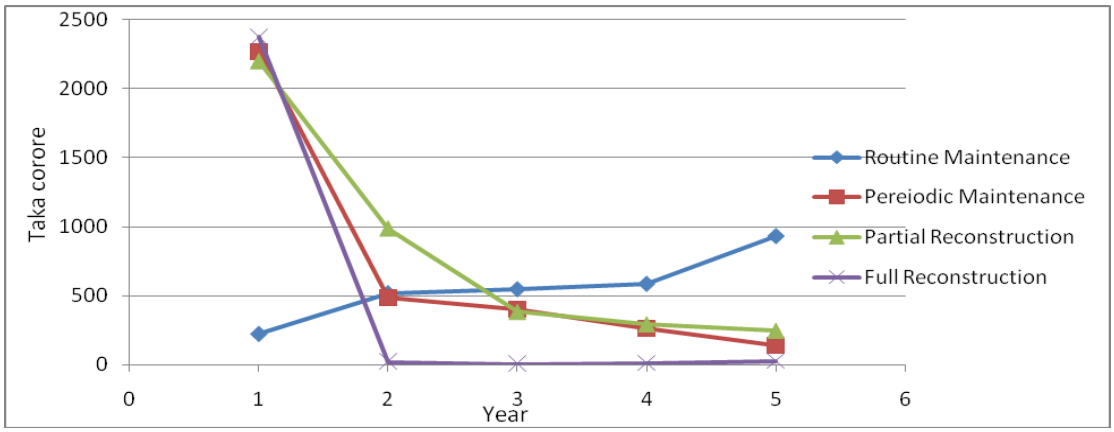



**Figure 4-2: Overall Maintenance Scatter Plot.**

The scatter plot of the year wise need gives is constant for routine maintenances is constant i.e. a constant amount of money is needed for routine maintenance. On the other hand periodic maintenance scatter plot gives decreasing trend. It means if the needed periodic maintenance and other amount is spent in the first year the maintenance need in the subsequent years will reduce. It is promising that the maintenance allocation has increased but still the amount is below the need.

Besides the maintenance allocation also includes the emergency works and the dues of the previous years. It is also a great concern for RHD that there is excessive amount of dues due to emergency repair during festival and natural calamities. The emergency works during the festivals and natural calamities cannot be termed as maintenance, it is rather temporary repair.

## 4.15 Procurement

The introduction of e-GP has limited the corrupt and fraudulent practice by the officers and the contractors. Now RHD have performing 100% e-GP tendering. The processes of the tendering followed are standard. The documents and standards are derived from European standard like International Federation of Consulting Engineers, FIDIC and New Engineering Contract, NEC. But there is lacking in the rules, PPR-2008 suggest the lowest bidder is to be awarded by tender evaluation committee. If the tender evaluation committee does not approve his bid then statue law permits him to go to court. Then the whole process will be hanged. Due to overcome the low cost quality there must be a minimum bar of bidding rate of every item. The whole lot or package of work should have lower limit but the every item should have lower limit.

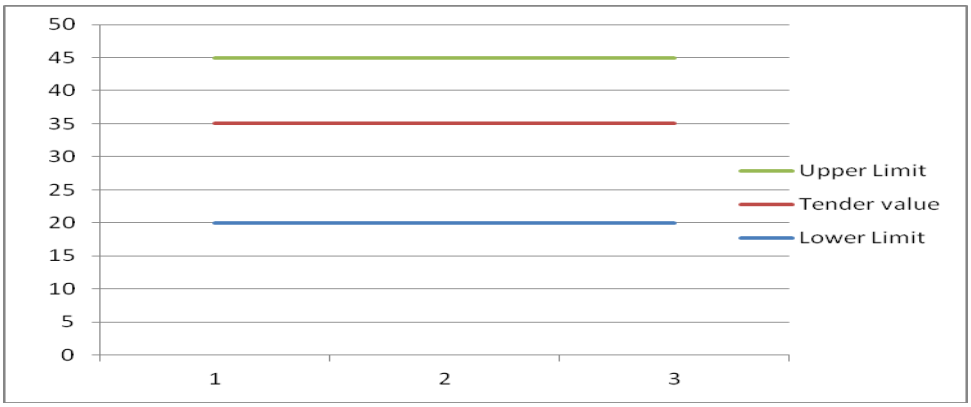



**Figure 4-3: Item Specific Upper and Lower limit.**

When the estimate is prepared then it should have control chart showing the upper, average and the lowest values for every item like Figure 4-5. By this the whole life costing concept can be taken into consideration in procurement.

### 4.15.1 Construction Management

Flowchart and Check list are maintained in construction management for quality impartment and management. Also world recognized standards and machineries are used in construction management. Besides these the progress of the ongoing projects are not up to the mark. For identify the problems two main projects, The Jaydevpur-Mymensing Road Improvement Project and the Dhaka Chittagong 4 lean Project is selected. The projects are fully government funded.

## 4.16 CBR

- Conduct on sample which remolded at OMC and dry density.
- Test should be done per km depend on soil type.
- If CBR less than 2% for 100 mm thickness then minimum CBR of 10% is to be provided to the sub-base for CBR of 2%.
- If CBR more than 15% no need to provide sub-base. (*link-5)*

### 4.16.1 CBR Testing Equipment

#### 4.16.1.1 CBR Lab Equipment (ASTM D1883)

- A good quality laboratory load frame with a capacity of 10,000lbf (44.5kN) or more that can operate at a strain rate of 0.05in (1.3mm) per minute is suitable for CBR penetration testing.
- Outfit the load frame with CBR Testing Components for load and displacement measurement, it will be ready to perform accurate, repeatable tests.
- For occasional CBR testing a Load Ring, Penetration Piston, and Dial Indicator Set will suffice.
- For efficient testing of multiple samples, Gilson recommends a Digital CBR Component Set which optimizes the collection, calculation, and reporting of data. The

set includes a 10,000lbf Load Cell, Penetration Piston, 2in Linear Variable Displacement Transducer, and a Two-Channel Data Readout.

- CBR Data Acquisition Software streamlines the calculation, graphing, and reporting process using real-time data collection, and plots results to ASTM/AASHTO requirements.
- CBR Test Set which includes required components to perform the CBR lab test.
- CBR Mold

  5lb Annular Surcharge Weight

  5lb Slotted Surcharge Weight

  Swell Plates

  CBR Filter Paper

  CBR Spacer Disc

  CBR Swell Tripod

  1x0.001in Mechanical Dial Indicator. (*Link 9*)

#### 4.16.1.2 CBR Field Testing Equipment (ASTM D4429)

- Penetration Piston for CBR is the same piston used for the laboratory method, but different equipment is required to provide enough resistance to load the piston.
- Field CBR Test Apparatus are various components positioned against a reaction load, such as a heavy truck or weighted framework, which applies force to the penetration piston through extension rods selected for proper spacing. Surcharge plates simulate loads from overlying materials, and a support bridge isolates the dial gauge to avoid interference from loads in the test area.

  2-speed or 3-speed Rotary Jack

  Connectors and Extension Rods

  10lb and 20lb Field Surcharge Plates

  Support Bridge

  1x0.001in Mechanical Dial Indicator. (*Link 9)*

## 4.17 Filed test of CBR

CBR Value Test by DCP

CBR = California Bearing Ratio.

DCP = Dynamic Cone Penetration.

CBR is a unit of bearing capacity of one layer. Which is expressed or calculated as a percentage.

We go to the street and talk to the engineer. He said i will do the compaction test in 1 week a

It that time we went.

It was a road of 300 feet road Purbachal, Dhaka.

1st They Dynamic cone penetration is installed. The value of CBR found in the field. If the design of the layer is equal to the value of CBR, work will start.

Base type = 1

Thickness = 200mm

Design CBR = 85%

I wrote down the initial reading after installing the device. I added thickness to it.

The initial reading was = (130 mm + thickness 200)

= 330mm

Then the DCP started throwing the hammer of the machine 330 passed.

He had to throw the hammer 6 times.

Then the rate of DCP penetration will be = (200 ÷ 68)

= 2.941

Let's apply this value to the CBR formula, = {292 ÷ (2.941) ^ 1.12}

= 87%

The standard CBR value Base Type-1 is 80%

But we got CBR value 87%.

This test showed that the CBR value of the said 200mm Layer of Base Type-1 is more than 85% of the design value. So it must be assumed that the layer has been compacted at the right rate.

## 4.18 Pavement components

Pavement component are 4 type

- Sub-grade
- Sub-base course
- Base course
- Surface Course

### 4.18.1 Subgrade

- To provide support to the pavement as its foundation.
- Top 30 cm of the cutting or embankment at formation level in rural roads consider as subgrade.
- A minimum of 100% of standard proctor compaction should be attain in subgrade.
- For clayey soil 95% and moisture content of 2% in excess of optimum value.
- Soil below subgrade should be compacted to 97% of standard proctor compaction.

(*Link-5)*

**Compaction sub grade** Compaction sub grade RHD manual thicknesses will be 150-300 mm But we went on the road and got the thickness 150-250 this is one of the reasons for the poor quality of roads in our country.

**Improved Sub-grade** is imported material (e.g. fine or coarse sand) that is locally available. It is intended to act as a cushioning layer between weak sub-grades and the road pavement layers. If the sub-grade is of sufficient strength (i.e. CBR value) then an improved sub-grade may be required.

- When the subgrade material is not adequate to support the necessary loads, then additional work should be done to make the material suitable for the construction.
- Normally, subgrade material is improved by installing geotextiles. They are used to prevent mixing of soft or inadequate soil that might affect the structural capacity of the subgrade.
- Geotextiles must have specific mechanical and hydraulic properties to ensure they have the right characteristics for their intended use.

### 4.18.2 Sub-base course

Selected materials placed on subgrade which is compacted to 98% of IS heavy compaction. Function of sub-base is to distribute the stresses over a wide area of the subgrade imposed by the traffic. Materials:

- CBR of 15%
- Passing through 425 micron IS sieve
- L.L<25 and P.I<6

Waste material such as Fly ash, Iron and steel slag Recycled concrete Municipal waste are also used. When subgrade is salty or clayey soil and annual rainfall of area is more than 1000 mm, a drainage layer of 100mm then formation width should be provided. (*Link-5)*

**Sub-base**: Sub-base RHD manually thickness will be 100mm-300mm. But we actually got 100mm the quality of the roads here has deteriorated. To make this bad thing better, RHD engineers need to check the quality of the road.

### 4.18.3 Base course

To with stand high stress concentrations which develop due to traffic under the wearing surface. Different types of base course used are:

- WBM
- Crusher-run macadam
- Dry lean concrete
- Soft aggregate base course
- Lime-fly ash concrete

**Base course**: The thickness of the base course will be 100mm-300mm but in reality I have seen that the following material has been used here. For this Very soon the road became potholes with cracks Accidents are happening.

### 4.18.4 Surface Course

Thickness of surface course depend upon the traffic volume and type of material used for it. For gravel roads extra thickness should be provided because of lost in thickness due to the traffic action. Bituminous wearing courses must be made up of good quality aggregate with aggregate impact value not exceeding 30 % in order to reduce degradation of aggregates by crushing. (*Link 5)*

**Surface course**: The thickness of the surface course will be 25-50 mm. But we saw they were giving 25-40 mm. For all these reasons, the bitumen of the road is going up when it is raining. And the road is being repaired every few days.

## 4.19 Bituminous Bound Materials

| Pavement Layer | Basic Properties | Brief Description of materials |
|---|---|---|
| Dense Bituminous Surfacing (DBS) | ACV of aggregate <30% | Mixture of Stone, fine filler and bitumen carefully graded to give a dense material with no voids. Mixed and laid by machine whilst hot. |
| Double bituminous surface treatment (DBST) | ACV of aggregate <28% | A combination of hot bitumen sprayed onto the road by machine and a single sized stones spread and rolled into the bitumen whilst hot. The process is then repeated using a second layer of bitumen and smaller sized stone. |
| Single bituminous surface treatment (SBST) | ACV of aggregate <28%. | A combination of hot bitumen sprayed onto the road by machine and single sized stones spread and rolled into the bitumen whilst hot. |
| Seal Coat | ------ | A mixture of bitumen and coarse sand/ pea gravels mixed hot before spreading and rolling. Usually carried out using labor intensive methods. |

| | | |
|---|---|---|
| Bituminous Carpeting | ACV of aggregate <30%. | A mixture of bitumen and graded stone mixed hot before spreading and rolling. Usually carried out using labor intensive methods. |
| Tack Coat | ------ | A coat of lightly cut-back bitumen sprayed onto an existing bituminous surfacing to provide a bond before laying a new bituminous layer such as carpeting or DBS. |
| Prime Coat | ------ | A coat of heavily cut-back bitumen sprayed onto an existing granular surfacing to provide a bond before laying a new bituminous layer such as carpeting or DBS. The spray rates for prime coats are normally about twice those of tack coats. |

**Table 4-1: Bituminous Bound Materials** *(link-5, p-15)*

The layer of soil immediately below the road pavement is referred to as the sub-grade and this is normally more carefully selected soil which is given additional compaction to increase its strength. In all cases the depth of sub-grade compaction should be 300mm. Because in Bangladesh it is often difficult to achieve satisfactory CBR values on naturally occurring sub- grades; improved sub-grades usually consisting of fine sand are normally used. The thickness of improved sub-grade is to be determined by the CBR of the natural sub-grade according to Table subjected to fulfillment of condition as per Article.

| Pavement Layer | Minimum CBR % (Lab. Test after 4 days soaking) | Maximum Field DCP Test mm/ blow | Maximum Aggregate Crushing Value % | Required Compaction | Typical Materials Likely to meet Specification. | Field result |
|---|---|---|---|---|---|---|
| Base Type I | 80% | 3.5 mm/ blow | 30% | 98% Vibrating Hammer / Heavy Compaction (Modified Proctor*) | Graded stone or graded stone with some brick or brick if it can meet specification | CBR value more than 85% |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sub base | 30% | 9.0 mm/ blow | 32% | 98% Vibrating Hammer / Heavy Compaction (Modified) | Graded materials consisting of brick or brick sand mixtures. Re- cycled pavement materials such as brick, broken concrete, old surfacing etc. | CBR value more than 45% |
| Improved Sub-grade | 8% | 22 mm/ blow | --- | 98% Vibrating Hammer / Heavy Compaction (Modified) | Usually locally occurring fine sand | ----- |
| Sub-grade (compacted min. 300mm thickness) | 4% | 30 mm/ blow | --- | 98% Standard Compaction | Natural soil of low plasticity | 48% |
| Earthwork in Embankment | 3% | 45 mm/ blow | --- | 95% Standard Compaction | Natural soil of low/ medium plasticity | 88% |

* Modified Proctor hereinafter abbreviated to Modified.

**Table 4-2: The CBR of the natural sub-grade (***link-5)*

| Min. CBR Value of Sub-grade material (at specified compaction) % | Thickness of Improved Sub-grade to give CBR of 8% |
|---|---|
| 2% | 450 mm |
| 3% | 300 mm |
| 4% | 250 mm |
| 5% | 200 mm |

 If CBR value of sub-grade is less than 4% procedure given in Article shall be followed. (*Link-5)*

**Table 4-3: Thickness of improved sub-grade for various sub-grade CBR value (***link-5***)**










## 1.1 Audit and Review

The audit and review system is weak in RHD & LGED. For quality in construction third party audit is important. BRRL was nominated by CE as the quality control auditor of RHD. But no fund is available for quality control audit. Without the third party audit quality in construction cannot be imparted. Review is necessary for future improvement. Monitoring circle of Planning and Maintenance wing has evaluation division to evaluate the works executed. But their activity is one off just after the project. Long term evaluation is necessary. Mainly the quality control field labs are now not sufficient to carry out field tests. There are some tests which are easy to conduct and frequently conducted these tests facilities should be established in the field divisions. Complex tests should be performed at the field labs. Field labs can be established in every field circle. Central Lab BRRL should have capacity of special tests and research.

# CHAPTER 5

# Conclusions and Future Works

## 5.1 Conclusions

It is obvious from chapter 3 and 4 that certain things should be improved in RHD & LGED to overcome quality related problems. Currently in follows international standard and processes. RHD is concerned about quality and have both short and long term plan for quality road construction. But the problems related to quality lies in implementation. Implementations of plans are not followed properly. There are also Quality Control of Roads Contraction in Bangladesh. The problems identified are not the only issues but if the identified issues can be solved than quality status of RHD & LGED will improve.

Some problems for quality degradation are identified in the study. For some problem the suggestions are given. But there are some problems which need further study as these issues have wide domain. But if the suggestion of the study is implemented properly the Roads & Highway Department and Local Government of Engineering Department will be able to provide safe, service able and cost effective road for the nation. The proper use of public money in road construction will help Bangladesh to become a medium income country of the world.

## 5.2 Limitations and Recommendations for Future Works

Followings are the recommendations of the study,

- The organizational structure should be expanded and the vacant posts should be filled in proper way.
- Quality related training programs should be started.
- Maintenance should be given priority. The total immediate maintenance of one year should be implemented to achieve value for money. The maintenance need can be covered from Road Maintenance Fund
- Despite low cost sourcing whole life costing should be considered. Item wise minimum coating limit should be imparted in PPR.
- To overcome financial constrains the projects should be implemented by Public Private Partnership, (PPP).

- Project Management should be strengthened and necessary actions should be taken to improve project management
- For quality testing of works the field labs should be established circle wise for the complex tests and at district level in every road division there must be provision of the simple testing. Specialized testing provision should be established in Bangladesh Road Research Laboratory (BRRL).
- The suggestions of the Road Master Plan like axle load control should be implemented.
- For proper supplier selection should be selected instead of low cost supplier selection. The technical ability of contractor should be given priority.
- Land acquisition should be managed properly.
- Third party audit should be done by BRRL and it should also be given financial support.
- Improving the Quality Assurance Plan a Total Quality Management Plan should be developed. The TQM plan will increase quality in every aspect of RHD & LGED and quality road will be it sequential out com.

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## Appendix

1. Pavement Design Guide for Roads and Highways Department.

## Question:

1. Why is quality control important?

   Answer: Quality control is important because it is the foundation of your project's success. We believe a robust quality plan inspires quality construction. Build it right the first time. Everything that goes into a construction build is dependent on a contract's quality plan. That means from the beginning of the project until the end, quality always remains at the forefront of everyone's minds. Poor quality can lead to a variety of problems such as defects, builds that won't last, confusion between parties involved and a lot of construction changes.

2. What is pavement?

   The pavement is a hard surface that's built with concrete or asphalt, like a road or a driveway.

3. How type are road pavement structure layers?

   Answer: The road pavement structure layers are as follows.

   - Subgrade or road bed
   - Sub base course.
   - Base Course.
   - Surface coarse or wearing course.

4. What are types of pavement?

   Answer: Types of pavement are mainly four.

   - Flexible pavement.
   - Rigid pavement.
   - Semi-rigid pavements.
   - Interlocking cement concrete block pavement (ICBP).

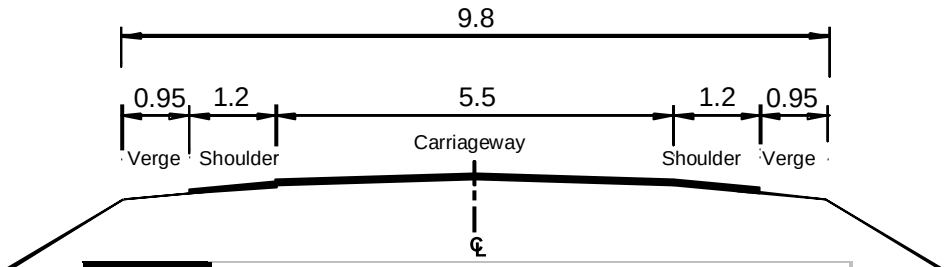
5. Why is Bitumen Used in Road Construction?

   Bitumen is used in road construction due to various properties and advantages it has over other pavement construction materials. Bitumen gain certain unique properties that are inbuilt in it during its manufacture. The bitumen as a raw material in flexible road construction and bitumen as a mix (composing other materials i.e. aggregates) serves certain advantages, that prompt to use bitumen widely in road construction.

# APPENDIX

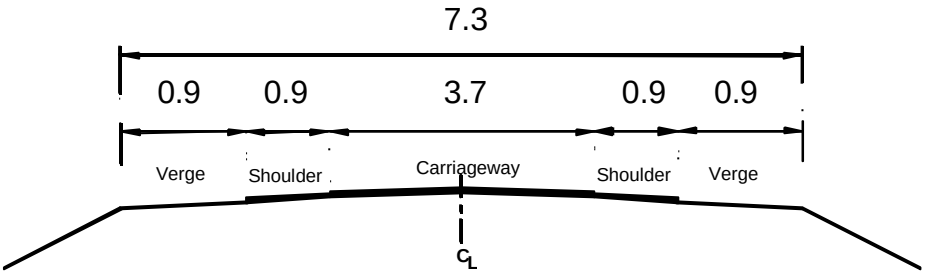
## Appendix A: Standard Pavement Designs

Type 5: 5.5m Carriageway




| | | | |
|---|---|---|---|
| | 40mm bituminous carpeting + 12mm seal coat | | |
| | 200mm base Type 1 | | |
| | 200mm sub-base | | |
| | | Existing Subgrade CBR | Improved Subgrade (mm) |
| | improved sub-grade (see table for thickness) | 3% | 300 |
| | | 4% | 250 |
| | | 5% | 200 |

**Type 6: 3.7m Carriageway**




| | | | |
|---|---|---|---|
| | 40mm bituminous carpeting + 7mm seal coat | | |
| | 150mm base Type 1 | | |
| | 150mm sub-base | | |
| | | Existing Subgrade CBR | Improved Subgrade (mm) |
| | improved sub-grade (see table for thickness) | 3% | 300 |
| | | 4% | 250 |
| | | 5% | 200 |

# Appendix B: Example of Pavement Design

**Background:** An existing 6.2m Regional Road that is located on an embankment requires full reconstruction. A check has been made and the existing road surface is 1.0m above the Highest Flood Level for a 50 year return period. Accordingly the embankment does not require to be raised.

A number of trial pits were undertaken and the CBR of the sub-grade beneath the existing road was found to be 3%.

A 24 hour classified traffic count was carried out on a typical weekday.

**Design:**
Half of the two-way flow of commercial vehicles is used to determine the cumulative ESAs over the design life of the road as follows:

| | **Existing Flow / day (0.5xtwo-way flow) (a)** | **ESA Factor (b)** | **Existing ESAs / day (a) x (b)** | **Annual ESAs (a) x (b) x365** |
|---|---|---|---|---|
| **Heavy truck** | 20 | 4.8 | 96 | 35,040 |
| **Medium truck** | 150 | 4.62 | 693 | 252,945 |
| **Light truck** | 50 | 1.00 | 50 | 18,250 |
| **Large bus** | 100 | 1.00 | 100 | 36,500 |
| | | | **Total** | **342,735** |

By reference to Table 4 and using the appropriate factor for a Regional road the cumulative ESAs over the design life for the road will be:

342,735 x 41.0 = 14 million ESAs

By reference to Table 6 an improved sub-grade will be required to achieve a sub- grade strength of 5% CBR and by reference to the design chart in Table 5 the required pavement layers will be:

130 mm DBS (40mm wearing course + 90mm base course)
250 mm Base Type 1
200 mm Sub-Base
300 mm improved sub-grade