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Graduation Project
Rehabilitation of Farsh Elhawa Street

Project Team

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Hebron – Palestine

2010

Abstract

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This project is a rehabilitation for Farsh Elhwa Street in Hebron city, the importance of this street is that it connects the rural areas of Hebron with the city.

This project is an application for engineering and technical specifications that have to be considered in highway design, the project consist of theory and calculations chapters as shown in the project scope, the project has two parts: field work and office work. The plans of the project contain: Horizontal plan, profile, horizontal and vertical curves, cross sections and the mass whole diagram.

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Chapter One

The Introduction

1-1 A historical overview of the development of the roads

Everybody travels, whether to work, play, for shopping, or do any activity, or visit people. All foodstuffs and raw materials must be carried from their place of origin to that of their consumption or adaptation, and manufactured goods must be transported to the marketplace and the consumer. Historically, people have travelled and goods have been moved: (1) by road, i.e. by walking and riding, using humans and various beasts to carry goods or to pull sleds, carts, carriages and wagons, and (since the late 19th century) using cycles and motor vehicles such as cars, buses and lorries; (2) By water, i.e. using (since early times) ships and boats on seas, rivers and canals; (3) by rail, i.e. initially using animals (in the early 19th century) and then steam-, oil- or electric-powered locomotives to pull passenger carriages and goods wagons; and (4) by air, i.e. using airships and aero planes (in the 20th century).

Whilst the birth of the road is lost in the mists of antiquity, there is no doubt but that the trails deliberately chosen by early man and his pack animals were the forerunners of today’s road. As civilization developed and people’s desire for communication increased, the early trails became pathways and the pathways evolved into recognized travel ways. Many of these early travel ways – termed *ridgeways* – were located high on hillsides where the underbrush was less dense and walking was easier; they were also above soft ground in wet valleys and avoided unsafe wooded areas.

1-2 Importance of the roads

A safe and efficient land transportation system is an essential element of sustainable regional or national economy. Roads have been and continue to be the backbone of the land transportation network that provides the accessibility for the required mobility to support economic growth and promote social activities. As more and more advanced and speedy modes of transportation are developed over time, and as the economic activities of the human society grow in pace and sophistication, the roles of roads have multiplied and their importance increased. At the same time, the potential adverse impacts of road development have also grown in magnitude, especially when proper planning, design, construction or management is not carried out.

To fully exploit the benefits of highway development and minimize possible adverse influences, the study of highway engineering must expand from merely meeting the basic needs of offering safe and speedy access from one point to another, to a field of study that not only covers the structural and functional requirements of highways and city streets, but also addresses the socio-economic and environmental impacts of road network development. Traditional engineering curriculum does not adequately cover these somewhat “softer” aspects of highway engineering and the societal roles of highway engineers.

1-3 Importance and goals of the project.

Justification for works A frequent justification for construction, rehabilitation and maintenance of highways in developing countries is that improved transport facilities are promoting road development. This is most explicitly demonstrated in the great number of cases where road works are financed by grants from national or international aid agencies or by loans from the World Bank or one of the regional development banks.

However, development is an ambiguous concept. Development is defined in different ways by different scholars. Various theories differently emphasize factors which Determine development and how a desired development can be promoted. Opinions on how different types of roads influence development have changed with time as more experience has been acquired.

The purpose from the reconstruction of the roads according to the geometric specifications Is to serve people, facilitate their movement to a accomplish their requirements, and to connect the regions together or for a civil or an agriculture development along the road, so we must put an ideal design to serve those purposes .

Goals of the project :

1-To serve the region through which the road is passing, and that to make it vital and developed.

2-Provision of security on the street by providing sidewalks and footpaths, and traffic signals necessary for the street as possible.

3-Design the street according to the technical specifications and engineering, according to the law and the Ministry of Public Works used in the West Bank.

٤- Legitimacy of the new location of the court where it can be accessed directly from the city of Hebron, without the need for progress on the road settlement in that region.

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1-4 Research method

- To identify the subject of research (rehabilitation of Farsh Elhawa Street) and inquire about the subject of the supervisor and the competent authorities such as Hebron municipality.
- Make a site visit (reconnaissance) of the site and took a thorough idea about the nature of the project and the problems related to it and the important details of the design and implementation in order to get the best results.
- Start to research in the library and on the Internet for references and sources that can be used in the project.
- The implementation of the field work with a survey of the street and including the details of the order processing schemes for the planning and design process. The process of field survey begins with the information from the point of coordinates resulted from link traverse which is adjusted by using the Adjustment by Least Squares so as to accuracy of survey work.
- A visit to the Municipality of Hebron in order to identify the width of the road.
- Begin the process of planning and design stages by different data from the field work.
- Start typing the introduction of the project taking into account the assets and the conditions to be provided in the introduction and taking in consideration the supervisor advice and opinion.

1-5 Structure of the project.

The research (the project) includes several chapters as follows:

- Chapter I: contains an introduction which describes the subject of research (rehabilitation of Farsh Elhawa Street), the importance, objectives, research method, the structure of the search, the previous studies on the subject and addresses the issue of roads in the city of Hebron in the past, present, and some of the problems on the subject, Obstacles and difficulties.
- Chapter II: talking about route planning and surveying works on the routing of the road, and the main factors that control the route planning.
- Chapter III: Looking at ways to know and determine the traffic volume from the enumeration and the types of vehicles on the road and means of conducting the census, and determine the terms of the census and determine the size of the current and future traffic.
- Chapter IV: talking about the horizontal and vertical design of the road and how the design of horizontal curves and progressive tendencies and occasional in

addition to the design of vertical curves and the basic elements of the curve, vertical and great vertical orientation of the Road.

- Chapter V: talking about the adjustment of the traverse by using Least Square method, and other methods to emphasis the results .
- Chapter VI: talking about the structural design of roads.
- Chapter VII: talking about the amount of the expense of drilling and filling necessary for the implementation of the project and the linear representation of the amount of drilling and filling (mass whole diagram).
- Chapter IX: talking about cost calculations and the tender documents for the design of (Farsh Elhawa Street).
- Chapter X: results and recommendations proposed by the Working Group.

1-6 Obstructions and difficulties.

1. Political and security conditions prevailing in the area where the street is near the road of the settlements in that region.
2. Difficulty of getting information from the responsible departments through the process of gathering information.

1-7 The Surveying instruments and software's used in this project.

1- Total Station (SoKKIA 630R).

2- AutoCAD program.

3- Autodesk Land Desktop program.

4- AutoCAD Civil 3D 2011 – British

5- Adjust program.

1-8Time table of the first semester.

Activity	No. of weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Collecting information	4																
Reconnaissance visits	1																
Field working	0																
Insert point and writing	2																
Preparation of the first Report	1																
Preparation of the final Report	2																

(Table1-1) Time table for the first semester.

1-9 Time table of the second semester .

Activity	No. of weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Accounting the number of vehicles	2																
Draw CL on the computer Insert circular curve on CL	2																
Draw profile on the computer & the design of vertical curves	2																
Laboratory tests and Structural design	4																
Draw cross-sections on the computer	2																
Calculation of areas and volumes	1																
Preparation of the final Report	2																

(Table1-2) Time table for the second semester.

1-10 The previous studies

Previous studies are of the most important pillars of the main pillars in the planning for a study of the implementation of any project. In any type of the projects must account studies and analysis of previous studies, because it has great benefit in terms of identifi-ication with the ideas you want to work in this project and try to take advantage of them and try to correct errors if they exist.

History of roads in the city of Hebron known since the twentieth century ,and the first paved roads in Hebron suitable for vehicles were the main streets from which the ate-ntion for rehabilitate the other roads was started.

No previous studies were found to this project so we decided to make all the required things for the success of this project. So we go to our supervisor to take his advices about field working and other things.

Chapter two

Field Work Surveys

2-1 Introduction.

In the evaluation or reconstruction of existing streets and the establishment of new ones, surveys are required for the development of project plans and the estimation of costs. The performance of good surveys requires well-trained engineers who have an understanding of the planning, design, and economic aspects of highway location and who are sensitive to the social and environmental impacts of streets development.

2-2 The project survey field works:

In our project the surveys fields work include two main stages:

* First stage Traverse field work, which is constructed from six main stations as link Traverse.

* Second stage, Land surveys of “Farsh Alhawa” street and all details on it such as buildings, pavement…etc.

The method of taking the details in the area in which we were working is to make control stations from a full control GPS points, then we use the total station to measure distances and angels and the following figure shows that

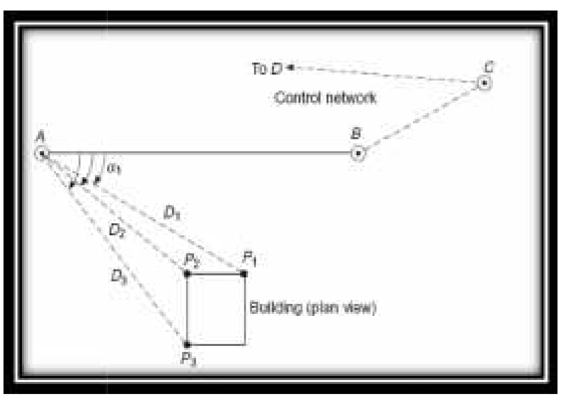


Figure (2.1) Taking details in the field [5].

2-3 Surveying Process

Surveying is concerned with the fixing of position whether it be control points or points of topographic detail and, as such, requires some form of reference system.

The establishment of two- or three-dimensional control networks is the most fundamental operation in the surveying of an area of large or small extent. The concept can best be illustrated by considering the survey of a relatively small area of land as shown in Figure 2.2. The processes involved in carrying out the survey can be itemized as follows:

1-A careful reconnaissance of the area is first carried out in order to establish the most suitable positions for the survey stations (or control points) *A*, *B*, *C*, *D*, *E* and *F*. The stations should be intervisible and so positioned to afford easy and accurate measurement of the distances between them.

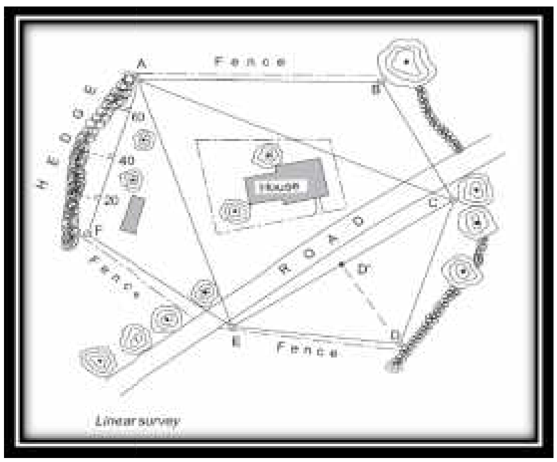


Figure (2.2) Linear Survey [5].

2-The distances between the survey stations are now obtained to the required accuracy.3-The proven network can now be used as a reference framework or huge template from which further measurements can now be taken to the topographic detail.

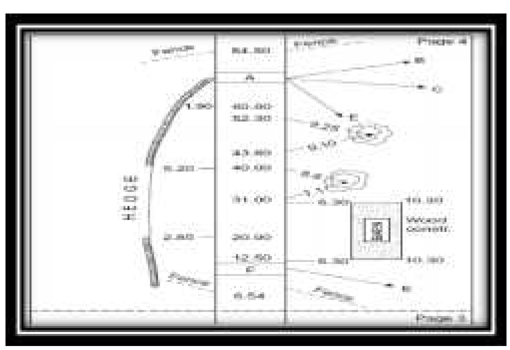


Figure (2.3) Field book [5].

The above comprises the steps necessary in carrying out this particular form of survey, generally referred to as a linear survey.
4-As the aim of this particular survey was the production of a plan, the accuracy of the survey is governed largely by the scale of the plan. For instance, if the scale was, say, 1 part in 1000, then a plotting accuracy of 0.1 mm would be equivalent to 100 mm on the ground and it would not be economical or necessary to take the offset measurements to any greater accuracy than this.
However, as the network forms the reference base from which the measurements are taken, its position would need to be fixed to a much greater accuracy.

2-4 Traversing

Since the advent of EDM equipment, traversing has emerged as the most popular method of establishing control networks not only in engineering surveying but also in geodetic work. In underground mining it is the only method of control applicable whilst in civil engineering it lends itself ideally to surveys and dimensional control of route-type projects such as highway and pipeline construction.

Types of traverse:

(1) Link traverse

Figure 2.4 illustrates a typical link traverse commencing from higher order point *Y* and closing onto point *W*, with terminal orienting bearing to points *X* and *Z*.

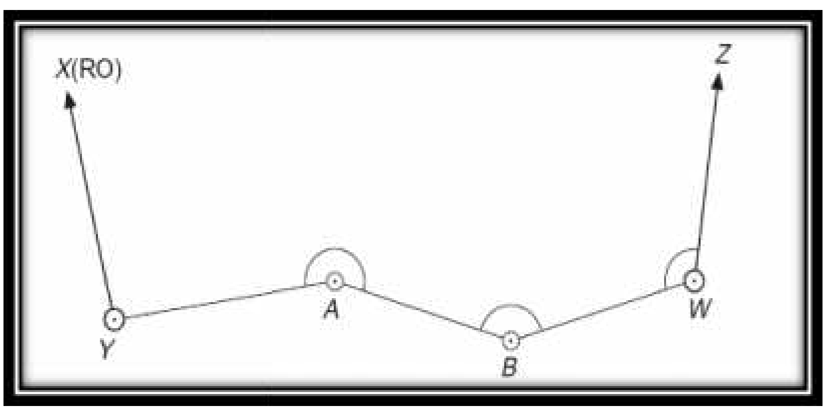


Figure (2.4) Link Traverse [5].

(2) Polygonal traverse (Closed).

Figure 2.5 illustrates the concept of a polygonal traverse. This type of network is quite popular and is used extensively for peripheral control on all types of engineering sites. If no orientation facility is available, the control can only be used for independent sites and plans and cannot be connected to other survey systems.

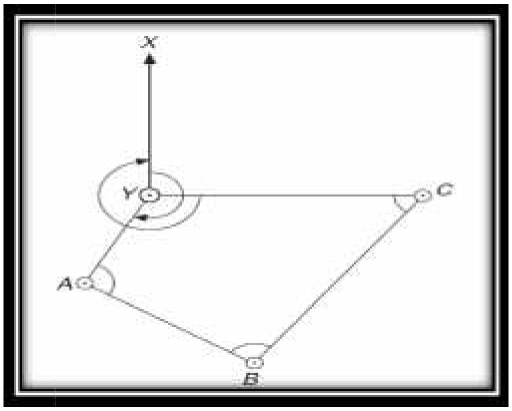


Figure (2.5) Closed Traverse[5].

(3) Open (or free) traverse

Figure 2.6 illustrates the open traverse which does not close into any known point and therefore cannot provide any indication of the magnitude of measuring errors. In all surveying literature, this form of traversing is not recommended due to the lack of checks. Nevertheless, it is frequently utilized in mining and tunnelling work because of the physical restriction on closure.

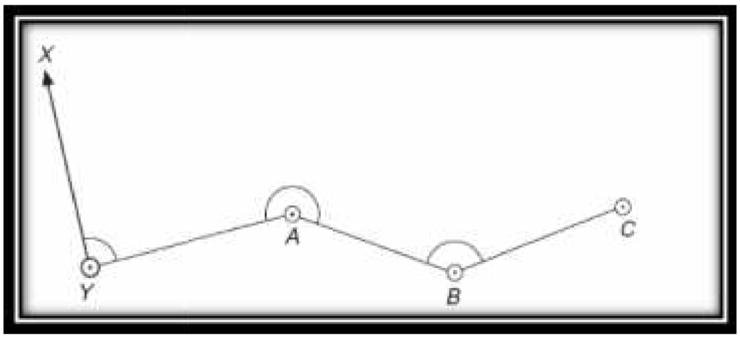


Figure (2.6) Open or (free traverse)[5].

Chapter three

Traffic volume and traffic signs

3-1 Introduction to volume studies

Traffic volume studies are conducted to collect data on the number of vehicles and/or pedestrians that pass a point on a highway facility during a specified time period. This time period varies from as little as 15 minute to as much as a year depending on the anti-cipated use of the data. The data collected also may be put into subclasses which may include directional movement , occupancy rates vehicle classification and pedestrian age .Traffic volume studies are usually conducted when certain volume characteristics needed, some which follow :

3-1-1 Average Annual Daily Traffic (AADT)

Is the average of 24-hour counts collected every day of year AADTs are used in several traffic and transportation analyses for

a- Estimation of highway user revenues
b- Computation of crash rates in terms of number of crashes per 100 million vehicle miles
c- Establishment of traffic volume trends
d- Evaluation of the economic feasibility of highway projects.
e- Development of freeway and major arterial street systems
f- Development of improvement and maintenance programs.

3-1-2 Average Daily Traffic (ADT)

is the average of 24-hour counts collected over a number of days greater than one but less than a year ADTs may be used for :

a- Planning of highway activities
b- Measurement of current demand
c- Evaluation of existing traffic flow

3-1-3 peak hour volume (PHV)

Is the maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes PHVs used for :

a- Functional classification of highways.
b- Design of the geometric characteristics of highway for example number of lanes intersection signalization or channelization.
c- Capacity analysis
d- Development of programs related to traffic operations for example one-way street systems of traffic routing
e- Development of parking regulations

3-1-4 vehicle classification (VC)

Records volume with respect to the type of vehicles, for example , passenger cars ,

two-axle trucks , or three-axle trucks .

VC is used in :

a- Design of geometric characteristics with particular reference to turning-radii requirements, maximum grads, lane widths and so forth.
b- Capacity analyses
c- Adjustment of traffic counts obtained by machines
d- Structural design of highway pavements

3-1-5 Vehicle Miles Of Travel (VMT)

Is a measure of travel along a section of road it is product of the traffic volume and the length of roadway in miles to which the volume is applicable VMTs are used mainly as a base for allocating resources for maintenance and improvement of highways

3-2 Methods of conducting volume counts

Traffic volume counts are conducted using two basic methods: manual and automatic a description of each counting method follows.

3-2-1 Manual method

Most applications of manual counts require small samples of data at any given location Manual counts are sometimes used when the effort and expense of automated equipment are not justified. Manual counts are necessary when automatic equipment is not available.

Manual Count Recording Methods

Manual counts are recorded using one of three methods: tally sheets, mechanical counting boards, or electronic counting boards.

3-2-1-1 Tally Sheets

Recording data onto tally sheets is the simplest means of conducting manual counts. The data can be recorded with a tick mark on a pre-prepared field form. A watch or stopwatch is necessary to measure the desired count interval.

3-2-1-2 Mechanical Counting Boards

Mechanical count boards consist of counters mounted on a board that record each direction of travel. Common counts include pedestrian, bicycle, vehicle classification, and traffic volume counts. Typical counters are push button devices with three to five registers. Each button represents a different stratification of type of vehicle or pedestrian being counted. The limited number of buttons on the counter can restrict the number of classifications that can be counted on a given board. A watch or a stopwatch is also necessary with this method to measure the desired count interval. See Figure 3.1 for an example mechanical counting board.

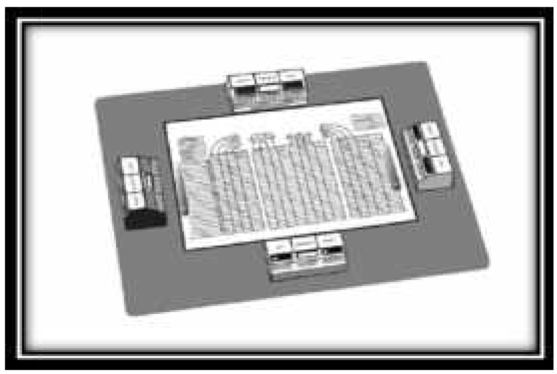


Figure (3.1) Mechanical counting Board [1]

3-2-1-3 Electronic Counting Boards

Electronic counting boards are battery-operated, hand-held devices used in collecting traffic count data. They are similar to mechanical counting boards, but with some important differences. Electronic counting boards are lighter, more compact, and easier to handle. They have an internal clock that automatically separates the data by time interval. Special functions include automatic data reduction and summary. The data can also be downloaded to a computer, which saves time. See Figure 3.2 for an example electronic counting board.

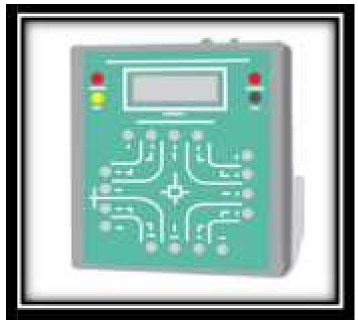


Figure (3.2) Electronic counting Board [1]

3-2-2 automatic method

The automatic count method provides a means for gathering large amounts of traffic data. Automatic counts are usually taken in 1-hour intervals for each 24-hour period. The counts may extend for a week, month, or year. When the counts are recorded for each 24-hour time period, the peak flow period can be identified.

Automatic counts are recorded using one of three methods: portable counters, permanent counters, and videotape.

3-2-2-1 Portable Counters

Portable counting is a form of manual observation. Portable counters serve the same purpose as manual counts but with automatic counting equipment. The period of data collection using this method is usually longer than when using manual counts. The portable counter method is mainly used for 24-hour counts. Pneumatic road tubes are used to conduct this method of automatic counts (see Figure 3.3). Specific information pertaining to pneumatic road tubes can be found in the users' manual.

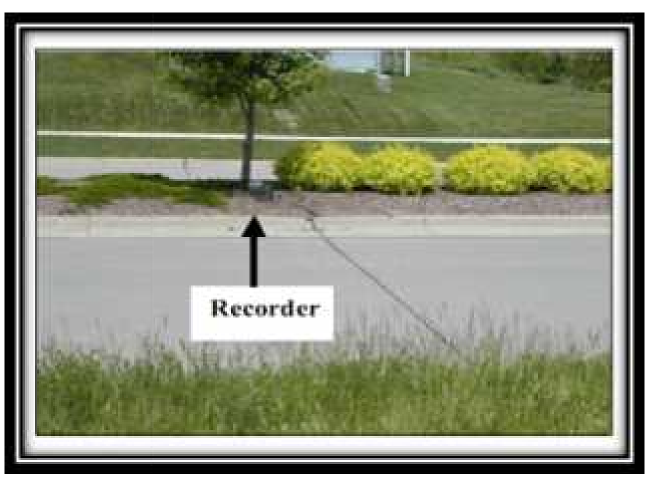


Figure (3.3) Pneumatic Road Tube and Recorder [1]

3-2-2-2 Permanent Counters

Permanent counters are used when long-term counts are to be conducted. The counts could be performed every day for a year or more. The data collected may be used to monitor and evaluate traffic volumes and trends over a long period of time. Permanent counters are not a cost-effective option in most situations. Few jurisdictions have access to this equipment.

3-2-2-3 Videotape

Observers can record count data by videotaping traffic. Traffic volumes can be counted by viewing videotapes recorded with a camera at a collection site. A digital clock in the video image can prove useful in noting time intervals. Videotaping is not a cost-effective option in most situations. Few small jurisdictions have access to this equipment.

Figure (3.4) Videotape [1]

3-3 calculation of traffic volume

Table (3-1) Field observation for the traffic volume

time	Small vehicle	Heavy vehicle
8-9	110	27
9-10	120	30
10-11	130	28
11-12	100	27
12-13	110	33
13-14	115	32
14-15	120	38
15-16	105	20
16-17	115	25
17-18	95	15
18-19	110	10
19-20	90	15
average	110	25

Type of the vehicle	Number of vehicle (vehicle\hour)	Equivalent number	Total number of vehicles
Small vehicle or taxi	110	1	110
Heavy vehicle	25	3	75
total			185

We will take the design period for the coming 20 years

Average of number of vehicle per hour =379

Average Annual Daily Traffic =185*24=4440 vehicle/day

If there is not enough information about design hourly volume (DHV) so it's possible to consider traffic volume for design as a ratio from the AADT.

DHV = K*ADT

To calculate the number of lanes to overcome the current traffic volume and the future one in a period of time (20 years), we multiply the ADT by the peak factor A.A.D.T=9096 vehicle /day

A.A.D.T $_{\text{(after 20 years)}}$ =4440 * 2.5=11100 vehicle/day

(Where 2.5 Is the peak factor)

Because there is not accurate information about the number of vehicles at peak hours so we consider the design traffic volume equal a percent of the A.D.T ,and this percent ranges from 0.12 to 0.24 and usually we take it as 0.16 so :

DHV = K*ADT

DHV = 0.16*11100=1776 vehicle /hour

The roads in Palestine are roads of the third class so we took the se3a tasmwmoa equal 850 vehicles /hour, number of lanes needed to overcome vehicles in the next 20 years equal

1776/850 = 2 lanes for each side.

3-4 Traffic Signs.

3-4-1 Introduction.

All movement on the road and intersections must be regulated so the use of traffic control devices might be needed to provide the road user limited, but essential, information regarding regulation, guidance, and warning.

Traffic control signs include intersection control (Stop and Yield), lane usage control (Right Lane Must Turn Right, etc.), movement prohibition (No U-Turn, etc.), speed limit, and parking signs among others.

In addition to separating opposing traffic and designating lanes for traffic moving in the same direction, pavement markings are used in many other ways. This includes designating where pedestrians are to cross the street (crosswalks), indicate where drivers should stop their vehicles (stop bars), and complement lane usage control signs (turn and through arrows).

3-4-2 Traffic Signs.

The most common and oldest method of traffic control is by means of the traffic sign. Signs functions are to control the movement of vehicles, to reduce the hazard of traffic operation, and to improve the quality of flow.

Signs should be placed as necessary for safety and proper regulation of traffic. However, the use of too many signs in a given location may reduce the effectiveness of all the signs at that location.

3-4-3 Purposes of Traffic Signs.

Traffic signs are devices placed along, beside, or above a highway, roadway, pathway, or other route to guide, warn, and regulate the flow of traffic, including motor vehicles, bicycles, pedestrians, equestrians, and other travelers.

It is possible, in many cases, to provide essential information to road users on low-volume roads with a limited number of traffic control devices. The focus might be on devices that:

A. Warn of conditions not normally encountered;

B. Prohibit unsafe movements; or

C. Provide minimal destination guidance.

As with other roads, the application of traffic control devices on low-volume roads is based on engineering judgment or studies.

Signs, like any other traffic control devices, must meet five fundamental requirements:

- Fulfill a need.
- Command attention.
- Convey a clear, simple meaning.
- Command respect from travelers.
- Give adequate time for proper response.

Signs should be placed only where warranted by facts and engineering studies. Signs that are unwarranted or ineffective may distract road users from more important traffic control devices, may breed disrespect for all signs in the area, and are often a waste of valuable public agency and taxpayers' resources.

3-4-4 Traffic sign Function.

These three functions are carried out by three different classifications of road sign, which are visually different to enable drivers to determine rapidly the category of any particular sign. Signs shall be defined by their function as follows:

1. Regulatory signs give notice of traffic laws or regulations.
2. Warning signs give notice of a situation that might not be readily apparent.

3. Guide signs show route designations, destinations, directions, distances, services, points of interest, and other geographical, recreational, or cultural information.

3-4-4-1 Regulatory signs.

Regulatory signs shall be used to inform road users of selected traffic laws or regulations and indicate the applicability of the legal requirements.

Regulatory signs shall be installed at or near where the regulations apply. The signs shall clearly indicate the requirements imposed by the regulations and shall be designed and installed to provide adequate visibility and legibility in order to obtain compliance.

Regulatory signs shall be retro reflective or illuminated to show the same shape and similar color by both day and night, unless specifically stated otherwise in the text discussion of a particular sign or group of signs.

The requirements for sign illumination shall not be considered to be satisfied by street, highway, or strobe lighting.

Regulatory signs inform the driver of the applicability of specific laws and regulations along indicated sections of road. Regulatory signs are posted where they can be seen clearly, and the section of road over which the regulation applies should be delineated clearly. Regulatory signs themselves can sub classify into:

1- Right of way signs
2- Speed signs
3- Movement sign
4- Parking signs
5- Pedestrian signs

3-4-4-2 Warning Signs.

Warning signs call attention to unexpected conditions on or adjacent to a highway or street and to situations that might not be readily apparent to road users. Warning signs alert road users to conditions that might call for a reduction of speed or an action in the interest of safety and efficient traffic operations.

The purpose of a warning sign is to provide advance warning to the road user of unexpected conditions on or adjacent to the roadway that might not be readily apparent.

The use of warning signs should be kept to a minimum as the unnecessary use of warning signs tends to breed disrespect for all signs. In situations where the condition or activity is seasonal or temporary, the warning sign should be removed or covered when the condition or activity does not exist.

Where caution is required, including in some cases the reduction of speed or a special alertness to conditions on or close to the road, warning signs alerts the driver. Warning signs may be erected under the following conditions:

1- To indicate changes in horizontal alignment.
2- To indicate an intersection.
3- To give warning that the driver should expected traffic control devices.
4- To warn converging traffic lanes.
5- To indicate narrow roadways
6- To indicate changes in highway geometry such as the end of a divided highway.
7- To advise of unexpected or unusual grades.
8- To indicate sudden changes in surface condition or poor pavement condition.

All warning signs shall be diamond-shaped (square with one diagonal vertical) with a black legend and border on a yellow background unless specifically designated otherwise. Such as "regarding conditions associated with pedestrians, bicyclist school buses, and schools".

The total time needed to perceive and complete a reaction to a sign is the sum of the times necessary for Perception, Identification (understanding), Emotion (decision making), and Volition (execution of decision), and is called the PIEV time. The PIEV time can vary from several seconds for general warning signs to 6 seconds or more for warning signs requiring high road user judgment.

Warning signs should be placed so that they provide adequate PIEV time Warning signs should not be placed too far in advance of the condition, such that drivers might tend to forget the warning because of other driving distractions, especially in urban areas.

Minimum spacing between warning signs with different messages should be based on the estimated PIEV time for driver comprehension of and reaction to the second sign. The effectiveness of the placement of warning signs should be periodically evaluated under 5-

3-4-4-3 Guide Signs.

The purpose of a guide sign is to inform road users regarding positions, directions, destinations, and routes.

The familiarity of the road users with the road should be considered in determining the need for guide signs on low-volume roads. Low-volume roads generally do not require guide signs to the extent that they are needed on higher classes of roads.

Because guide signs are typically only beneficial as a navigational aid for road users who are unfamiliar with a low-volume road, guide signs might not be needed on low-volume roads that serve only local traffic.

If used, destination names should be as specific and descriptive as possible, destinations such as campgrounds, ranger stations, recreational areas, and the like should be clearly indicated so that they are not interpreted to be communities or locations with road user services.

Guide signs may be used at intersections to provide information for road users returning to a higher class of roads.

Guide signs erected along highway to enable the traveler to find and follow routes in rural and urban areas and to identify and locate items of need and interest. The class of sign normally is considered composed of three categories:

1- Route markers and auxiliary markers.
2- Destination and distance signs.
3- Information signs.

3-4-5 Shape of the sign.

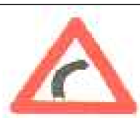
Particular shapes, as shown in Table (3-2), shall be used exclusively for specific signs or series of signs.

The shape of a road sign can tell you as much about the sign's message as its color.

Shape	Signs
Octagon	Stop
Equilateral triangle	Yield
Circle	Highway- rail grad Crossing (advanced warning) Emergency evaluating rout marker
Pennant shape/isosceles triangle	No Passing
Pentagogon	School Crossing Series County Rout Sign
Crossbuck (Two rectangles in an”x” configuration	Highway-Rail Grade Crossing
Diamond	Warning Series
Rectangle	Regulatory Series Guide Series Warning Series
Trapezoid	Recreational Series

Table 3-2 Uses of sign shape

The next table shows the main signs, which we use it in our project:

Warning Signs	**A meaning of the sign**
	Crossroads in intersection
	Crossroads in intersection to left
	Crossroads in intersection to right
	To indicate high turn to left
	To indicate high turn to right
	In front of you a crossing for the pedestrian
	Children are near the place
	Maximum speed limited

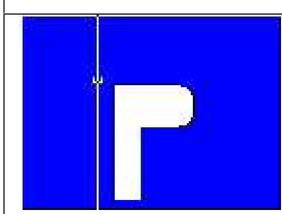
	Stop
	No left turn
	No Right turn
	T- junction
	Roundabout road
	Left-Right passing
	Parking

Table 3-3 Main signs [2]

3-5 Guard rail or guardrail

Sometimes referred to as guide rail or railing, is a system designed to keep people or vehicles from (in most cases unintentionally) straying into dangerous or off-limits areas. A handrail is less restrictive than a guard rail and provides both support and the protective limitation of a boundary.

We classify guardrails with hot dip zinc coating content requirements; also another way for us to divide the guardrails is according to the beam types.

1. Types According to Zinc Coating:

   Type I. hot dip galvanized: 550 g/m2 (40µ)

   Type II. hot dip galvanized:1100 g/m2 (80µ) or 1200 g/m2 (85µ)

2. Types According to Beam Types:

   Type I. W-beam guardrails

   Type II. Thrie beam guardrails

Steel guardrails provide a visual and physical barrier between traffic and work areas. It is used for protection against accidents due to lift trucks or other mobile equipment in dock areas, aisles, around special equipment, or offices. Reduce costly damage to equipment and inventory. Modular system is easily expanded or moved as needed. For indoor or outdoor use.

Figure (3.5) guardrail[1]

3-6 Highway Lighting

A primary purpose of lighting a roadway at night is to increase the visibility of the roadway and its immediate environment, thereby permitting the driver to maneuver more efficiently and safely. The visibility of an object is that property which makes it discernible from its surroundings. This property of an object depends on a combination of the following factors:

(1) The differences in luminance, hue, and saturation between the object and its immediate background (contrast).

(2) The angular size of the object at the eye of the observer.

(3) The luminance of the background against which it is seen.

(4) The duration of the observation.

3-6-1 Types of Lamp

Lamp is the bulb or light source. The lamps considered suitable for road lighting are of five main types. These are tungsten filament, sodium vapor, tubular fluorescent, high-pressure mercury fluorescent, and the uncorrected high-pressure mercury lamps.

In our project, we use the tungsten filament, because its use is now generally confined to residential streets and pedestrian areas such as sidewalk and shapping areas. The use of tungsten lamps in residential streets is due to their low initial cost, and the comfortable warm light.

In highway lighting we must define the following terms;

1- Lantern:

It consists of the lamp together with its hosing, reflectors to distribute the light and diffusers to decrease the glare effect.

2- Outreach:

This is the horizontal distance measured between the center of a lantern mounted on a bracket and the center of the supporting column or wall face.

3- Overhang:

The overhang is the horizontal distance between the center of a lantern and the adjacent edge of the carriageway.

3-6-2 Lighting On Intersection

Intersection Lighting: Normally there are four properties at an intersection that are directly affected by the installation of a street light. 75% of those property owners must agree with the installation and location of the light. If traffic safety issues can be documented, the light may be installed without 75% agreement. Installation is dependent on the availability of funding. County and State Road intersection lighting is controlled by the State Highway Administration, please contact the SHA. County and Private Road intersection lighting is the responsibility of the owners of the private road.

Long Line Lighting: This lighting provides roadway lighting between intersections in a subdivision or urbanized area. If the distance between intersections is between 800 and 1,000 feet, a light could be warranted. Funding for long line lighting is not generally available and would require an outside funding source such as a Home Owners Association or any other individual or group who is requesting the street light installation. This type of installation can only be accomplished in an area where underground electric cable is available.

Development Lighting: The developer provides public street lighting as a requirement of the development process. Streetlights are installed at County road intersections, at the end of a cul-de-sac that is a minimum of 500' in length, and between intersections at 400 to 500 foot spacing. Developments with lot sizes that are 2 acres or larger are not required to provide lighting between intersections unless there is a traffic safety issue. If street lighting is an issue with you, ask the builder or the Harford County Street Light Representative to advise you of the location, type and size of any street lighting proposed near your home site.

End of Roadway: If the street is 500' or longer to its terminus and 75% of the adjacent property owners agree with the street light installation, a light would be considered, dependent on the availability of funding.

Some of lights on intersection:

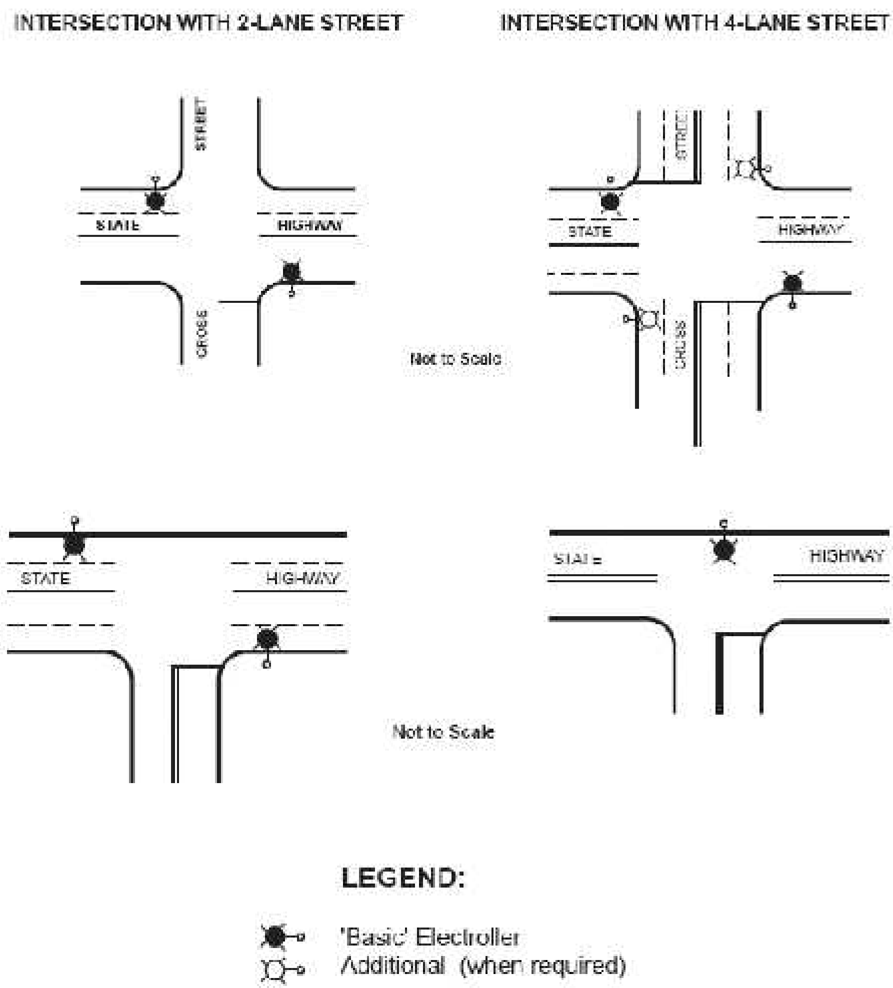


Fig. 3-6 Intersections lighting [1]

3-6-3Solar lighting systems

3-6-3-1 Functions

Unique Solar Powered Highway/Street lighting system utilizing the latest Xenon Gas Discharge Lighting Technology to provide a brilliant white light(more has twice the brightness of halogens) and many times brighter than compact fluorescents.

Illuminates an area over 100 feet in diameter (at only 15 feet high,) totally independent of any external power supply.
The self contained system consists of a light weight 9 foot structural aluminum lamp extension arm, with electronics & power supply housed in a single integrated assembly, mounted high on a customer supplied pole. There are no wires to run to the ground or provide easy access to vandals.

The system is preset at the factory to illuminate automatically at sunset & turn itself off after 12 hours (or at sunrise, whichever occurs first.) The lamp will not illuminate during the day (since a photocell is not used.) Consequently, false activations are completely eliminated.

3-6-3-2 Applications

Highways, intersections, residential streets, loading areas, driveways, parking lots, villages etc. or any situation where the cost of installing conventional power supply is prohibitive or inconvenient in remote locations.

3-6-3-3 System includes

1- Die cast aluminum Roadway lamp fixture with optics& glass lens mounted on a 9 foot extension arm.
2- High Tech. Eagle-1 electronics/gas discharge (no filament to burn out) lighting system with a lamp life of over 5,000 hours with a light out put of 3,600 lumens!

3- Twin "over 30 year life" high efficiency crystalline solar panels: considered the highest quality panels in the industry.

4- Powder painted aluminum solar panel exclusive top mount brackets rotate able 360 degrees and swivels 270 degrees for optimum alignment.

5- Electronics/timer housed in durable weatherproof die cast aluminum enclosure.

6- High Capacity Heavy Duty deep cycle Zero Maintenance (for life) battery.

7- Exclusive "posi-loc" connectors for easy field hook-up.

8- Rugged scratch resistant aluminum & steel battery case powder painted in "medical" white, vandal proof (pad lockable.)

9- Quality Marine Grade (USCG, UL, Lloyds, BV approved) tin coated copper heavy gage electrical cables: 6 feet to solar panel, 10 feet to lamp fixture, 3 feet to battery case.

10- Quality Stainless Steel hardware (corrosion resistant) included for mounting to customer's pole

Chapter Four

The horizontal and vertical alignment of the Streets

4-1 Introduction

The horizontal alignment of the streets consists usually from straight parts and circular ones , so we must connect these parts together by using curves that transmit us from the straight parts to the circular ones in a gradual way to avoid sudden movement, so we can reduce street's dangers to the minimum level.

In order to achieve a balanced design of the street , we must take in response the basics of the geometrical design that give us continuous traffic flow at the design speed .we must also take in response the relation between the design speed , the radiuses of the curves, and other things.

4-2 Centrifugal Force

The transition of the vehicle from the straight part to the curved one will expose it to a centrifugal force when it enters the curve, centrifugal force inversely proportional to the radius of the curve.

Figure (4.1) illustrates the forces acting on a vehicle of weight W as it is driven round a highway bend of radius R. The angle of incline of the street (super elevation) is termed a. P denotes the side frictional force between the vehicle and the highway, and N the reaction to the weight of the vehicle normal to the surface of the highway. C is the centrifugal force acting horizontally on the vehicle and equals c =M * v2/R where M is the mass of the vehicle.

As all the forces in Figure (4.1) are in equilibrium, they can be resolved along the angle of inclination of the street:

(Weight of vehicle resolved parallel to highway) + (Side friction factor)
= (Centrifugal force resolved parallel to highway)

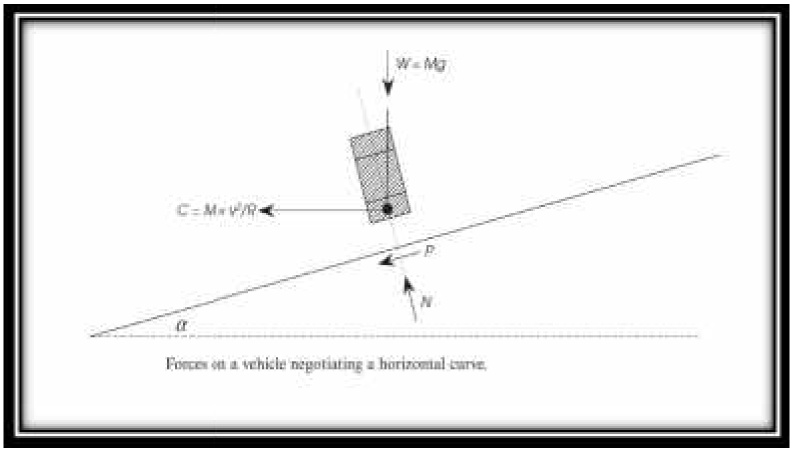


Figure (4.1) Force on vehicle negotiating a horizontal curve. [3]

$$p = \frac{m V^2}{R} \qquad \text{.........(4-1)}$$

Where:
P : Centrifugal force.
m: vehicle's mass.
R: Curve's radius.
V: vehicle's velocity.

From the relation above it is clear that the centrifugal force inversely proportional to the radius of the curve , so when the vehicle is on the straight part of the street the radius is infinity consequently the centrifugal force (P) equals zero. To prevent the rapid change of the centrifugal force from zero to a large value we resort to the transition curve.

4-3 Super Elevation

Superelevation is the banking (rotation) of a highway to counter some of the lateral force. As shown in figure (4.1), the banking causes a portion of the lateral acceleration to act normal (perpendicular) to the banked pavement. This is felt as a downward (with respect to the vehicle) force by the vehicle occupants. The remaining portion of the lateral force may act one of three ways depending on the banking and speed of the vehicle.

• If the speed is balanced for the banking, the lateral force acting outward on the vehicle will be countered by the forces pushing the vehicle down the slope of the banking. The vehicle and occupants will experience a downward force (perpendicular to the streetway) and the vehicle will travel around the curve with little steering input. This is a neutral or equilibrium condition.

• If the vehicle is traveling faster than the equilibrium speed, the resultant lateral force acts outward on the vehicle and occupants. At excessive speeds, the vehicle will skid or roll off the street.

• If the speed is lower than the equilibrium speed, the vehicle and occupants are forced inward. Extreme banking can cause top heavy vehicles to rollover towards the inside of the curve. Additionally, icy conditions can cause the vehicle to slide down the banking, particularly when the tires are spinning to accelerate in stop and go traffic.

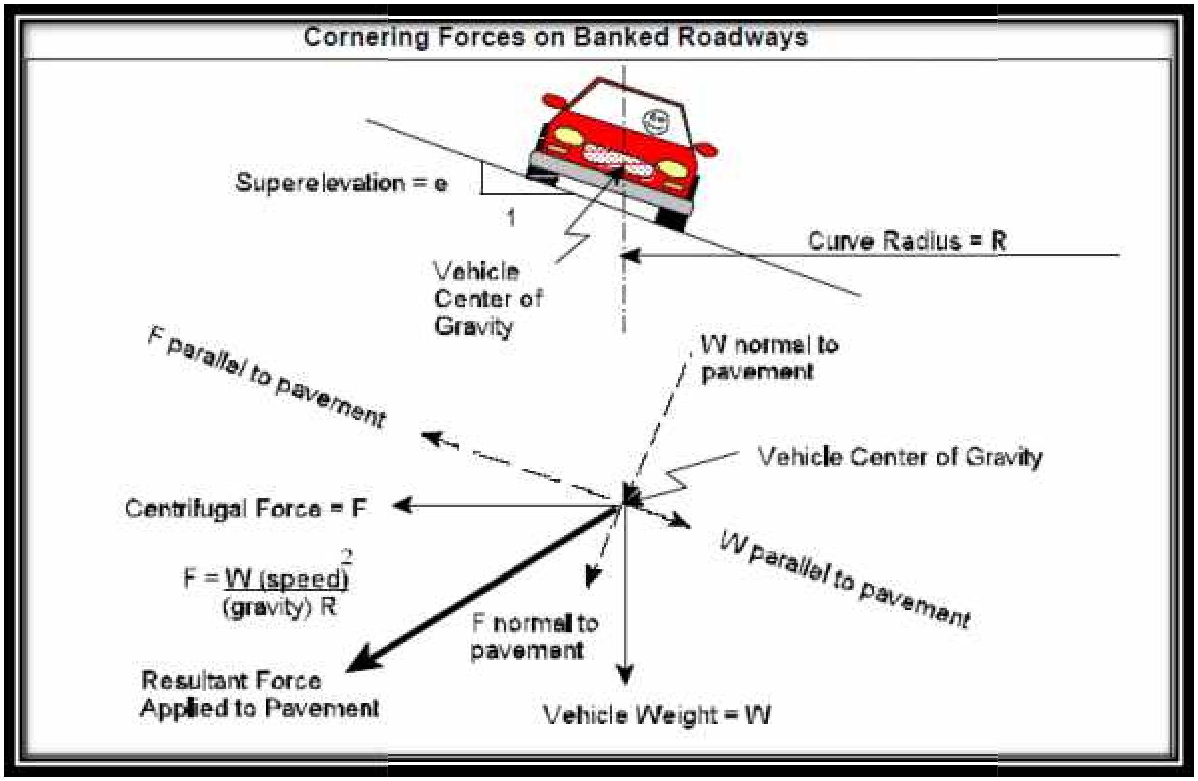


Figure (4.2) Centrifugal force.[3]

Maximum super elevation rates

High rates of super elevation may cause slow moving vehicles to slide down the banking in snow and ice. High super elevation rates can be difficult to attain in urban settings due to closely spaced intersections, numerous driveways, and limited right of way. Maximum super elevation rates are chosen to limit the adverse effects of super elevation.
Five maximum super elevation rates are commonly used.

1. Maximum super elevation rates of 4% and 6% are for urban areas.
2. Maximum super elevation rates of 6%and 8% are for areas that have frequent ice and snow.
3. Maximum super elevation rates of 10% and 12% in rural areas without ice or snow concerns

represent a practical limit to accommodate occasional slow moving vehicles, construction equipment, and maintenance equipment.

4- 4 Horizontal curve sight distance

Once you have a radius that seems to connect the two previously disjointed sections of streetway safely and comfortably, you need to make sure that you have provided an adequate stopping sight distance throughout your horizontal curve.

Sight distance can be the controlling aspect of horizontal curve design where obstructions are present near the inside of the curve. To determine the actual sight distance that you have provided, you need to consider that the driver can only see the portion of the street way ahead that is not hidden by the obstruction. In addition, at the instant the driver is in a position to see a hazard in the street way ahead, there should be a length of street way between the vehicle and the hazard that is greater than or equal to the stopping sight distance. See figure 4.3 below.

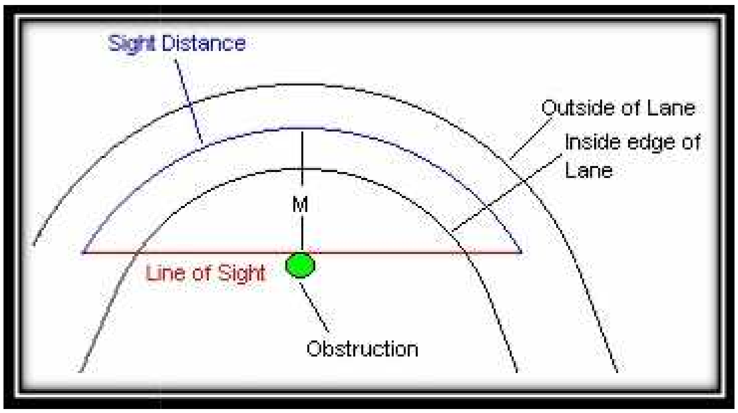


Figure 4.3: Sight Distance[٤]

Because the sight obstructions for each curve will be different, no general method for calculating the sight distance has been developed. If you do have a specific obstruction in mind, however, there is an equation that might be helpful. This equation involves the stopping sight distance, the degree of the curve, and the location of the obstruction.

$M = (5730/D)*(1 - \cos(SD/200))$ ……………………………………………… (4-2)

Where:
M = Distance from the center of the inside lane to the obstruction (ft.)
D = Degree of the curve. Where R = 5730/D
S = Stopping sight distance (ft)
R = Radius of the curve (ft)

Once your rough design has been adjusted to accommodate the sight distance restrictions, and you are satisfied with the aesthetic and financial consequences of your superelevation scheme, you can begin to polish your design into its final form.

4-5 Horizontal and Vertical Curves

In the geometric design of motorways, railways, pipelines, etc., the design and setting out of curves is an important aspect of the engineer's work.
The initial design is usually based on a series of straight sections whose positions are defined largely by the topography of the area. The intersections of pairs of straights are then connected by horizontal curves. In the vertical design, intersecting gradients are connected by curves in the vertical plane.

Curves can be listed under three main headings, as follows:

(1) Circular curves of constant radius.
(2) Transition curves of varying radius (spirals).
(3) Vertical curves of parabolic form.

4-5-1 Horizontal circular Curves

The horizontal curves are defined by the radius of the curve or by the degree of it, and so we must choose the radius of the curve to coincide with the design speed of the street. Horizontal curves are divided into four types as shown in the following figure:

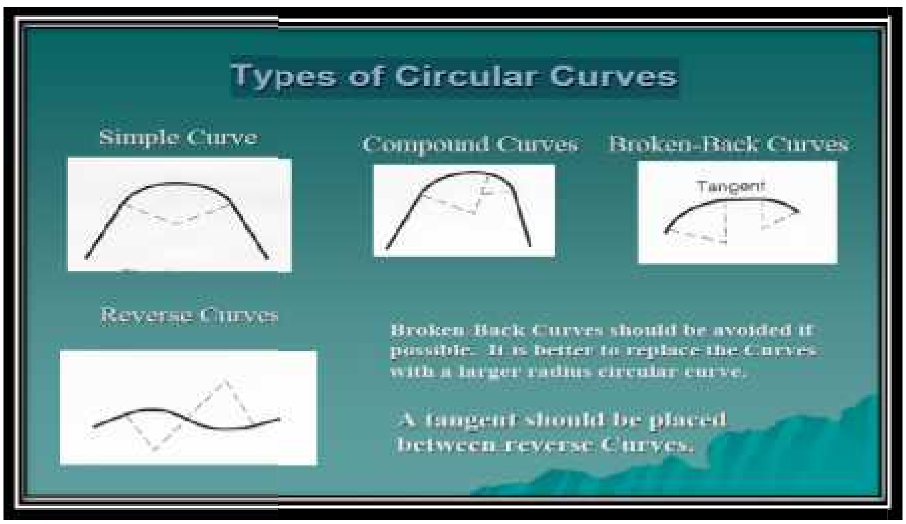


Figure (4.4) Types of circular curves

First: Simple circular curve

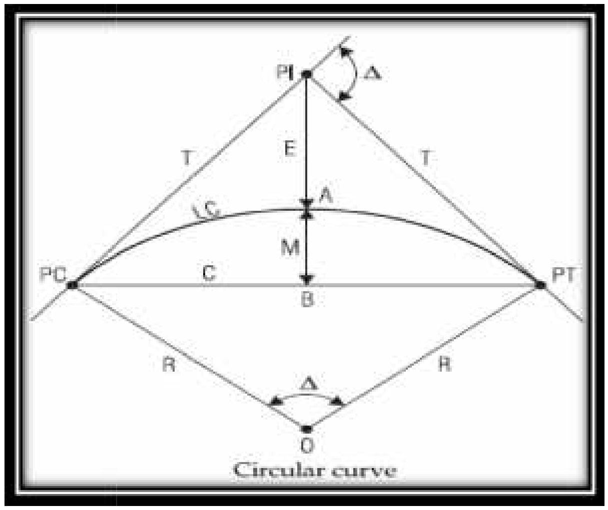


Figure (4.5) Circular curve[3]

A simple horizontal curve consists of a part of a circle tangent to two straight sections on the horizontal alignment. The radius of a curve preferably should be large enough that drivers do not feel compelled to slow their vehicles. Such a radius, however, is not always feasible, inasmuch as the alignment should blend harmoniously with the existing topography as much as possible and balance other design considerations, such as overall project economy, sight distance, and side friction.

Super elevation, usually employed on curves with sharp curvature, also should be taken into account .A curve begins at a point designated point of curvature or PC. There, the curve is tangent to the straight section of the alignment, which is called a tangent The curve ends at the point of tangency PT, where the curve is tangent to another straight section of the alignment. The angle D formed at PI, the point of intersection of the two tangents, is called the interior angle or intersection angle.

Using the radius and angle (Δ) we can calculate the elements of the simple circular curve from the following relations:

$$L = \frac{\text{®}\Delta R}{180} \qquad \text{...(4-3)}$$

$$T = R\left(\tan\frac{\Delta}{2}\right) \qquad \text{...(4-4)}$$

$$M = R\left(1 - \cos\frac{\Delta}{2}\right) \qquad \text{(4-5)}$$

$$E = R\left(\sec\frac{\Delta}{2} - 1\right) \qquad \text{(4-4)}$$

$$LC = 2R\left(\sin\frac{\Delta}{2}\right) \qquad \text{(4-6)}$$

Where:
T : Tangent length.
E : External distance.
M : Arc's arrow.
LC : Long string.
L : Curve's Length.
Δ : Angle of deviation of the two tangents.

Maximum Curvature for Normal Crown Section*

Design speed, mi/h	Average running speed, mi/h	Maximum degree of curve	Minimum curve radius, ft
20	20	3° 23′	1,700
30	28	1° 43′	3,340
40	36	1° 02′	5,550
50	44	0° 41′	8,320
55	48	0° 35′	9,930
60	52	0° 29′	11,690
65	55	0° 26′	13,140
70	58	0° 23′	14,690

*Adapted from "A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials.

Table(4-1) Maximum Curvature for Normal Crown section[3]

Second: Compound Circular curve

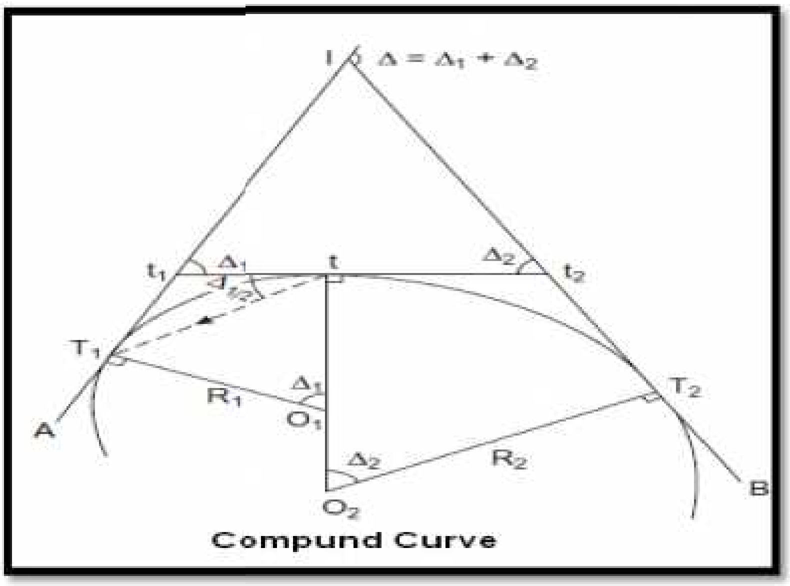


Figure (4.6) Compound curve[5]

The compound circular curve consist from two or more horizontal consecutive curves so that the second point of tangency of the first curve is the same as the first point of tangency of the second curve .This type of curves used to connect two straight lines by more than one circular curve , but under the following conditions:

1 - The radiuses of these curves are different.
2 - All the centers of these curves lie in the same side.
3 - The curves are contiguous at the points of connection between them.

Third: Broken-back curve

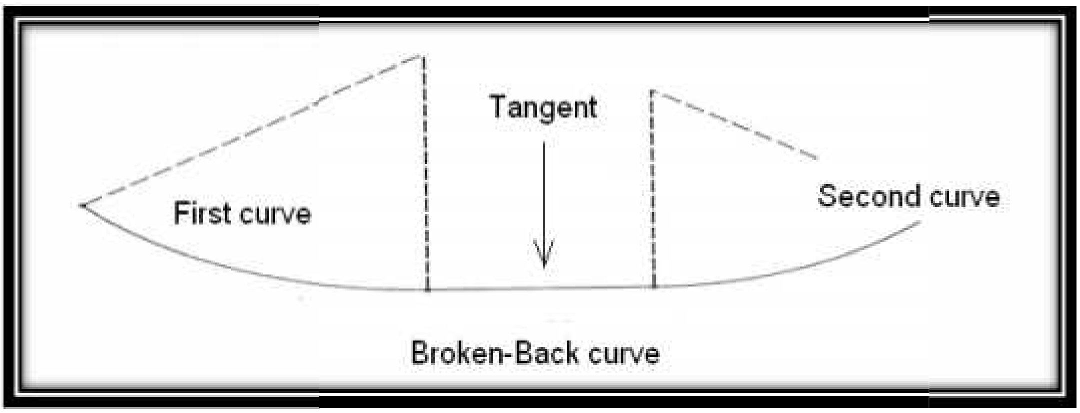


Figure (4.7) Broken-Back curve.[5]

This curve consists of two circular curves their centers lie in the same side and they are connected together by a common tangent it's length less than 30 m.

Fourth: Reveres curve

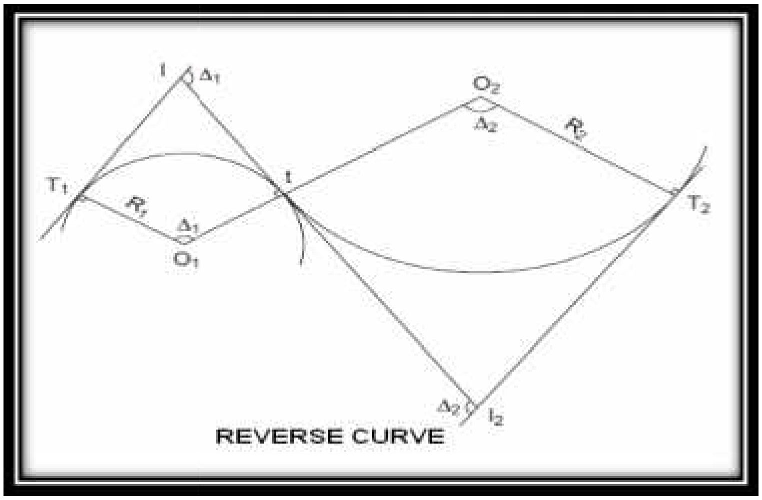


Figure (4.8) Reverse curve[5]

In this type of curves we connect the two straight lines by more than one circular curve under the following conditions:

1- The centers of the curves are not in the same side.
2- The radiuses of these curves may be equal or may be not .
3- The curves are contiguous at the points of connection between them.

4-5-2 Transition Curves

These curve types are used to connect curved and straight sections of highway.(They can also be used to ease the change between two circular curves where the difference in radius is large.) The purpose of transition curves is to permit the gradual introduction of centrifugal forces. Such forces are required in order to cause a vehicle to move round a circular arc rather than continue in a straight line. A finite quantity of time, long enough for the purposes of ease and safety, will be required by the driver to turn the steering heel. The vehicle will follow its own transition curve as the driver turns the steering wheel. The radial acceleration experienced by the vehicle travelling at a given velocity v changes from zero on the tangent to $v2/R$ when on the circular arc. The form of the transition curve should be such that the radial acceleration is constant. The radius of curvature of a transition curve gradually decreases from infinity at the intersection of the tangent and the transition curve to the designated radius R at the intersection of the transition curve with the circular curve.

Transition curves are normally of spiral or clothoid form:

$$RL = A2$$

Where:
*A*2 is a constant that controls the scale of the clothoid.
R is the radius of the horizontal curve.
L is the length of the clothoid.

Two formulae are required for the analysis of transition curves:

$$S = L2/24R \quad \text{.......... (4-7)}$$

$$L = V^3 / (3.6^3 * C * R \quad \text{.......... (4-8)}$$

Where:
S : the shift (m)
L : the length of the transition curve (m)
R : the radius of the circular curve (m)
V : the design speed (km/hr)
C : the rate of change of radial acceleration (m/s3)

The value of *C* should be within the range 0.3 to 0.6. A value above 0.6 can result in instability in the vehicle while values less than 0.3 will lead to excessively long transition curves leading to general geometric difficulties. The design process usually commences with an initial value of 0.3 being utilized, with this value being increased gradually if necessary towards its upper ceiling.

The length of transition should normally be limited to (24*R*)0.5 (TD 9/93), thus:

$$L_{max} = \sqrt{24R} \quad \text{.......... (4-9)}$$

Figure (4.7) illustrates the situation where transition curves are introduced between the tangents and a circular curve of radius *R*. Here, the circular curve

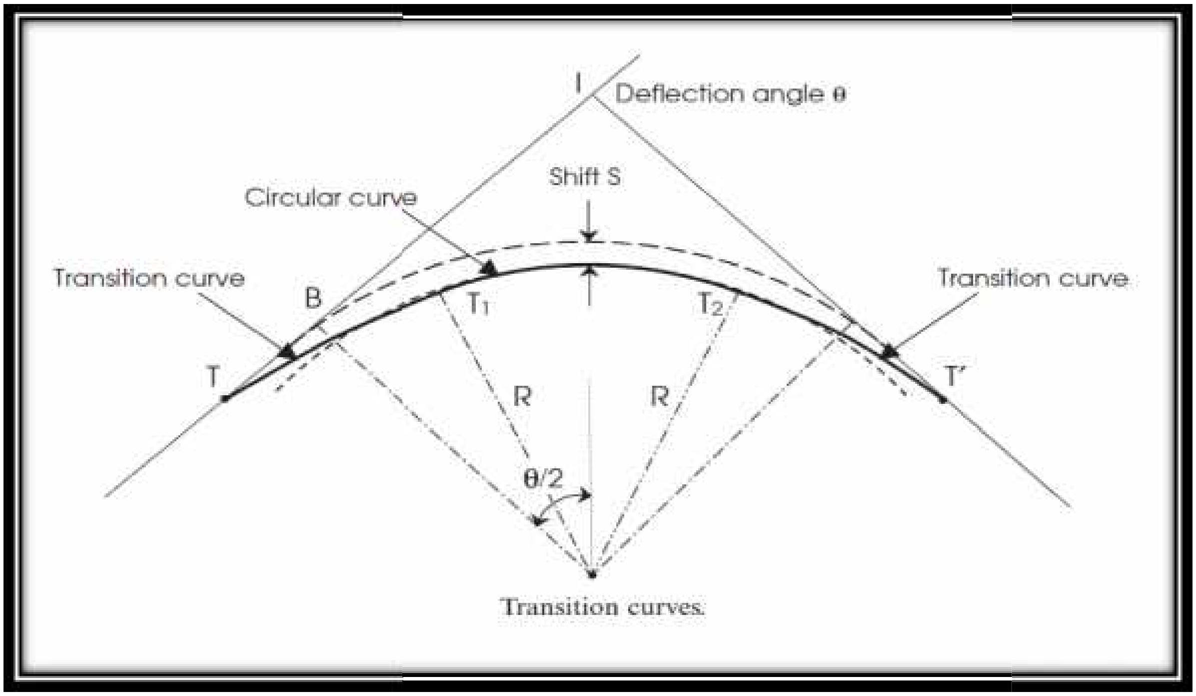


Figure (4.9) Transition curve.[3]

must be shifted inwards from its initial position by the value S so that the curves can meet tangentially. This is the same as having a circular curve of radius ($R+S$) joining the tangents replaced by a circular curve (radius R) and two transition curves. The tangent points are, however, not the same. In the case of the circular curve of radius ($R+S$), the tangent occurs at B, while for the circular/transition curves, it occurs at T (see Fig. 4.9). From the geometry of the above figure:

$$IB = (R + S)\ \tan(\theta/2) \quad \text{(4-10)}$$

It has been proved that B is the mid-point of the transition.
Therefore:

$$BT = L/2 \quad \text{(4-11)}$$

Combining these two equations, the length of the line IT is obtained:

$$IT = (R + S)\ \tan(\theta/2) + L/2 \quad \text{(4-12)}$$

If a series of angles and chord lengths are used, the spiral is the preferred form.
If, as is the case here, x and y co-ordinates are being used, then any point on the transition curve can be estimated using the following equations of the curve which takes the form of a cubic parabola (see Fig. 4.9):

$y = L$ ……………………………………………………………………… (4.13)

$x = y3 / 6RL$ ……………………………………………………………………… (4.14)

When y attains its maximum value of L (the length of the transition curve), then the maximum offset is calculated as follows:

$x = L3 / 6RL = L2 / 6R$ …………………………………………………… (4.15)

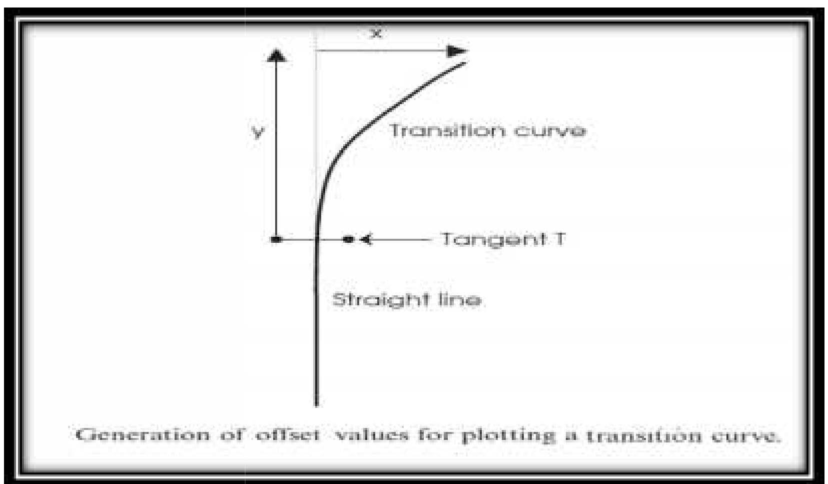


Figure (5.10)

Figure (4.10) Generation of offset values for plotting a transition curve.[3]

4-6 General notes about Horizontal alignment

In addition to the design elements in the horizontal alignment, there are some of the rules which are not restricted by any formula but they are of great importance to achieve safe ways .For example the excessive curvature, the wrong connection between curves and other problems. They all reduce the velocity and this will produce economical loss because of increasing the time of the trip and operating costs .So to avoid those bad things we must follow the following general steps:

a- To make the appropriate sight distance through the internal edge of the curve.

b- To make the appropriate drainage system for surface water.

c- Reducing as possible as we can from the earthworks.

d- Avoiding the short connecting curves, but using suitable transition curves.

e- To reduce the affects of the reveres curves if exist , we must increase the radius of the curve , decreasing the velocity , and put the required caution signs .

f- If there were obstructions for using one circular curve with a large radius , then we use a compound curve give us more reliability .

g- Superelevation should not exceed (12%) in all cases.

h- The preferable superelevation value is (6%).

i- The side friction should not exceed the maximum and allowable value of (16%).

j- Avoiding the use of reverse curves as possible as we can to avoid the following things:

- Sudden transition from a specific radius to another suddenly, leading to dangers especially if the driver does not give attention.
- Difficulty of dealing with the centrifugal force, because of the transition from the first curve to the second one with two cross slopes in different directions.

4-7 Intersections on the streets

An intersection is the junction or crossing of two or more streets at the same or different elevations. When the streets are at the same level, the intersection is called an at-grade intersection. When the streets are at different elevations, the intersection is referred to as a grade separation when there is no connection between the intersecting streets or as an interchange when connecting streets, such as ramps or turning streetways, permit movement of vehicles between the intersecting streets. Intersections should be kept simple so that necessary movements are obvious to drivers. Uniformity of intersections is important to avoid driver confusion. Factors to be considered for this purpose include design speed, intersection angles (90°is preferred), intersection curves, vehicle turning paths, streetway widths, and traffic control devices.

Intersection is an important part of the street, because the safety, velocity, affiance, operating costs they all depend on the intersection . It is not reasonable to design a highway which is wide with narrow intersections.

4-7-1 Horizontal and Vertical alignment at intersections

Alignment geometries play a critical role in the design of an at-grade intersection. In the vertical plane, it is important that the profiles of the intersecting streetways be as flat as possible (preferably less than 3% through the intersection). Also, the horizontal alignment should be as straight as practical. Grade and curvature have considerable impact on sight distance at intersections, where it is desirable to have sight distances greater than specified minimum values. Adverse sight-distance conditions can be the source of accidents, because of driver inability to see other vehicles or discern the messages of traffic-control devices.

4-7-2 Types of intersections

There are generally two types of intersections:
1-At-grade intersections.
2- Grade separated interchanges.

4-7-2-1 At-grade intersections

The junction or crossing of two or more highways at a point of common elevation is called an atgrade intersection. Intersections of highways and railways at grade should be provided with protective and warning devices. Sight distance is an important design consideration when only advance warning of approaching trains and railway cross buck signs are installed.

Geometric Design of At-Grade Intersections

Major influences on the geometric design of at grade intersections include human factors, traffic considerations, physical elements, and economic factors. The goal is to reduce or eliminate the potential for accidents involving vehicular, bicycle, or pedestrian traffic through the intersection. Also, natural transitional paths for traffic must be provided.

Human Factors

Design of an intersection is affected by human factors, such as driving habits, the ability of drivers to make decisions, adequate advance warning to drivers regarding the presence of an intersection, driver decision and reaction time, and the presence of pedestrians at the intersection.

Traffic Considerations

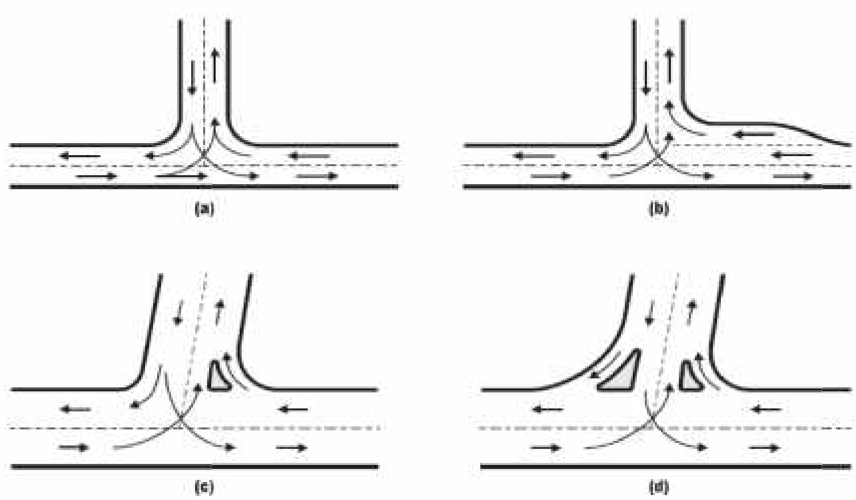
Traffic volume and movement impact the design of an at-grade intersection. Both the design and actual capacity of the intersecting highways should be taken into account. Also of concern are the design-hour turning movement and other movements, such as diverging, merging, weaving, and crossing. Other traffic criteria include vehicle size, speed and operating characteristics, transit involvement, and, if applicable, the history of accidents at the site.

Types of At-Grade Intersections

Each highway that radiates from an intersection and forms part of it is known as an intersection leg. The intersection of two highways generally results in four legs. Intersections with more than four legs are not recommended.

Three-Leg Intersections

A three-leg intersection is formed when one highway starts or terminates at a junction with another highway (Fig. 4.11). Unchannelized T intersections (Fig.4.11) are usually employed at the intersection of minor streets with more important highways at an angle not exceeding 30° from the normal. At times, a right-turn lane is provided on one side of the through highway (Fig. 4.11) this type of turn lane is used when right-turning traffic from the through highway is significant and left-turning traffic from the through highway is minor.

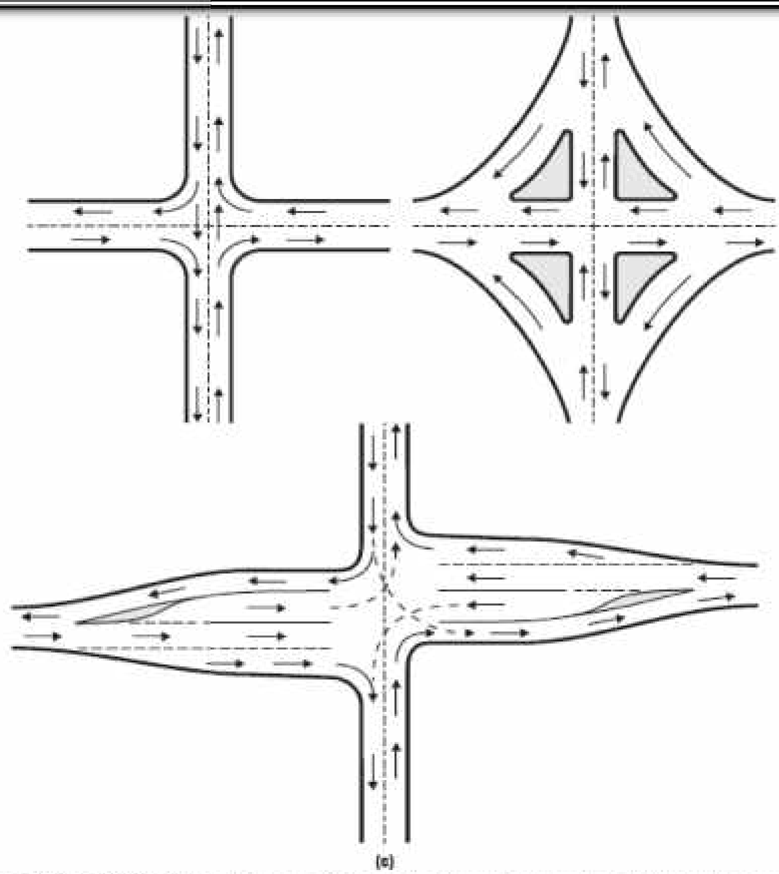


Types of at-grade T (three-leg) intersections: (a) unchannelized; (b) intersection with a rightturn lane; (c) intersection with a single-turning roadway; (d) channelized intersection with a pair of turning roadways.

Figure (4.11)[3]

Four-Leg Intersections

A four-leg intersection is formed when two highways cross at grade (Fig. 4.12). The design of four-leg intersections followsfollows many of the general guidelines for three-leg intersections. As with T intersections, the streetway intersection angle typically should not be more than 30° from the normal. Figure 4.12 shows a four-leg intersection of a through highway and a minor highway. The through highway is flared to provide additional capacity for through and turning movements.The flaring is provided through incorporation of parallel auxiliary lanes that are required for major highways requiring an uninterrupted flow capacity. Flaring may also be needed where cross traffic is sufficiently high to warrant signal control.

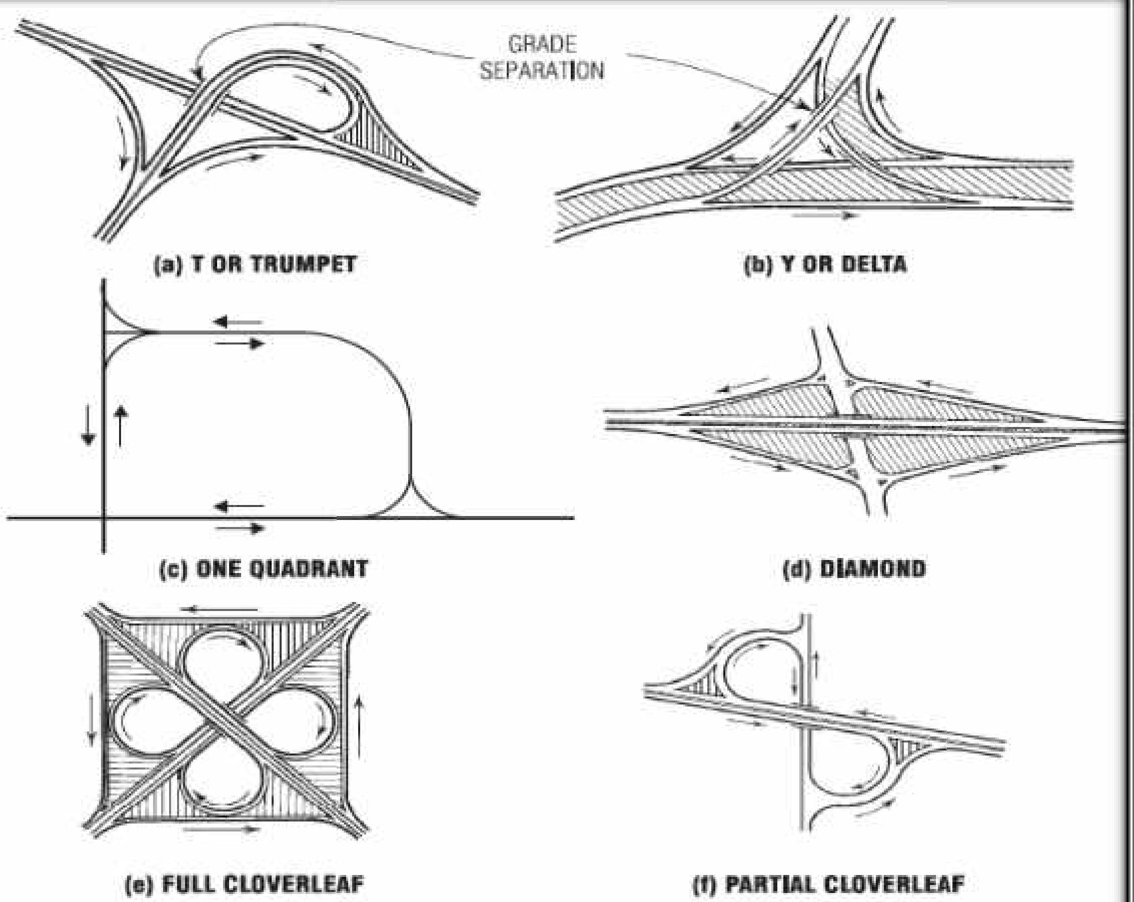


Types of at-grade four-leg intersections: (a) unchannelized; (b) channelized; (c) flared.

Figure (4.12) Types of at-grade four-leg intersections[3]

4-7-2-2 Grade intersection (Interchanges)

An interchange is a system of interconnecting streetways used in conjunction with one or more grade separations of highways (Fig. 4.13). It accommodates movement of traffic between two or more streetways at different elevations. In so doing, it eliminates grade crossings, which may be unsafe and are inefficient in accommodating both turning and through traffic.When highways carrying high volumes of traffic intersect each other, the greatest degree of safety, efficiency, and capacity is achieved with grade separations of the highways. There are in use numerous variations of the interchange types shown in Fig. 16.26. They vary in size and magnitude depending on the environment and scope of service for which they are intended. Design of an interchange is based on traffic volume, topography of the site, economic considerations, and environmental factors.



Types of interchanges for intersecting grade-separated highways.

Figure (4.13) Types of interchanges for intersecting grade-separated highways.[3]

Elements of intersection design

First : Traffic volume and pedestrian movement on the intersection

We must account for the pedestrian movement on the intersection as we must also make a full survey to determine traffic directions , volume , and vehicles .

Second: Drivers behavior on the intersection

The behavior of the driver should be taken in consideration to design the intersection according to the behavior of 85% of the drivers, not according to the ideal driver.

Fourth: The grade and the friction of the street at the intersections

It should, the radius at the intersection is very small which require a large slope, but it is difficult to make the appropriate slope without making sudden change in the slope of the street surface and because the distances are short large slopes are not used and instead of that the velocity is reduced depending on the side friction when turning over, and table (4.2) displays the slope of the street surface according to the velocity.

Table (4-2) The slope of the street surface according to the velocity[6]

Turning over Speed (Km/h)	٦٥	٥	٤٨	٤٠	٣٢	٢٥
Friction Factor	٠.١٧	٠.١٨	٠.٢٠	٠.٢٣	٠.٢٧	٠.٣٢
Slope of the street Surface	٠.٠٩	٠.٠٨	٠.٠٦	٠.٠٤	٠.٠٢	٠
Radius (m)	١٤٠	١٠٠	٧٥	٥٠	٣٠	١٥

Fifth: The algebraic difference between two slopes

The algebraic difference between two slopes should not exceeds the allowable value, because the driver who drive his vehicle when it is inclined to the left , if he forced to incline to the right he will be exposed to a danger because of the difference between the two slopes , so the slopes should be reduced as possible as we can.

The algebraic difference between two slopes of the street surface defined as the summation of the two slopes if they are in different directions, and it should not exceed the values in the following table.

Table (4-3) The algebraic difference between two slopes of the street surface[6]

Velocity (Km/h)	Algebraic Difference
٠.٠٨ – ٠.٠٥	25 -35
٠.٠٦ – ٠.٠٥	40 - 48
٠.٠٥ – ٠.٠٤	55 and more

Sixth: Friction

The friction decrease with the increasing velocity , we should choose a suitable value for friction factor on the curve , the friction factor ranges from 0.16 to 0.32 according to the roughness of the surface.

Seventh: Velocity at the intersection

It is necessary to control the speed of the intersection, by placing signs or through narrow passages, as the thresholds that have been developed previously relied on the speed less than 15 km / h. However, the speed must be commensurate with the speed on the street to the intersection, where depends on the type of intersection and traffic volumes at the intersection, and to find a balance between speed and radius in addition to friction and slope street surface, is used the following equation:

$$\frac{V}{gR} = u + i \quad \text{.......} \quad (4\text{-}16)$$

Where :

V : vehicle speed km / hour.

g : gravity, m/s ^{2}.

R : radius of the circle Surface.

u :coefficient of friction.

i : Slope of the street's surface .

Eighth : The width of the lane which is specified for turning over.

Must be introduced lane appropriate to allow vehicles to travel there with the survival of the vehicle away from the parties to pass a distance not less than 60 cm from each side, which controls the display lane vehicle size, type and volume of traffic and sharpness of the juncture, and there are three types of lanes allocated to the rotation, namely:

a- One lane which is not allowed to waive in it, and in this kind devoted to the movements of others are important, and a modest amount of traffic and short distances where the stops of a car is not possible.

b- One lane in one direction prevent the existence of a car and exceed it with the minimum velocity, and used to walk a moderate size, which requires only one leaked.

c- Two lanes in one or two direction with a heavy traffic.

Ninth: Stopping sight distance

The car which is approaching the intersection need to a distance vision before it is able to see the obstacle or danger and stop if it wishes, and we follow to find the distance the same methods used in the design of streets where the driver needed time to think and another to take action and use of brakes. Since the values of friction decreases with increasing speed, it will be considered a high coefficient of friction at low speed and low coefficient on high speed.

Table (4-4) Velocity versus sight distance.[6]

Velocity (Km/H)	٦٥	٦٠	٥٠	٤٠	٣٠	٢٥
Sight Distance(m)	٨٥	٧٥	٦٥	٥٠	٣٤	٢٤

Tenth: Islands

An island is a defined area established between traffic lanes in channelized intersections to direct traffic into definite paths. It may consist of curbed medians or areas delineated by paint. In general, islands are provided in channelized intersections to separate and control the angle of conflicts in traffic movement, reduce excessive pavement areas, protect pedestrians and waiting areas for turning and crossing vehicles, and provide a location for traffic-control devices.

An island may be curbed or uncurbed. It may be concrete, grass, or the same material as the traffic lanes. Islands may be used at intersections for the following reasons:

- Separation of conflicts.
- Control of angle of conflict.
- Reduction in excessive pavement areas.
- Favoring a predominant movement.
- Pedestrian protection.
- Protection and storage of vehicles.
- Location of traffic control devices.

The width of a median is the distance between the inside edges of the pavement. The width depends upon the type of facility, topography, and available right-of-way. In rural areas with flat or rolling terrain, the desirable median width for freeways is 60 to 84 ft. Although the minimum median width is normally 40 ft, narrower medians may be used in rugged terrain. A constant-width median is not necessary, and in fact, variable-width medians and independent profiles may be used for the two streetways. Narrow medians with a barrier (barrier medians) are normally used in urban areas. Under normal design, the median width will vary depending on the width of the barrier and the shoulder width required .

Medians are divided into types depending upon width and treatment of the applicable to urban areas, while wide, depressed medians apply to rural areas.

4-8Vertical Alignment

A vertical alignment defines the geometry of a highway in elevation, or profile. A vertical alignment can be represented by the highway centerline along a single tangent at a given grade, a vertical curve, or a combination of these.

4-8-1 Vertical Curve and it's elements.

These are used as a transition where the vertical alignment changes grade, or slope. Vertical curves are designed to blend as best as possible with the existing topography, consideration being given to the specified design speed, economy, and safety.

The tangents to a parabolic curve, known as grades, can affect traffic in many ways; for example,they can influence the speed of large tractortrailers and stopping sight distance.

Although a circular curve can be used for a vertical curve, common practice is to employ a parabolic curve. It is linked to a corresponding horizontal alignment by common stationing. Figure 4.1 shows a typical vertical curve and its constituent elements.

A curve like the one shown in Fig. 8.1 is known as a crest vertical curve; that is, the curve crests like a hill. If the curve is concave, it is called a sag vertical curve; that is, the curve sags like a valley. As indicated in Fig. 8.1, the transition starts on a tangent at *PVC*, point of vertical curvature, and terminates on a second tangent at PVT, point of vertical tangency. The tangents, if extended, would meet at *PVI*.

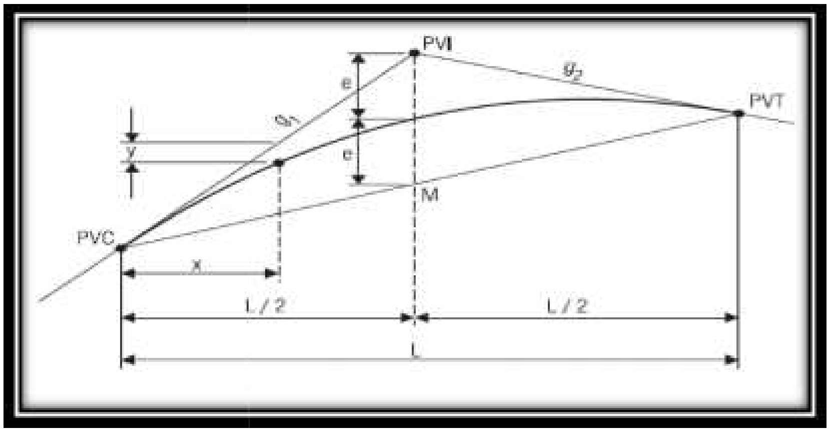


Figure (4.14) Parabolic Vertical curve.[3]

g1, g2 : the gradients.
BVC : the beginning of the vertical curve.
PI : intersection point.
EVC : the end of the vertical curve.
L : the length of the curve.
e : the external intermediate distance.

4-8-2 Gradients

In vertical curve design the gradients are expressed as percentages, with a negative for a downgrade and a positive for an upgrade.
e.g. A downgrade of 1 in 20 = 5 in 100 = –5% = –*g*1%
An upgrade of 1 in 25 = 4 in 100 = +4% = +*g*2%
The angle of deflection of the two intersecting gradients is called the *grade angle* and equals *A* in. The grade angle simply represents the change of grade through which the vertical curve deflects and is the algebraic difference of the two gradients
A% = (*g*1% – *g*2%) In the above example *A*% = (– 5% – 4%) = – 9% (negative indicates a sag curve).

4-8-3 Permissible approximations in vertical curve computation

In civil engineering, street design is carried out in accordance with the following documents:

(1) Layouts of Streets in Rural Areas.
(2) Streets in Urban Areas.
(3) Motorway Design Memorandum.

The desirable maximum gradients for vertical curve design are:
Motorways 3%.
Dual carriageways 4%.
Single carriageways 6%.

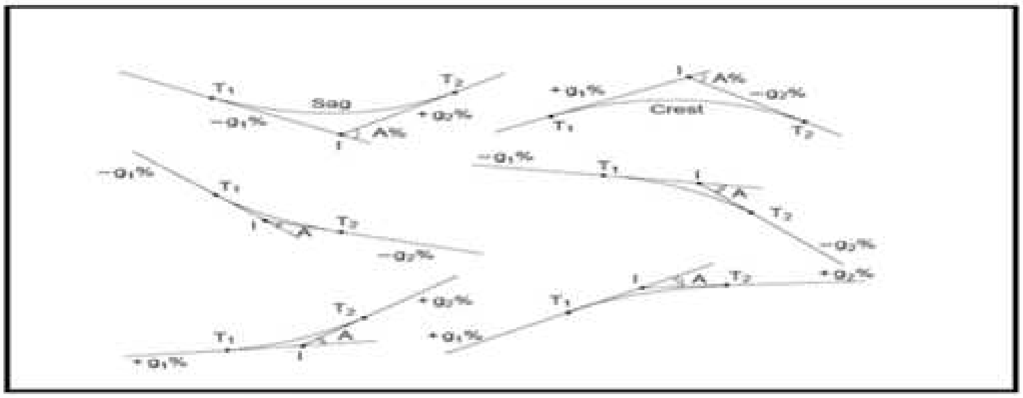


Figure (4.15) The six possible cases of gradiants.[3]

4-8-4 The characteristics of the parabolic curve.

The length of the curve equals the sum of the two tangents , so the front tangent $\ell 1$ and the back tangent $\ell 2$:

$$\mathbf{L} = \ell 2 + \ell 1 \quad \text{(4-17)}$$

$$\mathbf{y = ax2} \quad \text{(4-18)}$$

When the two tangents are in different directions:

$$\mathbf{e} = \frac{g\,1 + qg\;\;2}{400}\,\ell \quad \text{(4-19)}$$

When the two tangents are in the same direction:

$$\mathbf{e} = \frac{g\,1 - g\;2}{400}\,\ell \quad \text{(4-20)}$$

4-8-5 Maximum vertical slopes in the streets

The factors that controls the vertical curves:

1. Design Speed
2. Type of Topography in which the street pass through.
3. The length of the part which is under the vertical slope.

The following table shows the values of the vertical slopes taking in consideration the previous factors:

DESIGN SPEED KPH	FLAT %	HILLY %	MOUNTAINOUS %
50	6	٨	9
65	5	٧	8
80	4	5	7
90	3	4	6
100	3	4	6
110	3	4	5
120	3	4	-
130	3	4	-

Table (4-5).The maximum slopes according to the topography of the land and the design speed.[6]

4-8-6 Factors involved in the selection of the length of vertical curve

The main factors governing the selection and determine the lengths of vertical curve are as follow:

1- Stopping sight distance.
2- Comfort of the passengers.

4-8-6-1 stopping sight distance

This is the length of streetway needed between a vehicle and an arbitrary object (at some point down the street) to permit a driver to stop a vehicle safely before reaching the obstruction. This is not to be confused with passing sight distance, which AASHTO defines as the “length of streetway ahead visible to the driver. Table 4.5shows the parameters governing stopping sight distance on a crest vertical curve.

The minimum stopping sight distance is computed for a height of eye (driver eye height) of 3.50 ft and a height of object (obstruction in streetway) of 6 in. The stopping distance on a level streetway comprises the distance over which a vehicle moves during the brake reaction time, the time it takes a driver to apply the brakes on sighting an obstruction, and the distance over which the vehicle travels before coming to a complete stop (braking distance).Table 4.5 lists approximate stopping sight distances on a level streetway for various design speeds and wet pavements. If the vehicle is traveling uphill, the braking distance is less, because gravity aids in slowing the vehicle. For downhill movement, braking distance is more. A general rule of thumb is that the longer a vertical curve, the larger the safe stopping sight distance may be. Long curves, however, may be too costly to construct. Therefore, a balance should be reached between economy and safety without jeopardizing safety.

For crest vertical curves AASHTO defines the minimum length *L*min, ft, of crest vertical curves based on a required sight distance *S*, the height of the driver eye(H1), the height of the object above the street(H2) ft, as that given by Eq:

$$L_{min} = \frac{A*S^2}{100((2H1)^{0.5}+(2H2)^{0.5})2} \quad (S<L) \ldots\ldots \text{(4-21)}$$

Also, for crest vertical curves:

$$L_{min} = 25- \frac{200((2H1)^{0.5}+(2H2)^{0.5})2}{A*S^2} \quad (S>L) \ldots\ldots \text{(4-22)}$$

For sag vertical curves AASHTO defines the minimum length *L*min, ft, of sag vertical curves:

$$L_{min} = \frac{A*S^2}{120+3.5*S} \quad (S<L) \ldots\ldots \text{(4-23)}$$

$$L_{min} = 2S- \frac{120+3.5S}{A} \quad S>L) \ldots\ldots \text{(4-24)}$$

Design Controls for Vertical Curves Based on Stopping Sight Distance*

Design speed, mi/h	Average speed for condition, mi/h	Coefficient of friction *f*	Stopping sight distance (rounded for design), ft	Rate of vertical curvature *K*, ft per percent of *A* — For crest curves: Computed	For crest curves: Rounded for design	For sag curves: Computed	For sag curves: Rounded for design
20	20 – 20	0.40	125 – 125	8.6 – 8.6	10 – 10	14.7 – 14.7	20 – 20
25	24 – 25	0.38	150 – 150	14.4 – 16.1	20 – 20	21.7 – 23.5	30 – 30
30	28 – 30	0.35	200 – 200	23.7 – 28.8	30 – 30	30.8 – 35.3	40 – 40
35	32 – 35	0.34	225 – 250	35.7 – 46.4	40 – 50	40.8 – 48.6	50 – 50
40	36 – 40	0.32	275 – 325	53.6 – 73.9	60 – 80	53.4 – 65.6	60 – 70
45	40 – 45	0.31	325 – 400	76.4 – 110.2	80 – 120	67.0 – 84.2	70 – 90
50	44 – 50	0.30	400 – 475	106.6 – 160.0	110 – 160	82.5 – 105.6	90 – 110
55	48 – 55	0.30	450 – 550	140.4 – 217.6	150 – 220	97.6 – 126.7	100 – 130
60	52 – 60	0.29	525 – 650	189.2 – 302.2	190 – 310	116.7 – 153.4	120 – 160
65	55 – 65	0.29	550 – 725	227.1 – 394.3	230 – 400	129.9 – 178.6	130 – 180
70	58 – 70	0.28	625 – 850	282.8 – 530.9	290 – 540	147.7 – 211.3	150 – 220

* Adapted from "A Policy on Geometric Design of Highways and Streets," American Association of State Highway and Transportation Officials.

Table (4-6) Design controls for vertical curves based on stopping sight Distance.[3]

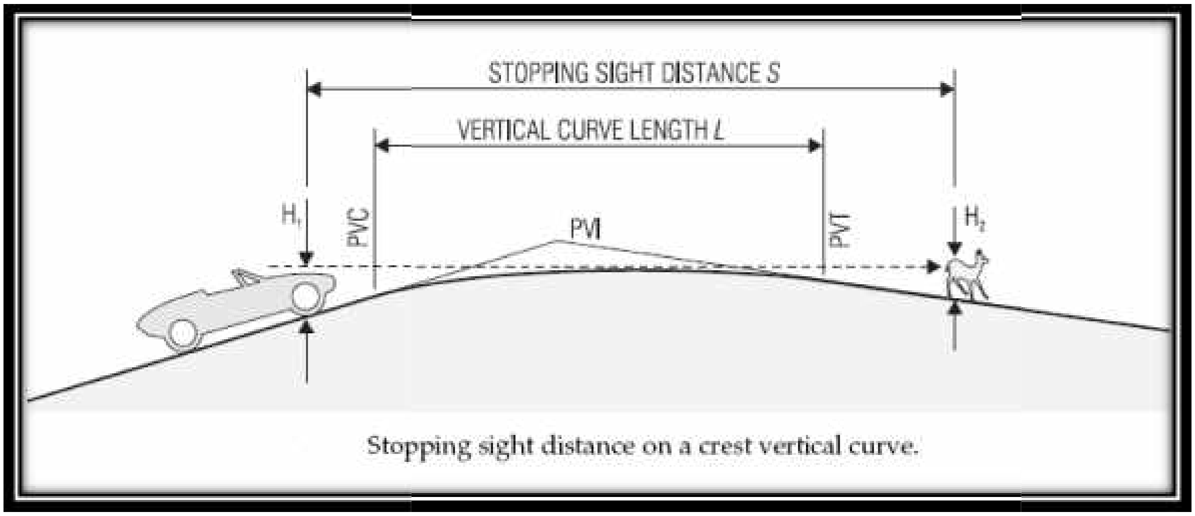


Figure (4.16) Stopping sight distance on a crest vertical curve.[3]

4-8-6-2 Comfort of the passengers

Where the vertical curves are designed on the basis of the provision of passenger comfort s the length of the curve is determined on the basis of centrifugal force which is equal to 0.6 m/s2

4-8-7 General considerations in the vertical deign

1- In the case of several lanes (four lanes, for example, or above) and in one direction, the stopping sight distance criterion for the length of vertical curve ,the reason for that is not likely to face another car in the opposite direction to the direction of excess, while in the case of streets with two lanes With the possibility of abuse for a vehicle going the same direction at sites of vertical curves, the passing sight distance is considered the safe factor for determination of the curve length.

2- The use of the passing sight distance is considered the as a safe factor for determination of the curve length, will increase the length of the curve which often causes an increase in drilling work.

3- In planning we must avoid refracted longitudinal bending (two vertical curves in the same direction separated by a short tangent) especially in the concave curves where the full scene for two curves together Unacceptable.

5-3 Calculations of the errors in the traverse measurements

We have 10 types of errors :

1. EDM (ppm).
2. EDM constant error.
3. Centring error.
4. Target alingment error.
5. Pointing error.
6. Horizental Circle error.
7. Direction error.
8. Prisma hight error.
9. Throdolite hight error.
10. Error in electronic distance observations.

5-3-1 EDM error (ppm):

Error = 2mm+2Dppm

5-3-2 EDM constant error:-

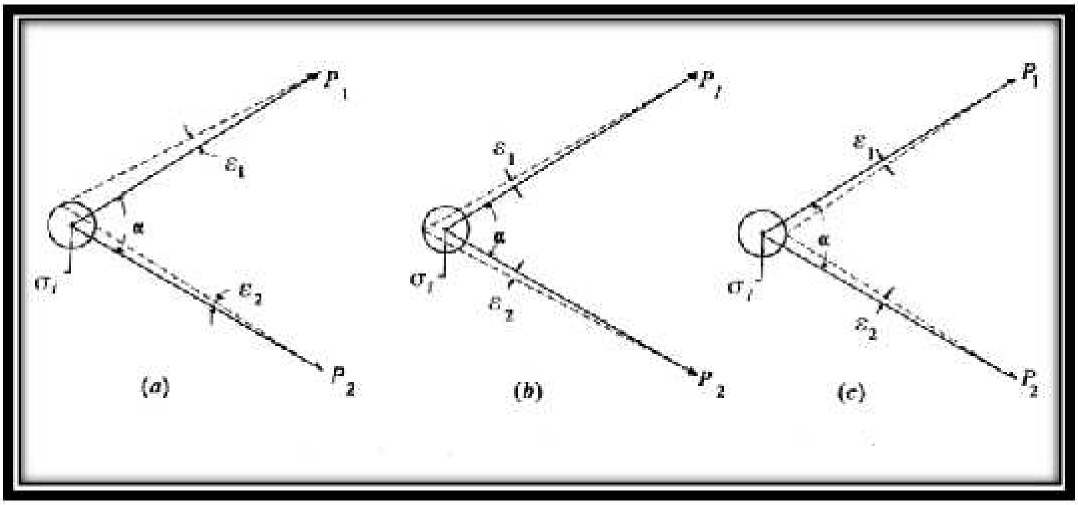
EDM constant error = 0.003 m

5-3-3 Centering error:

Every time an instrument is centered over a point, there is some error in its position with respect to the true station location. This error is dependent on the quality of the instrument and the state of adjustment of its optical plummet, the quality of the tripod, and the skill of surveyor. The error can be compensating, as shown in Figure 5.1(*a*), or it can be maximum when the instrument is on the angle bisector, as shown in Figure 5.1(*b*) and (*c*). Fo r any individual setup, this error is a constant; however , since the instrument's location is random with respect to the true station location, it will appear to be random in the adjustment of a network involving many stations. Like the target centering error, i t will appear also during a resurvey of the points. From Figure 8.1, the true angle α is

$\alpha= (P_2+\varepsilon_2)-(P_1+\varepsilon_1)=(P_2-P_1)+(\varepsilon_2-\varepsilon_1)$

where P_1 and P_2 are the true directions and ε_1 and ε_1 are errors in those directions due to faulty instrument centering. The error size for any setup is the error in the observed angle due to instrument centering errors is analyzed by propagating errors in a formula based on (*x*,*y*) coordinates. a coordinate system has been constructed with the *x* axis going from the true station to the foresight station. The *y* axis passes through the instrument's vertical axis and is perpendicular to the *x* axis.



Figure(5.1) Error in angle due to error in instrument centering.[7]

The final equation is :

$$Бαi = \frac{D3}{D1*D2} * \frac{Бi}{\sqrt{2}} * (206264.8) \ldots\ldots (5.1)$$

Where :

Бi = observer centers the instrument

D1&D2 =are the distances from the target to the instrument at stations 1 and 2,

5-3-4 Target alignment error.

Whenever a target is set over a station, there will be some error due to faulty centering. This can be attributed to environmental conditions, optical plummet errors, quality of the optics, plumb bob centering error, personal abilities, and so on. When care is taken, the instrument is usually within 0.001 to 0.01 ft of the true station location. Although these sources produce a constant centering error for any particular angle, it will appear as random in the adjustment of a network involving many stations since targets and instruments will center differently over a point.

This error will also be noticed in resurvey s o f the same points.An estimate of the effect of this error in an angle observation can be made by analyzing its contribution to a single direction. As shown in
Figure 8.2, the angular error due to the centering error depends on the position of the target. If the target is on line but off center, a s shown in

Figure 8.2(*a*), the target centering error does not contribute to the angular error. H ow ever, a s the target move s t o either side of the sight line, the error size increases. As shown in Figure 8.2(*d*), the largest error occurs when the target is offset perpendicular to the line of sight. Letting d
represent the distance the target is from the *true* station location, from Figure 5.2(*d*), the maximum error in an individual direction due to the target centering error is

$$e = +\frac{\sigma_d}{D} \quad \text{rad}$$

Where *e* is the uncertainty in the direction due to the target centering error,

the amount of a centering error at the time of pointing, and as shown in Figure 5.3, *D* is the distance from the instrument center to the target.

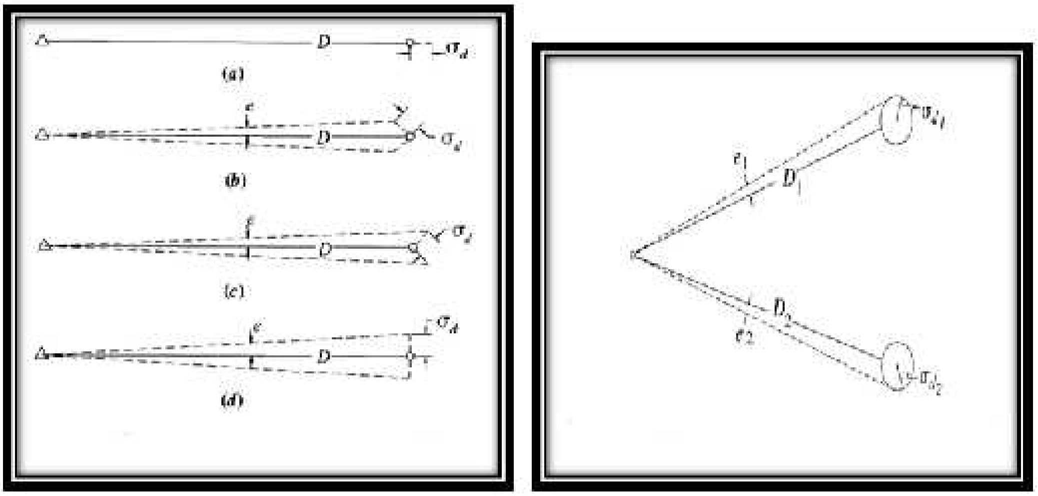


Figure (5.2) Error in angle due to target centering error.[7]

The final equation is :

$$Б\alpha t = \frac{\sqrt{D1^2+D2^2}}{D1*D2} * Бt\ (206264.8) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5.2)$$

Where :
Бt = the angular error due to the target centering error.
D1&D2 =are the distances from the target to the instrument at stations 1 and 2.

5-3-5 Pointing error:

Accuracy in pointing to a target depends on several factors. These include the optical qualities of the instrument, target size, the observer's personal ability to place the crosswires on a target, and the weather conditions at the time o f observation. Pointing errors are random, and they will occur in every angle observation no matter the method used. Since each repetition of an angle consists of two pointings, the pointing error for an angle that is the mean of *n* repetitions can be estimated using Equation (8.2) as

$$\sigma_{\alpha_p} = \frac{\sqrt{2\sigma_{p1}^2 + 2\sigma_{p2}^2 + \cdots + 2\sigma_{pn}^2}}{n} \quad \text{.....................................(5.3)}$$

where Бαp is the error due to pointing and Б*p*1, Б*p*2,…, Б*pn* ,Б*p*
are the estimated errors in pointings for the first repetition, second repetition, and so on. Again for a given instrument and observer, the pointing error can be assumed the same for each repetition
(i.e., Б*p*1= Б*p*2=…= Б*pn* = Б*p*), and Equation (5.2) simplifies to

$$Б\alpha p = \frac{Бp * \sqrt{2}}{\sqrt{n}} \quad \text{..(5.4)}$$

Where :

Бp= are the estimated errors in paintings' for the first repetition,
n= number of reading

5-3-6 Horizontal Circle error.

Is a fixed Б = 1.00"

5-3-7 Direction error.

$$Бp = \frac{Бr * \sqrt{2}}{\sqrt{n}}$$

Бr = 0.87"

5-3-8 Prism height error:

From the catolog of the prisma , this error = 0.002 m

5-3-9 Theodelite height error:

The theodolite hieght error is the precision of the tape , because it is measured using the tape.

Theodolite height error = 0.002 m

5-3-10 Error in electronic distance observations.

All EDM observations are subject to instrumental errors that manufacturers list as constant, *a* , and scalar, *b* , error. A typical specified accuracy is ± (*a* + *b* ppm). In this expression, *a* is generally in the range 1 to 10 mm, and *b* is a scalar error that typically has the range 1 to 10 ppm. Other errors involved in electronic distance observations stem from the target and instrument centering errors. Since in any survey involving several stations these errors tend to be random Thus, the estimated error in an EDM observed distance is

$$\sigma_D = \sqrt{\sigma_i^2 + \sigma_t^2 + a^2 + (D \times b \text{ ppm})^2} \qquad \text{..(5.5)}$$

Where:

БD = is the error in the observed distance *D* ,
Бi = the instrument centering error,
Б *t*= the reflector centering error,
and *a* and *b* the instrument's specified accuracy parameters.

5-3-11 errors calculation.

EDM (ppm):

D1 = 209.492 m

Error = 0.002 + $\frac{2*209.492}{10^6}$ = 0.0024 m

D2 = 219.375 m

Error = 0.002 + $\frac{2*219.375}{10^6}$ = 0.0024 m

D3 = 121.843 m

Error = 0.002 + $\frac{2*121.843}{10^6}$ = 0.0022 m

D4 = 186.584 m

Error = 0.002 + $\frac{2*186.584}{10^6}$ = 0.0024 m

D5 = 679.570 m

Error = 0.002 + $\frac{2*679.570}{10^6}$ = 0.0034 m

D6 = 77.813 m

Error = 0.002 + $\frac{2*77.813}{10^6}$ = 0.0022 m

D7 = 129.188 m

Error = 0.002 + $\frac{2*77.813}{10^6}$ = 0.0022 m

The avareg of this error = 0.003 m

EDM constant error = 0.003 m

Centring error:

Бαi = $\frac{D3}{D1*D2} * \frac{Бi}{\sqrt{2}}$*(206264.8)

Бαi 1 = 4.75"

Бαi 2 = 2.68"

Бαi 3 = 3.65"

Бαi 4 = 3.84"

Бαi 5= 1.98"

Бαi 6= 4.16"

Бαi 7= 5.9"

Бαi 8= 4.72"

Target alignment error:

Бαt = $\frac{\sqrt{D1^2+D2^2}}{D1*D2} *$ Бt (206264.8)

Бαt 1 = 5.2"

Бαt 2 = 2.72"

Бαt 3 = 3.87"

Бαt 4 = 4.04"
Бαt 5= 2.29"
Бαt 6= 5.33"
Бαt 7= 6.18"
Бαt 8= 4.74"

Pointing error:

$Бαp = \frac{Бp*\sqrt{2}}{\sqrt{n}}$

$Бp= \frac{Бr*\sqrt{2}}{\sqrt{n}}$

Бr = 1.5"

Бαp = 0.5"

Horizontal circle error:

Б = 1.00"

Direction error :

$Бp= \frac{Бr*\sqrt{2}}{\sqrt{n}}$

Бr = 0.87"

Prisma hieght error :

From the catolog of the prisma , this error = 0.002 m

Theodolite hieght error:

The theodolite hieght error is the precision of the tape , because it is measured using the tape.

Theodolite hieght error = 0.002 m

Error in electronic distance observations.

$$\sigma_D = \sqrt{\sigma_i^2 + \sigma_r^2 + a^2 + (D \times b\ \text{ppm})^2}$$

Бd = 7mm

Бd = 4mm

Бd = 5.7mm

Бd = 6mm

Бd = 3.6mm

Бd = 7mm

Бd = 8.7mm

Total angle error

$\theta = \overline{\text{Б}i^2} + \overline{\text{Б}t^2} + \overline{\text{Б}p^2} + \overline{\text{Б}r^2}$

θ1= 7"

θ2= 4"

θ3= 5.5"

θ4= 5.75"

θ5= 3.34"

θ6= 6.9"

θ7= 8.66"

θ8= 6.8"

Table (5-1) Error in the angle

angle	reading	mean	Бαi	Бαt	Бαp		Prism height error	Theodelite height error
α1	36' 10.5"°162							
α1	35' 54"°162	35' 59.8"°162	4.75"	5.2"	0.5"	0.87"	0.002	0.002
α1	35' 55"°162							
α2	55' 20"°199							
α2	55' 21.5"°199	55' 20.5"°199	2.68"	2.72"	0.5"	0.87"	0.002	0.002
α2	55' 20"°199							
α3	50' 14.5"°156							
α3	50' 18"°156	50' 16.6"°156	3.65"	3.87"	0.5"	0.87"	0.002	0.002
α3	50' 17.5"°156							
α4	42' 9.5"°208							
α4	42' 09"°208	42' 9.83"°208	3.84"	4.04"	0.5"	0.87"	0.002	0.002
α4	42' 11"°208							
α5	33' 30.5"°162							
α5	33' 31"°162	33' 30.1"°162	1.98"	2.29"	0.5"	0.87"	0.002	0.002
α5	33' 29"°162							
α6	38' 37.5"°94							
α6	38' 39"°94	38' 39.17"°94	4.16"	5.33"	0.5"	0.87"	0.002	0.002
α6	38' 41"°94							
α7	29' 44"°201							
α7	29' 39"°201	29' 40.1"°201	5.9"	6.18"	0.5"	0.87"	0.002	0.002
α7	29' 37.5"°201							
α8	03' 50.5"°168					0.87"		
α8	03' 57"°168	03' 53.3"°168	4.72"	4.74"	0.5"		0.002	0.002
α8	03' 52.5"°168							

Table (5-2) Error in the distance

distance	reading	Mean(m)	Ϭd(mm)	EDM (PPM)
D1	209.492			
D1	209.490	209.492	7	0.0024
D1	209.494			
D2	219.380			
D2	219.375	219.375	4	0.0024
D2	219.371			
D3	121.841			
D3	121.840	121.843	5.7	0.0022
D3	121.85			
D4	186.596			
D4	186.574	186.584	6	0.0024
D4	186.584			
D5	679.59			
D5	679.57	679.57	3.6	0.0034
D5	679.56			
D6	77.81			
D6	77.83	77.813	7	0.0022
D6	77.80			
D7	129.171			
D7	129.210	129.188	8.7	0.0022
D7	129.183			

5-4 Computations of lines azimuth:

$$Az_{(100-200)} = \tan^{-1}\frac{(Y200-Y100)}{(X200-X100)} + c$$

$$Az_{(100-200)} = \tan^{-1}\frac{(158554.972-158634.762)}{(107267.435-107236.175)} + 360 = 291^\circ 23' 39''$$

$$Az_{(200-100)} = 291^\circ 23' 39'' - 180^\circ 00' 00'' = 111^\circ 23' 39''$$

$Az_{(2-1)}$ 111 23 39

+ 162 36 00 (<1)

$Az_{(2-3)}$ 273 59 39

-180

$Az_{(3-2)}$ = 93 59 39

$Az_{(3-2)}$ = 93 59 39

+ 199 55 21 (<2)

$Az_{(3-4)}$ 293 55 00

- 180

$Az_{(4-3)}$ = 113 55 00

$Az_{(4-3)}$ 113 55 00

+156 50 17 (<3)

$Az_{(4-5)}$ 270 45 17

-180

= 90 45 17

$Az_{(5-4)}$ 90 45 17

+ 208 42 10 (<4)

$Az_{(5-6)}$ = 299 27 27

- 180

= 119 27 27

$Az_{(6-5)}$ 119 27 27

+ 162 33 30 (<5)

Az(6-7) = 282 00 57

- 180

= 102 00 57

Az(7-6) 102 00 57

+ 94 38 39 (<6)

Az(7-8) = 196 39 36

-180

= 16 39 36

Az(8-7) = 16 39 36

+ 201 29 40 (<7)

= 218 09 16

-180

= 38 09 16

Az(8-9) 38 09 16

+168 03 53 (<8)

Az9-10 = 266 13 09

The angular misclosure of the traverse

The difference between the azimuth computed for course 9-10 (206º 13´ 09´´) and its actual value (206º 13´ 02´´) is (00º 00´ 07´´).

Where allowable error = $90'' \sqrt{n}$

= $90'' \sqrt{9}$ = (00º 04´ 30´´)

.

The linear misclosure of the traverse

When we compute the latitude and departure of a line, the following equations are used.

Lat = D * cos(Az) (7-6)

Dep = D * sin(Az) (7-7)

Where

Lat → latitude (line) Dep → departure(line) Az → azimuth(line)

D → is the horizontal length of the line.

Course	Length	Azimuth	Dep	Lat
1-2	85.695	291°23'39.0"	-79.7900	31.2600
2-3	209.490	273°59'39.0"	-208.9812	14.5920
3-4	219.375	293°55'00.0"	-200.5386	88.9363
4-5	121.483	270°45'17.0"	-121.4725	1.6002
5-6	186.584	299°27'27.0"	-162.4626	91.7579
6-7	679.570	282°00'57.0"	-664.6807	141.4742
7-8	77.810	196°39'36.0"	-22.3075	-74.5438
8-9	129.188	38°09'16.0"	79.8102	101.5868
9-10	117.417	266°13'09.0"	-117.1615	-7.7425
Sum =	1,826.612		-1497.5842	388.9211

The calculated values for the station 900 coordinates are:

$X_{(900)}$ = 157174.53 + 129.188 *sin 38°09'16.0" = 157094.72

$Y_{(900)}$ = 107531.25 + 129.188 *cos 38°09'16.0" = 107429.67

The fixed values for the station 900 coordinates (obtained from GPS) are:

X_{900} =157094.800

Y_{900} =107429.520

Misclosure in Easting Δx = 157094.80 - 157094.72=0.08 m.

Misclosure in Northing Δy = 107429.52- 107429.67=-0.15 m.

To drive the estimated error in the line’s latitude or departure, the following partial equations are required:

$$\frac{\partial Lat}{\partial D} = \cos(Az)$$
$$\frac{\partial Lat}{\partial Az} = -D * \sin(Az)$$

$$\frac{\partial Dep}{\partial D} = \sin(Az)$$
$$\frac{\partial Dep}{\partial Az} = D * \cos(Az)$$

J matrix =

$$\begin{bmatrix} \cos(Az_{ab}) & -D_{ab}\sin(Az_{ab}) & \longrightarrow & \text{Zeros} & \\ \sin(Az_{ab}) & D_{ab}\cos(Az_{ab}) & & \downarrow & \\ \downarrow & & \searrow & & \\ \text{Zeros} & \longleftarrow & & \cos(Az_{ra}) & -D_{ra}\sin(Az_{ra}) \\ & & & \sin(Az_{ra}) & D_{ra}\cos(Az_{ra}) \end{bmatrix}$$

15*12

Then we should form our Weight matrix

W matrix =

$$\begin{bmatrix} \pm_{D_{ab}}^{\ 2} & .. & .. & .. & .. \\ .. & \left(\frac{\pm_{Az_{ab}}}{\circ}\right)^2 & .. & .. & .. \\ .. & .. & .. & .. & .. \\ .. & .. & .. & \pm_{Djk}^{\ 2} & .. \\ .. & .. & .. & .. & \left(\frac{\pm_{Az_{jk}}}{\circ}\right)^2 \end{bmatrix}$$

5-5 Calculations of traverse points coordinates

Results of adjustment by civil 3D program:

Angular error = 0-00-07

Angular error/set = 0-00-01 Over

Error North : -0.1667

Error East : 0.0740

Absolute error: 0.1823

Error Direction: S 06-21-52 E

Perimeter : 1623.8650

Precision : 1 in 2433.3435

Number of sides: 7

SURVEY LEAST SQUARES CALCULATION

Total # of Unknown Points: 6

Total # of Points : 10

Total # of Observations: 16

Degrees of Freedom : 4

Confidence Level : 99%

Number of Iterations : 2

Chi Square Value : 4.31847

Goodness of Fit Test : Pass at the 1% Level

Standard Deviation of Unit Weight: 1.12

OBSERVATIONS

****

Type	Pnt1	Pnt2	Pnt3	Measured	StdDev	Adjusted	Resid
DIST	700	800		77.8130	0.003	77.8141	0.0011
ANG	600	700	800	94-38-39.00	4.300	94-38-37.85	-1.15
DIST	500	600		186.5840	0.003	186.5561	-0.0279
ANG	400	500	600	208-42-10.00	4.500	208-41-54.92	-15.08
DIST	200	300		209.4920	0.003	209.4646	-0.0274
ANG	100	200	300	162-36-00.00	5.000	162-35-15.35	-44.65
DIST	800	900		129.1880	0.003	129.1792	-0.0088
ANG	700	800	900	201-29-40.00	5.900	201-30-16.57	36.57
DIST	600	700		679.5700	0.004	679.5320	-0.0380
ANG	500	600	700	162-33-30.00	3.400	162-33-15.75	-14.25
DIST	300	400		219.3750	0.003	219.3467	-0.0283
ANG	200	300	400	199-55-21.00	3.800	199-55-06.35	-14.65
DIST	900	1000		0.0000	0.003	117.4172	117.4172
ANG	800	900	1000	168-03-53.00	5.000	168-05-02.92	69.92
DIST	400	500		121.8430	0.003	121.8177	-0.0253
ANG	300	400	500	156-50-17.00	4.300	156-49-53.18	-23.82

****

ADJUSTED COORDINATES

Std Deviations are at 99% Confidence Level

Point	Northing	Easting	StdDevNth	StdDevEst
300	107281.9800	158346.0130	0.0514	0.0630
400	107370.8472	158145.4747	0.0931	0.0706
500	107372.4027	158023.6669	0.1056	0.0734
600	107464.0696	157861.1850	0.1016	0.0688
700	107605.1736	157196.4645	0.0979	0.0715
800	107530.6137	157174.1969	0.0724	0.0595

****

2D LEAST SQUARES ERROR ANALYSIS

****

Semi-Axes are at 99% Confidence Level

Point	Semi-Major Axis	Semi-Minor Axis	NE-Axis Whole Circle Bearing
300	0.0631	0.0513	0-49-57
400	0.0955	0.0673	11-56-12
500	0.1077	0.0702	9-38-38
600	0.1037	0.0655	6-27-24
700	0.1100	0.0510	25-19-25
800	0.0865	0.0360	33-34-24

****

Blunder Detection/Analysis

****

Type	Pnt1	Pnt2	Pnt3	Adjusted	Reside	Redun	Estimate	Reliability Tests Marg	Ext
DIST	700	800		77.814	0.001	0.009	-0.119	P	P
ANG	600	700	800	94-38-37.85	-1.155	0.269	4.294	P	P
DIST	500	600		186.556	-0.028	0.137	0.203	P	P
ANG	400	500	600	208-41-54.92	-15.08	0.153	98.485	P	P
DIST	200	300		209.465	-0.027	0.153	0.180	P	P
ANG	100	200	300	162-35-15.35	-44.653	0.466	95.765	P	P
DIST	800	900		129.179	-0.009	0.038	0.231	P	P
ANG	700	800	900	201-30-16.57	36.574	0.407	-89.896	F	F
DIST	600	700		679.532	-0.038	0.208	0.183	P	P
ANG	500	600	700	162-33-15.75	-14.253	0.090	158.504	P	P
DIST	300	400		219.347	-0.028	0.145	0.194	P	P
ANG	200	300	400	199-55-06.35	-14.647	0.195	74.980	P	P
DIST	900	1000		117.417	117.417	0.195	-601.055	F	F
ANG	800	900	1000	168-05-02.92	69.919	0.417	-167.514	F	F
DIST	400	500		121.818	-0.025	0.141	0.179	P	P
ANG	300	400	500	156-49-53.18	-23.821	0.171	139.069	P	P

Redundancy is the observation's contribution to the degree of freedom.

(From 0 to 1 with 1 being best)

Estimate is used to estimate the blunder which might cause large residuals.

Marg is a reliability test for a single blunder (Type II error).

Ext is an external reliability test for an observation

P = PASS FAIL = FAIL

Least Squares Input File

Generated By Survey

	Point	Northing	Easting	Level
NE	100	107236.175000	158634.762000	
NE	200	107267.435000	158554.972000	
NE	300	107282.027173	158345.988827	
NE	400	107370.963472	158145.450239	
NE	500	107372.568404	158023.617810	
NE	600	107464.326299	157861.155267	
NE	700	107605.800617	157196.474590	
NE	800	107531.253985	157174.166234	
NE	900	107429.004000	157094.430000	
NE	1000	107323.666000	157042.558000	

****

	From Point	At Point	To Point	Angle	Distance	Angle Std Error	Distance Std Error
D		700	800		77.8130		0.0030
A	600	700	800	94.38390		0.00043	
D		500	600		186.5840		0.0031
A	400	500	600	208.42100		0.00045	
D		200	300		209.4920		0.0031
A	100	200	300	162.36000		0.00050	
D		800	900		129.1880		0.0030
A	700	800	900	201.29400		0.00059	
D		600	700		679.5700		0.0036
A	500	600	700	162.33300		0.00034	
D		300	400		219.3750		0.0031

```
A    200   300   400      199.55210              0.00038
D          900   1000                 0.0000                  0.0030
A    800   900   1000     168.03530              0.00050
D          400   500                  121.8430                0.0030
A    300   400   500      156.50170              0.00043
```

****

The rules of this input file are as follows:

- All observations must reference known or unknown (to be determined) points.
- Angular errors are in DMS.
- Angles (A) are in DMS.
- Distance errors are in METERS.
- Distances (D) are in METERS.
- Whole Circle Bearing errors are in DMS.
- Whole circle bearings (WCB) are in DMS.
- Coordinates are in METERS.
- An exclamation (in the first column) ignores any text on line
- Fields are separated by spaces (space delimited).

Results of adjustment by Adjust program:

Travers of the Project

Number of Control Stations --4

Number of Unknown Stations --6

Number of Distance observations --7

Number of Angle observations -- 8

Number of Azimuth observations --0

****

Initial approximations for unknown stations

****

Station	X	Y
300	158,345.991	107,282.027
400	158,145.452	107,370.096
500	158,023.980	107,372.564
600	157,861.517	107,464.321
700	157,196.837	107,605.796
800	157,174.529	107,531.252

Control Stations

****

Station	X	Y
100	158,634.762	107,236.175
200	158,554.972	107,267.435
900	157,094.430	107,429.004
1000	157,042.558	107,323.666

****

Distance Observations

****

Station Occupied	Station Sighted	Distance	S
200	300	209.490	0.003
300	400	219.375	0.004
400	500	121.483	0.003
500	600	186.584	0.003
600	700	679.570	0.004
700	800	77.810	0.003
800	900	129.188	0.003

****

Angle Observations

****

Station Back sighted	Station Occupied	Station Foresighted	Angle	S
100	200	300	162°36'00"	7"
200	300	400	199°55'21"	4"
300	400	500	156°50'17"	6"
400	500	600	208°42'10"	6"
500	600	700	162°33'30"	3"
600	700	800	94°38'38"	7"
700	800	900	201°29'40"	9"
800	900	1000	168°03'53"	7"

****

Adjusted stations

****

			Standard error ellipse computed				
Station	X	Y	Sx	Sy	Su	Sv	t
300	158,346.022	107,281.971	0.0630	0.0514	0.0631	0.0513	0.8325°
400	158,145.473	107,370.839	0.0706	0.0931	0.0955	0.0673	11.94°
500	158,023.666	107,372.403	0.0734	0.1056	0.1077	0.0702	9.6438°
600	157,861.185	107,464.070	0.0688	0.1016	0.1037	0.0655	6.456°
700	157,196.465	107,605.174	0.0715	0.0979	0.1100	0.0510	25.32°
800	157,174.197	107,530.616	0.0595	0.0724	0.0865	0.0360	33.57°

****

Adjusted Distance Observations

****

Station Occupied	Station Sighted	Distance	V	S	Std.Res.	Red.#
200	300	209.464	0.0461	0.0631	12.681	0.269
300	400	219.347	0.0133	0.0404	11.405	0.085
400	500	121.817	0.0308	0.0546	12.880	0.176
500	600	186.555	0.0281	0.0573	11.009	0.181
600	700	679.533	0.0118	0.0366	12.185	0.072
700	800	77.828	0.0176	0.0730	17.069	0.022
800	900	129.179	0.0498	0.0865	17.077	0.112

****

Adjusted Angle Observations

****

Station Backsig.	Station Occ.	Station Foresig.	Angle	V	S"	Std.Res.	Red.#
100	200	300	162°35'15"	-58.7"	50.5	-11.5	0.533
200	300	400	199°55'04"	-16.6"	39.5	-11.7	0.126
300	400	500	156°49'53"	-16.4"	52.9	-7.3	0.168
400	500	600	208°41'54"	-15.9"	56.0	-7.1	0.149
500	600	700	162°33'16"	0.2"	34.4	0.2	0.046
600	700	800	94°38'38"	45.6"	61.1	12.2	0.295
700	800	900	201°30'17"	46.8"	70.2	8.5	0.409
800	900	1000	168°05'02"	8.9"	57.6	2.2	0.356

****

Adjustment Statistics

****

Iterations = 3

Redundancies = 3

Reference Variance = 111.309

Reference So = ±1.06

Pass X^2 test at 99% significance level!

X^2 lower value = 0.22

X^2 upper value = 9.35

Possible blunder in observations with Std.Res. > 35

Convergence!

5-6 Adjustment of Level

5-6-1 Introduction

Differential leveling observations are used to determine differences in elevation between stations. As with all observations, these measurements are subject to random errors that can be adjusted using the method of least squares. In this chapter the observation equation method for adjusting differential leveling observations by leastquares is developed, and several examples are given to illustrate the adjustment procedures.

5-6-2 Adjustment of the project level net.

To apply the method of least squares in leveling adjustments, a prototype observation equation is first written for any elevation difference. Figure 5.4illustrates the functional relationship for the elevation difference observed between two stations, *I* and *J*. The equation is expressed as

$$E_j - E_i = \Delta Elev._{ij} + \upsilon_{\Delta Elev.ij} \quad \text{...} \quad (5\text{-}9).$$

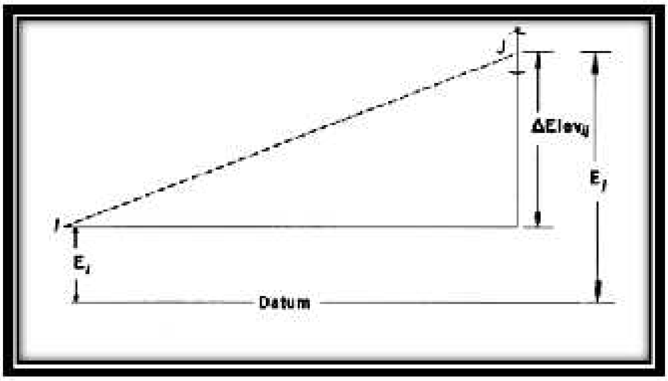


Figure (5.3) Differential Leveling Observations.[7]

Elevation of the control stations are as follows:

Station	Elevation(m)
1000(A)	984.860
2000(B)	977.958
9000(I)	961.186
10000(J)	955.975

Now the observed elevation differences are as follows:

Line	Observed elevation difference(m)
AC	-11.952
BC	-5.05
BD	-6.71
CD	-1.66
CE	-3.337
DE	-1.677
DF	-9.16
EF	-7.483
EG	-6.534
FG	0.949
FH	4.909
GH	3.96
GI	-1.986
HI	-5.946

Using least square solution

AX = L + V…………………………………………………(5-10)

A matrix =

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ -1 & 1 & 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & 0 & -1 & 0 & 1 \\ 0 & 0 & 0 & 0 & -1 & 1 \\ 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 0 & -1 \end{bmatrix}$$

$$L = \begin{bmatrix} 972.908 \\ 972.908 \\ 971.248 \\ -1.66 \\ 3.337 \\ -1.677 \\ -9.16 \\ -7.483 \\ -6.534 \\ 0.949 \\ 4.909 \\ 3.96 \\ -963.037 \\ -966.997 \end{bmatrix}$$

Solving for the *X* matrix, the adjusted elevations of the stations are as bellow:

$$X= \begin{bmatrix} 971.8704 \\ 971.7501 \\ 971.5926 \\ 963.1122 \\ 963.9608 \\ 967.6463 \end{bmatrix}$$

Compute the residuals using the matrix expression $V = AX - L$:

$$V= \begin{bmatrix} -1.038 \\ -1.038 \\ 0.502 \\ 1.540 \\ -3.615 \\ 1.52 \\ 0.522 \\ -0.997 \\ -1.098 \\ -0.100 \\ -0.375 \\ -0.274 \\ -0.924 \\ -0.649 \end{bmatrix}$$

Calculate the reference standard deviation for the adjustment using the matrix expression of the following equation:

$$S_o = \sqrt{\frac{V^T V}{m-n}} \quad \text{……………………………………………………………} (5\text{-}11)$$

Where:

V : the residuals.

m: number of observations.

n: number of unknowns.

$S_o = 1.736$

Tabulate the results showing the adjusted elevation differences, their residuals, and final adjusted elevations.

From	To	Adjusted Δ Ele.	Residual	Station	Adjusted Elevation
A	C	-12.99	-1.038	A	984.86
B	C	-6.088	-1.038	B	977.958
B	D	-6.208	0.502	C	971.87
C	D	-.012	1.540	D	971.750
C	E	-6.952	-3.615	E	971.593
D	E	-0.157	1.52	F	963.112
D	F	-8.638	0.522	G	963.961
E	F	-8.48	-0.997	H	967.646
E	G	-7.632	-1.098	I	966.997
F	G	0.849	-0.100	J	961.051
F	H	4.534	-0.375		
G	H	3.686	-0.274		
G	I	-2.91	-0.924		
H	I	-6.595	-0.649		

Chapter five

Adjustment of the Traverse

5-1Introduction

All surveying observations are subject to errors from varying sources. For example, when observing an angle, the major error sources include instrument placement and leveling, target placement, circle reading, and target pointing. Although great caremay be taken in observing the angle, these error sources will render inexact results. Toappreciate fully the need for adjustments, survey or must be able to identify the major observational error sources, know their effects on the measurements, and understand how they can be modeled. In this chapter, emphasis is placed on analyzing the errors in observed horizontal angles and distances.

5-2 Calculations of the traverse angles and distances

Measuring Angle 1

Station	F.R	F.L
1000	0˚ 00' 00"	179˚ 59' 30"
3000	162˚ 35' 32"	342˚ 36' 19"
1000	0˚ 00' 00"	180˚ 00' 10"
3000	162˚ 35' 45"	342˚ 36' 13"
1000	0˚ 00' 00"	180˚ 00' 05"
3000	162˚ 35' 40"	342˚ 36' 15"

First trial = $\frac{162^{\circ}35'32'' - 0^{\circ}00'00'' + (342^{\circ}36'19'' - 179^{\circ}59'30'')}{2}$

First trial = 162˚ 36' 10.5"

Second trial = $\frac{162^\circ 35' 45'' - \cdot 0^\circ 00' 00'' + (342^\circ 36' 13'' - 180^\circ 00' 10'')}{2}$

Second trial = 162˚ 35' 54"

Third trial = $\frac{162^\circ 35' 40'' - \cdot 0^\circ 00' 00'' + (342^\circ 36' 15'' - 180^\circ 00' 05'')}{2}$

Third trial = 162˚ 35' 55"

Mean = $\frac{162^\circ 36' 10.5'' + 162^\circ 35' 54'' + 162^\circ 35' 55''}{3}$

M = 162˚ 35' 59.8"

Xi	M	υ=Xi - M	(Xi - M)2
162˚ 36' 10.5"	162˚ 35' 59.8"	00˚ 00' 10.7"	114.49
162˚ 35' 54"	162˚ 35' 59.8"	-00˚ 00' 5.8"	33.64
162˚ 35' 55"	162˚ 35' 59.8"	-00˚ 00' 4.8"	23.04
		00˚ 00' 00"	

Б = $\overline{171.71/2}$ = 9.26"

Max. Er. = 2.576Б = 3*9.26"= 23.853"

There is no blunders.

Measuring Angle 2

Station	F.R	F.L
2000	0˚ 00' 00"	179˚ 59' 52"
4000	199˚ 55' 15"	19˚ 55' 17"
2000	0˚ 00' 00"	180˚ 00' 12"
4000	199˚ 55' 25"	19˚ 55' 30"
2000	0˚ 00' 00"	180˚ 00' 05"
4000	199˚ 55' 20"	19˚ 55' 25"

First trial = $\frac{199^\circ 55' 15'' - 0^\circ 00' 00'' + (19^\circ 55' 17'' - 179^\circ 59' 52'' + 360^\circ)}{2}$

First trial = $199^\circ\ 55'\ 20''$

Second trial = $\frac{199^\circ 55' 25'' - 0^\circ 00' 00'' + (19^\circ 55' 30'' - 180^\circ 00' 12'' + 360^\circ)}{2}$

Second trial = $199^\circ\ 55'\ 21.5''$

Third trial = $\frac{199^\circ 55' 20'' - 0^\circ 00' 00'' + (19^\circ 55' 25'' - 180^\circ 00' 05'' + 360^\circ)}{2}$

Third trial = $199^\circ\ 55'\ 20''$

$$Mean = \frac{199˚55' 20'' + 199˚55' 21.5'' + 199˚55' 20''}{3}$$

M = 199˚ 55' 20.5"

Xi	M	υ =Xi - M	(Xi - M)2
199˚ 55' 20"	199˚ 55' 20.5"	-00˚ 00' 0.5"	0.25
199˚ 55' 21.5"	199˚ 55' 20.5"	00˚ 00' 1.00"	1.00
199˚ 55' 20"	199˚ 55' 20.5"	-00˚ 00' 0.5"	0.25
		00˚ 00' 00"	

Б = $\sqrt{1.5/2}$ = 0.866"
Max. Er. = 2.576Б = 2.576*0.866"= 2.231"

There is no blunders.

Measuring Angle 3

Station	F.R	F.L
3000	⠂0˚ 00' 00"	180˚ 00' 00"
5000	156˚ 50' 40"	336˚ 49' 49"
3000	⠂0˚ 00' 00"	179˚ 59' 55"
5000	156˚ 50' 41"	336˚ 49' 50"
3000	⠂0˚ 00' 00"	180˚ 00' 00"
5000	156˚ 50' 50"	336˚ 49' 45"

$$\text{First trial} = \frac{156^{\circ}50'40'' - 0^{\circ}00'00'' + (336^{\circ}49'49'' - 180^{\circ}00'00'')}{2}$$

First trial = 156˚ 50' 14.5"

$$\text{Second trial} = \frac{156^{\circ}50'41'' - 0^{\circ}00'00'' + (336^{\circ}49'50'' - 179^{\circ}59'55'')}{2}$$

Second trial = 156˚ 50' 18"

$$\text{Third trial} = \frac{156^{\circ}50'50'' - 0^{\circ}00'00'' + (336^{\circ}49'45'' - 180^{\circ}00'00'')}{2}$$

Third trial = 156˚ 50' 17.5"

Mean $= \frac{156^{\circ}50'14.5''+156^{\circ}50'18''+156^{\circ}50'17.5''}{3}$

M = 156° 50' 16.6"

Xi	M	υ =Xi - M	(Xi - M)2
156° 50' 14.5"	156° 50' 16.6"	-00° 00' 2.1"	4.41
156° 50' 18"	156° 50' 16.6"	00° 00' 1.4"	1.96
156° 50' 17.5"	156° 50' 16.6"	00° 00' 0.9"	0.81
		00° 00' 00"	

Б = $\sqrt{7.18/2}$ = 1.894"

Max. Er. = 2.576Б = 2.576*1.894"= 4.225"

There is no blunder.

Measuring Angle 4

Station	F.R	F.L
4000	0˚ 00' 00"	180˚ 00' 05"
6000	208˚ 42' 13"	28˚ 42' 11"
4000	0˚ 00' 00"	180˚ 00' 10"
6000	208˚ 42' 08"	28˚ 42' 20"
4000	0˚ 00' 00"	180˚ 00' 03"
6000	208˚ 42' 10"	28˚ 42' 15"

First trial = $\frac{208^\circ 42' 13'' - 0^\circ 00' 00'' + (28^\circ 42' 11'' - 180^\circ 00' 05'' + 360^\circ)}{2}$

First trial = 208˚ 42' 9.5"

Second trial = $\frac{208^\circ 42' 08'' - 0^\circ 00' 00'' + (28^\circ 42' 20'' - 180^\circ 00' 10'' + 360^\circ)}{2}$

Second trial = 208˚ 42' 09"

Third trial = $\frac{208^\circ 42' 10'' - 0^\circ 00' 00'' + (28^\circ 42' 15'' - 180^\circ 00' 03'' + 360^\circ)}{2}$

Third trial = 208˚ 42' 11"

Mean $= \frac{208^{\circ}42'9.5''+208^{\circ}42'09''+208^{\circ}42'11''}{3}$

M = 208˚ 42' 9.83"

Xi	M	υ =Xi - M	(Xi - M)2
208˚ 42' 9.5"	208˚ 42' 9.83"	-00˚ 00' 0.33"	0.1089
208˚ 42' 09"	208˚ 42' 9.83"	-00˚ 00' 0.83"	0.688
208˚ 42' 11"	208˚ 42' 9.83"	00˚ 00' 1.17"	1.3689
		00˚ 00' 00"	

Б = $\sqrt{2.1658/2}$ = 1.04"

Max. Er. = 2.576Б = 2.576*1.04"= 2.679"

There is no blunder.

Measuring Angle 5

Station	F.R	F.L
5000	٠0° 00' 00"	179° 59' 50"
7000	162° 33' 37"	342° 33' 14"
5000	٠0° 00' 00"	179° 59' 45"
7000	162° 33' 27"	342° 33' 20"
5000	٠0° 00' 00"	180° 00' 05"
7000	162° 33' 30"	342° 33' 28"

First trial = $\frac{162^\circ 33' 37'' - \cdot 0^\circ 00' 00'' \; + (342^\circ 33' 14'' - 179^\circ 59' 50'')}{2}$

First trial = 162° 33' 30.5"

Second trial = $\frac{162^\circ 33' 27'' - \cdot 0^\circ 00' 00'' \; + (342^\circ 33' 20'' - 179^\circ 59' 45'')}{2}$

Second trial = 162° 33' 31"

Third trial = $\frac{162^\circ 33' 30'' - \cdot 0^\circ 00' 00'' \; + (342^\circ 33' 28'' - 180^\circ 00' 00'')}{2}$

Third trial = 162° 33' 29"

$$Mean = \frac{162^\circ 33' 30.5'' + 162^\circ 33' 31'' + 162^\circ 33' 29''}{3}$$

M = 162˚ 33' 30.1"

Xi	M	υ =Xi - M	(Xi - M)2
162˚ 33' 30.5"	162˚ 33' 30.1"	00˚ 00' 0.4"	0.16
162˚ 33' 31"	162˚ 33' 30.1"	00˚ 00' 0.9"	0.81
162˚ 33' 29"	162˚ 33' 30.1"	-00˚ 00' 1.1"	1.21
		00˚ 00' 00"	

Б = $\sqrt{2.18/2}$ = 1.044"

Max. Er. = 2.576Б = 2.576*1.044"= 2.689’’

There is no blunder.

Measuring Angle 6

Station	F.R	F.L
6000	٠0˚ 00' 00"	180˚ 00' 00"
8000	94˚ 38' 30"	274˚ 38' 45"
6000	٠0˚ 00' 00"	179˚ 59' 55"
8000	94˚ 38' 33"	274˚ 38' 40"
6000	٠0˚ 00' 00"	180˚ 00' 03"
8000	94˚ 38' 35"	274˚ 38' 50"

First trial = $\frac{94^\circ 38' 30'' - \cdot 0^\circ 00' 00'' + (274^\circ 38' 45'' - 180^\circ 00' 00'')}{2}$

First trial = 94˚ 38' 37.5"

Second trial = $\frac{94^\circ 38' 33'' - \cdot 0^\circ 00' 00'' + (274^\circ 38' 40'' - 179^\circ 59' 55'')}{2}$

Second trial = 94˚ 38' 39"

Third trial = $\frac{94^\circ 38' 35'' - \cdot 0^\circ 00' 00'' + (274^\circ 38' 50'' - 180^\circ 00' 03'')}{2}$

Third trial = 94˚ 38' 41"

$$\text{Mean} = \frac{94^{\circ}38'\,37.5''+94^{\circ}38'\,39''+94^{\circ}38'\,41''}{3}$$

M = 94˚ 38' 39.17"

Xi	M	υ =Xi - M	(Xi - M)2
94˚ 38' 37.5"	94˚ 38' 39.17"	-00˚ 00' 1.16"	1.3456
94˚ 38' 39"	94˚ 38' 39.17"	-00˚ 00' 0.17"	0.0289
94˚ 38' 41"	94˚ 38' 39.17"	00˚ 00' 1.38"	1.9044
		00˚ 00' 00"	

$Б = \sqrt{3.2789/2} = 1.28''$

Max. Er. = 2.576Б = 2.576*1.28"= 3.297"

There is no blunder.

Measuring Angle 7

Station	F.R	F.L
7000	٠0˚ 00' 00"	180˚ 00' 10"
9000	201˚ 29' 43"	21˚ 29' 55"
7000	٠0˚ 00' 00"	180˚ 00' 02"
9000	201˚ 29' 35"	21˚ 29' 45"
7000	٠0˚ 00' 00"	180˚ 00' 05"
9000	201˚ 29' 40"	21˚ 29' 40"

First trial = $\frac{201^{\circ}29'43'' - \cdot 0^{\circ}00'00'' \;\; +(21^{\circ}29'55'' - 180^{\circ}00'10'')}{2}$

First trial = 201˚ 29' 44"

Second trial = $\frac{201^{\circ}29'35'' - \cdot 0^{\circ}00'00'' \;\; +(21^{\circ}29'45'' - 180^{\circ}00'02'')}{2}$

Second trial = 201˚ 29' 39"

Third trial = $\frac{201^{\circ}29'40'' - \cdot 0^{\circ}00'00'' \;\; +(21^{\circ}29'40'' - 180^{\circ}00'05'')}{2}$

Third trial = 201˚ 29' 37.5"

Mean $= \frac{201^\circ 29' 44'' + 201^\circ 29' 39'' + 201^\circ 29' 37.5''}{3}$

M = 201° 29' 40.1"

Xi	M	υ =Xi - M	(Xi - M)2
201° 29' 44"	201° 29' 40.1"	00° 00' 3.9"	15.21
201° 29' 39"	201° 29' 40.1"	-00° 00' 1.1"	1.21
201° 29' 37.5"	201° 29' 40.1"	-00° 00' 2.6"	6.76
		00° 00' 00"	

Б = $\sqrt{23.18/2}$ = 3.4"

Max. Er. = 2.576Б = 2.576*3.4"= 8.758"

There is no blunder.

Measuring Angle 8

Station	F.R	F.L
8000	٠0˚ 00' 00"	179˚ 59' 40"
10000	168˚ 03' 46"	348˚ 03' 35"
8000	٠0˚ 00' 00"	179˚ 59' 45"
10000	168˚ 03' 54"	348˚ 03' 45"
8000	٠0˚ 00' 00"	179˚ 59' 50"
10000	168˚ 03' 50"	348˚ 03' 45"

First trial = $\frac{168^\circ 03' 46'' - 0^\circ 00' 00'' + (348^\circ 03' 35'' - 179^\circ 59' 40'')}{2}$

First trial = 168˚ 03' 50.5"

Second trial = $\frac{168^\circ 03' 54'' - 0^\circ 00' 00'' + (348^\circ 03' 45'' - 179^\circ 59' 45'')}{2}$

Second trial = 168˚ 03' 57"

Third trial = $\frac{168^\circ 03' 50'' - 0^\circ 00' 00'' + (348^\circ 03' 45'' - 179^\circ 59' 50'')}{2}$

Third trial = 168˚ 03' 52.5"

Mean $= \frac{168^\circ 03' 50.5'' + 168^\circ 03' 57'' + 168^\circ 03' 52.5''}{3}$

M = 168˚ 03' 53.33"

Xi	M	υ =Xi - M	(Xi - M)2
168˚ 03' 50.5"	168˚ 03' 53.33"	-00˚ 00' 2.83"	8.0089
168˚ 03' 57"	168˚ 03' 53.33"	00˚ 00' 3.67"	13.4689
168˚ 03' 52.5"	168˚ 03' 53.33"	-00˚ 00' 0.83'	0.6889
		00˚ 00' 00"	

Б = $\overline{22.1667/2}$ = 3.329"

Max. Er. = 2.576Б = 2.576*3.329"= 8.575"

There is no blunder.

Distance Calculations

D (2000-3000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
209.492	209.492	0.00	0.00
209.490	209.492	-0.002	0.000004
209.494	209.492	0.002	0.000004
		00.00	

Mean $= \frac{209.492+209.490+209.494}{3}$

M = 209.492 m

Б = $\sqrt{0.0000008/2}$ = 0.002 m

Max. Er. = 2.576Б = 2.576*0.002 = 0.005 m

There is no blunder.

Distance Calculations

D (3000-4000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
219.380	219.375	0.005	0.000025
219.375	219.375	00.00	00.00
219.371	219.375	-0.004	0.000016
		00.00	

Mean $= \frac{219.38+219.37.5+219.37}{3}$

M = 219.375 m

Б = $\overline{0.000041/2}$ = 0.0045 m

Max. Er. = 2.576Б = 2.576*0.0045 = 0.01m

There is no blunder.

Distance Calculations

D(4000-5000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
121.841	121.843	-0.002	0.00004
121.840	121.843	-0.003	0.00009
121.85	121.843	0.007	0.000049
		00.00	

Mean $= \frac{121.841+121.840+121.85}{3}$

M = 121.843 m

Б = $\overline{0.000179/2}$ = 0.00946 m

Max. Er. = 2.576Б = 2.576*0.00946 = 0.024m

There is no blunder.

Distance Calculations

D(5000-6000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
186.596	186.584	0.012	0.000144
186.574	186.584	-0.010	0.0001
186.584	186.584	0.00	00.00
		00.00	

Mean $= \frac{186.596+186.574+186.584}{3}$

M = 186.584 m

Б = $\sqrt{0.000244/2}$ = 0.011 m

Max. Er. = 2.576Б = 2.576*0.011 = 0.028 m

There is no blunder.

Distance Calculations

D(6000-7000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
679.59	679.57	0.02	0.0004
679.57	679.57	00.00	00.00
679.56	679.57	-0.01	0.0001
		00.00	

Mean $= \frac{679.59+679.57+679.57}{3}$

M = 679.57 m

Б = $\overline{0.0005/2}$ = 0.015 m

Max. Er. = 2.576Б = 2.576*0.015 = 0.038m

There is no blunder.

Distance Calculations

D(7000-8000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
77.81	77.813	-0.003	0.000009
77.83	77.813	0.017	0.000289
77.80	77.813	-0.013	0.000169
		00.00	

Mean $= \frac{77.81+77.83+77.80}{3}$

M = 77.813 m

Б = $\sqrt{0.000467/2}$ = 0.015 m

Max. Er. = 2.576Б = 2.576*0.015 = 0.038m

There is no blunder.

Distance Calculations

D(8000-9000)

Xi(m)	M	υ =Xi - M	(Xi - M)2
129.171	129.188	-0.017	0.000289
129.210	129.188	0.022	0.000484
129.183	129.188	-0.005	0.000025
		00.00	

Mean $= \frac{129.171+129.210+129.183}{3}$

M = 129.188 m

Б = $\overline{0.000798/2}$ = 0.0199 m

Max. Er. = 2.576Б = 2.576*0.0199 = 0.051 m

There is no blunder.

Chapter Six

The Structural design and Laboratory Tests

6-1 Introduction

The structural design of the road is to find the thickness of each of the sub base, the base course and the asphalt layers and to define their prosperities in order to carry loads of the vehicles travelling on it according to the laboratory tests and the traffic volume on it.

6-2 Laboratory Tests

Laboratory Tests includes several tests applied on the pavement layers of the road and the soil of the site.

The most important tests are:

1 - Compaction test.

2 - CBR test.

6-2-1 Compaction test (Proctor Compaction Test)

Introduction:

Compaction is one kind of densification that is realized by rearrangement of soil particles without outflow of water. It is realized by application of mechanic energy. It does not involve fluid flow, but with moisture changing altering.

Objectives:

The chief purpose of running the compaction test is to determine the maximum dry unit weight of a soil. After determining this maximum dry unit weight, specifications can be determined for filed compaction of the soil.

Soils are compacted for the following reasons:

1- To increase strength and stability.
2- To decrease permeability.
3- To enhance resistance to erosion.
4- Decrease compressibility under load and minimize settlement.

Standard Proctor Compaction Test Equipments:

1- Compaction mould.
2- Sieve No.4
3- Standard proctor hammer (5.5Ib (24.5n)).
4- Balances (0.01 Ib sensitivity and 0.1g sensitivity)
5- A large flat pan.
6- Jack.
7- Steel straight edge. Moisture cans.
8- Drying oven.
9- Plastic squeeze bottle with water.

Procedure:

1- Obtain approximately 10Ib (4.5kg) of air-dried in the mixing pan, break all the lumps so that it passes No.4 sieve
2- Add approximate amount of water to increase the moisture content by about 5%
3- Determine the weight of empty proctor mould without the base plate and the collar. W1,(Ib).(Row #1 of the table).
4- Fix the collar and base plate .(ask your instruction regarding how to fill the mould and take the steps 5 and 6)
5- Place the first portion of the soil in the proctor mould and compact the layer applying 25 blows.
6- Scratch the layer with a spatula forming a grid to ensure uniformity in distribution of compaction energy to the subsequent layer. Place the second layer, apply 25 blows, place the last portion and apply 25 blows.
7- The final layer should ensure that the compacted soil is just above the rim of the compaction mould when the collar is still attached.
8- Detach the collar carefully without disturbing the compacted soil inside the mould and using a straight edge trim the excess soil leveling to the mould.
9- Determine the weight of the mould with the moist soil W2,(Ib). Extrude the sample and break it to collect the simple for water content determination preferably from the middle of the specimen.
10- Weigh an empty moisture can, W3,(g) and weigh again with the moist soil obtained from the extruded sample in step 9 , W4,(g) .Keep this can in the oven for water content determination.
11- Break the rest of the compacted soil with hand (visually ensure that it passes US Sieve No.4) .

12- Repeat steps 4 to 11 .During this process the weight W2 increases for some time with the increase in moisture and drops suddenly. Take two moisture increments after the weights starts reducing. Obtain at least 4 points to plot the dry unit weight, moisture content variation.
13- After 24 hrs recover the sample in the oven and determine the weight W5, (g).

Calculations and results:

The values of wet density, dry density and the other information about the base coarse layer appear in the tables (6-1), (6-2) respectively. And The optimum moisture content appears in the figure (6-1) such that:

The height of Proctor's template = 116.5 mm

The radius of the template = 152.4 mm

The volume of the template = $(r^2 * \pi) *$ height

V = $(152.4^2 * \pi) * 116.5 = 2125$ cm^3 and this volume constant for all samples.

The weight of the empty template = 7749 g.

The compaction was applied on five layers, and each layer was hit 55 blows with the proctor's hammer.

Table (6-1) the values of wet density for base coarse samples

Sample No.	Sample weight + Template(g)	Weight of the wet sample(g)	Volume of the sample (cm^3)	Wet density (g/ cm^3)
1	9608	4492	Volume of the template = 2125	2.11
2	9910	4794		2.25
3	10125	5009		2.35
4	10114	4998		2.35
5	10022	4906		2.30

Table (6-2) the values of dry density and moisture content for base coarse samples

Sample No.	Vine No.	Weight of empty Vine	Weight of the wet sample +vine (g)	Weight of the dry sample +vine (g)	Water weight (g)	Weight of the dry sample(g)	Moisture ratio (%)	Dry density (g/ cm^3)
1	A2	31.85	307.85	298.60	9.25	266.75	3.5	2.05
2	A7	31.45	304.80	291.40	13.40	259.95	5.16	2.15
3	E12	32.80	276.05	259.20	16.85	226.40	7.44	2.20
4	D4	31.70	300.50	278.60	21.90	246.90	8.90	2.16
5	A11	29.15	239.95	219.30	20.65	190.15	10.90	2.09

From the results in tables (6-1), (6-2)

Wet density (1) = Weight of the wet sample / Volume of the sample

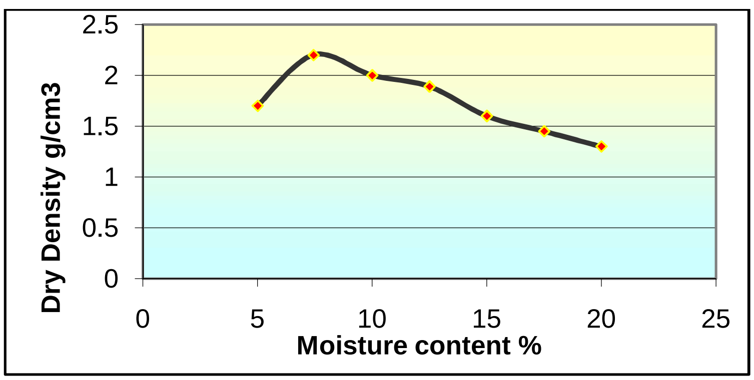
Wet density (1) = 4492/2125= 2.11 g/ cm^3

Moisture ratio (1) = Water weight / Weight of the dry sample

Moisture ratio (1) = 9.25 / 266.75= 3.5 %

Dry density (1) = Wet density / (1+ Moisture ratio)

Dry density (1) = 2.11 / (1+3.5) = 2.05 g/ cm^3



From the above figure we find that:

The maximum density = 2.2 g/ cm^3.

The optimum moisture content = 7.44 %.

The following table shows wet density for the soil samples:

Table (6-3) the values of wet density for soil samples

Sample No.	Sample weight + Template(g)	Weight of the wet sample(g)	Volume of the sample (cm^3)	Wet density (g/ cm^3)
1	9433	4317	Volume of the template = 2125	2.03
2	9625	4509		2.12
3	9690	4574		2.15
4	9545	4429		2.08
5	9403	4287		2.01

Table (6-4) the values of dry density and moisture ratio for soil samples

Sample No.	Vine No.	Weight of empty Vine	Weight of the wet sample +vine (g)	Weight of the dry sample +vine (g)	Water weight (g)	Weight of the dry sample(g)	Moisture ratio (%)	Dry density (g/ cm^3)
1	A14	31.95	246.44	228.5	17.94	196.55	9.12	1.86
2	B6	31.75	245.87	225.4	20.47	193.65	10.57	1.91
3	C13	30.55	246.81	220.5	26.31	189.95	13.85	1.89
4	A3	30.55	215.28	186.5	28.78	155.95	18.45	1.75
5	8	29	320.20	268.3	51.90	239.30	21.68	2.09

From the results in tables (6-3), (6-4)

Wet density (1) = Weight of the wet sample / Volume of the sample

Wet density (1) = 4317/2125= 2.03 g/ cm^3

Moisture ratio (1) = Water weight / Weight of the dry sample

Moisture ratio (1) = 17.94 / 196.55= 9.12 %

Dry density (1) = Wet density / (1+ Moisture ratio)

Dry density (1) = 2.03 / (1+9.12) = 1.86 g/ cm^3

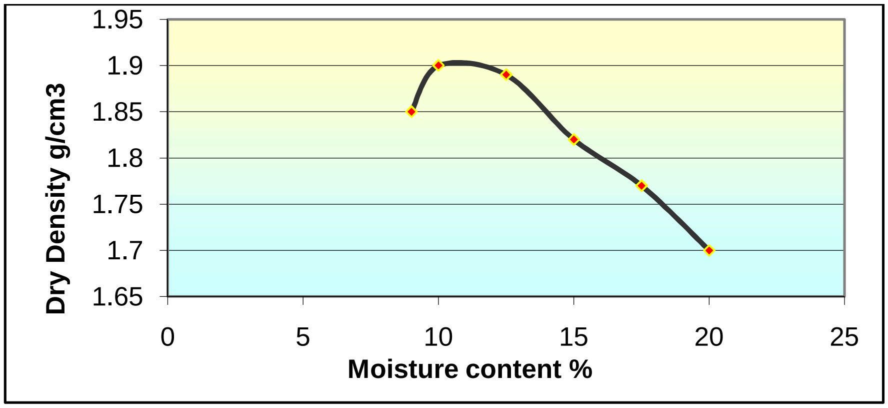


Figure (6 -1) the relation between moisture ratio and dry density.

From the above figure we find that:

The maximum density = 1.91 g/ cm^3.

The optimum moisture content = 10.57 %.

6-2-2 CBR Test

Introduction

The CBR test is one of the most commonly used methods to evaluate the strength of a sub grade soil, sub base, and base course material for design of thickness for highways and airfield pavement.

Definition of CBR:

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

The California Bearing Ratio Test (CBR Test) is a penetration test developed by California State Highway Department (U.S.A.) for evaluating the bearing capacity of subgrade soil for design of flexible pavement.

Tests are carried out on natural or compacted soils in water soaked or un-soaked conditions and the results so obtained are compared with the curves of standard test to have an idea of the soil strength of the subgrade soil.

CBR Test PROCEDURE:

- Normally 3 specimens each of about 7 kg must be compacted so that their compacted densities range from 95% to 100% generally with 10, 30 and 65 blows.
- Weigh of empty mould.
- Add water to the first specimen (compact it in five layer by giving 10 blows per layer).
- After compaction, remove the collar and level the surface.
- Take sample for determination of moisture content.
- Weight of mould + compacted specimen.
- Place the mold in the soaking tank for four days (ignore this step in case of unsoaked CBR.
- Take other samples and apply different blows and repeat the whole process.
- After four days, measure the swell reading and find %age swell.
- Remove the mould from the tank and allow water to drain.
- Then place the specimen under the penetration piston and place surcharge load of 10lb.
- Apply the load and note the penetration load values.
- Draw the graphs between the penetration (in) and penetration load (in) and find the value of CBR.
- Draw the graph between the %age CBR and Dry Density, and find CBR at required degree of compaction.

APPARATUS Used

- Three steel Moulds.
- Steel cutting collar
- Spacer Disc
- Surcharge weight
- Dial gauges
- IS sieves
- Penetration Plunger
- Loading Machine
- Miscellaneous Apparatus

Figure (6.2) the penetration device[1]

Results and Calculations

The California Bearing Ratio Test (CBR) = (Load causing 0.1'' penetration / Load causing the same penetration to a standard sample)*100%

Table (6-5) Resistance to penetration relation CBR (55) for base coarse

Depth of Penetration (mm)	Standard Resistance To penetration (Kg/ cm^2)	Dial Reading (div.)	Resistance (Kg/ cm^2)
0.5		61	8.01
1		120	15.75
1.5		190	24.94
2		275	36.09
2.5	49.22	375	49.22
3		475	62.35
3.5		580	76.13
4		680	89.26
4.5		780	102.38
5	114.20	870	114.20
5.5		965	126.67
6		1065	139.79
6.5		1170	153.58
7		1225	160.80
7.5		1310	171.9587
8		1375	180.491
8.5		1445	189.6796
9		1530	200.8372
9.5		1615	211.99
10		1690	221.84

Table (6-6) Resistance to penetration relation CBR (55) for soil

Depth of Penetration (mm)	Standard Resistance To penetration (Kg/ cm^2)	Dial Reading (div.)	Resistance (Kg/ cm^2)
0.5		30	3.94
1		70	9.19
1.5		100	13.13
2		125	16.41
2.5	19.16	146	19.16
3		165	21.66
3.5		185	24.28
4		200	26.25
4.5		215	28.22
5	30.19	230	30.19
5.5		245	32.16
6		257	33.74
6.5		271	35.57
7		282	37.02
7.5		292	38.33
8		303	39.77
8.5		314	41.22
9		325	42.66
9.5		335	43.97
10		344	45.16

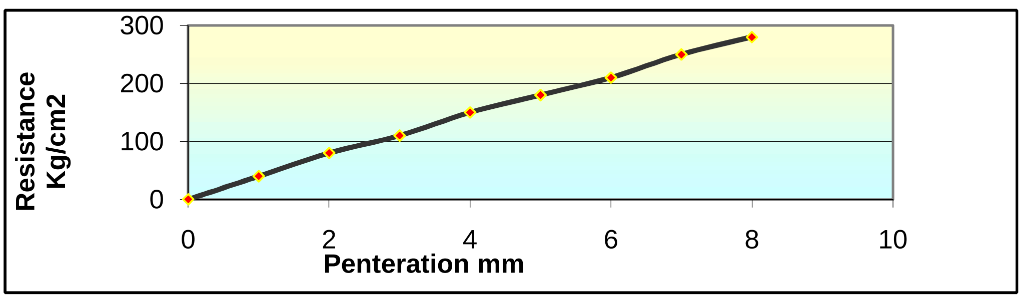


Figure (6.3) Resistance-Penetration Relationship

No. of blows	Dry Density	CBR at 2.5	CBR at 5
55	2.07	49.22	144.20

From the previous figure we calculate the CBR at 95%density and that from the maximum value of the dry density.

6-3 Pavement

There are two main types of pavement:

1- Flexible pavement.
2- Rigid pavement.

6-3-1 Flexible Pavement

Flexible pavements are so named because the total pavement structure deflects, or flexes, under loading. A flexible pavement structure is typically composed of several layers of material. Each layer receives the loads from the above layer, spreads them out, and then passes on these loads to the next layer below. Thus, the further down in the pavement structure a particular layer is, the fewer loads (in terms of force per area) it must carry (see Figure 6.4).

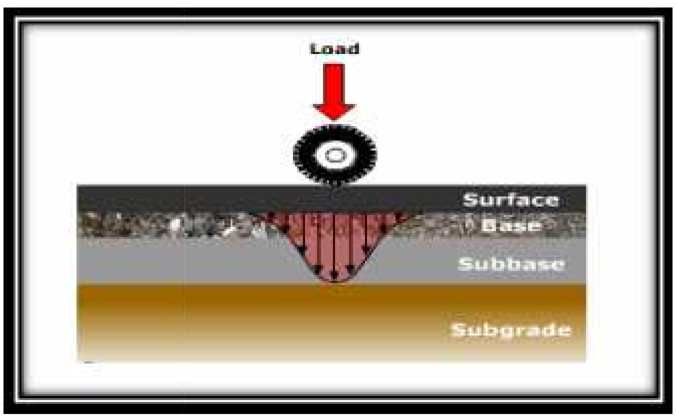


Figure (6.4) Flexible Pavement load distribution[1]

6-3-1-1 General principles of flexible pavement design

In this design of flexible pavement, the pavement structure is usually considered as a multilayered elastic system, with the material in each layer characterized by certain physical properties that may include the modulus of elasticity, the resilient modulus, and the Poisson ratio. It is usually assumed that the subgrade layer is infinite in the both the horizontal and vertical direction, whereas the other layers are finite in the vertical direction and infinite in the horizontal direction.

The maximum vertical stresses are compressive and occur directly under the wheel load These decrease with increase in depth from the surface .The maximum horizontal stresses also occur directly under the wheel load but can be either tensile or compressive.

When the load and pavement thickness are within certain ranges, horizontal compressive stresses will occur above the neutral axis, whereas horizontal tensile stresses will occur below the neutral axis .The temperature distribution within the pavement structure, will also have an effect on the magnitude of the stresses. The design of the pavement is therefore generally based on strain criteria that limit both the horizontal and vertical strains below those that will cause excessive cracking and excessive permanent deformation. These criteria are considered in terms of repeated load applications, because the accumulated repetitions of traffic loads are of significant importance to the development of cracks and permanent deformation of the pavement.

Design Procedure

The principle adopted in the design procedure is to determine the minimum thickness of the asphalt layer that will adequately withstand the stresses that develop for the two strain criteria discussed earlier that is , both the vertical compressive strain at the surface of the subgrade and the horizontal tensile strain at the bottom of the asphalt layer.

6-3-1-2 Structural components of a flexible pavement

Figure (6.5) shows the components of flexible pavement the subgrade or the prepared road bed , the subbase , the base and the wearing surface. The performance of the pavement depends on the satisfactory performance of each component, which requires proper evaluation of the properties of each component separately.

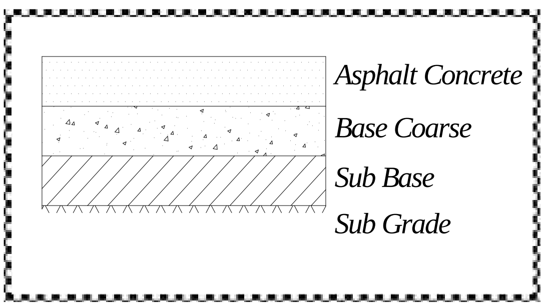


Figure (6.5) Schematic of flexible pavement[6]

Sub grade(prepared road bed)

The sub grade is usually the natural material located along the horizontal alignment of the pavement and serves as the foundation of the pavement structure. The sub grade may also consist of a layer of selected borrow materials, well compacted prescribe specification. It may be necessary to treat the sub grade material to achieve certain strength properties required for the type of pavement being constructed.

Sub base Coarse

Located immediately above the sub grade , the sub base components consists of materials of superior to that which generally is used for sub grade construction .The requirements of sub base materials are usually given in terms of the gradation , plastic characteristics , and strength . When the quality of the sub grade material meets the requirements of the sub base materials , the sub base component may be omitted .In case where suitable sub base materials is not readily available, the available material can be treated with other materials to achieve the necessary properties .This process of treating soil to improve their engineering properties is known as stabilization.

Base Course

The base course lies immediately above the sub base. It is placed immediately above the sub grade if a sub base course is not used. This course usually consists of granular materials such as crushed stone, crushed or uncrushed slag, crushed or uncrushed gravel, and sand. The specifications for base course materials usually include stricter requirements than those for sub base materials, particularly with respect to their plasticity, gradation, and strength. Materials that do not have the required properties can be used as base materials if they are properly stabilized with Portland cement, asphalt, or lime. In some cases, high-quality base course materials may also be treated with asphalt or Portland cement to improve the stiffness characteristics of heavy-duty pavements.

Surface Course

The surface course is the upper course of the road pavement and is constructed immediately above the base course. The surface course in flexible pavements usually consists of a mixture of mineral aggregates and asphaltic materials. It should be capable of withstanding high tire pressures, resisting the abrasive forces due to traffic, providing a skid-resistant driving surface, and preventing the penetration of surface water into the underlying layers. The thickness of the wearing surface can vary from 3 in, to more than 6 in, depending on the expected traffic on the pavement.

6-3-2 Rigid Pavement

Rigid pavements are so named because the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. A rigid pavement structure is typically composed of a PCC surface course built on top of either (1) the subgrade or (2) an underlying base course. Because of its relative rigidity, the pavement structure distributes loads over a wide area with only one, or at most two, structural layers (see Figure 6.5).

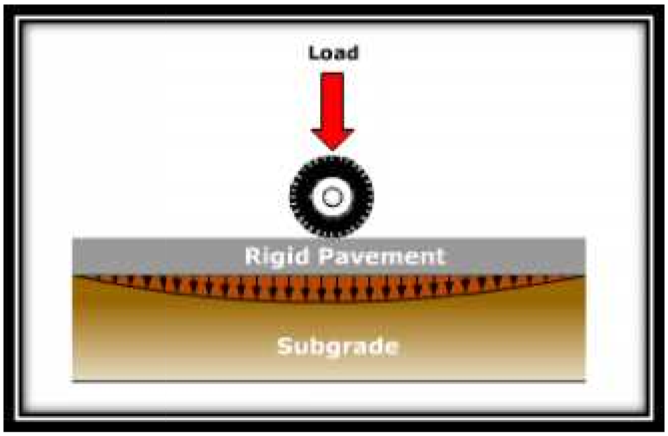


Figure (6.6) Rigid Pavement load distribution[1]

6-3-2-1 Design of Rigid Pavements

Rigid highway pavements are normally constructed of Portland cement and may or may not have a base course between the sub grade and the concrete surface .When a base course is used in rigid pavement construction, it is usually referred to as a sub base course .It is common, however, for only the concrete surface to be referred to as the rigid pavement, even where there is a base course .In this text ,the terms "rigid pavement" and "concrete pavement "are synonymous. Rigid pavement have some flexural strength that permits them to sustain a beamlike action across minor irregularities in the underlying material. Thus the minor irregularities may not be reflected in the concrete pavement. Properly designed and constructed rigid pavement has long service lives and usually is less expensive to maintain than flexible pavements.

Thickness of highway concrete pavement normally ranges from 6 in to 13 in . Different types of rigid pavement are described later in this chapter .These pavement types usually are constructed to carry heavy traffic loads, although they have been used for residential and local roads.

This section describes the typical rigid pavement structure consisting of:

- Surface course. This is the top layer, which consists of the PCC slab.
- Base course. This is the layer directly below the PCC layer and generally consists of aggregate or stabilized sub grade.
- Subbase course. This is the layer (or layers) under the base layer. A subbase is not always needed and therefore may often be omitted.

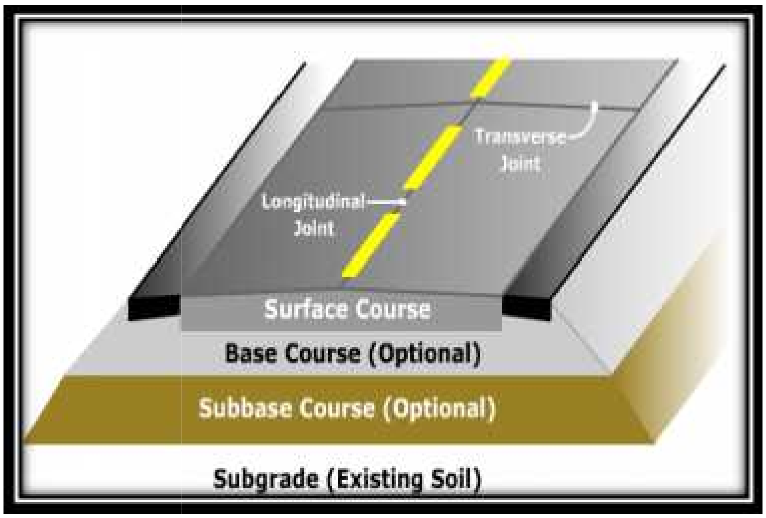


Figure (6.7) Basic Rigid Pavement Structure[1].

6-3-2-2 Materials Used In Rigid Pavements

The Portland cement concrete commonly used for rigid pavements consists of Portland cement, coarse aggregate, fine aggregate, and water .Steel reinforcing rod may or may not be used, depending on the type of pavement being constructed. A description of the quality requirements for each of the basic materials is presented in the following paragraphs.

Portland cement

Portland cement is manufactured by crushing and pulverizing a carefully prepared mix of limestone, marl, and clay or shale and by burning the mixture at a high temperature (about 2800°F) to form a clinker. The clinker is then allowed to cool, a small quantity of gypsum is added, and then the mixture is ground until more than 90 percent of the material passes the No.200 sieve. The main chemical constituents of the material are tricalcium silicate (C3S), dicalcium silicate (C2S), and tetracalcium alumino ferrite (C4AF).

Most highway agencies use either the American Society for Testing Materials (ASTM) specifications (ASTM Designation C150) or the American Association of State Highway and Transportation Officials (AASHTO) specifications (AASHTO Designation M85) for specifying Portland cement quality requirements used in their projects. The AASHTO specifications list five main types of Portland cement.

Type I: is suitable for general concrete construction, where no special properties are required. A manufacturer will supply this type of cement when no specific type is requested.

Type II: is suitable for use in general concrete construction, where the concrete will be exposed to moderate action of sulphate or where moderate heat of hydration is required.

Type III: is suitable for concrete construction that requires a high concrete strength in a relatively short time. It is sometimes referred to as high early strength cement.

Types IV, V, and IV are similar to types I, II, and III, respectively, but contain a small amount (4 percent to 8 percent of total mix) of entrapped air. This is achieved during production by thoroughly mixing the cement with air-entraining agents and grinding the mixture. In addition to the properties listed for types I, II, and III, types IV, V, and VI are more resistant to calcium chloride and de-icing salts and are therefore more durable.

Type IV is suitable for projects where low heat of hydration is necessary, and type V is used in concrete construction projects where the concrete will be exposed to high sulphate action.

Coarse Aggregates

The coarse aggregates used in Portland cement concrete are inert materials that do not react with cement and are usually comprised of crushed gravel, stone, or blast furnace slag. The coarse aggregates may be anyone of the three materials or else a combination of any two or all three. One of the major requirements for coarse aggregates used in

Portland cement concrete is the gradation of the material. The material is well graded; with the maximum size specified .Material retained in a No.4 sieve is considered coarse aggregate.

Fine Aggregates

Sand is mainly used as the fine aggregate in Portland cement concrete. Specifications for this material usually include grading requirements, soundness, and cleanliness. Standard specifications for the fine aggregates for Portland cement concrete (AASHTO Designation M6) give grading requirements normally adopted by state highway agencies.

Water

The main water requirement stipulated is that the water used should also be suitable for drinking. This requires that the quantity of organic matter, oil, acids, and alkalies should not be greater than the allowable amount in drinking water.

Reinforcing Steel

Steel reinforcing may be used in concrete pavements to reduce the amount of cracking that occurs, as a load transfer mechanism at joints, or as a means of tying two slabs together.

Steel reinforcement used to control cracking is usually referred to as temperature steel whereas steel rods used as load transfer mechanisms are known as dowel bars, and those used to connect two slabs together are known as tie bars.

6-3-2-3 Types of rigid highway pavement

Rigid highway pavements can be divided into three general types: plain concrete pavements, simply reinforced concrete pavements, and continuously reinforced concrete pavements. The definition of each pavement type is related to the amount of reinforcement used.

1-Plain Concrete Pavement

Plain concrete pavement has no temperature steel or dowels for load transfer. However, steel tie bars are often used to provide a hinge effect at longitudinal joints and to prevent the opening of these joints. Plain concrete pavements are used mainly on low-volume "highways or when cement-stabilized soils are used as sub base. Joints are placed at relatively shorter distances (10 to 20 ft) than with the other types of concrete pavements to reduce the amount of cracking. In some cases, the transverse joints of plain concrete pavements are skewed about 4 to 5 ft in plan, such that only one wheel of a vehicle passes through the joint at a time. This helps to provide a smoother ride.

2- Simply Reinforced Concrete Pavement

Simply reinforced concrete pavements have dowels for the transfer of traffic loads across joints, with these joints spaced at larger distances, ranging from 30 to 100 ft. Temperature steel is used throughout the slab, with the amount dependent on the length of the slab. Tie bars are also commonly used at longitudinal joints.

3-Continuously Reinforced Concrete Pavement

Continuously reinforced concrete pavements have no transverse joints, except onstruction joints or expansion joints when they are necessary at specific positions, such as at bridges. These pavements have a relatively high percentage of steel, with the minimum usually at 0.6 percent of the cross section of the slab. They also contain tie bars across the longitudinal joints.

6-4 Asphalt Institute Method for calculating loads and layers thickness

In the Asphalt Institute design method, the pavement is represented as a multilayered elastic system. The wheel load W is assumed to be applied through the tire as a uniform vertical pressure p_0 , which is then spread by the different components of the pavement structure and eventually applied to subgrade as a much lower stress p_1.Experince , established theory and test data are then used two specific stress-strain conditions.

So now we will calculate the ESAL (Equivalent Accumulated 18,000 Ib Single Axel Load)

ESAL = $f_d * G_f *$ AADT* 365 * $N_i * f_E$…………………………(6.1)

Where:

ESAL : Equivalent Accumulated 18,000 Ib Single Axel Load.

F_d: design lane factor.

G_f : Growth factor.

AADT: First year annual average daily traffic.

N_i : Number of axels on each vehicle.

f_E : Load equivalency factor.

The value of (f_d) is obtained from the table (6-7):

Table (6-7) Percentage of vehicle in the design lane.

Number of Traffic lanes (Two Directions)	Percentage of vehicle in the design lane (%)
2	50
4	45(35-48)
6 or more	40(25-48)

The value of Growth factor (G_f) is obtained from the table (6-8):

Table (6-8) Growth factor.

Design period years	Annual Growth Rate (%)							
	No. growth	2	4	5	6	7	8	10
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31

4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	22.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	2.21	30.48	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	51.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.05	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

As we know the design of any road is on the ground that the validity of the road is usually taken for 20 years in the future, and the expected annual increase of 4%,so the value of (G_f) is =29.78%.

The value of Growth factor is obtained from the table of AADT:

Passenger cars (10 kN / axle) = 59%

Axle single-unit busses (100 kN / axle) = 8%

Axle single-unit trucks (110 kN / axle) = 33%

After the weights of vehicles are converted to standard loads which obtained from the following table as follows:

Load equivalency factor for a cars ($f_{E(car)}$) = 0.0003135 (single axle)

Load equivalency factor for a busses ($f_{E(bus)}$) = 0.198089 (tandem axle)

Load equivalency factor for a trucks ($f_{E(truck)}$) = 0.29419 (tandem axle)

Table (6-9) Load Equivalency factor[6].

Gross Axle Load		Load Equivalency factor		Gross Axle Load		Load Equivalency factor	
KN	Ib	Single Axle	Tandem Axle	KN	Ib	Single Axle	Tandem Axle
4.45	1,000	0.00002		182.5	41,000	23.27	2.29
8.9	2,000	0.00018		187.0	42,000	25.64	2.51
13.35	3,000	0.00072		191.3	43,000	28.22	2.75
17.8	4,000	0.00209		195.7	44,000	31.00	3.00

22.25	5,000	0.00500		200.0	45,000	34.00	3.27
26.7	6,000	0.01043		204.5	46,000	37.24	3.55
31.15	7,000	0.01960		209.0	47,000	40.74	3.85
35.6	8,000	0.03430		213.5	48,000	44.50	4.17
40.0	9,000	0.0562		218.0	49,000	48.54	4.51
44.5	10,000	0.0877	0.0068	222.4	50,000	52.88	4.86
48.9	11,000	0.1311	0.0100	226.8	51,000		5.23
53.4	12,000	0.189	0.0144	231.3	52,000		5.63
57.8	13,000	0.264	0.0199	235.7	53,000		6.04
62.3	14,000	0.360	0.0270	240.2	54,000		6.47
66.7	15,000	0.478	0.0360	244.6	55,000		6.93
71.2	16,000	0.623	0.0472	249.0	56,000		7.41
75.6	17,000	0.796	0.0608	253.5	57,000		7.92
80.0	18,000	1.00	0.0773	258.0	58,000		8.45
84.5	19,000	1.24	0.0971	262.5	59,000		9.01
89.0	20,000	1.51	0.1206	267.0	60,000		9.59
93.4	21,000	1.83	0.148	271.3	61,000		10.20
97.8	22,000	2.18	0.180	275.8	62,000		10.84
102.3	23,000	2.58	0.217	280.2	63,000		11.52
106.8	24,000	3.03	0.260	284.5	64,000		12.22

111.2	25,000	3.53	0.308	289.0	65,000		12.96
115.6	26,000	4.09	0.364	293.5	66,000		13.73
120.0	27,000	4.71	0.426	298.0	67,000		14.54
124.5	28,000	5.39	0.495	302.5	68,000		15.38
129.0	29,000	6.14	0.572	307.0	69,000		16.26
133.5	30,000	6.97	0.658	311.5	70,000		17.19
138.0	31,000	7.88	0.753	316.0	71,000		18.15
142.3	32,000	8.88	0.857	320.0	72,000		19.16
146.8	33,000	9.98	0.971	325.0	73,000		20.22
151.2	34,000	11.18	1.095	329.0	74,000		21.32
155.7	35,000	12.5	1.23	333.5	75,000		22.47
160.0	36,000	13.93	1.38	338.0	76,000		23.66
164.5	37,000	15.50	1.53	342.5	77,000		24.91
169.0	38,000	12.20	1.70	347.0	78,000		26.22
173.5	39,000	19.06	1.89	351.5	79,000		27.58
178.0	40,000	21.08	2.08	365.0	80,000		28.99

And then calculates the value of (ESAL) for each type of vehicle types according to the equation, and then combine the three values to get Total ESAL as follows:

$$ESAL_{car} = 0.5 \times 29.78 \times 4097 \times 0.59 \times 365 \times 2 \times 0.0003135 = 0.008237 \times 10^6$$

$$ESAL_{car} = 0.5 \times 29.78 \times 4097 \times 0.59 \times 365 \times 2 \times 0.0003135 = 0.008237 \times 10^6$$

$$ESAL_{car} = 0.5 \times 29.78 \times 4097 \times 0.59 \times 365 \times 2 \times 0.0003135 = 0.008237 \times 10^6$$

Table (6-10) California rate and type of each layer of the pavement

Layer	CBR(Kentuky)	Substance used
Asphalt	……….	Plant Mix.
Base Coarse	28.9	Crushed Stone
Sub Base	20.8	Sandy Gravel
Sub Grade	12.9	……….

The layers of the flexible pavement are calculated as follows:

$$SN = a_1 D_1 + a_2 D_2 + a_3 D_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6-2)$$

Where:

- SN: Structural Number.
- a_1,a_2,a_3: layer coefficients representative of surface, base course, and sub base
- D_1, D2, D3: actual thickness, of surface, base course, and sub base.

The Regional factor is calculated from the equation:

$$R = \frac{N_d}{12} \times R_d + \frac{N_s}{12} \times R_s \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6-3)$$

where:

- R: Regional Factor
- Nd : Number of dry months in a year
- Rd: Regional Factor for soils dry
- Ns: Number of saturated months in a year
- Rs: Regional Factor for soils saturated

Table (6-11) Regional Factor

case	Suggested Regional Factor
Roadbed soil frozen 5in or more	0.2 –1.0
Roadbed soils dry	0.3 – 1.5
Roadbed soils saturated	4.0 – 5.0

In Hebron 4 months of the year are saturated and 8 months are dry so R value in Hebron

$$R = \frac{8}{12} \times 0.9 + \frac{4}{12} \times 4.5 = 2.1$$

The process of calculating SN is as follows:

1- By determining the value of CBR the corresponding (S-soil support value) for each layer is determined.

(S-soil support value) = 10.2

(S-soil support value) = 7.1

(S-soil support value) = 6.5

2- Appoint the values of (S-soil support value) and concluded with the point set on the scale of(ESAL = 4238) and then extend the line on the straight path to get ranking (SN-structural Number) as follows:

(SN-structural Number) = 1.75

(SN-structural Number) = 2.7

(SN-structural Number) = 2.9

3- Then reach these points with the point set on the scale of (Regional Number) and then extend the line on the straight path to find that the SN scale at a certain point so SN values are as follows:

SN_1 = 3.08 (from enter CBR for base course in chart)

SN_2 = 2.8 (from enter CBR for sub base course in chart)

SN3 = 3.2 (from enter CBR sub grade in chart)

4- The values of (a_1,a_2,a_3)are obtained from the following tables:

Table (6-12) Layer coefficient for asphalt

Case of the Pavement	a1 suggested
Road mix (low stability)	0.2
Plant mix (high stability)	0.44
Sand Asphalt	0.40

Table (6-13) Layer coefficient for base course

Case of the base course	a2 suggested
Sandy gravel	0.07
Crushed stone	0.14
Cement-treated(650psi or more)	0.23
Cement-treated(400-650psi)	0.20
Cement-treated(400 or less)	0.15
Coarse –graded bituminous-treated	0.34
Sand asphalt	0.30
Lime - treated	0.15-0.30

From the previous tables

a1 = 0.44

a2 = 0.14

The thickness of the first layer (the pavement layer) is calculated as follow:

SN1 = a1 D1 → 2.1 = 0.44D1 → D1 = 4in = 4*2.54 = 12 cm.

Take (D1 = 12cm).

SN1= (12/2.54)*0.44= 2.1 in.

The thickness of the second layer (the base curse layer)

SN2 = SN1 + a1 D1 → 2.8 = 2.1 + 0.14D2

→ D2 = 5 in = 5*2.54 = 12.7 cm.

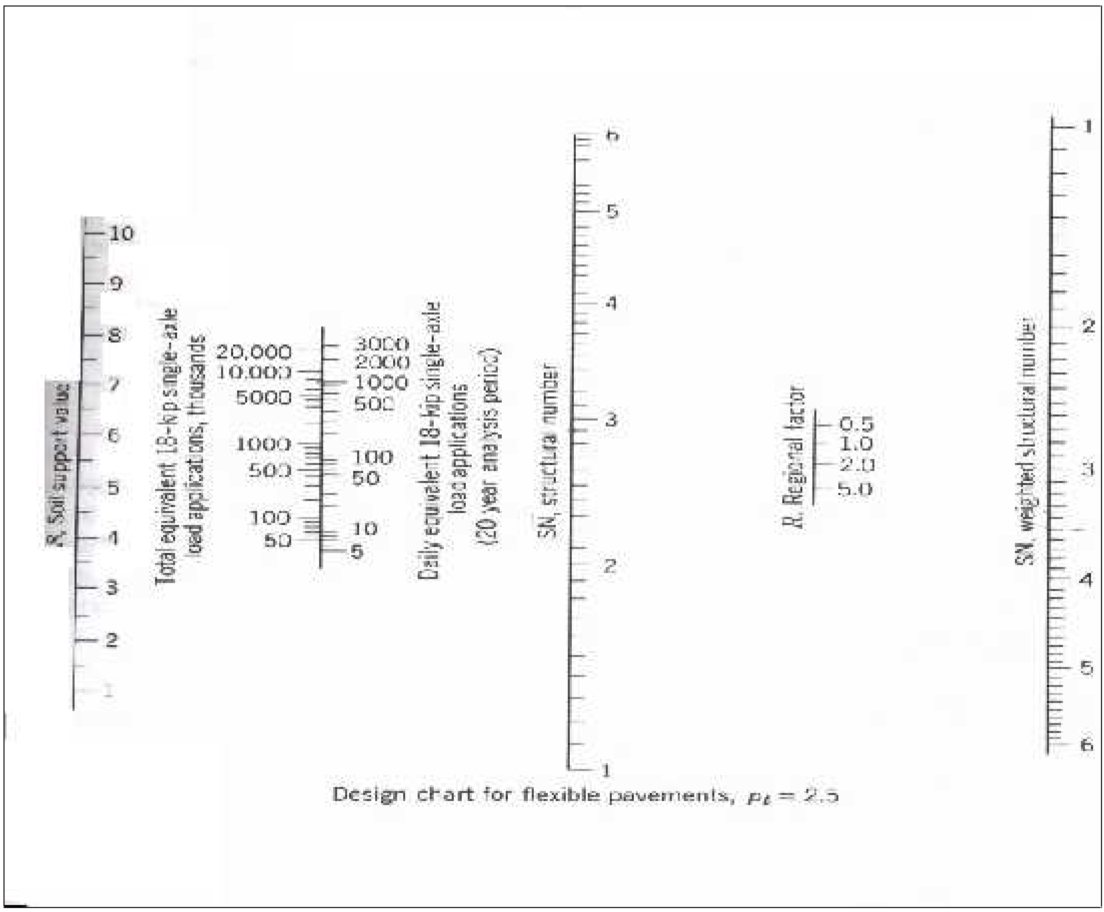
Take (D2 = 20 cm).

The thickness of the third layer (the sub base layer)

SN3 = SN2 + a3 D3 → 3.9 = 3.58 + 0.11D3

→ D3 = 2.91 in = 2.91·2.54 = 7.39 cm.

Take (D2 = 20 cm).



Figure(6-8) (AASHTO flexible-pavement design)[3]

6-5 Final Results

After working according to the AASHTO, and taking in considerations all the factors affecting the design the layers of the pavement and after making calculations we obtain the following results:

Table (6-14) shows layer's thickness

Layer	Thickness(cm)
asphalt	12
Base course	20
Sub base	20

Chapter Seven

Calculation of areas and volumes

7-1 Calculation of area of cross section

Finding the areas of cross-sections is the first step in obtaining the volume of earthwork to be handled in route alignment projects (road or railway), or reservoir construction, for example. In order to illustrate more clearly what is meant by the above statement, let us consider a road construction project. In the first instance an accurate plan is produced on which to design the proposed route. The centre-line of the route, defined in terms of rectangular coordinates at 10 to30–m intervals, is then set out in the field. Ground levels are obtained along the centre-line and also at right-angles to the line (Figure 7.1). The levels at right-angles to the centre

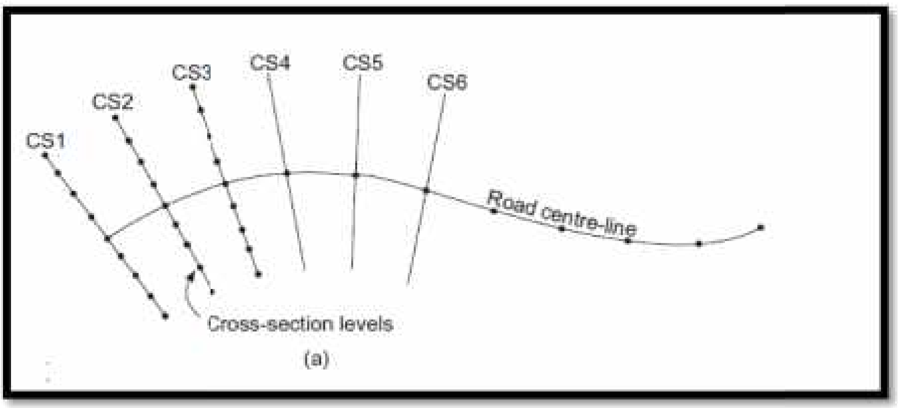


Figure (7.1) cross section level[5]

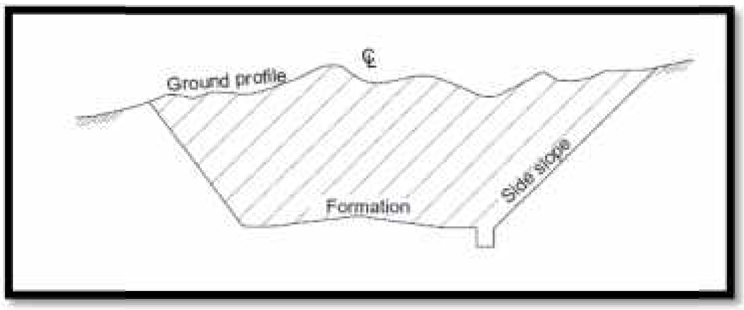


Figure (7.2) Cross sectional area of cut[5]

We can calculate the area of the cross sections by three main methods:

1- Analytical method.
2- Planning method.
3- Mechanical method.

7-2 Coordinates method for calculating areas of the cross sections

Using appropriate field data it may be possible to define the area by its rectangular coordinates the following rule may be used when the total coordinates only are given. Multiply the algebraic sum of the northing of each station and the one following by the algebraic difference of the easting of each station and the one following. The area is half the algebraic sum of the products.

The equation is:

$$\text{Area} = \tfrac{1}{2}[N_A (E_B - E_E) + N_B (E_C - E_A) + N_C (E_D - E_B) + N_D (E_E - E_C) + N_E (E_A - E_D)]$$

7.3 Calculation of volumes and quantities

In road projects and after final design of both the horizontal and vertical alignment quantities of cut and fill will be needed to reach a specific level (the level of the road surface).

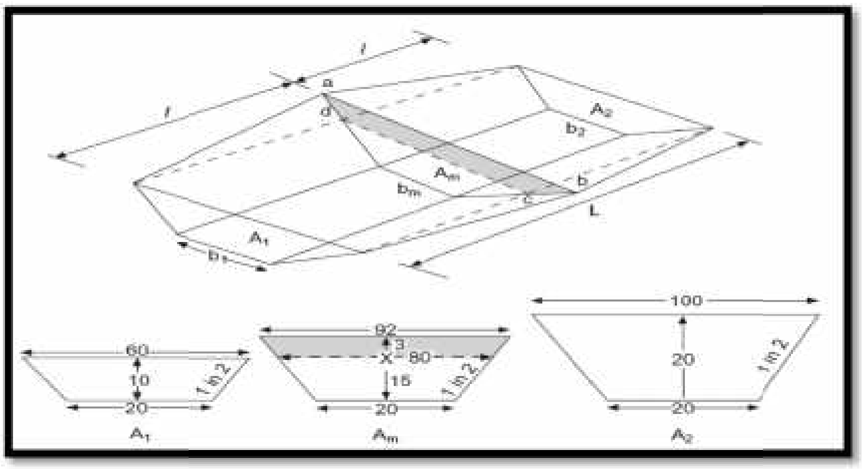
After obtaining the required information for the cross sections from the field that enable us to calculate their areas, we can calculate the volumes of cut and fill by several ways.

7.3.1.1 Calculation of volumes by the End-area method

Consider Figure 7.3, then

$$V = \frac{A_1 + A_2}{2} \times L$$

I.e. the mean of the two end areas multiplied by the length between them. This equation is correct only when the mid-area of the prismoid is the mean of the two end areas.



The above formula can be applied to the two successive cross sections which are in a complete cut region or a complete fill region.

7.3.1.2 Cases of two successive cross sections

1- Two successive cross sections which are in a complete cut region or a complete fill region.

In our project there are no two successive cross sections that are in a complete cut region or a complete fill region.

2- First cross sections cut and the other mixed.

We calculate the cut & fill according to the following:

Fill according to the equation:

$$V_{fill} = \frac{1}{3}(F_{i+1}) \times (D)$$

Cut according to the equation:

$$V_{cut} = \frac{1}{2}(C_i + C_{i+1}) \times (D)$$

Where:

(F_{i+1}): Fill area in the mixed cross section.

(C_{i+1}): Cut area in the mixed cross section.

(C_i): Cut area in the complete cut cross section.

(D): The distance between the two cross sections.

We choose these two cross sections which stations are (Station12+80) & (Station13+00) and figures (7.4) & (7.5) shows them

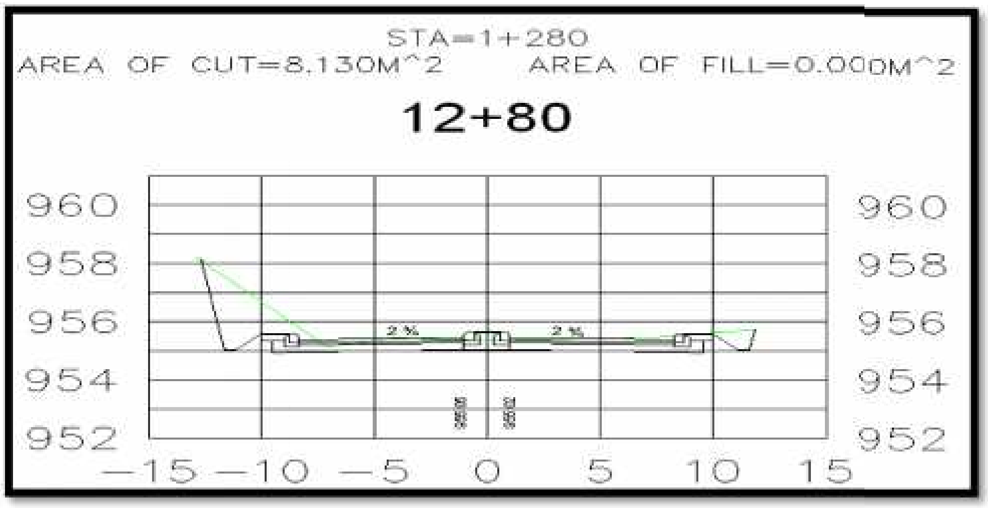


Figure (7.4) First cross section - Cut

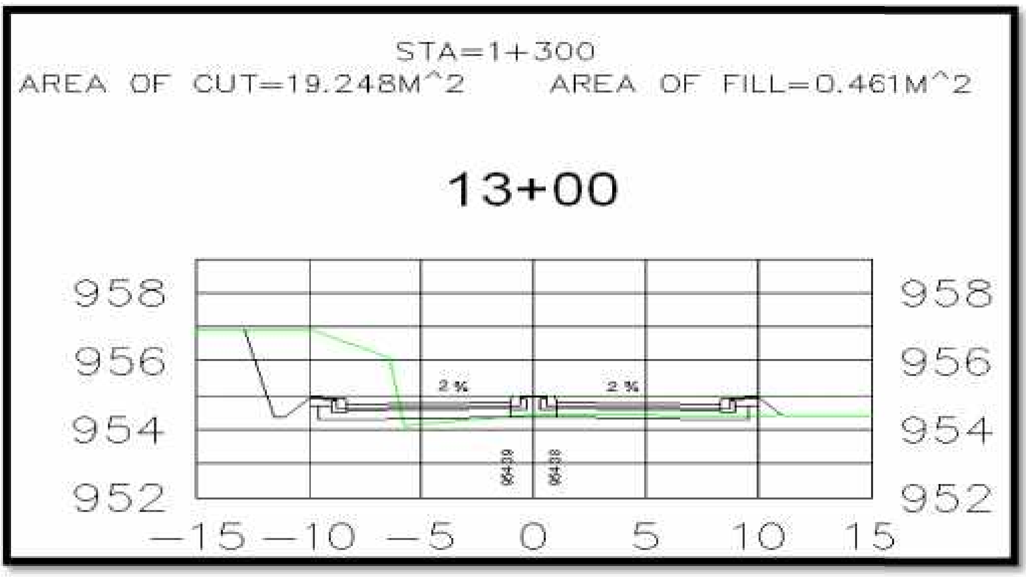


Figure (7.5) Second cross section – Cut fill

(F_{i+1}): Fill area in the mixed cross section=0.461 m^2

(C_{i+1}): Cut area in the mixed cross section=19.248 m^2

(C_i): Cut area in the complete cut cross section=8.13 m^2

(D): The distance between the two cross sections= 20 m

Fill volume:

$$V_{fill} = \frac{1}{3}(0.461) \times (20)$$

$$V_{fill} = 3.07 \text{ m}^3$$

Cut volume:

$$V_{cut} = \frac{1}{2}(8.13+19.248) \times (20)$$

$$V_{cut} = 273.78 \text{ m}^3$$

3-First cross sections fill and the other mixed

We calculate the cut & fill according to the following:

Cut according to the equation:

$$V_{cut} = \frac{1}{3}(C_{i+1}) \times (D)$$

Fill according to the equation:

$$V_{fill} = \frac{1}{2}(F_i+F_{i+1}) \times (D)$$

We choose these two cross sections which stations are (Station14+40) & (Station14+60) and figures (7.6) & (7.7) shows them

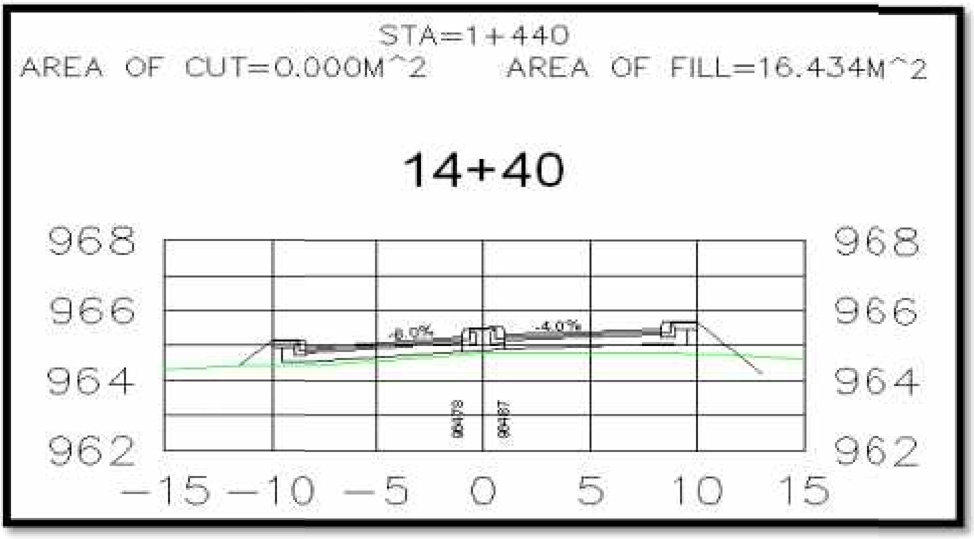


Figure (7.6) First cross section - Fill

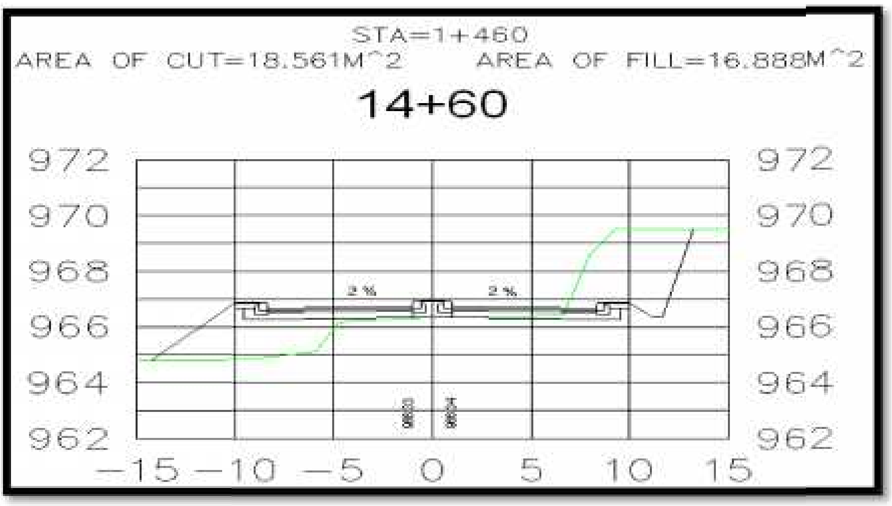


Figure (7.7) Second cross section – Cut fill

(F_{i+1}): Fill area in the mixed cross section=16.888 m^2

(C_{i+1}): Cut area in the mixed cross section=18.561 m^2

(F_i): Fill area in the complete Fill cross section=16.434 m^2

(D): The distance between the two cross sections= 20 m

$$V_{cut} = \frac{1}{3}(18.561) \times (20) = 123.74 \ m^3$$

$$V_{fill} = \frac{1}{2}(16.888+16.434) \times (20) = 333.22 \ m^3$$

4-The cross sections have fill and cut.

We calculate the cut & fill according to the following:

Cut according to the equation:

$$V_{cut} = \frac{1}{2}(C_{i+1} + C_i) \times (D)$$

Fill according to the equation:

$$V_{fill} = \frac{1}{2}(F_i + F_{i+1}) \times (D)$$

We choose these two cross sections which stations are (Station13+00) & (Station13+20) and figures (7.8) & (7.9) shows them

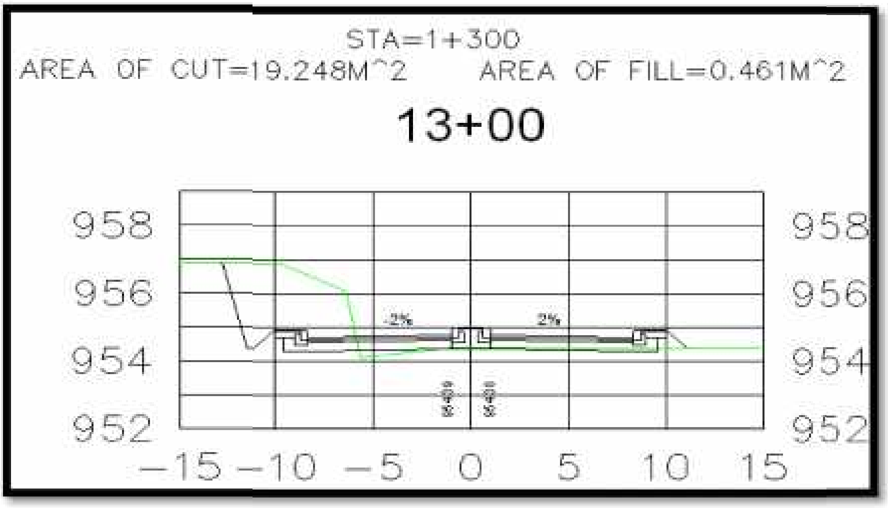


Figure (7.8) First cross sections cut & fill

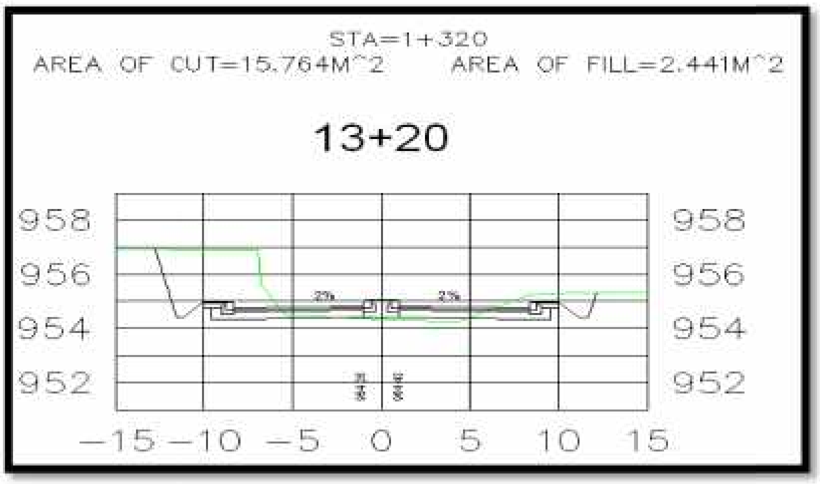


Figure (7.9) Second cross sections cut & fill

(F_{i+1}): Fill area in the second mixed cross section=2.441 m^2

(C_{i+1}): Cut area in the second mixed cross section=15.764 m^2

(F_i): Fill area in the first cross section=0.461 m^2

(C_i): Cut area in the first cross section = 19.248 m

(D): The distance between the two cross sections= 20 m

$V_{cut} = \frac{1}{2}(15.764+19.248) \times (20) = 350.12 \ m^3$

$V_{fill} = \frac{1}{2}(2.441+0.461) \times (20) = 29.02\ m^3$

7-4 Mass Haul diagram

Once you consider the equipment and workforce needed to excavate, move, waste, compact and/or test soil, costs add up quickly. For this reason contractors and engineers rely on mass haul diagrams to reduce the guesswork involved in road grading tasks, and to ensure everyone gets paid fairly for moving soil.

Consider the following example. The figure below (7.10) shows an idealized mass haul diagram where the net volume at the last station is zero. This diagram also assumes no unsuitable materials are excavated from the site. Notice how certain features of the mass haul diagram line up with the profile. In this case, the free haul distance agreed upon by the contractor is 200.' That means that excavation outside of this range is a different pay item from excavation inside the range.

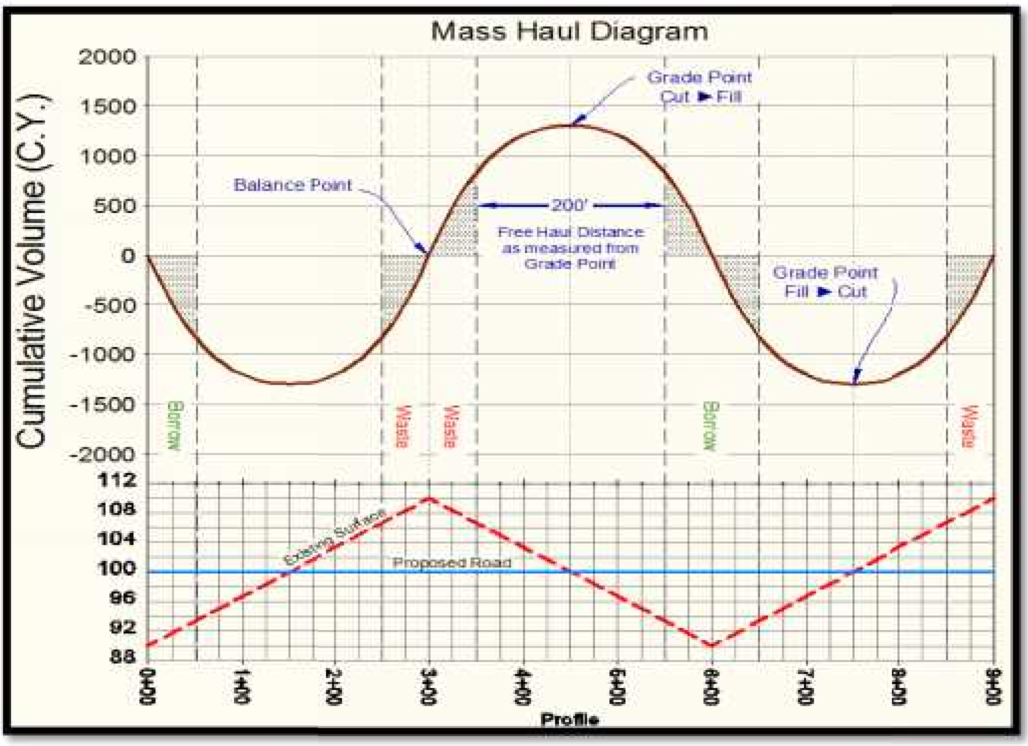


Figure (7.10) an example of Mass Haul diagram

Terms to Know about Mass Haul Diagram:

Balance Point – Anywhere the mass haul line crosses the 0 (zero) cumulative volume line on a mass haul diagram. This indicates that up to this station the cumulative cut and fill volumes are equal.

Borrow – Fill material that was not initially excavated from the project site.

Free Haul Distance – The distance the contractor has agreed to move earth without additional fees.

Grade Point – Transition between cut and fill on a mass haul diagram. This point coincides with a design profile intersecting the original ground profile. A “crest” on the mass haul line indicates a transition from cut to fill, and “sag” indicates a transition from fill to cut.

Mass Haul Diagram - A graph of cumulative volume moved on a project (usually a roadway project) along its length. Station values are along the X-axis and cumulative volume is on the Y-axis.

Over Haul Distance – Distances along the project that do not fall into a free haul area. Material in this area may be borrowed or wasted if it is more economical for the contractor.

Waste – Cut material that cannot be used on the project site, either because it is unsuitable material or because it is outside of a free haul distance.

7-5 Mass Haul diagram of our project and the net cut and fill volumes

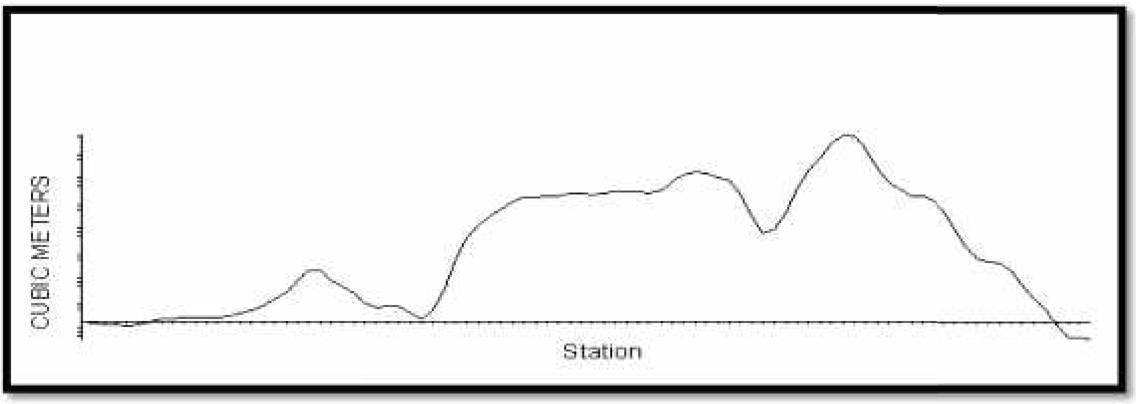


Figure (7.11) Mass Haul diagram of our project.

Total cut volume = 13686.835 m^3

Total fill volume = 14053.964 m^3

The difference between the cut and fill is equal

Δ= 14053.964 -13686.835= 367.129 m^3 of fill.

The Compressibility factor = 1.1

So a (367.129*1.1) = 403.84 m^3 of fill must be brought to the site.

Chapter Eight

Cost calculation

8-1 Introduction

The cost of any project must be known to provide the financing people with the total costs that must be overcome for the accomplishing of the project. In this chapter we will calculate the costs of each layer of the pavement along the road in addition to the costs of cut and fill.

8-2 Cost Calculation

As described previously the road consist of three layers :

1- Asphalt layer.
2- Base course layer.
3- Sub base layer.

8-2-1 Cost of the pavement

First we have 4 lanes two for each side so we calculate the area of the lanes as follows:

The area of the lanes = 1777*14.6=25944.2 m^2

After calculating the area of the lanes we will calculate the volume of the three layers:

1- Asphalt volume = area of the lanes* Pavement thickness

Asphalt volume = 25944.2 * 0.12=3113.3 m^3

2- Base coarse volume = area of the lanes* Base coarse thickness

Base coarse volume = 25944.2 * 0.2 = 5188.84 m^3

3- Sub base volume = area of the lanes* Sub base thickness

Sub base volume = 25944.2 * 0.2 =5188.84 m^3

To calculate the costs we took the standard costs of tenders of Hebron municipality and they are as follows:

1 m^3 of asphalt layer = 15 $

1 m^3 of base coarse layer = 6 $

1 m^3 of sub base layer = 4.5$

1- Asphalt cost = volume of asphalt* cost of 1 m^3

Asphalt cost = 3113.3 * 15=46699.5 $

2- Base coarse cost = volume of Base coarse * cost of 1 m^3

Base coarse cost = 5188.84 * 6 =31133.04 $

3- Sub base cost = volume of sub base* cost of 1 m^3

Sub base cost = 5188.84 * 4.5 =23349.78 $

8-2-2 Cost of cut ant fill

Total cut volume =13686.835 m^3

Total fill volume =14053.964 m^3

Cost of 1 m^3 of cut = 7 $

Cost of 1 m^3 of fill = 5 $

Cut cost = Total cut volume * Cost of 1 m^3 of cut

Cut cost = 13686.835 * 7= 95807.845 $

Fill cost = Total fill volume * Cost of 1 m^3 of fill

Fill cost = 14053.964 * 5= 70269.82 $

Total cut and fill cost = Cut cost+ Fill cost

Total cut and fill cost = 95807.845 + 70269.82 =166077.665 $

8-2-3 Cost of cleaning the road and spraying bituminous before pavement

The cost of cleaning and spraying bituminous for 1 m^2 of the road = 2 $

Cleaning & spraying cost = area of the road *2

Cleaning & spraying cost = 25944.2 *2 =51888.4 $

8-2-4 Cost Road marking

The cost of 1 m^2 of road marking equal 27 $
The area of road marking of the road on which we are working was calculated to be equal to 30 m^2 so:
The cost = 30* 27= 810 $

8-2-5 Cost of curbstones and sidewalks

Length of road =1775 m
Total length of curbstones used =1775*4-(20*6*2)= 6860 m

Cost of 1 m of curbstone = 6 $
Total cost of curbstones = 41160 $

Area of right and left sidewalks = (1775 * 1.7) *2= 6035 m^2

Cost of 1 m^2 of sidewalk stones = 14 $
Total cost of sidewalks stones = 84490 $

Area of the median = (1575 *1.7) + (80*0.85) = 2745.5 m^2
Cost of 1 m^2 of median stones = 14 $

Total cost of median stones = 38437 $

8-2-6 Cost of pavement maintenance

Highway pavements, once constructed, will not last forever. After a time, signs of wear will appear. These signs include cracking, rutting and polishing of the road's surface. A point will arrive where the wear and tear is at such an advanced stage that the integrity of the pavement and hence the standard of service provided by it has diminished. Maintenance is required at this point to prolong the highway's useful life.

The cost of maintenance of 1 m^2 according to Hebron municipality is equal to 17 $

Total maintenance cost = asphalt area * cost of maintenance of 1 m^2
Total maintenance cost = 25944.2 * 17 = 441051.4 $

8-2-7 The net total cost of the project

The following table shows the costs of pavement layers

Material	Total cost ($)
Sub base	23349.78
Base coarse	31133.04
Asphalt	46699.5
Total	101182.32

Table (8-1) cost of pavement layers

The following table shows the costs of cut and fill

Working Type	Quantity (m^3)	Cost of 1 m^3($)	Total cost ($)
Cut	13686.835	7	95807.845
Fill	14053.964	5	70269.82
Total			166077.665

Table (8-2) cost of cut and fill

The following table shows the costs of sidewalk and median stones

Type	Quantity (m^2)	Cost of 1 m^2($)	Total cost ($)
Sidewalk stones	6035	14	84490
Median stones	2745.5	14	38437
Total			122927

Table (8-3) cost of sidewalk and median stones

The following table shows the costs of curbstones

Type	Quantity (m)	Cost of 1m ($)	Total cost ($)
Sidewalk stones	6860	6	41160
Total			41160

Table (8-4) cost of curbstones

The net cost:

Cost of pavement layers=101182.32 $

Cost of cut and fill =166077.665$

Cost of road marking =810$

Cost of Cleaning & spraying =51888.4 $

Cost of curbstones =41160 $

Cost of sidewalk stones = 84490 $

Cost of median stones = 38437 $

The total final cost of the project =484045.385 $

Chapter Nine

The Results & Recommendations

9-1 Results

1-The preparation of the horizontal and vertical designs and all the necessary information needed to stake out them

2-The thickness of the layers was calculated.

3-The volume of cut and fill was calculated in addition to the volume of the base coarse and the asphalt layers.

4-The total cost of the project was calculated.

9-2 Recommendations

1- The communication between the university and the institutions of civil society to put projects out of concern of these institutions.
2- The graduation projects with the practical application need to be of a joint between the various parts of civil engineering department in order to achieve integration.
3- Focus on training students to modern software applications in various fields through the presence of flexibility in lesson plans.
4- Prepare specifications for the special ways in the Palestinian territories.

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Reference of table and figures

Number of reference	name of the reference
1	www.mutcd.fhwa.dot.gov/manual.htm
2	Evaluation and Redesign of Certain Intersections In Hebron City
3	Highway Engineering
4	http://www.webs1.uidaho.edu
5	Engineering Surveying
6	تصميم شارع احنينه الماجور
7	Adjustment Computations

APPENDIX – 1

Details of the field working

A.1 traverse & Study Area(A3):

A.2 Project points Coordinates.

Number	Northing	Easting	Elevation	Full Desc.
1	107365.9	158150.2	968.293	a
2	107361.4	158161.9	971.335	a
3	107359.2	158175.4	971.329	a
4	107364	158174.5	971.6	tp
5	107364	158173.3	971.795	ep
6	107352.7	158194.4	971.531	a
7	107353.1	158201.8	971.702	ep
8	107351.1	158210.6	972.107	cw
9	107354.9	158212.4	972.288	b
10	107346.5	158211.3	971.64	a
11	107353.3	158214.7	972.304	bc
12	107334	158242.4	971.856	a
13	107341.9	158246.7	973.702	b
14	107337.4	158249.6	972.944	hvp
15	107334.4	158253.5	973.276	tp
16	107323.1	158269.2	972.075	a
17	107317	158293.5	972.217	ep
18	107317	158294.7	972.809	cw+sw
19	107309.1	158309.8	973.031	sw
20	107307	158313.7	972.738	sw
21	107303	158312	972.326	a
22	107304.3	158322	973.164	ep
23	107296.5	158326.8	972.237	a
24	107297.9	158341.5	973.133	sw
25	107293.9	158343.9	972.293	sw
26	107300.5	158346.8	972.242	sw
27	107299.9	158349.5	972.332	sw
28	107294	158349.4	972.658	sw
29	107293.2	158349.7	972.48	ep
30	107284.6	158372	972.907	a
31	107288.7	158387.9	973.479	ep+sw
32	107282	158347.9	972.91	a
33	107286.5	158407.4	973.693	sw
34	107284.5	158421.3	973.925	mh
35	107278.8	158437.7	974.055	a

36	107284.1	158440.7	974.614	ep
37	107285.4	158440.8	976.983	cw+sw
39	107288.1	158441.1	974.565	cw
40	107287.8	158444.6	974.604	b
41	107286.9	158444.8	976.121	bc
42	107286.7	158444	974.524	mh
43	107284.9	158469.8	974.637	b
44	107284.3	158469.8	974.296	bc
45	107284.9	158470.3	974.586	mh
46	107283.4	158477.3	975.806	cw+sw
47	107274.9	158477.3	974.429	a
48	107278.8	158491.2	974.659	ep
49	107271.6	158505.1	975.026	a
50	107277.2	158518.7	975.901	b+sw
51	107276.1	158518.6	975.85	bc
52	107275.3	158526.7	976.249	bc
53	107274.6	158531.7	976.33	mh
54	107275.1	158533.1	976.589	b
55	107273.4	158533.3	976.528	ep
56	107255.4	158508.2	975.253	b
57	107259.1	158488.9	975.116	b
58	107260	158489	975.929	bc
59	107256.4	158508.1	975.927	bc
60	107259.8	158485.7	975.054	cw
61	107259.4	158485.4	975.52	ep
62	107260.6	158481.2	975.024	b
63	107261.9	158479.1	974.941	bc
64	107263	158468	973.506	bc
65	107264.1	158467.9	974.572	b
66	107266.7	158467.7	975.309	tp
67	107265.5	158459.7	974.9	b
68	107267.4	158460.8	974.286	cw
69	107270	158461.3	974.218	a
70	107267.1	158486.3	974.612	a
71	107269.3	158441.2	974.206	cw
72	107272.3	158441.8	974.074	a
73	107268.2	158427.6	975.03	sw
74	107267.1	158415.5	973.617	a
75	107267.6	158413.3	972.601	z

76	107269.1	158386.4	972.479	z
77	107271	158393.4	973.564	cw
78	107271.4	158386.8	973.353	cw
79	107274.1	158386.3	973.32	cw
80	107274.3	158383.7	973.413	cw
81	107269.4	158383.3	974.479	b
82	107270.4	158383.3	975.229	bc
83	107272.3	158370.8	973.657	bc
84	107272.5	158368.3	973.088	bc
85	107273.6	158359.9	974.329	bc
86	107279.9	158361	972.865	a
87	107283.3	158345.3	972.609	a
88	107280.3	158344.1	972.83	hvp
89	107282	158336.5	972.678	cw
90	107282.9	158336.2	972.633	tp
91	107283.9	158332.3	973.001	b
92	107288.1	158323.1	972.437	b
93	107289.6	158319.7	972.405	cw
94	107291.1	158316.4	972.378	cw
96	107269.1	158554.2	977.52	ep
97	107270.8	158547	976.88	m
98	107262.1	158551.1	977.132	m
99	107265.9	158561.2	977.715	m
100	107277.4	158461.6	974.319	a+st
101	107275	158558.8	977.538	m
102	107274	158548.8	977.043	m
103	107260.8	158512.6	975.394	tp+cw
104	107252.6	158531.2	975.643	b
105	107255.1	158525.2	976.554	b
106	107255.9	158522.9	976.387	bc
107	107257.2	158515.6	978.821	b
108	107247.4	158529.8	984.033	b
109	107245.5	158553.1	982.595	b
110	107257.2	158535.3	976.489	tp+a
111	107255.8	158539.4	976.746	a
112	107254.1	158544.7	976.998	a
113	107251.2	158552.8	977.311	a
114	107248.6	158557.2	977.659	a
115	107247.7	158554.1	976.916	tp

116	107243.3	158562.3	978.25	a
117	107244.4	158563.5	978.224	paltel
118	107234.1	158568.5	978.544	a
119	107225.8	158572.5	978.731	a
120	107210.9	158594.2	979.322	a
121	107209.2	158595.1	979.495	hvp
122	107224.1	158593.4	979.513	a
123	107230	158594.7	979.915	a
124	107233	158597.7	980.406	a
125	107232.8	158595.1	980.091	a
128	107234.1	158601.4	980.904	a
129	107234.8	158617.4	982.627	a
130	107252.2	158617.2	982.664	a
131	107243.6	158615.1	982.657	a
132	107242.6	158589.5	979.972	a
133	107251.8	158600.6	981.009	a
134	107253.5	158592.2	979.945	a
135	107254	158593.5	980.329	tp
136	107256.4	158585.7	979.36	a
137	107254.1	158586	979.369	paltel
138	107262.3	158578.3	978.587	a
139	107270.5	158571.9	978.124	a
140	107288.8	158564	977.272	a
141	107297.6	158558.6	976.563	a
142	107297.6	158559.6	976.56	tp
143	107298.1	158561.6	976.349	tp
144	107296.9	158561.5	976.426	mh
145	107310.2	158554.7	975.64	a
146	107309.3	158545.8	975.584	a
147	107308.9	158544.3	975.624	a
148	107296.6	158547.2	976.497	a
149	107297	158549.1	976.472	a
150	107284.9	158553.8	977.271	a
151	107284.5	158549.4	977.16	a
152	107292.1	158540	976.64	a
153	107289.9	158538.4	976.919	b
154	107290	158539.3	976.86	bc
155	107283.4	158540	976.994	b
156	107283.2	158541.1	976.889	bc

157	107284.4	158542	976.926	a
158	107275.7	158538.7	976.761	a
159	107273.3	158534.9	976.464	a
160	107246.9	158577.8	978.775	m
161	107262.1	158568.1	978.171	m
162	107257.3	158564.5	978.087	m
163	107249.7	158563.2	978.078	m
164	107243.4	158568.8	978.39	m
165	107235.8	158573.5	978.656	m
166	107239.5	158575.9	978.794	m
167	107250.3	158563.4	978.054	m
168	107255.7	158569.8	978.482	lp
169	107251.5	158583.1	979.125	m
170	107243.7	158591.8	979.601	m
171	107248.5	158589.9	979.855	m
172	107236.5	158587.2	979.536	m
173	107231	158588.6	979.471	m
174	107236.8	158592.6	979.99	m
175	107242.7	158594.2	980.495	lp
176	107289.5	158549.7	977.071	lp
177	107230.7	158582.3	978.995	mh
178	107223.6	158583.7	979.403	lp
179	107214.7	158585.3	979.38	lp
180	107297.4	158303.1	972.662	tp
181	107298.5	158306.1	972.605	a
182	107303.8	158291	972.533	a
183	107303.1	158289.2	972.577	cw
184	107313.4	158273.1	972.348	a
185	107310.5	158271.6	974.715	tp
186	107315.2	158253.6	976.43	b
187	107314.6	158252	976.387	b
188	107321.9	158247.2	973.54	mh
189	107326.2	158241.1	972.117	paltel
190	107327.2	158241.3	972.051	a
191	107321.7	158243.2	972.482	cw
192	107325.5	158235	972.146	tp
193	107336.8	158207.5	972.429	b
194	107341.3	158198.8	975.041	ep
195	107335.4	158200	974.353	e

196	107339.1	158187.3	974.545	e
197	107346.9	158168.9	974.563	e
198	107350.6	158164.4	972.329	tp
199	107355.5	158163.9	971.426	a
200	107266.7	158555.4	977.686	st
201	107357.6	158155.8	971.522	a
202	107349.2	158153.5	973.821	ep
203	107349.9	158153.3	973.605	cw
204	107350.7	158150.9	971.881	b
205	107351.4	158150.3	971.982	bc
206	107353.2	158131.1	972.139	b
207	107353.4	158134.5	972.073	bc
208	107357.2	158132.1	971.704	tp
209	107359.8	158131.4	971.317	a
210	107382.7	158169.5	967.541	e
211	107378	158186.9	967.479	e
212	107373.3	158147.7	971.423	cw
213	107373.4	158139.6	971.377	cw
214	107375.3	158139.6	971.293	cw
215	107375.3	158147.6	971.303	cw
216	107366.6	158135.2	971.365	a
217	107352.3	158122.5	971.448	e
218	107351.9	158105.5	972.544	e
219	107360	158140.1	971.351	a
220	107365.3	158106.4	971.008	a
221	107370.6	158106.4	971.106	ep
222	107372.2	158104.5	971.052	cw
223	107373.3	158091.9	968.536	e
224	107373.8	158072.5	969.118	e
225	107369.4	158074	970.294	ep
226	107354.4	158101.8	971.706	cw
227	107358.7	158102.2	971.139	a
228	107355.6	158098.1	971.159	tp
229	107358.6	158078.7	970.64	a
230	107368.4	158140.3	970.788	mh
231	107349.5	158073.1	971.084	b
232	107349.7	158066.1	970.592	b
233	107350.8	158065.9	970.579	bc
234	107351.3	158061.8	970.598	b

235	107352.5	158062.2	970.555	bc
236	107370.3	158027.9	968.821	b
237	107351.8	158057.4	970.581	b
238	107353	158057.8	970.57	bc
239	107351	158057	970.634	b
240	107352.4	158053	970.554	b
241	107371.6	158025.5	1003.724	bc
242	107351.6	158052.6	970.621	b
243	107353	158048.6	970.549	b
244	107356.6	158048.4	970.359	mh
245	107356.8	158043.2	970.464	b
246	107360	158036.1	970.917	b
247	107362.4	158029.3	970.263	b
248	107364.3	158023.5	970.338	b
249	107363	158021.6	970.89	b
250	107368.7	158021.5	970.058	b
251	107369.1	158021.4	970	ep
252	107369.8	158020.8	969.941	tp
253	107358.4	158070	970.345	paltel
254	107359.5	158069.9	970.357	a
255	107363.3	158051.9	970.086	a
256	107368.8	158034.7	969.743	a
257	107378.6	158028.4	969.402	a
258	107371	158048	969.852	a
259	107366.4	158066.8	970.109	a
260	107368.2	158066.2	971.2	mh
261	107374.2	158070.3	970.407	b
262	107375.3	158065.5	970.346	b
263	107376.2	158061.8	970.354	b
264	107377.2	158058.2	970.357	b
265	107378	158055.4	970.279	b
266	107379.1	158052	970.136	b
267	107380.4	158048.5	970.176	b
268	107379.9	158048	970.207	b
269	107381.9	158044.7	970.205	b
270	107381.6	158044.5	970.218	bc
271	107385.7	158035.6	969.908	b
272	107393.1	158020.2	969.723	b
273	107392.4	158020.7	969.454	mh

274	107370.6	158018.3	969.411	b
275	107375.8	158008.5	969.2	b
276	107376.4	158009.2	969.185	bc
277	107378.3	158007.6	969.091	tp
278	107380.4	158008.4	969.029	a
279	107386.7	157996.2	968.686	a
280	107393.1	157984.3	968.225	a
281	107392.8	157984.8	967.828	tp
282	107389.5	157983.1	968.707	cw
283	107386.2	157984.3	968.944	mh
284	107384.2	157983.5	969.375	b
285	107403.2	157964.9	967.427	a
286	107404.7	157959.2	967.362	mh
287	107413.4	157940.9	966.777	tp
288	107429	157915.5	965.364	a
289	107428.2	157912	965.544	mh
290	107433.9	157905.7	964.831	a
291	107442.1	157888.8	963.77	a
292	107449.6	157887.9	963.598	a
293	107441.3	157906.4	964.699	a
294	107433.9	157920.8	965.503	a
295	107440.3	157925.7	966.124	b
296	107436.1	157933.1	966.256	b
297	107430.6	157936.4	966.305	ep
298	107420	157947.2	966.539	a
299	107422.7	157960.2	967.653	e
300	107410.5	157975.3	967.754	ep
301	107411.3	157982.5	966.527	e
302	107398.8	157987.3	968.051	a
303	107400.1	157988	968.064	mh
304	107393.2	158006.2	968.951	ep
305	107397.4	158015.2	965.82	e
306	107383	158018.1	968.977	a
307	107386.2	157969.8	972.854	e
308	107398.7	157951.8	971.782	e
309	107405.1	157933.1	972.287	e
310	107413.1	157915.1	971.299	e
311	107446.2	157907	964.66	ep
312	107447.9	157907.7	964.842	tp

313	107462.1	157881.8	963.295	b
314	107469.1	157865.2	963.596	b
315	107465.6	157864.3	962.277	b
316	107425.6	157900	969.021	e
317	107435.3	157873	966.994	e
318	107441.3	157854.4	965.046	e
319	107445	157847.9	964.793	e
320	107453	157854.6	961.429	tp
321	107455.8	157853.9	961.58	a
322	107454.8	157847.3	961.349	mh
323	107460.4	157843	960.938	a
324	107451.5	157834.5	962.673	e
325	107452.8	157825.9	961.748	e
326	107453.4	157816.7	960.614	e
327	107462.7	157795.7	958.373	e
328	107468.5	157772.9	957.2	e
329	107476.9	157774.7	957.812	tp
330	107484.6	157773.6	955.802	a
331	107490.2	157756.5	954.447	a
332	107493.8	157742.4	953.334	a
333	107501.2	157745.8	953.402	a
334	107497.6	157774.4	957.399	hvp
335	107500	157786.8	957.222	e
336	107493.7	157806.1	958.98	e
337	107484.5	157834.8	962.559	e
338	107475.5	157852.4	963.52	e
339	107471	157813.4	958.711	a
340	107465.4	157809.9	960.685	tp
341	107483.4	157814.2	958.672	ep
342	107478.1	157813.2	958.629	a
343	107495.1	157767.7	955.2	mh
344	107483.4	157771.5	955.622	mh
345	107502.3	157696.4	951.139	st
346	107490	157715.3	951.732	
347	107490.1	157705.2	951.393	
348	107473.9	157692.5	951.632	
349	107490.4	157684.9	950.915	a
350	107490	157678.2	950.926	cw
351	107497.8	157678.2	950.677	a

352	107499.1	157700.9	950.731	a
353	107501.7	157703	950.696	a
354	107505.7	157701.7	950.458	a
355	107515.1	157670.6	949.281	a
356	107517.5	157671.4	949.138	a
357	107525.4	157673	949.07	a
358	107518.1	157696.3	949.969	a
359	107512.1	157716.1	951.085	mh
360	107513.8	157715.8	951.616	ep
361	107503.8	157737.8	952.782	a
362	107497.5	157658.9	950.706	cw
363	107499.4	157656.1	950.725	b
364	107490	157654.3	950.892	tp+ce
365	107489.5	157653.7	950.81	ep
366	107497.7	157641.1	950.766	b
367	107488.7	157636.7	950.888	a
368	107493.1	157634.1	950.912	a
369	107485.7	157623.8	951.242	a
370	107491.4	157622	951.095	a
371	107481.3	157609.8	952.056	a
372	107487	157607.6	952.045	a
373	107488.8	157601.2	952.637	ep
374	107479.7	157607.2	952.457	tp
375	107477	157593.8	953.659	a
376	107482.4	157591.6	953.599	a
377	107473.7	157606.4	952.685	cw
378	107472.8	157601.2	953.036	b
379	107475.2	157585.7	954.374	a
380	107481.2	157584.8	954.288	a
381	107474.2	157572.6	955.686	a
382	107480.2	157571.3	955.507	a
383	107474.7	157562.6	956.461	a
384	107480.8	157562.6	956.304	a
385	107468.4	157556.1	957.021	a
386	107474.1	157554	956.902	ST
387	107478	157545.4	957.679	a
388	107480	157539.7	958.078	a
389	107483.5	157532.5	958.41	a
390	107489	157522	958.784	a

391	107494	157512.1	959.392	a
392	107499.3	157499.9	960.008	a
393	107505.2	157485.9	960.208	a
394	107510.8	157472.9	961.163	a
395	107516.4	157474.6	960.277	a
396	107510.7	157487.9	960.063	a
397	107505.6	157499.4	959.877	a
398	107500	157512.1	959.437	a
399	107499.8	157514.6	959.202	ep
401	107491.1	157530.7	958.35	a
402	107486	157540.8	957.82	a
403	107484.2	157546.1	957.518	a
404	107482.2	157552.7	957.024	a
405	107480.8	157562.4	956.31	a
406	107470.5	157544.6	957.627	e
407	107489.4	157542.1	956.597	e
408	107487.2	157548.1	957.103	e
409	107499.3	157529.2	957.18	e
410	107479.8	157529.8	959.394	e
411	107484.8	157520.8	958.81	e
412	107494	157506	959.609	tp
413	107508	157507.4	957.485	e
414	107515.2	157486	960.656	ep
415	107522.3	157487.4	956.989	e
416	107526.9	157473	956.413	e
417	107530.2	157461.6	956.117	e
418	107536.7	157452.6	955.835	e
419	107540.6	157438.2	955.364	e
420	107536.6	157402.4	957.193	e
421	107528	157396.7	958.948	ep
422	107519.3	157389.1	958.872	a
423	107524.6	157391.4	958.7	a
424	107524.7	157419.4	959.681	a
425	107523.3	157401.3	959.26	a
426	107518.9	157415.9	959.782	a
427	107518.1	157424	959.942	cw
428	107518	157430.7	959.888	cw
429	107516.7	157448.9	960.061	cw
430	107518.2	157448.9	960.042	a

431	107514.2	157448.6	962.983	b
432	107509.9	157465.2	961.683	b
433	107515.3	157448.9	964.062	bc
434	107510.8	157465.5	964.015	bc
435	107512.3	157465.5	960.506	cw
436	107510.1	157472.8	960.433	cw+tp
437	107502.9	157502.2	960.198	sw
438	107515.1	157482.7	960.452	cw
439	107525.9	157453.1	959.853	cw
440	107526.9	157440	959.843	ep
441	107524	157450.7	959.927	a
442	107524.9	157426.2	959.783	a
443	107513.9	157399.1	961.779	b
444	107515.3	157388	961.952	b
445	107518.5	157385	960.774	cw+sw
446	107520.1	157385	960.49	a
447	107526.1	157384.6	960.136	a
448	107535.2	157351.2	958.7	a
449	107537.4	157350.4	957.162	ep
450	107529.1	157347.2	957.437	tp
451	107528.6	157347.4	957.458	cw
452	107526.7	157352	957.642	sw
453	107516.5	157351.6	958.574	e
454	107512.6	157369.7	960.462	e
455	107538.6	157372.1	957.398	e
456	107547.4	157350.7	956.272	e
457	107556.8	157325.6	954.45	e
458	107545.7	157324.1	956.196	a
459	107538.3	157323.4	956.318	sw+cw
460	107543.6	157311.9	956.037	sw
461	107546.6	157302.7	955.913	sw
462	107546.4	157302.5	957.623	ep+cw
463	107555.9	157282.9	955.025	cw
464	107552.3	157290.1	954.844	cw
465	107567.6	157264.4	956.836	a
466	107564	157266.8	957.29	cw
467	107565.8	157263.2	955.879	sw
468	107571.6	157268.4	956.618	a
469	107584.8	157250.2	957.975	a

470	107571.9	157275.5	957.963	tp
471	107579.2	157247.3	957.934	a
472	107576.7	157246	957.843	sw
473	107537.5	157334.7	1082.52	sw+ep
474	107594.5	157230.5	959.985	a
475	107591.1	157233.5	959.599	sw
476	107599.8	157233.5	960.13	a
477	107599	157222.8	961.147	sw
478	107598.3	157222.6	961.192	a
479	107604.4	157224.7	961.318	a
480	107599.3	157218	962.42	cw
481	107602.2	157213.5	962.724	a
482	107607.4	157214.1	962.951	a
483	107602.5	157208.9	963.386	a
484	107599.3	157210.1	963.512	cw
485	107607.9	157210	963.451	a
486	107607.3	157202.9	964.305	a
487	107602.6	157206.9	963.767	a
488	107599.7	157204.9	964.321	cw
489	107559.2	157292.4	953.846	a
490	107559.3	157292.1	953.86	a
491	107552	157308.9	953.612	a
492	107546.6	157305.6	953.728	a
493	107543.9	157328.8	954.25	a
494	107535.3	157333.5	954.571	a
495	107430.8	157094.7	961.083	a
496	107448.1	157107.3	962.046	a
497	107446.8	157104.5	962.095	cw
498	107454.7	157104.6	963.93	e
499	107472	157115.7	965.113	e
500	107478.7	157120.3	965.152	e
501	107483.5	157130.4	964.528	a
502	107484.5	157129	964.941	a
503	107484.1	157127.9	964.43	ep
504	107490.1	157132.4	964.984	cw+sw
505	107491.3	157134.3	964.992	tp
506	107526.5	157169.3	964.82	a
507	107503.8	157142.9	965.702	sw
508	107515.7	157153.8	966.714	a

509	107516.4	157152.3	967.093	sw
510	107522.1	157157	967.092	ep
511	107545.7	157176.3	967.072	a
512	107544.2	157172.2	967.07	ep
513	107548.2	157169.3	969.642	e
514	107566.9	157185.1	965.451	a
515	107579.5	157188.1	964.821	a
516	107589.8	157188.9	964.393	a
517	107597.3	157200.6	962.991	tp
518	107596.5	157199.2	963.413	cw
519	107598.5	157197.3	963.358	a
520	107594.5	157196.5	963.948	cw
521	107594.5	157195.3	963.862	a
522	107581	157194	964.653	a
523	107574.7	157194.1	965.011	cw
524	107533.1	157175.3	965.45	a
525	107568.8	157191.9	965.278	a
526	107567.9	157185.5	965.349	a
527	107564.9	157191	965.548	a
528	107563	157192.3	965.872	sw
529	107558.5	157188.8	966.057	a
530	107549.2	157185	966.712	a
531	107540.7	157180.5	967.095	a
532	107535	157176.5	967.014	a
533	107515.7	157161.8	966.686	a
534	107508.1	157155.5	966.437	a
535	107500.8	157149.2	965.662	a
536	107570.9	157185	964.932	ep
537	107491	157144.6	964.819	tp
538	107490.6	157142.2	964.883	a
539	107479.6	157135.2	964.172	a
540	107451.7	157108.5	962.425	ep
541	107524.2	157152.8	967.984	e
542	107562.8	157196.2	964.553	e
543	107542.9	157191.6	964.488	e
544	107526.1	157186.9	962.694	e
545	107517	157177.9	963.503	e
546	107507	157168.3	963.976	e
547	107492.8	157152.5	963.216	e

548	107511.8	157143.9	967.241	e
549	107493.1	157130.6	966.188	e
550	133013.8	157595.1	966.18	e
551	107572.5	157178.5	969.49	e
552	107559	157180.1	968.115	ep
553	107472.5	157130.6	963.686	a
554	107449.3	157115.8	962.103	a
555	107432.1	157105	961.158	a
556	107413.4	157092	960.383	a
557	107399	157082.3	959.365	a
558	107383.7	157072.6	958.326	a
559	107365.1	157062.2	957.306	a
560	107355	157056.6	956.865	a
561	107344.2	157051.6	956.467	a
562	107325.5	157043.7	955.751	a
563	107327	157037.7	955.962	a
564	107343.7	157045	956.492	a
565	107357.5	157051.1	956.954	a
566	107368.8	157057.2	957.414	a
567	107378.2	157062.5	957.965	a
568	107388.6	157068.6	958.491	a
569	107403	157077.8	959.546	a
570	107413.3	157085	960.49	a
571	107425	157084.6	961.71	a
572	107426.4	157089.9	961.192	a
573	107427.6	157089.7	961.444	cw
574	107429.8	157092.3	961.301	cw
575	107425.2	157091.4	960.926	mh
576	107412.2	157079.4	960.923	a+ep
577	107419.5	157075.9	962.444	a
580	107294	157027.8	954.867	a
581	107294.3	157022.5	954.842	a
582	107294	157045.4	957.133	e
583	107323.1	157027.7	958.234	e
584	107330	157036.9	957.484	ep
585	107410.5	157075.5	961.174	e
586	107373.4	157053.4	959.276	e
587	107349.7	157038.8	960.046	e
588	107391.7	157082	955.487	e

589	107356.9	157067.2	953.642	e
590	107339.9	157060.1	952.867	e
591	107318.2	157049.6	951.919	e
592	107344.6	157053.1	951.805	e
888	107516.8	157473.6	960.246	ST888
999	107528.1	157353.6	957.834	st999
1000	107236.2	158634.8	984.86	ST
2000	107267.4	158555	977.958	ST
3000	107282	158346	972.908	ST
4000	107371	158145.5	971.248	ST
5000	107372.6	158024	969.571	ST
6000	107464.3	157861.5	962.088	ST
7000	107605.8	157196.8	963.037	ST
8000	107531.3	157174.5	966.997	ST
9000	107429.7	157094.7	961.051	ST
10000	107323.7	157042.6	955.975	ST

APPENDIX – 2

Horizontal Incremental Stationing Report.

Tangential Direction	Easting	Northing	Station
١٦-١٦-٢٧٦	١٥٨٥٦٢.١٢٦	١٠٧٢٥٩.٥٠٨	٠٠+٠
١٦-١٦-٢٧٦	١٥٨٥٤٢.٢٤٦	١٠٧٢٦١.٦٩٣	٢٠+٠
١٦-١٦-٢٧٦	١٥٨٥٢٢.٣٦٦	١٠٧٢٦٣.٨٧٧	٤٠+٠
١٦-١٦-٢٧٦	١٥٨٥٠٢.٤٨٥	١٠٧٢٦٦.٠٦٢	٦٠+٠
١٦-١٦-٢٧٦	١٥٨٤٨٢.٦٠٥	١٠٧٢٦٨.٢٤٧	٨٠+٠
١٦-١٦-٢٧٦	١٥٨٤٦٢.٧٢٥	١٠٧٢٧٠.٤٣١	٠٠+١
١٦-١٦-٢٧٦	١٥٨٤٤٢.٨٤٤	١٠٧٢٧٢.٦١٦	٢٠+١
١٦-١٦-٢٧٦	١٥٨٤٢٢.٩٦٤	١٠٧٢٧٤.٨٠١	٤٠+١
١٦-١٦-٢٧٦	١٥٨٤٠٣.٠٨٤	١٠٧٢٧٦.٩٨٥	٦٠+١
١٦-١٦-٢٧٦	١٥٨٣٨٣.٢٠٣	١٠٧٢٧٩.١٧٠	٨٠+١
١٦-١٦-٢٧٦	١٥٨٣٦٣.٣٢٣	١٠٧٢٨١.٣٥٥	٠٠+٢
٥٢-٤٢-٢٨٥	١٥٨٣٤٣.٦٦٥	١٠٧٢٨٤.٨٧٨	٢٠+٢
٣٠-٥٦-٢٩٢	١٥٨٣٢٤.٩٦٨	١٠٧٢٩١.٩٢٩	٤٠+٢
٣٠-٥٦-٢٩٢	١٥٨٣٠٦.٥٥٠	١٠٧٢٩٩.٧٢٥	٦٠+٢
٣٠-٥٦-٢٩٢	١٥٨٢٨٨.١٣٢	١٠٧٣٠٧.٥٢١	٨٠+٢
٣٠-٥٦-٢٩٢	١٥٨٢٦٩.٧١٤	١٠٧٣١٥.٣١٧	٠٠+٣
٣٠-٥٦-٢٩٢	١٥٨٢٥١.٢٩٦	١٠٧٣٢٣.١١٣	٢٠+٣
٣٠-٥٦-٢٩٢	١٥٨٢٣٢.٨٧٨	١٠٧٣٣٠.٩٠٩	٤٠+٣
٣٠-٥٦-٢٩٢	١٥٨٢١٤.٤٦٠	١٠٧٣٣٨.٧٠٥	٦٠+٣
٣٠-٥٦-٢٩٢	١٥٨١٩٦.٠٤٢	١٠٧٣٤٦.٥٠١	٨٠+٣
٣٠-٥٦-٢٩٢	١٥٨١٧٧.٦٢٤	١٠٧٣٥٤.٢٩٦	٠٠+٤
١١-٠٨-٢٨٦	١٥٨١٥٨.٩٥٧	١٠٧٣٦١.٤٣٣	٢٠+٤
٣٨-٤٠-٢٧٤	١٥٨١٣٩.٣١٨	١٠٧٣٦٥.٠٣٩	٤٠+٤
٠٥-٢٧-٢٦٨	١٥٨١١٩.٣٣١	١٠٧٣٦٥.٠٨٩	٦٠+٤
٠٥-٢٧-٢٦٨	١٥٨٠٩٩.٣٣٨	١٠٧٣٦٤.٥٤٨	٨٠+٤
٠٥-٢٧-٢٦٨	١٥٨٠٧٩.٣٤٦	١٠٧٣٦٤.٠٠٨	٠٠+٥
٤٦-٥٢-٢٧٨	١٥٨٠٥٩.٤٠٩	١٠٧٣٦٥.١٢١	٢٠+٥
١٩-٢٠-٢٩٠	١٥٨٠٤٠.٠٨٧	١٠٧٣٧٠.١٥٧	٤٠+٥
٣٣-١٤-٢٩٧	١٥٨٠٢٢.٠٠٠	١٠٧٣٧٨.٦٥٤	٦٠+٥
٣٣-١٤-٢٩٧	١٥٨٠٠٤.٢١٨	١٠٧٣٨٧.٨١٠	٨٠+٥
٣٣-١٤-٢٩٧	١٥٧٩٨٦.٤٣٧	١٠٧٣٩٦.٩٦٥	٠٠+٦
٣٣-١٤-٢٩٧	١٥٧٩٦٨.٦٥٥	١٠٧٤٠٦.١٢٠	٢٠+٦
٣٣-١٤-٢٩٧	١٥٧٩٥٠.٨٧٤	١٠٧٤١٥.٢٧٥	٤٠+٦
٣٣-١٤-٢٩٧	١٥٧٩٣٣.٠٩٢	١٠٧٤٢٤.٤٣٠	٦٠+٦
٣٣-١٤-٢٩٧	١٥٧٩١٥.٣١١	١٠٧٤٣٣.٥٨٥	٨٠+٦
٣٣-١٤-٢٩٧	١٥٧٨٩٧.٥٢٩	١٠٧٤٤٢.٧٤١	٠٠+٧
٣٣-١٤-٢٩٧	١٥٧٨٧٩.٧٤٨	١٠٧٤٥١.٨٩٦	٢٠+٧
٠٦-٠٣-٢٩٣	١٥٧٨٦١.٨٥٠	١٠٧٤٦٠.٨١٠	٤٠+٧
٤٣-٣٩-٢٨٦	١٥٧٨٤٢.٨٨٩	١٠٧٤٦٧.١٣٣	٦٠+٧
٤٣-٣٩-٢٨٦	١٥٧٨٢٣.٧٢٩	١٠٧٤٧٢.٨٦٨	٨٠+٧
٤٣-٣٩-٢٨٦	١٥٧٨٠٤.٥٦٩	١٠٧٤٧٨.٦٠٢	٠٠+٨
٤٣-٣٩-٢٨٦	١٥٧٧٨٥.٤٠٩	١٠٧٤٨٤.٣٣٧	٢٠+٨
٤٣-٣٩-٢٨٦	١٥٧٧٦٦.٢٤٨	١٠٧٤٩٠.٠٧١	٤٠+٨

١٤-٣٤-٢٨٠	١٥٧٧٤٦.٩٤٥	١٠٧٤٩٥.٢٥٩	٦٠+٨
٤٢-٠٦-٢٦٩	١٥٧٧٢٧.٠٥٠	١٠٧٤٩٦.٩٤٤	٨٠+٨
١٩-٠١-٢٦٣	١٥٧٧٠٧.١٤٩	١٠٧٤٩٥.٠٧٧	٠٠+٩
١٩-٠١-٢٦٣	١٥٧٦٨٧.٢٩٨	١٠٧٤٩٢.٦٤٧	٢٠+٩
١٩-٠١-٢٦٣	١٥٧٦٦٧.٤٤٦	١٠٧٤٩٠.٢١٧	٤٠+٩
١٩-٠١-٢٦٣	١٥٧٦٤٧.٥٩٤	١٠٧٤٨٧.٧٨٧	٦٠+٩
١٩-٠١-٢٦٣	١٥٧٦٢٧.٧٤٢	١٠٧٤٨٥.٣٥٨	٨٠+٩
١٩-٠١-٢٦٣	١٥٧٦٠٧.٨٩٠	١٠٧٤٨٢.٩٢٨	٠٠+١٠
١٩-٠١-٢٦٣	١٥٧٥٨٨.٠٣٨	١٠٧٤٨٠.٤٩٨	٢٠+١٠
٠٧-٥٩-٢٦٩	١٥٧٥٦٨.١٢٦	١٠٧٤٧٨.٨٠٤	٤٠+١٠
٤٠-٢٦-٢٨١	١٥٧٥٤٨.٢٥٩	١٠٧٤٨٠.٧٩٢	٦٠+١٠
١٦-٣٧-٢٩٢	١٥٧٥٢٩.١٨٢	١٠٧٤٨٦.٦٨٧	٨٠+١٠
١٦-٣٧-٢٩٢	١٥٧٥١٠.٧٢١	١٠٧٤٩٤.٣٨٠	٠٠+١١
١٦-٣٧-٢٩٢	١٥٧٤٩٢.٢٥٩	١٠٧٥٠٢.٠٧٢	٢٠+١١
١٦-٣٧-٢٩٢	١٥٧٤٧٣.٧٩٨	١٠٧٥٠٩.٧٦٥	٤٠+١١
٢٧-١٠-٢٨٩	١٥٧٤٥٥.٢٧٠	١٠٧٥١٧.٢٨٩	٦٠+١١
٥٥-٤٢-٢٧٧	١٥٧٤٣٥.٨٥١	١٠٧٥٢١.٩٣٢	٨٠+١١
٢٢-١٥-٢٦٦	١٥٧٤١٥.٨٩٦	١٠٧٥٢٢.٦٢٤	٠٠+١٢
١٣-٥٠-٢٧٢	١٥٧٣٩٥.٩٢٩	١٠٧٥٢١.٨٦٥	٢٠+١٢
٤٦-١٧-٢٨٤	١٥٧٣٧٦.١٨٥	١٠٧٥٢٤.٨٤٠	٤٠+١٢
٥٠-٢٤-٢٩٢	١٥٧٣٥٧.٣٥٨	١٠٧٥٣١.٥٢١	٦٠+١٢
٥٠-٢٤-٢٩٢	١٥٧٣٣٨.٨٦٩	١٠٧٥٣٩.١٤٧	٨٠+١٢
٥٠-٢٤-٢٩٢	١٥٧٣٢٠.٣٨٠	١٠٧٥٤٦.٧٧٣	٠٠+١٣
٥٠-٢٤-٢٩٢	١٥٧٣٠١.٨٩١	١٠٧٥٥٤.٣٩٩	٢٠+١٣
٥٠-٢٤-٢٩٢	١٥٧٢٨٣.٤٠٢	١٠٧٥٦٢.٠٢٥	٤٠+١٣
٣٣-٠٥-٢٩٤	١٥٧٢٦٤.٩٢٩	١٠٧٥٦٩.٦٩٠	٦٠+١٣
٠٦-٣٣-٣٠٥	١٥٧٢٤٧.٦٠٧	١٠٧٥٧٩.٦٢٠	٨٠+١٣
٥٢-٣٦-٢٩٩	١٥٧٢٣٢.٣٩٢	١٠٧٥٩٢.٥١٠	٠٠+١٤
٠٢-٢٥-٢٦١	١٥٧٢١٣.٠٩٠	١٠٧٥٩٦.٠٩٣	٢٠+١٤
١٢-١٣-٢٢٣	١٥٧١٩٥.٧٠٦	١٠٧٥٨٦.٩٧٣	٤٠+١٤
٤٢-٠٨-١٩٦	١٥٧١٨٧.١٣١	١٠٧٥٦٩.١٧٨	٦٠+١٤
٣٩-٢١-٢٠٢	١٥٧١٨١.٠١١	١٠٧٥٥٠.١٥٠	٨٠+١٤
١٢-٤٩-٢١٣	١٥٧١٧١.٦١٠	١٠٧٥٣٢.٥٣٦	٠٠+١٥
٣٥-٤٨-٢١٤	١٥٧١٦٠.٢٠٥	١٠٧٥١٦.١٠٦	٢٠+١٥
٣٥-٤٨-٢١٤	١٥٧١٤٨.٧٨٨	١٠٧٤٩٩.٦٨٥	٤٠+١٥
٣٥-٤٨-٢١٤	١٥٧١٣٧.٣٧١	١٠٧٤٨٣.٢٦٤	٦٠+١٥
٣٥-٤٨-٢١٤	١٥٧١٢٥.٩٥٤	١٠٧٤٦٦.٨٤٣	٨٠+١٥
٣٥-٤٨-٢١٤	١٥٧١١٤.٥٣٧	١٠٧٤٥٠.٤٢٢	٠٠+١٦
٣٥-٤٨-٢١٤	١٥٧١٠٣.١٢٠	١٠٧٤٣٤.٠٠١	٢٠+١٦
٣٥-٤٨-٢١٤	١٥٧٠٩١.٧٠٣	١٠٧٤١٧.٥٨٠	٤٠+١٦
٣٥-٤٨-٢١٤	١٥٧٠٨٠.٢٨٥	١٠٧٤٠١.١٥٩	٦٠+١٦
٣٤-١٥-٢١٠	١٥٧٠٦٩.١٣٢	١٠٧٣٨٤.٥٦٥	٨٠+١٦
١٠-٠٥-٢٠٦	١٥٧٠٦٠.١٠٢	١٠٧٣٦٦.٧٢٤	٠٠+١٧
١٠-٠٥-٢٠٦	١٥٧٠٥١.٣٠٨	١٠٧٣٤٨.٧٦٢	٢٠+١٧
١٠-٠٥-٢٠٦	١٥٧٠٤٢.٥١٣	١٠٧٣٣٠.٧٩٩	٤٠+١٧
١٠-٠٥-٢٠٦	١٥٧٠٣٣.٧١٩	١٠٧٣١٢.٨٣٦	٦٠+١٧

APPENDIX – 3

Horizontal Alignment Station and Curve Report.

Station Spiral/Curve Data Northing Easting

PI 0+00 107259.508 158562.126
Length: 218.170 Course: 276-16-16

PI 2+18.17 107283.339 158345.262
Length: 211.863 Course: 292-56-30
Delta: 16-40-14

Tangent Data
١٥٨٥٦٢.١٢٦ ١٠٧٢٥٩.٥٠٨ ٠٠+٠
١٥٨٣٥٩.٨٢٦ ١٠٧٢٨١.٧٣٩ ٠٣.٥٢+٢
Length: 203.518 Course: 276-16-16

Circular Curve Data
PC 2+03.52 107281.739 158359.826
CC 107381.141 158370.749
PT 2+32.61 107289.050 158331.770
Delta: 16-40-14 Type: RIGHT
Radius: 100.000 DOC: 57-17-45
Length: 29.096 Tangent: 14.651
Mid-Ord: 1.056 External: 1.068
Chord: 28.993 Course: 284-36-23
Es: 1.068

PI 4+29.83 107365.922 158150.157
Length: 98.304 Course: 268-27-05
Delta: 24-29-25

Tangent Data
١٥٨٣٣١.٧٧٠ ١٠٧٢٨٩.٠٥٠ ٣٢.٦١+٢
١٥٨١٧٠.١٤٣ ١٠٧٣٥٧.٤٦٢ ٠٨.١٢+٤
Length: 175.509 Course: 292-56-30

Circular Curve Data
PC 4+08.12 107357.462 158170.143
CC 107265.372 158131.164
PT 4+50.87 107365.336 158128.462
Delta: 24-29-25 Type: LEFT

Radius: 100.000 DOC: 57-17-45
Length: 42.743 Tangent: 21.703
Mid-Ord: 2.275 External: 2.328
Chord: 42.419 Course: 280-41-48
Es: 2.328

PI 5+27.47 107363.266 158051.889
Length: 215.563 Course: 297-14-33
Delta: 28-47-28

Tangent Data
١٥٨١٢٨.٤٦٢ ١٠٧٣٦٥.٣٣٦ ٥٠.٨٧+٤
١٥٨٠٧٧.٥٤٧ ١٠٧٣٦٣.٩٥٩ ٠١.٨٠+٥
Length: 50.934 Course: 268-27-05

Circular Curve Data
PC 5+01.80 107363.959 158077.547
CC 107463.923 158074.844
PT 5+52.05 107375.015 158029.068
Delta: 28-47-28 Type: RIGHT
Radius: 100.000 DOC: 57-17-45
Length: 50.250 Tangent: 25.667
Mid-Ord: 3.140 External: 3.242
Chord: 49.723 Course: 282-50-49
Es: 3.242

PI 7+41.95 107461.941 157860.236
Length: 128.404 Course: 286-39-43
Delta: 10-34-50

Tangent Data
١٥٨٠٢٩.٠٦٨ ١٠٧٣٧٥.٠١٥ ٥٢.٠٥+٥
١٥٧٨٦٨.٤٦٩ ١٠٧٤٥٧.٧٠٣ ٣٢.٦٩+٧
Length: 180.636 Course: 297-14-33

Circular Curve Data
PC 7+32.69 107457.703 157868.469
CC 107368.795 157822.693
PT 7+51.15 107464.596 157851.366
Delta: 10-34-50 Type: LEFT
Radius: 100.000 DOC: 57-17-45
Length: 18.467 Tangent: 9.260
Mid-Ord: 0.426 External: 0.428
Chord: 18.441 Course: 291-57-08
Es: 0.428

PI 8+70.30 107498.758 157737.224

Length: 184.566 Course: 263-01-19
Delta: 23-38-24

Tangent Data
١٥٧٨٥١.٣٦٦ ١٠٧٤٦٤.٥٩٦ ٥١.١٥+٧
١٥٧٧٥٧.٢٧٣ ١٠٧٤٩٢.٧٥٧ ٤٩.٣٧+٨
Length: 98.216 Course: 286-39-43

Circular Curve Data
PC 8+49.37 107492.757 157757.273
CC 107396.956 157728.601
PT 8+90.63 107496.215 157716.452
Delta: 23-38-24 Type: LEFT
Radius: 100.000 DOC: 57-17-45
Length: 41.259 Tangent: 20.927
Mid-Ord: 2.120 External: 2.166
Chord: 40.967 Course: 274-50-31
Es: 2.166

PI 10+54.27 107476.335 157554.025
Length: 125.176 Course: 292-37-16
Delta: 29-35-57

Tangent Data
١٥٧٧١٦.٤٥٢ ١٠٧٤٩٦.٢١٥ ٩٠.٦٣+٨
١٥٧٥٨٠.٢٥٠ ١٠٧٤٧٩.٥٤٥ ٢٧.٨٥+١٠
Length: 137.218 Course: 263-01-19

Circular Curve Data
PC 10+27.85 107479.545 157580.250
CC 107578.804 157568.101
PT 10+79.51 107486.497 157529.637
Delta: 29-35-57 Type: RIGHT
Radius: 100.000 DOC: 57-17-45
Length: 51.660 Tangent: 26.420
Mid-Ord: 3.317 External: 3.431
Chord: 51.088 Course: 277-49-18
Es: 3.431

PI 11+78.26 107524.482 157438.479
Length: 53.641 Course: 265-19-42
Delta: 27-17-34

Tangent Data
١٥٧٥٢٩.٦٣٧ ١٠٧٤٨٦.٤٩٧ ٧٩.٥١+١٠
١٥٧٤٦٠.٨٩٠ ١٠٧٥١٥.١٤٤ ٥٣.٩٨+١١
Length: 74.477 Course: 292-37-16

Circular Curve Data

PC 11+53.98 107515.144 157460.890
CC 107422.837 157422.426
PT 12+01.62 107522.505 157414.282
Delta: 27-17-34 Type: LEFT
Radius: 100.000 DOC: 57-17-45
Length: 47.635 Tangent: 24.278
Mid-Ord: 2.823 External: 2.905
Chord: 47.186 Course: 278-58-29
Es: 2.905

PI 12+30.98 107520.113 157385.016
Length: 139.732 Course: 292-24-50
Delta: 27-05-09

Tangent Data

١٥٧٤١٤.٢٨٢ ١٠٧٥٢٢.٥٠٥ ٠١.٦٢+١٢
١٥٧٤٠٩.٠٢٣ ١٠٧٥٢٢.٠٧٥ ٠٦.٩٠+١٢
Length: 5.276 Course: 265-19-42

Circular Curve Data

PC 12+06.90 107522.075 157409.023
CC 107621.743 157400.879
PT 12+54.17 107529.298 157362.749
Delta: 27-05-09 Type: RIGHT
Radius: 100.000 DOC: 57-17-45
Length: 47.274 Tangent: 24.087
Mid-Ord: 2.781 External: 2.860
Chord: 46.835 Course: 278-52-16
Es: 2.860

PI 13+69.81 107573.393 157255.840
Length: 12.744 Course: 306-56-20
Delta: 14-31-29

Tangent Data

١٥٧٣٦٢.٧٤٩ ١٠٧٥٢٩.٢٩٨ ٥٤.١٧+١٢
١٥٧٢٦٧.٦٢١ ١٠٧٥٦٨.٥٣٤ ٥٧.٠٧+١٣
Length: 102.902 Course: 292-24-50

Circular Curve Data

PC 13+57.07 107568.534 157267.621
CC 107660.979 157305.751
PT 13+82.42 107581.051 157245.654
Delta: 14-31-29 Type: RIGHT
Radius: 100.000 DOC: 57-17-45
Length: 25.351 Tangent: 12.744
Mid-Ord: 0.802 External: 0.809

Chord: 25.283 Course: 299-40-35
Es: 0.809

PI 13+82.42 107581.051 157245.654
Length: 59.757 Course: 313-50-08
Delta: 6-53-48

PI 14+42.18 107622.439 157202.550
Length: 81.033 Course: 196-08-42
Delta: 117-41-26

Tangent Data
١٥٧٢٤٥.٦٥٤ ١٠٧٥٨١.٠٥١ ٨٢.٤٢+١٣
١٥٧٢٣٨.٣٤٥ ١٠٧٥٨٨.٠٦٩ ٩٢.٥٥+١٣
Length: 10.133 Course: 313-50-08

Circular Curve Data
PC 13+92.55 107588.069 157238.345
CC 107566.429 157217.568
PT 14+54.18 107574.771 157188.751
Delta: 117-41-26 Type: LEFT
Radius: 30.000 DOC: 190-59-09
Length: 61.623 Tangent: 49.624
Mid-Ord: 14.479 External: 27.988
Chord: 51.346 Course: 254-59-25
Es: 27.988

PI 14+85.58 107544.602 157180.017
Length: 194.392 Course: 214-48-35
Delta: 18-39-53

Tangent Data
١٥٧١٨٨.٧٥١ ١٠٧٥٧٤.٧٧١ ٥٤.١٨+١٤
١٥٧١٨٤.٥٨٧ ١٠٧٥٦٠.٣٨٧ ٦٩.١٥+١٤
Length: 14.975 Course: 196-08-42

Circular Curve Data
PC 14+69.15 107560.387 157184.587
CC 107588.194 157088.531
PT 15+01.73 107531.109 157170.636
Delta: 18-39-53 Type: RIGHT
Radius: 100.000 DOC: 57-17-45
Length: 32.576 Tangent: 16.434
Mid-Ord: 1.324 External: 1.341
Chord: 32.432 Course: 205-28-39
Es: 1.341

PI 16+79.69 107384.996 157069.048
Length: 97.896 Course: 206-05-10
Delta: 8-43-25

Tangent Data
١٥٧١٧٠.٦٣٦ ١٠٧٥٣١.١٠٩ ٠١.٧٣+١٥
١٥٧٠٧٣.٤٠٢ ١٠٧٣٩١.٢٥٨ ٧٢.٠٦+١٦
Length: 170.331 Course: 214-48-35

Circular Curve Data
PC 16+72.06 107391.258 157073.402
CC 107334.173 157155.507
PT 16+87.28 107378.145 157065.694
Delta: 08-43-25 Type: LEFT
Radius: 100.000 DOC: 57-17-45
Length: 15.226 Tangent: 7.628
Mid-Ord: 0.290 External: 0.290
Chord: 15.211 Course: 210-26-52
Es: 0.290

PI 17+77.55 107297.072 157026.001

Tangent Data
١٥٧٠٦٥.٦٩٤ ١٠٧٣٧٨.١٤٥ ٨٧.٢٨+١٦
١٥٧٠٢٦.٠٠١ ١٠٧٢٩٧.٠٧٢ ٧٧.٥٥+١٧
Length: 90.269 Course: 206-05-10

APPENDIX – 4

Vertical Alignment Report

PVI Stations and Curves

Units: meter

Horizontal Alignment Information

Curve Calculation Options

Vertical Alignment: Center FG

PVI	Station	Elevation	Grade Out (%)	Curve Length
1	0+00	977.884	-3.049	
2	0+60	974.854	-1.370	50.000
	Vertical Curve Information: (sag curve) PVC Station: 0+35 Elevation: 976.116 PVI Station: 0+60 Elevation: 974.854 PVT Station: 0+85 Elevation: 974.512 Grade in (%): -3.049 Grade out (%): -1.370 Change (%): 1.679 K: 13.591 Curve Length: 50.000 Headlight Distance: 78.605			
3	2+40	972.388	-0.262	100.000
	Vertical Curve Information: (sag curve) PVC Station: 1+90 Elevation: 973.073 PVI Station: 2+40 Elevation: 972.388 PVT Station: 2+90 Elevation: 972.257 Grade in (%): -1.370 Grade out (%): -0.262 Change (%): 1.109 K: 90.199 Curve Length: 100.000 Headlight Distance: Infinite			
4	4+20	971.917	-1.833	50.000
	Vertical Curve Information: (crest curve) PVC Station: 3+95 Elevation: 971.982 PVI Station: 4+20 Elevation: 971.917 PVT Station: 4+45 Elevation: 971.458			

PVI	Station	Elevation	Grade Out (%)	Curve Length
	Grade in (%): -0.262 Grade out (%): -1.833 Change (%): 1.571 K: 31.818 Curve Length: 50.000 Passing Distance: 325.922 Stopping Distance: 153.624			
5	5+60	969.350	-3.625	40.000
	Vertical Curve Information: (crest curve) PVC Station: 5+40 Elevation: 969.717 PVI Station: 5+60 Elevation: 969.350 PVT Station: 5+80 Elevation: 968.625 Grade in (%): -1.833 Grade out (%): -3.625 Change (%): 1.792 K: 22.325 Curve Length: 40.000 Passing Distance: 283.924 Stopping Distance: 132.810			
6	7+59.86	962.106	-5.535	100.000
	Vertical Curve Information: (crest curve) PVC Station: 7+09.86 Elevation: 963.918 PVI Station: 7+59.86 Elevation: 962.106 PVT Station: 8+09.86 Elevation: 957.838 Grade in (%): -3.625 Grade out (%): -5.535 Change (%): 1.910 K: 20.366 Curve Length: 100.000 Passing Distance: 146.306 Stopping Distance: 90.735			
7	9+00	950.145	1.569	100.000
	Vertical Curve Information: (sag curve) PVC Station: 8+50 Elevation: 954.412 PVI Station: 9+00 Elevation: 950.145 PVT Station: 9+50 Elevation: 950.929 Grade in (%): -5.535 Grade out (%): 1.569 Change (%): 7.104 K: 9.897 Curve Length: 100.000 Low Point: 9+34.47 Elevation: 950.807 Headlight Distance: 55.825			
8	10+00	951.714	8.966	60.000
	Vertical Curve Information: (sag curve)			

<table>
<tr><th>PVI</th><th>Station</th><th>Elevation</th><th>Grade Out (%)</th><th>Curve Length</th></tr>
<tr><td></td><td colspan="4">PVC Station: 9+70 Elevation: 951.243
PVI Station: 10+00 Elevation: 951.714
PVT Station: 10+30 Elevation: 954.403
Grade in (%): 1.569 Grade out (%): 5.966
Change (%): 4.397 K: 8.112
Curve Length: 60.000
Headlight Distance: 48.421</td></tr>
<tr><td>9</td><td>11+40</td><td>964.266</td><td>-4.663</td><td>200.000</td></tr>
<tr><td></td><td colspan="4">Vertical Curve Information: (crest curve)
PVC Station: 10+40 Elevation: 955.300
PVI Station: 11+40 Elevation: 964.266
PVT Station: 12+40 Elevation: 957.603
Grade in (%): 4.966 Grade out (%): -6.563
Change (%): 10.629 K: 12.797
Curve Length: 200.000
High Point: 11+54.73 Elevation: 960.443
Passing Distance: 110.013 Stopping Distance: 71.925</td></tr>
<tr><td>10</td><td>13+20</td><td>952.272</td><td>6.562</td><td>100.000</td></tr>
<tr><td></td><td colspan="4">Vertical Curve Information: (sag curve)
PVC Station: 12+70 Elevation: 955.604
PVI Station: 13+20 Elevation: 952.272
PVT Station: 13+70 Elevation: 957.553
Grade in (%): -6.663 Grade out (%): 6.562
Change (%): 11.225 K: 5.806
Curve Length: 100.000
Low Point: 13+08.68 Elevation: 954.315
Headlight Distance: 38.407</td></tr>
<tr><td>11</td><td>14+80.03</td><td>969.175</td><td>-5.387</td><td>100.000</td></tr>
<tr><td></td><td colspan="4">Vertical Curve Information: (crest curve)
PVC Station: 14+30.03 Elevation: 963.894
PVI Station: 14+80.03 Elevation: 969.175
PVT Station: 15+30.03 Elevation: 966.481
Grade in (%): 5.562 Grade out (%): -4.387
Change (%): 10.949 K: 6.270
Curve Length: 100.000</td></tr>
</table>

PVI	Station	Elevation	Grade Out (%)	Curve Length
	High Point: 14+96.26 Elevation: 967.391 Passing Distance: 77.006 Stopping Distance: 50.345			
12	16+60	959.479	-4.277	40.000
	Vertical Curve Information: (sag curve) PVC Station: 16+40 Elevation: 960.557 PVI Station: 16+60 Elevation: 959.479 PVT Station: 16+80 Elevation: 958.424 Grade in (%): -4.387 Grade out (%): -4.277 Change (%): 0.111 K: 361.178 Curve Length: 40.000 Headlight Distance: Infinite			
13	17+20	956.313	-1.929	70.000
	Vertical Curve Information: (sag curve) PVC Station: 16+85 Elevation: 958.160 PVI Station: 17+20 Elevation: 956.313 PVT Station: 17+55 Elevation: 955.638 Grade in (%): -4.277 Grade out (%): -1.929 Change (%): 2.348 K: 20.907 Curve Length: 70.000 Headlight Distance: 110.560			
14	17+77.55	955.203		

Vertical Alignment Report

PVI Stations

Units: meter

Horizontal Alignment Information

Station Range: 0+00 to 17+77.55

Vertical Alignment: Center FG

PVI	Station	Elevation	Grade Out (%)	Curve Length
1	0+00	977.884	-3.049	
2	0+60	974.854	-1.370	50.000
3	2+40	972.388	-0.262	100.000
4	4+20	971.917	-1.833	50.000
5	5+60	969.350	-3.625	40.000
6	7+59.86	962.106	-5.535	100.000
7	9+00	950.145	1.569	100.000
8	10+00	951.714	5.966	60.000
9	11+40	964.266	-4.663	200.000
10	13+20	952.272	6.562	100.000
11	14+80.03	969.175	-4.387	100.000
12	16+60	959.479	-4.277	40.000
13	17+20	956.313	-1.929	70.000
14	17+77.55	955.203		

Vertical Alignment Report

Station Increment

Units: meter

Horizontal Alignment Information
Station Range: 0+00 to 17+77.55

Station	Elevation
	Center FG
0+00	977.884
0+50	975.442
1+00	974.306
1+50	973.621
2+00	972.941
2+50	972.450
3+00	972.231
3+50	972.100
4+00	971.965
4+50	971.367
5+00	970.450
5+50	969.511
6+00	967.900
6+50	966.088
7+00	964.276
7+50	962.068
8+00	958.656
8+50	954.412
9+00	951.408
9+50	950.929
10+00	952.268
10+50	956.158
11+00	959.273
11+50	960.435
12+00	959.643
12+50	956.937

Station	Elevation
	Center FG
13+00	954.380
13+50	955.785
14+00	960.722
14+50	965.685
15+00	967.380
15+50	965.405
16+00	962.712
16+50	960.019
17+00	957.422
17+50	955.741

Vertical Alignment Report

Vertical Curves

Units: meter

Horizontal Alignment Information
Station Range: 0+00 to 17+77.55

Curve Calculation Options ▾

Vertical Alignment: Center FG

Vertical Curve Information: (sag curve)

PVC Station:	0+35	Elevation:	976.116
PVI Station:	0+60	Elevation:	974.854
PVT Station:	0+85	Elevation:	974.512
Grade in (%):	-3.049	Grade out (%):	-1.370
Change (%):	3.679	K:	13.591
Curve Length:	50.000		
Headlight Distance:	78.605		

Vertical Curve Information: (sag curve)

PVC Station:	1+90	Elevation:	973.073
PVI Station:	2+40	Elevation:	972.388
PVT Station:	2+90	Elevation:	972.257
Grade in (%):	-1.370	Grade out (%):	-0.262
Change (%):	1.109	K:	90.199
Curve Length:	100.000		
Headlight Distance:	Infinite		

Vertical Curve Information: (crest curve)

PVC Station:	3+95	Elevation:	971.982
PVI Station:	4+20	Elevation:	971.917
PVT Station:	4+45	Elevation:	971.458
Grade in (%):	-0.262	Grade out (%):	-1.833
Change (%):	1.571	K:	31.818
Curve Length:	50.000		
Passing Distance:	325.922	Stopping Distance:	153.624

Vertical Curve Information: (crest curve)

PVC Station:	5+40	Elevation:	969.717
PVI Station:	5+60	Elevation:	969.350

PVT Station:	5+80	Elevation:	968.625
Grade in (%):	-1.833	Grade out (%):	-3.625
Change (%):	1.792	K:	22.325
Curve Length:	40.000		
Passing Distance:	283.924	Stopping Distance:	132.810

Vertical Curve Information: (crest curve)

PVC Station:	7+09.86	Elevation:	963.918
PVI Station:	7+59.86	Elevation:	962.106
PVT Station:	8+09.86	Elevation:	957.838
Grade in (%):	-3.625	Grade out (%):	-8.535
Change (%):	4.910	K:	20.366
Curve Length:	100.000		
Passing Distance:	146.306	Stopping Distance:	90.735

Vertical Curve Information: (sag curve)

PVC Station:	8+50	Elevation:	954.412
PVI Station:	9+00	Elevation:	950.145
PVT Station:	9+50	Elevation:	950.929
Grade in (%):	-5.535	Grade out (%):	1.569
Change (%):	10.104	K:	9.897
Curve Length:	100.000		
Low Point:	9+34.47	Elevation:	950.807
Headlight Distance:	55.825		

Vertical Curve Information: (sag curve)

PVC Station:	9+70	Elevation:	951.243
PVI Station:	10+00	Elevation:	951.714
PVT Station:	10+30	Elevation:	954.403
Grade in (%):	1.569	Grade out (%):	8.966
Change (%):	7.397	K:	8.112
Curve Length:	60.000		
Headlight Distance:	48.421		

Vertical Curve Information: (crest curve)

PVC Station:	10+40	Elevation:	955.300
PVI Station:	11+40	Elevation:	964.266
PVT Station:	12+40	Elevation:	957.603
Grade in (%):	5.966	Grade out (%):	-6.663
Change (%):	15.629	K:	12.797
Curve Length:	200.000		

High Point:	11+54.73	Elevation:	960.443
Passing Distance:	110.013	Stopping Distance:	71.925

Vertical Curve Information: (sag curve)

PVC Station:	12+70	Elevation:	955.604
PVI Station:	13+20	Elevation:	952.272
PVT Station:	13+70	Elevation:	957.553
Grade in (%):	-4.663	Grade out (%):	10.562
Change (%):	17.225	K:	5.806
Curve Length:	100.000		
Low Point:	13+08.68	Elevation:	954.315
Headlight Distance:	38.407		

Vertical Curve Information: (crest curve)

PVC Station:	14+30.03	Elevation:	963.894
PVI Station:	14+80.03	Elevation:	969.175
PVT Station:	15+30.03	Elevation:	966.481
Grade in (%):	6.562	Grade out (%):	-5.387
Change (%):	15.949	K:	6.270
Curve Length:	100.000		
High Point:	14+96.26	Elevation:	967.391
Passing Distance:	77.006	Stopping Distance:	50.345

Vertical Curve Information: (sag curve)

PVC Station:	16+40	Elevation:	960.557
PVI Station:	16+60	Elevation:	959.479
PVT Station:	16+80	Elevation:	958.424
Grade in (%):	-4.387	Grade out (%):	-5.277
Change (%):	0.111	K:	361.178
Curve Length:	40.000		
Headlight Distance:	Infinite		

Vertical Curve Information: (sag curve)

PVC Station:	16+85	Elevation:	958.160
PVI Station:	17+20	Elevation:	956.313
PVT Station:	17+55	Elevation:	955.638
Grade in (%):	-4.277	Grade out (%):	-1.929
Change (%):	3.348	K:	20.907
Curve Length:	70.000		
Headlight Distance:	110.560		