



Wolkite University, College of Engineering and Technology

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**Title: Street Design Project in Wolkite University from Entrance 2
To Entrance 3 (Infront Wolkite university dormitories).**

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Preface

This document is a report as a part of fulfilment for a Bachelor of science in Civil Engineering.

The study is conducted by **Kedir Abas, Amanuel Mathewos, Anuwar Miftah, Dawit Wujira, Nurhusen Kemal and Balow Lijalem**

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And also, we would like to acknowledge yet importantly, group members all are participated actively and some peoples they live at our project area for them great motivation, ideal supporting, and by giving full information about site condition and need of society. Lastly bout not the end, we would like to give great thanks for Mr. Mikre, who is chief surveyor, we also thanks for those soil laboratory technicians at Wolkite University.

ABSTRACT

Street, as an element which forms the largest portion of public spaces in a city, is of great importance. Since their formation, the streets have been the center of the social, cultural and economic life of cities.

Our Proposed project covers design of Local Street In our country there are different problems on highway, most of the problems are regarding to the design and material quality. With regarding this problem, we will try to give clamp down the problem associated to this. Therefor as much as possible as streamline we are performing the project consideration as follow, identifying topography of project terrain type, perform geometric design depend on design standard of AACRA 2013, Using good pavement material throughout conducting essential test and providing adequate thickness, providing well drainage system, and throughout a year using Proper maintenance.

This Report is concern with the design of Urban highway design case study of Entrance 2 to 3 in Wolkite University Local Street Project Engineering Design Report. The main report is divided into Ten chapters. In this street design Report, the first is Introduction to street design and the context of urban street, second chapter includes details and description of the location project, critical evaluation of climate, topography, geology, economy, the and third chapter is traffic survey controls and analysis which is design period entail traffic volume (AADT), traffic growth rate.

The Fourth chapter dells upon the geometric design those are like Terrain, horizontal alignment, vertical alignment, gradient, cross section element, selection and configuration of the elements that comprise the roadway cross section and describes about the elements used in carrying out detailed cross section design. fifth describes about Crossectional elements of street design. The Sixth chapter describes about earthwork including earthwork quantity and mass haul diagram.

The seventh chapter is referees to about pavement design which is flexible pavement by both AACRA and AASHTO with the help of traffic analysis and soil laboratory result. Chapter Eight is also study about highway drainage and culvert design using annual average rainfall & climate of our project area. Chapter Nine deals about miscellanies of the project with related to traffic signals so as to reduce traffic accident. The last chapter describes about general conclusions and recommendation of this project.

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ACRONYMS

AADT: Average Annual Daily Traffic
AASHTO: American Association of State Highway and Transportation Officials
ADT: Average Daily Traffic
ASTM: American Society for Testing Materials
BS: British Standards
CBR: California Bearing Ratio
CL: Chord length
DC: Design Class
DTM: Digital terrain model
DV: Design Vehicle
ERA: Ethiopian Roads Authority
ESA: Equivalent Standard Axle
ESAL: Equivalent standard axle load
FHD: Free haul distances
GDP: Gross domestic product
LL: Liquid Limit
MDD: Maximum Dry Density
OMC: Optimum Moisture Content
PC: Point of curvature
PT: Point of tangency
PI: Plasticity Index
PL: Plastic Limit
PSD: Passing site distance
ROW: Right of Way
SN: Structural Number

INTRODUCTION

Street is a type of urban spaces which forms the highest percentage among different types of it and is regarded as an important part of the main structure of a city. This space performs like a catalyst in urban evolutions and can bring vitality back to the urban environment[1]. (GDCI; global street design guide, 2016). Social, cultural and economic activities have always existed in the streets since the creation of cities, but with the advent of modernism, the role of the street has completely altered, and since then it has been designed for the movement of automobiles. Therefore, wide lanes for private cars and insignificant space for pedestrians became the fundamental rules of road design around the world. However, in recent years due to the increasing attention to the importance of walk able design, the immediate manner has changed into creating livable streets[2].

In recent decades, designing the streets has been conducted by the transportation planning engineers. They help automobiles to move freely in the streets via increasing the number and width of the lanes, eliminating on-street parking spaces and decreasing the sidewalks' spaces and hence they gradually came in for being regarded as the main designers of the streets[3]. These streets that were designed to encourage the movement and high speed of automobiles could not guarantee the safety of people. Therefore, a high number of street design manuals were provided the world over, to restore the safety of streets and encourage the movement of pedestrians, cyclists and public transportation. Preparing these manuals shows the widespread paradigm shift in terms of street design[4].

1.2. Objectives of the project

1.2.1. General objective

As a highway engineer the main objective of this project is to design safe, easy and economical road and street design project for the root entrance 2 to entrance 3 in Wolkite University South Nation Nationality and peoples Region.

1.2.2. Specific objectives

The specific objectives of the project include:

- To carry out detailed Engineering design and topographic survey.
- To exercise working manuals (ERA, AACRA and AASTHO) manuals
- Design of street and design economic and safe local street concept and pedestrian-friendship street
- To consider traffic modeling, loading and forecasting.
- To design pavement and geometric elements and to determine numbers layers required

- To establish the horizontal and vertical alignment of road cross sections etc.

1.3 The Role of Street

Streets, as mentioned by Jane Jacobs, are regarded as the place of social interactions, vitality and sense of community. (Jacobs, 2016) Social, cultural and economic lives were the prerogative of streets since thousands of years ago. In fact, this old and traditional space is a symbol of freedom, vitality, face-to-face communication and evolution[1].

With the advent of modernism, the traditional pattern of streets and city structures completely altered. For the modernists, street was a corridor for moving from A to B and the city life was not a significant aspect of it. In fact, with the advent of modernism, streets changed from a place for life to a place for mobility. In the plan of Contemporary City that was prepared in 1922, Le Corbusier presented a complex of towers, open spaces and a new type of street[5]. This new type of street was like an instrument for the movement of motor vehicles and was designed exclusively for the personal cars, without considering the pedestrians and land uses. This trend in the early decades of the 20th century resulted in deterioration of streets and consuming a great deal of outlay and energy to construct highways[4].

1.4 Urban Street Design

According to Appleyard, the author of “Livable Street”, street is regarded as space which can be experienced differently depending on people’s various perceptions, has undergone many evolutions in its structure over time. In the early years of the modern era, the streets were designed according to the high-speed vehicle movements and private car access. From the beginning of the recent century in North America, the idea of "Complete Street" presented as the pattern of street design which aimed to provide safe accessibility for all street users. The term "Complete Street" or "Street for everyone" was first used by the League of American Bicyclist. According to Appleyard, the author of “Livable Street”, street is regarded as space which can be experienced differently depending on people’s various perceptions, has undergone many evolutions in its structure over time. In the early years of the modern era, the streets were designed according to the high-speed vehicle movements and private car access[5].

In 2013, the National Association of City Transportation Officials (NACTO) represented “Urban Street Design Guide” in New York City. It has laid out the principles and vision for a new generation of city street design which seeks to more pedestrian-friendly streets and more sustainable public transit design[2].



Figure 1. urban street design[2]

Global Street Design Guide introduces great designed streets as a public space where multi-functional activities, urban furniture, green infrastructures and social life promotion are included. This guideline suggests ten key design principles for designing streets and intersections including[3]:

1. Streets for everyone (Inclusive Design for children, seniors and people with disabilities)
2. Streets are multidimensional spaces (People experience with all their senses)
3. Streets for safety (Design to be safe and comfortable for all users)
4. Streets for health (Support healthy environments and life style choices)
5. Streets are public spaces (A place for cultural expression, social interaction and public demonstration)
6. Streets as ecosystems (Improve the biodiversity and quality of urban ecosystems)
7. Streets for context (Support current and planned contexts and multiple scales)
8. Streets are multimodal (Design for a range of mobility choices)
9. Great streets, Great values (To be an economic asset as well as a functional element)
10. Streets can change (Allowing people to experience the streets differently)

1.5 Our Project and Street from Global Manuals perspective

“Global Street Design Guide” has presented urban street design principles and claims that its proposed solutions can be applied in all cities of the world with regard to their local culture and context. In this manual, streets are categorized according to their width, and their function and samples of similar projects are presented[2]. Entrance 2 to entrance 3 Street with the width of 50m in Wolkite University (in front of dormitories) can be placed in the category of "Main Local Street". According to the special role of Street which is in to the Wolkite University and its related buildings, it is needed to design it more distinct than a main local street. In Global Street Design Guide, a category is presented named “Special Conditions”, and some features of these conditions are similar to features of Entrance 2 to 3 Street. For instance, there are conditions such as wide travel lane, low traffic volume, high speed, Considering the emphasis pedestrian movements and cycling, measurements such as reducing the street width to a single lane, widening sidewalks and providing green infrastructure along with the creation of urban furniture and artworks on both sides of the street are suggested.

1.6 Proposed plan of the project

The status entrance 2 to 3 Streets indicates its compatibility with the features of the collector-distributor Street which is a subcategory of minor arterials or Local Street, in the AACRA Design Manual. Through on-site observation, it has been acquired that the width of the lanes is 3.5m and the design speed is 30km/h, and no measurement has been taken to decrease the speed of vehicles.

In this study, the design of the Entrance 2 to 3 Street is presented with a new approach in accordance with the Global Street Design Guide and AACRA to prioritize pedestrian movement, increasing its open and public spaces and improving the identity of this street. The solutions used in this plan are illustrated in FIGURE 2. Those are the recommendations that can be adapted to the context of this street. Therefore, they can be used to reduce the speed of vehicles, increase the safety of pedestrians and improve the quality and quantity of open and public spaces.

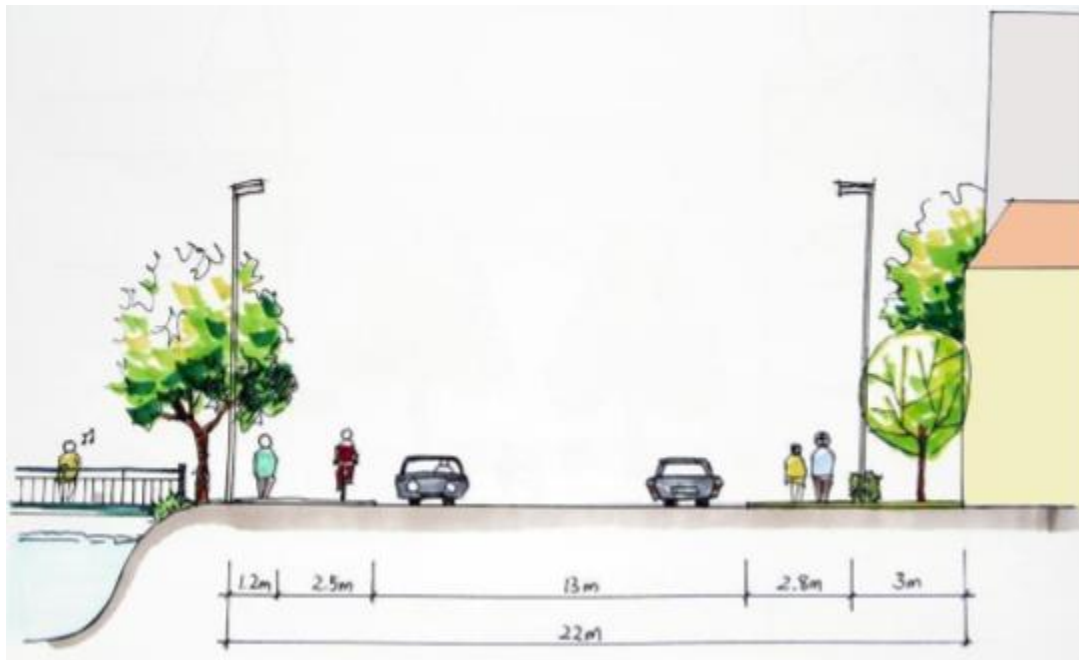


Figure 2:-Design Solutions Concerning the Global Street Design Guide and the Context of Street Design ([2])

1.7. General Methodology

In this project, the reconnaissance surveying is conducted to obtain the general information about the area, control points were established, Next centerline of the proposed road was set out and detail topographic data were collected. Then, soil samples were taken at different stations and required tests are undertaken. Traffic forecasting and modeling were conducted. Based on the test result the detail

pavement design was conducted. Using collected data and additional information gathered from different sources, the hydraulics and geometric design were done. Finally, the earthwork was computed and plan was prepared. For surveying data collection, the latest surveying instrument (Total station) was used. For data processing the popular engineering software (Auto Cad civil 3d 2020) will have utilized. In addition, the ERA, AACRA and AASHTO Design manuals are fully consulted

2 The project Area

2.1 Location

The project area is located in South Nation Nationalities and Peoples in Wolkite University. The project is the proposed local street in Wolkite University (from entrance 2 to 3). It covers total 1.335km. This street is at the central part of the Wolkite University and in fronts of dormitories and hence it is a very important corridor for good and safe local street design. The project location map is shown in the figure taken from Google Earth pro.



Figure 3. location of the study Area in Wolkite University[6]

2.2 Rainfall

Gubre weather station has respective annual, *belg* and *kiremt* mean rainfall of 1182.2, 282.26 and 796.43 mm. The annual and seasonal rainfall totals showed that the area has moderate to high variable rainfall condition. Observed trends also indicated decreasing in *belg* rainfall and an increasing in annual and *kiremt* rainfall totals, but trend was non-significant[7]

2.3 Temperature

The study area has a mean annual, *belg* and *kiremt* maximum temperature of 27.03, 27.7 and 24.1 OC and Also has a mean annual, *belg* and *kiremt* minimum temperature of 12.8, 12.9 and 13.4 OC, respectively. Annual and *belg* maximum temperature showed an increasing trend, but *kiremt* maximum temperature revealed a decreasing trend. However, the temporal variability of maximum temperature is less as

Compared to minimum temperature. The changes in maximum temperature during *belg* and *kiremt* season were statistically significant, but not in the annual basis. Significant decreasing trends were also found in annual, *belg* and *kiremt* minimum temperatures[7].

2.4. Topography

Terrain type, which is the measure of the natural topography, has an influence on the selection of alignment and gradient. Construction cost also varies with terrain type and sub grade nature of the area. By measuring the two-point slope using AUTOCAD CIVIL 3D 2019 software, the slope of this project terrain type is flat to rolling terrain.

2.5 Economy

The major economic activity of the population along the road corridor and its influence area is agriculture. The area is intensively cultivated for crop production.

Finally, the road plays a great role in the development of the area and ultimately the development of the country as a whole[7].

2.6 Limitation

During performing the overall activity of this work, we have got challenges like transportation problem to access project site, lab class limitation which has internet connection, availability of data limitation and economical limitation. As a whole there is less coordination of government and society in design and construction of infrastructure that plays great role to develop our country.

3 TRAFFIC SURVEYS

For the purpose of traffic survey is taking the design parameters or controls as they influence the selection and calculation of the parameters[8],[9]. These controls are:

- Level of service
- The functional classification of the road
- Natural terrain of the road site
- The design vehicle which the road is expected to serve
- The expected volume and load of traffic
- Economic consideration

As these factors have a major role in the design process they should be properly analyzed and studied.

3.1. Level of service

Level of Service relates to the operating conditions encountered by traffic. It is a qualitative measure of such factors as speed, trip time, interruptions, interference, freedom to overtake, ability to maneuver, safety, comfort, convenience and vehicle operating costs[9].

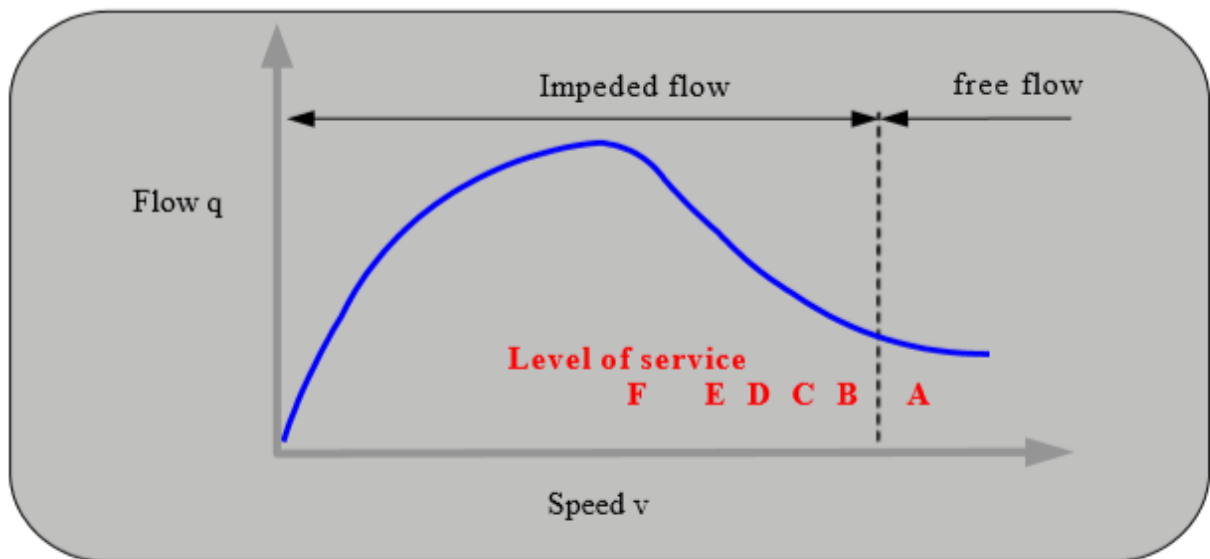


Figure 4 level of service (AACRA fig 5.2.4)

Table 1: level of service (AACRA 2013 fig 5.2.4)

Level of Service	Freeways	Other Arterial Roads
A	Free flow. Average travel speeds at or greater than 112 km/h. Service flow rate of 700 passenger cars per hour per lane, or 32% of capacity.	Average travel speed of about 90% of free flow speed. Stopped delay at signalized intersections is minimal.
B	Reasonably free flow conditions. Average travel speed at or greater than 112 km/h. Service flow rate not greater than 1,120 passenger cars per hour per lane, or 51% of capacity.	Average travel speeds drop due to intersection delay and inter-vehicular conflicts, but remain at 70% of free flow speed. Delay is not unreasonable.
C	Operation stable, but becoming more critical. Average travel speed of 110 km/h. Service flow at 75% of capacity or not more than flow rate of 1,650 passenger cars per hour per lane.	Stable operations. Longer queues at signals result in average travel speeds of about 50% of free flow speeds. Motorists will experience appreciable tension
D	Lower speed range of stable flow. Operation approaches instability and is susceptible to changing conditions. Average travel speeds approximately 101 km/h. Service flow rates at 92% of capacity. Flow rate cannot exceed 2,015 passenger cars per hour per lane.	Approaching unstable flow. Average travel speeds down to 40% of free flow speed. Delays at intersections may become extensive.
E	Unstable flow. Average travel speeds of 96 km/h. Flow rate at capacity or 2,200 passenger cars* per hour per lane. Traffic stream cannot dissipate even minor disruptions. Any incident may produce a serious breakdown. backed up from downstream bottleneck. Average travel speeds range from near 50 km/h to	Average travel speeds 33% of free flow speed. Unstable flow. Continuous backup on approaches to intersections.
F	Forced flow. Freeway acts as a storage for vehicles backed up from downstream bottleneck. Average travel speeds range from near 50 km/h to stop and-go operation	Average travel speed between 25 and 33% of free flow speed. Vehicular backups, and high approach delays at signalized intersections.

Level of service characteristics

It is desirable to aim for Level of Service C for off peak travel, accepting that peak hours will operate closer to capacity conditions[10]. Therefore, for our road project we maintain this level of service. The level of service is enhanced by providing:

- Full lane widths
- Appropriate storage lanes at intersections
- left turn lanes at intersections and accesses where appropriate
- Control or absence of crossing or entering traffic at minor intersections
- Control or absence of parking
- Control or absence of left turns by banning left turns at difficult intersections
- Good coordination of traffic signals
- Good lighting of the road for night time driving

3.2. Traffic Loading and Volume

Traffic is the most important factor in pavement design and stress analysis. Traffic constitutes the load imparted on the pavement causing the stresses, strains and deflections in the pavement layers and the sub grade. Hence, the pavement design must account for traffic load expected over its design life.

The traffic loads on pavement can be characterized by:

- Magnitude of load (wheel load or axle load)
- Configuration of load (axle and wheel configuration – single/dual wheel, single/tandem/tridem axle, wheel and axle spacing): - these relate to the number of contact points per vehicle (no. of wheels) and their spacing. As spacing between wheels gets smaller, then their influence areas will overlap and one has to consider the combined effect of all interacting wheel loads instead of dealing with a single wheel load.
- Load repetitions: Loads, along with the environment, damage pavement over time. Each individual load (from commercial vehicles) inflicts a certain amount of unrecoverable damage. This damage is cumulative over the life of the pavement and when it reaches some maximum value, the pavement is considered to have reached the end of its useful service life.

- Other considerations include tire pressure, contact area, vehicle speed, and traffic distribution across the pavement etc.

3.3. Natural terrain of the road site (terrain classification)

According to ERA Terrain classification is based on the transversal slope of the area. The terrain classification shows the topographical aspect of the road. We used ERA’s manual to classify the terrain. We used a corridor width of 20m.

Table 2. ERA Manual terrain classification

	Terrain type	Slope (%)	Terrain character
1	Flat	0-5%	Flat or gently rolling country offers few obstacles unrestricted horizontal and vertical alignment
2	Rolling	5-25%	Rolling, hilly or foothill country Slopes rise and fall Moderately occasional steep slopes some restrictions in alignment
3	Mountainous	25-50%	Rugged, hilly and mountainous country and river gorges definite restrictions of alignment long steep grades and limited sight distance
4	Escarpment	>50%	switchback roadway side hill transverse sections where earthwork quantities are considerable

For our project the terrain type will be identified after geometric design analyzes.

3.4 Traffic Analysis

The deterioration of paved roads is caused by traffic results from both the magnitude of the individual wheel loads and the number of times these loads are applied. Hence, to design a paved highway, it is necessary to consider not only the traffic volume or the total number of vehicles that will use the road but also to predict the number of repetitions of each axle load group (or wheel load group) during the design period. To convert the traffic volumes into cumulative equivalent standard axle loads (ESAL or CESAL, which is one design parameter in pavement design) equivalency factors are used[11],[10].

On the other hand, the mechanism of deterioration of gravel roads differs from that of paved roads. Design of thickness of gravel roads is directly related to the number of vehicles using the road rather than the number of equivalent standard axles as that for paved roads. The traffic volume is therefore used in the design of unpaved roads (gravel roads), as opposed to the paved roads which require the conversion of

traffic volumes into the appropriate cumulative number of equivalent standard axles. In this section, method of determining the traffic volume and CESAL with reference to Ethiopian Roads Authority (ERA) Pavement Design Manual will be discussed.

- The deterioration of paved roads by traffic results both from magnitude of load repetition of Load[10].

Hence, to design a paved highway, it is necessary to consider the traffic volume or the total number of vehicles that will use the road &

- To predict the number of repetitions of each axle load group (or wheel load group) during the design period

The traffic volume is converted into cumulative equivalent standard axle loads (ESAL or CESAL) using equivalency factors (EALF). CESAL is one design parameter in pavement design[10].

- Design of thickness of gravel roads is more related to the number of vehicles using the road rather than the CESAL.
- The Traffic Volume in terms of initial AADT is used in the design of unpaved roads (gravel roads),
- Gravel Roads - mechanism of deterioration of gravel roads different from that of paved roads

The following Parameters and Considerations/Steps are involved in Traffic Analysis for pavement design.

3.5 Traffic Growth Rate (Traffic Forecast)

I. Traffic growth rate

Based on road traffic survey information, it is reasonable in most circumstances to assume traffic volumes will increase geometrically.in the absence of growth figures (mainly GDP) AACRA recommends to select the growth rate based on economic growth zone in which the road project is located and the design period[10]. The following growth rate matrix provides an appropriate growth rate for road projects in Addis Ababa.

- ✓ Very uncertain process

- ✓ Requires making analysis and forecast of past and future traffic growth trends, social and economic development trends, etc.

Table 3 Table 4 Economic Growth Rate Zones in Addis Ababa

classification	Economic growth zone					
	1	2	3	4	5	6
Arterial	7.0	11.2	7.0	11.1	7.2	9.3
Sub-arterial	6.5	9.3	6.5	9.2	6.6	8.2
Collector	6.0	7.4	6.0	7.4	6.1	6.8
Local	5.5	5.5	5.5	5.5	5.5	5.5

After carefully analyzing Wolkite university master plan we classified the road project area to be in growth zone of 6. With this growth zone and a local street road class the required growth rate can easily be read from the growth matrix to be 5.5%.

II. Traffic Forecasting

In forecasting, traffic characterized in to the following:

Normal Traffic: Traffic that would pass along the existing road or track even if no new or improved pavement provided. The most common method of forecasting normal traffic is to extrapolate data on traffic levels and assume that growth will either remain constant in absolute terms i.e. a fixed number of vehicles per year, or constant in relative terms (a fixed percentage increase). As a general rule it is only safe to extrapolate forward for as many years as reliable traffic data exist from the past, and for as many years as the same general economic conditions are expected to continue.

As an alternative, growth can be related linearly to anticipate growth of Gross Domestic Product (GDP). This is normally preferable since it explicitly takes into account changes in overall economic activity. Whatever the forecasting procedure used, it is essential to consider the realism of forecast future levels.

Diverted Traffic: Traffic that changes from another route to the project road because of the improved pavement, but still travels between the same origin and destination. Where parallel routes exist, traffic will usually travel on the quickest or cheapest route although this may not necessarily be the shortest. Thus, surfacing an existing road may divert traffic from a parallel and shorter route because higher speeds are possible on the surfaced road. Origin and destination surveys should preferably be carried out to provide data on the traffic diversions likely to arise. But by referring different completed projects from the existing condition of Entrance 2 to 3 in Wolkite University Road project, we apply diverted traffic 13%, since there is no alternative route around this road and so the diverted traffic is not present throughout this route.

Generated Traffic: Additional traffic which occurs in response to the improvement of the road. Generated traffic arises either because a journey becomes more attractive by virtue of a cost or time reduction or because of the increased development that is brought about by the road investment. Generated traffic is also difficult to forecast accurately and can be easily overestimated. For this specific project we use an approximate value of generated traffic 30% of normal traffic by due consideration their capacity and economic standards of the society that they live around the corridor of Entrance 2 to 3.

3.6 Design period

The design period is the length of time expected in years before it is anticipated that rehabilitation of the pavement will be necessary to restore shape, repair other forms of distress, or to provide additional pavement strength. Rehabilitation which may consist of granular or asphalt overlay, major patching or improvements or removal of selected areas of pavement materials, initiates a new design period. The design period starts when the completed pavement is opened to public traffic over the entire length of a construction project[9].

From AACRA manual for most road projects an economic period of 20 years from the date of opening is appropriate. Therefore, for our road project a design period of 20 years is selected.

- It may arise either because a journey becomes more attractive by virtue of a cost or time reduction or because of the improved development that is brought about by the road investment.

3.7 Functional classification of the road

For this purpose, AACRA classified the roads into five categories. These are freeway, arterial, sub arterial, collector and local streets. Based on the given traffic volume and property access issues we can now select our project road class.

Freeways: freeway status is applied only too high speed, high volume arterial roads with full control of access. Freeway is grade separated multi-lane roads with no property access allowed[9].

Urban arterial and sub-arterial: are the major traffic routes in Addis Ababa. Urban arterials are usually dual function facilities providing service to;

- Through traffic (primary function)
- Local traffic and property access (secondary function)[9]

Feeder and local streets: the road layout should conform to the requirements of the external road network and satisfy the transport provisions of the city master plan[10]. The internal road system should not provide through routes that are more convenient than the external road network. Where a road is needed that provides a convenient through route, then sub arterial road (local crossing route) could be considered with appropriate capacity and abutting land use[9].

Table 4.1 AACRA Functional Road Classification (Table 6.2)

Road classification	AADT (two way)	Typical percentages (%)				
		car	Light	medium	heavy	articulated
Freeway	-	-	-	-	-	-
Arterial	10,000	80%	17%	2%	0%	1%
Sub-arterial	9000	89%	9%	1%	0%	1%
Collector	4000	91%	8%	1%	0%	0%
Local street	1500	97%	3%	0%	0%	0%

Our estimate data 1500 AADT exactly coincide with typical percentage of vehicle classes for Local Street Road. Also, the property access criteria are satisfied. Therefore, we chose our road section to be local street. The traffic data was collected based on an Origin Destination survey. The count is as given below;

Table 5. counted AADT value

Road Section	AADT (Two Way)	CAR	Light	Medium	Articulated
WKU from entrance 2 to 3	1500	1455	45	-	-










3.8 Vehicle classification

Small axle loads from private cars and other light vehicles do not cause significant pavement damage. --- Damage caused by heavier vehicles (commercial vehicles)[9].

Hence, important to distinguish and grouping vehicles into categories.

- The proportion of vehicles which cause pavement damage (commercial vehicles) from total traffic. To do this, we need to have a vehicle classification system,
- To distinguish between commercial vehicles and small cars. Distinguish between the different types of commercial vehicles and group them according to their type, size (loading), configuration[9], etc.

Table 6. AACRA vehicle classification system (Table 6.1)

Category	Cars	Light	Medium	Heavy	Articulated
Axles	2	2	3	4	>4
Tyres	4	6	10	14	>14
Length	<3 m	3m – 7.5m	3m – 7.5m	>7.5m	>7.5m
GVW	<3.5T	3.5T-12T	>12T	>12T	>12T
Includes	Cars  Utility  Minibus  4WD 	Bus  1 Axle Truck 	2 Rear Axle Truck 	4 Axle Truck 	Large Truck 

3.8.1 Determine Traffic Volume (ADT, AADT)

I) Traffic Count

Traffic Count necessary

- ☞ To assess the traffic-carrying capacity of different types of roads
- ☞ Examine the distribution of traffic between the available traffic lanes
- ☞ In the preparation of maintenance schedules for in-service roads
- ☞ In the forecasting of expected traffic on a proposed new road from traffic studies on the surrounding road system
- ☞ Traffic volume data determined from

- ☞ Historical traffic data available in relevant authorities (ERA conducts regular 3 times a year (Feb., Jul., Nov.) traffic counts on its major road network).
 - By conducting classified traffic counts
 - On the road to be designed- if the road is an existing road
 - On other parallel routes and /or adjacent roads – for new roads
- ✓ Traffic volume data may vary daily, weekly and seasonally
- ✓ Hence to avoid error in traffic analysis and capture the average yearly trend, minimum seven days count recommended
- ✓ ERA recommended procedure
 - conduct seven days classified traffic count
 - 5 days for 16 hrs.
 - Minimum 2 days for 24 hrs[12].

II) ADT (Average Daily Traffic)

- ADT is determined from the traffic count data as follows
- Adjust the 16hrs traffic count data into 24hr data by multiplying with the average night adjustment factor

Night adjustment factor = (24hr traffic)/ (16hr traffic): - obtained from the two days 24hr count data.

- (ADT)_o = the current Average Daily Traffic= Average of the 7 days 24 hr. traffic volume data[8].

III) (AADT)_o (Annual Average Daily Traffic = total annual traffic in both directions divided by 365)

- In order to capture the average annual traffic flow trend, adjustment must be made for seasonal traffic variation,
- Hence traffic count as above must be made at different representative seasons (ERA conducts traffic counts on February, July and November)

- Make adjustment to (ADT)_o – based on the season at which the current traffic count belongs to and based on seasonal adjustment factors for the road (or similar roads) derived from historic traffic data (ERA or other regional/national sources)

(AADT)_o = (ADT)_o adjusted for seasonal variation[9].

IV) Axle Load Survey

All design of bitumen surfaced road pavements shall be based on axle load survey. The surveys shall be carried out separately from weigh-bridge measurements under taken for the purpose of enforcing axle loads limits. (AACRA)

- Carried out together with the traffic count
- Portable vehicle(wheel) weighing devices or weigh in motion (WIM) devices can be used for survey
- Each axle of the vehicle is weighed and EALF computed for each axle

Equivalency Factor = $(Lx/80)^{4.5}$ **Equation 3.1** [9]

Table 6. Typical Equivalency factor for Addis Ababa

Vehicle Class	Typical	Lower	Upper
Car	0.03	0.00	0.10
Light	0.73	0.39	1.07
Medium	1.31	0.73	1.89
Heavy	1.61	1.05	2.18
Articulated	3.15	2.15	4.14

AASHTO pavement design procedure considers each passage of a tandem or tridem axle assembly as one repetition and EALF calculated correspondingly.

V) Truck factor

- Truck factor can be computed for each vehicle by summing up the number of ESAL per vehicle
- Average truck factor can be computed for each vehicle category (for example for Buses, Light Trucks, Medium Trucks, etc.), by sum min up the ESAL of all the vehicles in each category and dividing by the number of vehicles (of that category) weighed:

$TF_i = \sum \frac{ESAL_j}{n}$ **Equation 3.2**[9]

Where TF_i = Truck factor for the i th vehicle category

n = number of vehicles weighed (of the i th vehicle category) during the axle load survey

$ESAL_j$ = number of equivalent standard axle loads for the j th vehicle.

3.9 Design Traffic Loading

The data and parameters obtained from the studies discussed in the preceding sections now can be used to estimate the design cumulative design traffic volume and loading.

i) Adjustment for Lane and Directional Distribution of Traffic – the AADT should be adjusted as follows

Lane Distribution Factor (P): accounts for the proportion of commercial vehicles in the design lane. For two lane highways, the lane in each direction is the design lane, so the lane distribution factor is 100%. For multilane highways, the design lane is the heavily loaded lane (outside lane).

Table 7. Lane Distribution Factor (ERA/AASHTO)

Numbers of Lanes in each direction	Traffic percent (ESAL) in design lane
1	100
2	80-100
3	60-80
4	50-75

Directional Distribution Factor (D): factor that accounts for any directional variation in total traffic volume or loading pattern. It is usually 0.5 (50%). However, could be adjusted based on actual condition (if there is directional tendency to commercial vehicle distribution (volume or loading); for example, if the heavy vehicles in one direction are loaded and come back empty in the other direction).

ii) Calculating (AADT)¹

- $AADT_1$ = Annual Average Daily Traffic (both directions) at year of Road Opening (year at which construction works are completed and the whole road is made open for traffic).

- If time between traffic count year (design time) and estimated year of road opening = x, then

$$AADT_1 = AADT_0 (1+r)^n \dots\dots\dots \text{Equation 3.3}$$

- Simple calculation for truck
- Note that AADT1 is used as the Design Traffic Parameter for Gravel Roads (**ERA Pavement Design Manual**)

iii) Cumulative Traffic Volume (T) – can be computed for all traffic (T) or for each vehicle class (Ti)

$$T_i = 365 (P) (D) AADT_{1i} [(1+r_i)^N - 1] / (r_i) \dots\dots\dots \text{Equation 3.4[9]}$$

Where;

Ti = cumulative volume of traffic for the ith commercial vehicle class in the design lane over the design period (adjusted for lane distribution and direction).

ri = annual growth rate for the ith commercial vehicle class

P = Lane distribution factor;

D = Directional distribution factor

N = Design Period in years

Simple calculation for truck

$$T_i = 365 (P) (D) AADT_{1i} [(1+r_i)^N - 1] / (r_i) \dots\dots\dots \text{Equation 3.5[9]}$$

iv) Design Traffic (Cumulative Equivalent Standard Axle Load –

CESAL) – is computed by multiplying the total traffic volume for each vehicle category (Ti) by its corresponding truck factor (TFi)

$$\text{Design Traffic Load} = \text{CESAL} = \sum (T_i \times T_{Fi}) \dots\dots\dots \text{Equation 3.6[9]}$$

The CESAL is used to determine the traffic class to be employed for pavement design.

4. Geometric Design

4.1 General

Geometric design for transportation facilities includes the design of geometric cross sections, horizontal alignment, vertical alignment, intersections, and various design details[8]. These basic elements are common to all linear facilities, such as roadways, railways, and airport runways and taxiways[12]. Although the details of design standards vary with the mode and the class of facility, most of the issues involved in geometric design are similar for all modes. In all cases, the goals of geometric design are to maximize the comfort, safety, and economy of facilities, while minimizing their environmental impacts[10]. This chapter focuses on the fundamentals of geometric design, and presents standards and examples from different modes.

Topographic surveying

In this project the team undertook route location and detailed topographic surveying along the project route. Detailed topographic surveys along the length of the alignment have been carried out using *sokkiaset* series total station. The surveying includes:

Reconnaissance surveying to rough examination the route, determine minimum possible gradients, approximate length, and selection of stations etc.

Establishment of control points (BM): In order to tie the project horizontal coordinate (Easting and Northing) with the Ethiopian National Grid System, the Control points and bench marks of the grid system are tied with EMA points near the project area. Their coordinates were acquired from Adama City Administration. The national grid point of the project has been identified and obtained from Ethiopian Mapping Agency. These control points are visible for anyone and about 40cm high from natural ground materialized with tapered concrete monuments and firm iron bars for precise pinpoint. Other control points (BMs') were established using the techniques of traversing. These points are 5 in number.



Fig.4.1 surveying activity

Collection of detail topographic data: Detailed ground survey along the length of the project road was carried out to examine the road alignment and collection of cross-sectional data at 20m interval and 60m width. In addition, other topographic data were collected that are considered necessary to complete the detailed design and the estimation of quantities.

Finally, the data was downloaded to Desktop computer further design.

4.2 Cross section elements of the road

Highway cross sections consist of traveled way, shoulders (or parking lanes), and drainage channels. Shoulders are intended primarily as a safety feature. They provide for accommodation of stopped vehicles, emergency use, and lateral support of the pavement[9].

4.2.1. Medians

A median is the strip of road that separates opposing travelled ways. On freeways, the median width includes the adjacent shoulders. Residual median is the median excluding any shoulders[9].

Medians:

- ✓ Significantly reduce the risk of collision with opposing traffic (clear zone principle)
- ✓ provides space for median barriers and street lighting
- ✓ provide space for traffic signals
- ✓ provide space for direction and regulatory signs

- ✓ improve capacity by restricting access to property and minor side streets
- ✓ provide a safety refuge for pedestrians making it easier and safer to cross busy roads
- ✓ prevent indiscriminate U-turn movements
- ✓ Direct left turn movements to signalized intersections and/or left turn bays
- ✓ provide a place to collect run-off from the road and carry the water to the drainage system
- ✓ accommodate glare screening
- ✓ provide space for public transport (HOV lanes and bus stops, and light rail tracks and platforms), landscape planting
- ✓ provide space for future additional traffic lanes
 - ✓ provide space for underground trunk services and overpass piers
 - ✓ provide space for skylights to pedestrian underpasses, visibility offset on horizontal curves
 - ✓ provide space for parking (town center slow speed streets only)

Medians should be provided on all freeways, arterial roads, sub-arterial roads and most commercial area roads.

We considered a uniform median width of 1.2 m throughout the entire length of the project.

4.2.2. Carriageway

Each carriageway will provide two, three or four through lanes depending on design flows. At intersections, additional lanes for left turns and right turns are usually necessary. Lane widths are normally 3.5m, but lanes as narrow as 3.0m may be appropriate if the right of way is restricted. We selected the carriage width to be 3.5m[9].

Table 8:- Arterial & Sub-Arterial Road Border & Carriageway Dimensions (AACRA table 7.55-A)

Case	Width
Away from intersections absolute minimum pedestrian refuge	1.2
Median barrier (Type F)	1.6
Away from intersections pedestrian/pram/cycle refuge (limited landscape planting – no trees)	2.5
Away from intersections landscape planting with trees 60km/h speed limit	7.0
Away from intersections landscape planting with trees 70km/h speed limit	9.0
Signalized intersection one left turn lane (residual median to be 2.5m for signal pedestal and maintenance plus pedestrian refuge)	5.5-6.0
Signalized intersection two left turn lanes lane (residual median to be 2.5m for signal pedestal and maintenance plus pedestrian refuge)	8.5-9.5
Away from intersections for light rail* no stops	8.5
Away from intersections for light rail* with stops and shelter**	13.0
Near intersections one 3.0m left turn lane and light rail* with stops and shelter**	15.7
Near intersections two 3.0m left turn lanes and light rail* with stops and shelter**	21.7
Median parking with central aisle parallel to carriageways 2.0m clear zone	21.0

4.1.3. Borders on local street Roads

Functions of Borders

- I. Borders on arterial roads and local streets provide room for:
- II. Pedestrian movement on footpaths,
- III. Turning movements between the carriageways and adjacent property entrances
- IV. Road signs and lighting standards
- V. Landscaping, Bus bays
- VI. Providing space for the provision of underground and above ground services
- VII. Providing space for landscaping to improve the appearance of the street environment
- VIII. Providing a drainage function for overland flows providing adequate sight distances for traffic on the road (including cyclists and pedestrians on a path) to see vehicles pedestrians or cyclists entering the roadway from blocks.
- IX. Providing a buffer area for reduction in traffic noise level at dwellings

X. Providing for level differences between carriageway and blocks

XI. providing areas for parking off the carriageway if the road pavement is narrow

The co-location of public telephones, post boxes, bus stops and drop-off bays to create activity nodes on borders is good practice[12].

Border Crossfall

It is usual to slope the footpath and the rest of the border towards the road so that water does not drain on to adjoining properties. Where it is not possible to do this, drainage onto adjacent properties will have to be arranged with the property owners. The slope of the footpath should be 2% - 2.5% so that it drains but is useable by wheelchairs.

An area of approximately 2.5 meters at 2% grade towards the curb is required adjacent to the curb for the following reasons[9]:

- (i) to enable driveway access to blocks without vehicles scraping
- (ii) to provide freeboard for stormwater gutter flows
- (iii) for rubbish bin placement if curb side collection is required
- (iv) for pedestrian and cycle refuge

4.1.4. Shoulders

The shoulder is that portion of freeway carriageway beyond the traffic lanes, adjacent to, and flush with the surface of the pavement. Its purpose is to accommodate stopped vehicles and provide lateral support to the road pavement layers. It also forms part of the clear zone.

The shoulder width is measured from the edge of the traffic lane to the verge. All safety barriers, signs, guide posts, drains and curbs are to be contained outside the shoulder within the verge. Shoulders are not used on urban roads other than freeways. On these roads, parking lanes perform similar functions[9].

4.1.5. Crossfall

i. Pavement Crossfall

Crossfall is defined as the side slope, normal to the alignment, of the surface of any part of the carriageway. Crossfall is provided primarily to facilitate pavement drainage.

The usual arrangement for straight sections of road is for the pavement crossfall to slope down from either the centerline or the median. However, the designer should not be limited to this arrangement as inwards sloping crossfall, or one-way crossfall may be useful for certain grades, drainage or side slope

situations. Crossfall has the important function of shedding water from the roadway to reduce the possibility of a vehicle aquaplaning in wet conditions[9].

Table 9:-Typical Pavement Crossfalls (AACRA table7.8.14-A)

Road surface	Traffic Lane (%)	Shoulder (%)
Cement concrete	2.0-3.0	2.0-4.0
Asphaltic concrete	2.5-3.0	2.5-4.0
Sprayed seal	3.0-3.5	3.0-4.0

Since our street has asphaltic road surface, we took the crossfall for both traffic lane and shoulder to be 2.5%.

ii. Median Crossfall

Medians up to 8 m wide are generally level or follow the crossfall of the road.

Depressed medians greater than 8 m wide should have a desirable crossfall of 1 on 10.

At intersections where signals are to be installed, the median cross slope must match the slope of the road through the intersection and should not be greater than 6%. We selected a median crossfall the same as that of the pavement crossfall (2.5%).

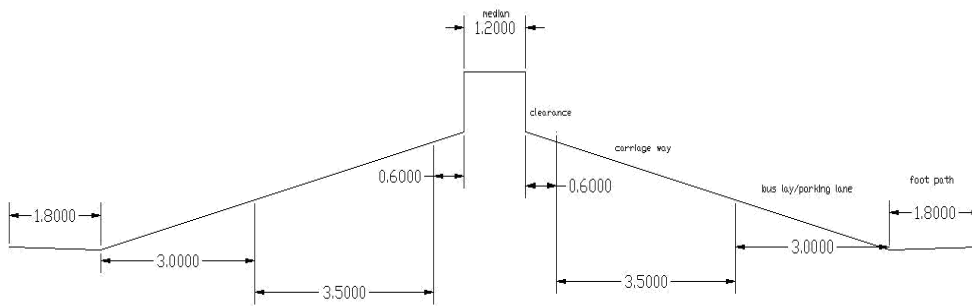


Figure 5 cross section elements

4.2. Number of lane determination

The number of lane for our project was determined using the highway capacity manual. The procedure is shown below.

Basic equation

$$V_p = \frac{V}{phf * N * fhv * fp} \dots\dots\dots \text{Equation 4.1}^{(8)}$$

Where V_p = passenger car equivalent flow rate, pc/hr/ln

V = peak hourly volume, veh/hr

Phf = peak hour factor

N = number of lanes

Fhv = heavy vehicle adjustment factor, and

fp = driver population factor

Rearranging gives the equation for number of lanes to be;

$$N = \frac{V}{phf * V_p * fhv * fp} \dots\dots\dots \text{Equation 4.2}^{(8)}$$

Now each variable can be estimated separately and number of lanes can then easily be calculated.

Peak hourly volume (V)

The peak hourly volume is the highest hourly volume within a 24-hour period. Since the traffic count data is not on hourly basis assuming a percentage of the total traffic count (13% of the average annual daily traffic AADT for our project),

we get $V=0.13*12117=788$ veh/hr

Peak hour factor (phf)

Peak-hour factor (PHF) represents the temporal variation in traffic flow within an hour. Observations of traffic flow consistently indicate that the flow rates found in the peak 15-minute period within an hour are not sustained throughout the entire hour.

Can also be defined as the ratio of the hourly volume to the peak 15-minute flow (V_{15}) enlarged to an hourly value.

$$PHF = V/(V_{15} *4). \dots\dots\dots \text{Equation 4.3}^{(8)}$$

As stated above, the data we are given should be detailed even to 15 min counts to calculate phf. Since it is not, we took the most commonly used range of phf (0.8 to 0.9) for this specific project $phf=0.85$.

Passenger car equivalent flow rate (V_p)

To estimate V_p , first we need to determine the free flow speed.

Free flow speed

Can be determined in two ways. Directly from field measurement and estimated analytically. The free-flow speed of a highway can be determined directly from a speed study conducted in the field. If field measured data are used, no subsequent adjustments are made to free-flow speed. The speed study should

be conducted at a representative location within the highway segment being evaluated; for example, a site on a short upgrade should not be selected within a segment that is generally level. It is recommended that the field study be conducted in periods of low traffic flow (up to a two-way flow of 200 pc/h). The speed study should measure the speeds of all vehicles or a systematic sample (e.g., every 10th vehicle). The speed study should not only measure speeds for unimpeded vehicles but should also include a representative sample of impeded vehicles. A sample of at least 100 vehicle speeds should be obtained. The free-flow speed can be computed based on field data as shown below;

$$FFS = Sfm + 0.0125 V_f / fhv \dots\dots\dots \text{Equation 4.4}^{(8)}$$

Where Sfm= mean speed of traffic measured in field, km/hr
 Vf= observed flow rate for the period when field data were obtained, veh/hr And
 fhv= heavy vehicle adjustment factor, will be discussed later.

The free-flow speed can be estimated indirectly when field data are not available. The free-slow speed is estimated using Equation;

$$FFS = BFFS - fLS - fA \dots\dots\dots \text{Equation 4.5}^{(8)}$$

Were,
 BFFS= base free flow speed, km/hr
 fLS= adjustment for lane width and shoulder width
 fA = adjustment for access points

Base free flow speed is considered to be 11km/hr higher than the speed limit for 65 and 70 km/hr and 8 km/hr higher for 80 and 90 km/hr speed limits (according to HCM). Based on this for our road project with a speed limit of 80 km/hr, BFFS=70+11= 81km/hr. The first adjustment that is used to modify the estimated free-flow speed relates to the effects of lane and shoulder widths. The table below presents the adjustment to modify the estimated free -flow speed for narrower lanes and shoulders.

Table 10:-Adjustment for Lane Width and Shoulder Width (fLS) (HCM)

Lane Width (m)	Reduction in Free-Flow Speed (km/hr)			
	Shoulder Width (m)			
	≥ 0.0 < 0.6	≥ 0.6 < 1.2	≥ 1.2 < 1.8	≥ 1.8
2.7 < 3.0	10.3	7.7	5.6	3.5
≥ 3.0 < 3.3	8.5	5.9	3.8	1.7
≥ 3.3 < 3.6	7.5	4.9	2.8	0.7
≥ 3.6	6.8	4.2	2.1	0.0

Table below presents the adjustment for access-point density. The data indicate that each access point per kilometer decreases the estimated free-flow speed by about 0.4 km/h. The access-point density is found by dividing the total number of intersections and driveways within the roadway segment (including access points on both sides of the roadway) by the length of the segment in kilometers. An intersection or driveway should only be included by the analyst if it is considered to have a significant influence on traffic flow. Access points that are difficult for the driver to identify or where there is little activity should not be included. Such access points might include private driveways to individual residences or service driveways at commercial sites.

Table 11:- Adjustment (Fa) For Access- Point Density (Hcm Manual)

Access Points per km	Reduction in Free-Flow Speed (km/h)
0	0.0
6	2.5
12	5.0
18	7.5
24 or more	10.0

From the survey data we are given and physical observation we found the number of access points to be 5. Since length of our road project is 1.233km the access point density is thus $5/1.233 = 4.1$. Now the reduction in free flow speed can thus be interpolated between 0 km/hr and 2.5 km/hr. after interpolating a reduction in speed of 1.58 km/hr is obtained. Finally, the free flow speed is calculated as; $FFS = 31 - 6.8 - 1.58 = 26.62$ km/hr.

(Approximated to 30 km/hr)

Table 12:- level of service and corresponding parameters (HCM manual)

Free-Flow Speed	Criteria	Level of service (LOS)				
		A	B	C	D	E
100 km/h	Max density (pc/km/ln)	7	11		22	25
	Average speed (km/h)	100.0	100.0		91.5	88.0
	Max v/c	0.33	0.50		0.94	1.00
	Max service flow rate (pc/h/ln)	700	1100		2015	2200
90km/h	Max density (pc/km/ln)	7	11		22	26
	Average speed (km/h)	90.0	90.0		84.7	80.8
	Max v/c	0.31	0.47		0.89	1.00
	Max service flow rate (pc/h/ln)	630	990		1860	2100
80km/h	Max density (pc/km/ln)	7	11		22	27
	Average speed (km/h)	80.0	80.0		77.6	74.1
	Max v/c	0.30	0.44		0.85	1.00
	Max service flow rate (pc/h/ln)	560	880	1280	1705	2000
70km/h	Max density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.6	67.9
	Max v/c	0.28	0.41	0.59	0.81	1.00
	Max service flow rate (pc/h/ln)	490	770	1120	1530	1900

4.3. Sight distance

Sight distance is defined as the length of carriageway that the driver can see in both the horizontal and vertical planes.

Sight distance is the distance over which visibility occurs between a driver and an object or between two drivers at specific heights above the carriageway. For safety on the road, sufficient sight distance must be provided to enable drivers to control their vehicles to avoid collisions with other vehicles or objects on the road [9].

4.3.1. Sight Distance Parameters

Truck Sight Distance Check

Roads and junctions must be designed to provide safe operating conditions for both cars and trucks. Both truck and car stopping distance requirements need to be considered. The design speed for cars shall be in urban areas is usually 10km greater than the posted speed limit. The truck sight distance check shall be undertaken using the speed limit (usually 10km/h less than the car design speed) or the estimated truck operating speed, whichever is the lower. Allowance for the different operating speeds of cars and trucks should be made. For example, on an uphill grade truck speeds will be reduced and the truck stopping distance will be reduced by the effect of gravity[9].

Both of these effects reduce the sight distance required, and cars are usually the most demanding design vehicle. Downhill, truck speeds will be similar to cars and truck stopping distance will increase due to gravity. In this case, the requirements for trucks usually are the most critical.

Truck braking distances increase substantially on steep down grades, and truck sight distance is likely to be the governing factor on horizontal curves on downgrades[12]. Lower speed limits for trucks may be appropriate if an economic design is not possible otherwise. On long steep downgrades, trucks may be required to engage low gear in addition to or instead of the speed limit restriction[13].

Truck Speeds on Grades

Trucks speeds on upgrades can be estimated from chart below. Which is based on the observed performance of trucks with 120kg weight for each kW of power.

These charts may be used to estimate truck operating speed and the appropriate truck sight distance checks carried out. On downgrades, the truck should be assumed not to exceed the speed limit[9].

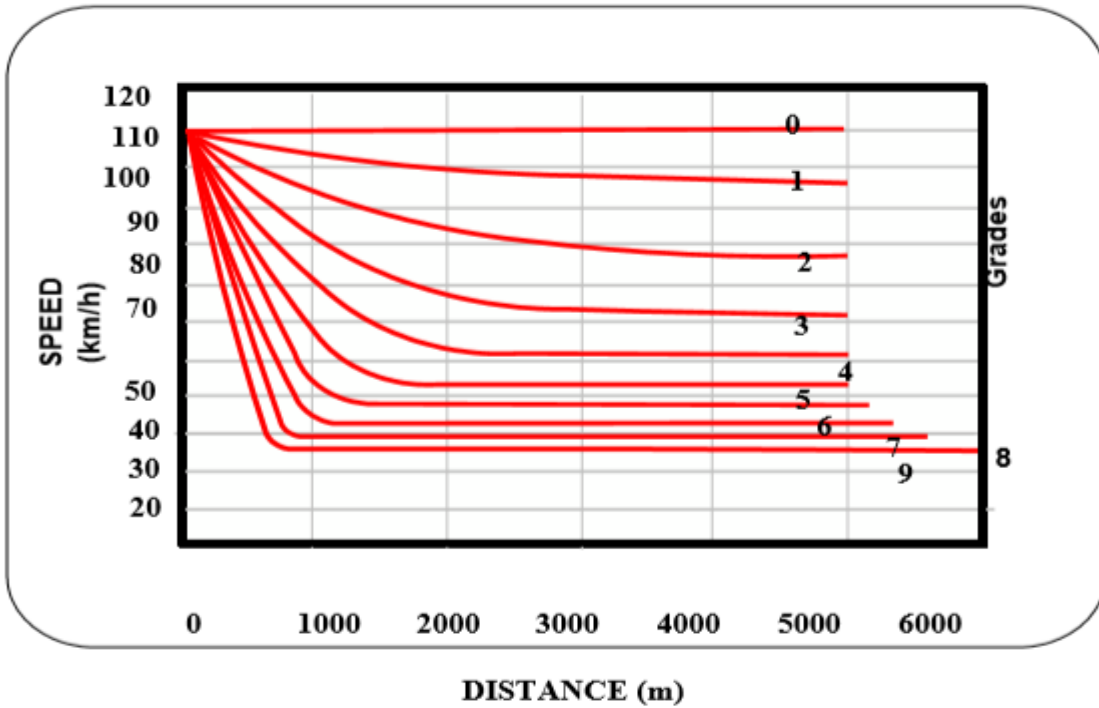


Figure 6 Truck speed on uphill grade (AACRA fig 9.2.2-A)

Driver Reaction Time

The representative driver reaction time for sight distance calculation purposes is 2.5 seconds. Absolute minimum stopping sight distances based on a 2.0 second reaction time may be used for mid-block sections where an economic design cannot be achieved using 2.5 second reaction time. Junction design must be based on 2.5 second reaction time. We used reaction time of 2.5 sec to be on the safe side of design[9].

Driver Eye Height

The representative height for design calculations of the car driver’s eye is 1.05m. The representative height of a truck driver’s eye for design calculations is 2.40m[9].

Stopping Sight Distance Derivation

SSD = d1 + d2..... Equation 4.6⁽⁸⁾

Where:

d1 = reaction distance (m)= RTV/3.6

d2 = braking distance (m) = V²/254(F1+0.01G)

RT = reaction time (sec)

V = Operating speed (km/h)

F1 = longitudinal friction factor

G =longitudinal grade % (+ for upgrades, - for downgrades)

Longitudinal Friction Factors

the table below provides longitudinal friction factors for cars and trucks used for stopping distance calculations for bituminous and concrete surfaces[9].

Table 13:- Longitudinal Friction Factors (AACRA table 9.3.2-A)

Operating Speed								
Vehicle	40	50	60	70	80	90	100	110
Cars	0.56	0.52	0.48	0.45	0.43	0.41	0.39	0.37
Truck	0.29	0.29	0.29	0.29	0.29	0.29	0.28	0.26

Thus, the friction factors for a speed of 40km/hr we have friction factors of cars and trucks to be 0.56 and 0.29 respectively. On level grades where G=0, the SSD for each vehicle type can be calculated as;

SSD for cars

$$d1 = 2.5 * 40 / 3.6 = 27.78m$$

$$d2 = 40^2 / (254 * 0.56) = 11.25m$$

$$SSD = 27.78 + 11.25 = 39.03 \text{ SSD for trucks } 23$$

$$d1 = 27.78m$$

$$d2 = 60^2 / (254 * 0.29) = 21.72m$$

$$SSD = 27.78 + 21.72 = 49.5 \approx 50m$$

Based on the above calculation the SSD for trucks govern[9]. This calculation is done and provided in table with corrections to be applied for upgrade and downgrade slopes (very much significant in truck ssd, since trucks are affected greatly by gravity due to their weight)[12]. The following table gives these sight distances. The corrections for SSD will be applied later on vertical curves section.

Table 14:- Truck Stopping Sight Distance (AACRA table 9.3.4-A)

		Car speed km/ha							
		40	50	60	70	80	90	100	110
Friction Factor		0.29	0.29	0.29	0.29	0.29	0.28	0.26	0.29
SSD Level grade	2.5sec reaction time	50	69	91	116	143	173	201	259
<i>SSD Level grade</i>	<i>2.0sec reaction time</i>	<i>44</i>	<i>62</i>	<i>82</i>	<i>106</i>	<i>131</i>	<i>160</i>	<i>197</i>	<i>244</i>
Correction for Upgrade	2%	-4	-6	-9	-12	-16	-20	-24	-30
	4%	-7	-11	-16	-22	-28	-36	-44	-53
	6%	-10	-15	-22	-30	-39	-49	-60	73
	8%	-12	-19	-27	-36	-47	-60	-74	90
Correction for grade downgrade	-2%	5	8	11	15	20	25	31	37
	-4%	11	18	35	46	46	58	71	86
	-6%	20	32	46	62	81	102	126	153
	-8%	33	52	74	101	132	167	206	249

Table 16 Car Stopping Sight Distance (AACRA table 9.3.3-A)

		Car speed km/ha							
		40	50	60	70	80	90	100	110
Friction Factor		0.56	0.52	0.48	0.45	0.4 3	0.41	0.39	0.37
SSD Level grade	2.5 sec reaction time	39	54	71	91	114	140	170	205
<i>SSD Level grade</i>	<i>2.0 sec reaction time</i>	<i>33</i>	<i>47</i>	<i>63</i>	<i>82</i>	<i>103</i>	<i>128</i>	<i>157</i>	<i>190</i>
Correction for grade Upgrade	2%	0	0	-1	-2	-3	-4	-5	-7
	4%	0	-1	-2	-4	-5	-7	-9	-13
	6%	-1	-2	-3	-5	-7	-10	-14	-18
	8%	-1	-3	-4	-7	-9	-13	-17	-23
Correction for grade downgrade	-2%	-	-	1	2	3	4	6	7
	-4%	-	2	3	4	6	8	12	16
	-6%	1	3	4	7	10	13	18	25
	-8%	2	4	6	3	9	19	26	36

Overtaking Sight Distance

Overtaking sight distance is of relevance on two-way roads in rural areas. In urban areas, overtaking sight distance is not usually a design consideration on local streets. Arterial roads and freeways are normally dual carriageway or multi-lane, and overtaking sight distance is again not an issue[9].

Sight Distance on Horizontal Curves

Sight distance on horizontal curves is frequently an issue in urban road design. This is due to the need to use curves of relatively low radius to meet site constraints on the road alignment. Obstructions such as bridge piers and abutments, tunnels, etc. all block truck sight lines as well as car sight lines. Due to this reason structures alongside of a curve must have an offset distance from the center[9]. These offsets (visibility offset) can be calculated using the formula;

$$M_s = R (1 - \cos (28.65 * SD/R)) \dots\dots\dots \text{Equation 4.7}^{(8)}$$

Where R; radius of curve

SD; stopping sight distance

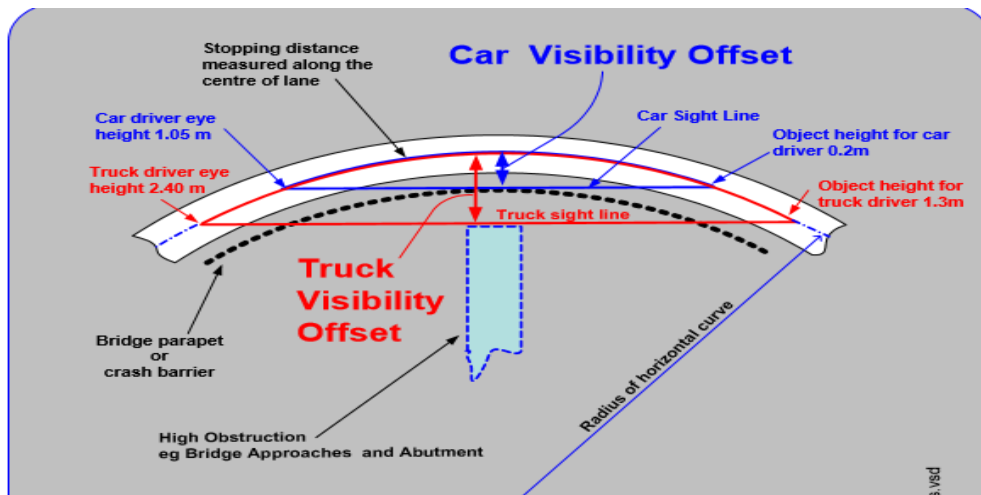


Figure 6:-visibility offset for ssd requirement (AACRA 9.3.6=A)

These visibility offsets are calculated for each curve in the horizontal alignment section later depending on the radius of each curve.

4.4. Horizontal alignment

Horizontal alignment for linear transportation facilities such as highways and railways consist of horizontal tangents, circular curves, and possibly transition curves. In the case of highways, transition curves are not always used[9].

4.4.1. Horizontal Tangents

Horizontal tangents are described in terms of their lengths (as expressed in the stationing of the job) and their directions. Directions may be either expressed as bearings or as azimuths and are always defined in the direction of increasing station. Azimuths are expressed as angles turned clockwise from due north; bearings are expressed as angles turned either clockwise or counterclockwise from either north or south[9].

4.4.2. Movement on a Circular Path

As a vehicle traverses a circular curve, it is subject to forces associated with the circular path. According to the principle of inertia, in the absence of forces, a moving body will travel in a straight line. A force must be applied to change direction. For a circular change of direction, the force is called centripetal force and, in road design, this is provided by side friction developed between the tyres and the pavement, and by superelevation[9].

Superelevation is the crossfall that is provided on the pavement on a horizontal curve in order to assist a vehicle to maintain a circular path.

For normal values of superelevation, side friction and radius, the following formula is used:

$$e + f = \frac{v^2}{gR} \quad R = \frac{V^2}{127(e + f)} \quad \text{and}$$

$$R_{\min} = \frac{V^2}{127(e_{\max} + f_{\max})} \quad \dots \dots \dots \text{Equation 4.8}^{(8)}$$

Where;

e = pavement superelevation (m/m or tangent of angle). This is taken as positive if the pavement falls towards the center of the curve

f = coefficient of side friction force developed between the vehicle tyres and the road pavement this is taken as positive if the frictional force on the vehicle acts towards the Centre of the curve.

g = acceleration due to gravity = 9.8m/s² v = speed of vehicle (m/s)

V = speed of vehicle (km/h)

R = curve radius (m)

Where f equals zero in the formula, all of the centripetal force is provided by the superelevation.

This condition can occur on large radius curves with positive superelevation or for slow moving vehicles on curves of any radius. At low speeds, f can be negative, and the curve is then over-superelevated for that speed. Curves are generally designed, however, so that a positive f is required for the range of vehicle speeds likely to occur. On short length horizontal curves, the radius of the vehicle path can be considerably larger than the centerline or edge line radius. In these cases, the curve radius R should be made equal to the vehicle path radius in lieu of the horizontal curve radius[9].

4.4.3. Maximum Side Friction (f max)

Research has shown that articulated vehicles may roll over at values of side friction in the range 0.2 (even less for some vehicles carrying livestock) to 0.35[9]. The absolute maximum for trucks turning at low speed is usually taken as 0.25

Table 15 Maximum Design Values for Side Friction (Cars on Sealed Pavements) (AACRA table 11.3.1-A)

Design Speed km/h	Coefficient of Side Friction	
	Absolute Maximum	Desirable Maximum
40	0.35	0.30
50	0.35	0.30
60	0.33	0.24
70	0.31	0.19
80	0.26	0.16
90	0.20	0.13
100	0.16	0.12
110	0.12	0.12

Table 16 - Maximum Design Values for Side Friction (Trucks on Sealed Pavements) (AACRA table 11.3.1-B)

Operating Speed km/h	Coefficient of Side Friction	
	Absolute Maximum	Desirable Maximum
40	0.25	0.21
50	0.25	0.21
60	0.24	0.17
70	0.23	0.14
80	0.20	0.13
90	0.15	0.13
100	0.12	0.12

For our road: -

f_{max} for truck = 0.24 (absolute maximum)

f_{max} for car=0.17 (desirable maximum)

4.4.4. Curve Superelevation

It is normal practice for horizontal curves to be superelevated. This allows a component of the vehicle weight to provide some of the centripetal force that is needed for the vehicle to move in a circular path[9].

If a curve is not superelevated, the curve is said to have adverse or negative superelevation. Therefore, „e“ is then expressed as a negative value in

With adverse superelevation, there is a component of the vehicle weight that acts opposite to the centripetal force that is needed for the vehicle to move in a circular path. This in turn requires greater side friction than for a curve of given radius with positive superelevation if the vehicle is to take the curve at the same speed.

The amount of superelevation is chosen primarily on the basis of safety, but other factors are comfort and appearance. The superelevation that is applied to a horizontal curve should take into account the following:

- Tendency to increase the tracking of the rear wheels of slow-moving vehicles towards the Centre Stability of high laden commercial vehicles
- Stability of vehicle loads
- Difference between inner and outer formation level, especially in flat country
- Length available to introduce the necessary superelevation

The need to avoid major changes in side friction demand between successive horizontal curves

The amount of centripetal force provided by superelevation versus that provided by side

The amount of superelevation required for a given radius, speed and coefficient of friction can be calculated by rearranging the Equation as follows:

$$e = V^2/127R - f \dots\dots\dots \text{Equation 4.9}^{(8)}$$

The absolute maximum and desirable maximum values of the coefficient of side friction „f“ can be obtained from AACRA.

4.4.5. Maximum Values of Superelevation and Increases in Side Friction

Maximum values of superelevation to be used in urban areas is 5%. The minimum radius horizontal curve (**Rmin**) that is suitable for a given speed requires the use of maximum allowable superelevation and maximum allowable coefficient of side friction. With horizontal curves that are larger than **Rmin**, it is normal practice to provide the same proportions of superelevation and side friction that apply to **Rmin**. This practice helps (partly but not completely) ensure that any increase in side friction demand between successive horizontal curves is kept within acceptable limits[9].

Large increases in side friction demand over what drivers have become accustomed to can lead to a change in vehicle response that is not anticipated by some drivers. Furthermore, these situations may create hazards for motorcyclists because they have difficulty in maintaining control when there is a sudden change in side friction demand.

Therefore, the need to limit changes in side friction demand becomes a desirable secondary control for ensuring geometric consistency. However, the limits on decrease in speed between horizontal alignment elements that are set out in Section 11.1 (10km/h desirable max. decrease, 15km/h absolute max.) are the primary requirement for geometric consistency. The desirable maximum changes in speed will often ensure that changes in side friction demand are acceptable.

Increases in side friction are considered to be a secondary control because drivers select their speed through their perception of the horizontal curvature. In turn, the selected speed reflects driver experience with a number of factors relating to vehicle control, including side friction demand.

It is not possible to prescribe simple limits on the increase in side friction demand from one horizontal curve to another. However, the following guidelines are provided:

The desirable maximum increase in side friction demand from one horizontal curve to the next is about 25%. (This condition only needs to apply when the side friction factor on the latter curve is greater than about 0.12 as this is a comfortable limit for drivers, even at high operating speeds)[9].

If a curve has a „generous“ radius for its design speed (this can still easily occur in a restricted speed environment due to preceding curvature), then a larger increase than the desirable 25% is likely to occur with the next curve. Even when the latter curve has a side friction demand comfortably below the maximum for its design speed, the increase may be greater than 25%. Therefore, an increase of more than 25% is acceptable when a curve follows a „generous“ curve. However, it will be necessary to check on any increase in side friction between the latter curve and any curves prior to the 'generous' radius curve. The purpose is to check the side friction demand against the level that drivers have become aware of.

Sections of existing road or sections of road that involve a reduction in desired speed may involve larger increases in side friction. In these cases, the increase will be acceptable when the side friction demand does not exceed the desirable maximum for the curve design speed.

Curves with a side friction demand greater than the desirable maximum for the curve design speed should be preceded by a curve that alerts drivers to the required side friction. May be used to limit an increase in side friction.

4.4.6. Super elevation on Horizontal Curves with Radius > R min

It is normal practice to have super elevation provide a significant amount of the centripetal force that is needed for a vehicle to move in a circular path. This is because super elevation is a positive and permanent

feature, whereas side friction is subject to roadway surface and vehicle variations. Even so, it is common to have two to three times as much centripetal force provided by side friction as that provided by super elevation[9].

There are a number of methods to determine the super elevation (and hence resultant side friction) for curves with a radius larger than the minimum radius for a given design speed[13].

The method that will normally be used for new works, is for the super elevation to be varied linearly from 0 for

$R = \text{infinity}$ to **emax** for **Rmin**.

This then means that all curves that are designed for a given speed will have approximately the same proportions of super elevation and side friction demand although for construction expediency, super elevation values are normally rounded (upwards) to a multiple of 1% so that there is a corresponding adjustment of side friction[13].

Other methods have been used in the past so that there are likely to be many cases where the reuse of existing pavement will dictate a different super elevation. This is acceptable if the resultant side friction is suitable for the curve design speed and consistent with that for any adjacent curves.

With the “linear distribution method”, the super elevation „e” for a curve of radius R that is greater than R_{min} is given by:

$$e = (v^2/v) e_{\max}/127R(e_{\max}+f_{\max}) \dots\dots\dots \text{Equation 4.10}^{(8)}$$

Note that **f_{max}** may be either the absolute maximum value or the desirable maximum value for the design speed V.

The value of e is usually rounded upwards (e.g. 4.0% stays 4.0% but 4.1% becomes 5%) and the corresponding coefficient of side friction is calculated from:

$$f = V^2 / 127R - e \text{ rounded } \dots\dots\dots \text{Equation 4.11}^{(8)}$$

With different possibilities for **e_{max}** and **f_{max}** (absolute maximum vs. desirable maximum) different values of super elevation may be attributed to a given combination of radius and design speed. However, the subjective basis of the “linear distribution method” (and indeed most other methods) and the practice of rounding the super elevation value, allows a practical rationalization to be made. Hence Table 11.4.6 B covers the majority of urban cases. It also shows corresponding super elevation runoff requirements and transition lengths for urban areas, rationalization has been achieved by distributing from the combination of 5% maximum super elevation and the desirable maximum value of coefficient of side friction. For design speeds less than or equal to 100 km/h, curves with a radius less than that corresponding to 5% super elevation and the desirable maximum coefficient of side friction, maintain the 5% superelevation with increasing side friction until **f_{max}**. This practice helps ensure that the relatively low maximum superelevation is applied before vehicles have to make use of increasing side friction

Table 17 Horizontal Curve Design Parameters for Urban Roads avoid use of values in italics (AACRA table 11.4.6-B)

Curve Design Speed (km/h)	Radius ² , (m)	Super-elevation ^{1,8v}	Friction coefficient ⁸	Plan Transition Type and Length ⁴	Super Criteria Satisfied	Desirable min. curve length ⁷
40	<i>32</i>	<i>5</i>	<i>0.35</i>	<i>U25</i>	<i>R,g1,g2</i>	<i>40</i>
	36	5	0.30	U20	R,g1	40
	45	4	0.24	U20	R,g1,g2	40
	60	3	0.18	U15	R,g1,g2	40
50	<i>49</i>	<i>5</i>	<i>0.35</i>	<i>U25</i>	<i>R,g1</i>	<i>50</i>
	56	5	0.30	U30	R,g1,g2	50
	56	5	0.30	U25	R,g1	50
	70	4	0.24	U25	R,g1,g2	70
	94	3	0.18	U20	R,g1,g2,g3	70
60	<i>75</i>	<i>5</i>	<i>0.33</i>	<i>S40</i>	<i>R,g1,g2,g3</i>	<i>100</i>
	98	5	0.24	S40	R,g1,g2,g3	100
	122	4	0.19	U30	R,g1,g2,g3	100
	163	3	0.14	U20	R,g1,g2	100
70	<i>107</i>	<i>5</i>	<i>0.31</i>	<i>S40</i>	<i>R,g1,g2</i>	<i>140</i>
	161	5	0.19	S40	R,g1,g2	140
	200	4	0.15	U30	R,g1,g2	140
	268	3	0.11	U30	R,g1,g2,g3	140
80	<i>163</i>	<i>5</i>	<i>0.26</i>	<i>S60</i>	<i>R,g1,g2,g3</i>	<i>180</i>
	240	5	0.16	S60	R,g1,g2,g3	180
	<i>300</i>	<i>4</i>	<i>0.13</i>	<i>U40</i>	<i>R,g1,g2,g3</i>	<i>180</i>
	<i>400</i>	<i>3</i>	<i>0.10</i>	<i>U30</i>	<i>R,g1,g2,g3</i>	<i>180</i>
	<i>440</i>	<i>3</i>	<i>0.08</i>	<i>U30</i>	<i>R,g1,g2,g3</i>	<i>180</i>
	441	3	0.08	U30	R,g1,g2,g3	180
90	<i>255</i>	<i>5</i>	<i>0.18</i>	<i>S60</i>	<i>R,g1,g2,g3</i>	<i>230</i>
	<i>354</i>	<i>5</i>	<i>0.13</i>	<i>U50</i>	<i>R,g1,g2</i>	<i>230</i>
	<i>440</i>	<i>5</i>	<i>0.10</i>	<i>U50</i>	<i>R,g1,g2,g3</i>	<i>230</i>
	443	4	0.10	U50	R,g1,g2,g3	230
	600	3	0.08	U50	R,g1,g2,g3	230
100	<i>375</i>	<i>5</i>	<i>0.16</i>	<i>S60</i>	<i>R,g1,g2,g3</i>	<i>280</i>
	463	5	0.12	S60	R,g1,g2,g3	280
	579	4	0.10	U50	R,g1,g2,g3	280
	772	3	0.07	U50	R,g1,g2,g3	280
110	560	5	0.12	S80	R,g1,g2,g3	340
	700	4	0.10	U60	R,g1,g2,g3	340
	934	3	0.07	U60	R,g1,g2,g3	340
120	709		0.11	S80	R,g1,g2,g3	400
	886		0.09	U60	R,g1,g2,g3	400
	1200		0.07	U60	R,g1,g2,g3	400

4.4.7. Minimum Length of Superelevation on Horizontal Curves

In constrained situations such as mountainous terrain or urban roads, curves should be fully superelevated even if only instantaneously. But it is desirable that there be at least 30m of fully superelevated curve[13].

4.4.8. Superelevation Development Length

Superelevation is developed by rotating the roadway cross-section about some axis; most commonly the horizontal control line.

Superelevation development length is defined as the length required to rotate the pavement from the point of normal crossfall on the approach tangent (straight) to the point where the full superelevation for the curve is attained. In turn, this superelevation development length has two components[13]:

Superelevation runoff length - this is the length from the point where the pavement has been rotated to zero crossfall to the point where the full curve superelevation has been attained

Tangent runoff -this is the residual length from the point of normal crossfall to the point of zero crossfall (this component lies on the approach tangent)

There are two criteria that are used to determine the length of superelevation development:

Maximum rate of rotation of crossfall

Relative grade between the edge of the carriageway and the control line

The superelevation development length to be adopted will generally be the longer value calculated for the two criteria above, notwithstanding normal minimum lengths of superelevation runoff. The maximum rate of rotation criterion is a mandatory standard that must be adopted as a minimum. The relative grade criterion is for appearance purposes and should be obtained at all locations unless economic or safety considerations dictate otherwise e.g., between reverse curves on steep grades.

Except for constrained situations such as mountainous areas or urban roads, it is normal practice to recognize minimum lengths for superelevation runoff for both transitioned and un-transitioned curves.

This is due to the fact that most vehicles describe some transition path when entering or leaving a curve with the minimum length of the transition path being about 30 to 50 m.

This in turn relates to the practices of:

basing transition curve lengths on recommended superelevation runoff lengths and hence, matching the superelevation runoff with the transition

Not providing transitions when there is sufficient room within a traffic lane for vehicles to make their own transition paths

Therefore, the normal minimum lengths for superelevation runoff for a curve are:

40 m for transitioned curves, which ties to a 40 m minimum transition length 50 m for an un-transitioned curve when the curve design speed is greater than 80 km/h, with this length normally being equidistant

about the curve tangent point 30 m for an un-transitioned curve when the curve design speed is less than or equal to 80 km/h, with this length normally being equidistant about the curve tangent point.

Criteria 1: Maximum Rate of Rotation of Crossfall: - the following maximum rates of rotation are applicable:

0.025 radians per second for most road types including roads with vehicles that carry livestock
 0.035 radians per second in low-speed areas (70km/h) - this includes roads in steep terrain and geometry consisting of reverse curves with little or no straight between the curves
 0.04 radians per second in low-speed areas (<60km/h) with extremely constricted horizontal alignment i.e. sections of roads in steep terrain and geometry consisting of small radius reverse curves with little or no straight between the curves[9]

The minimum superelevation development length based on the above criteria is given by

$$L_e = 0.278 V (e_2 - e_1) / r \dots\dots\dots \text{Equation 4.12}^{(8)}$$

Where **L_e** = superelevation development length (m)

V = design speed (km/h)

e₁, e₂= crossfall or superelevation at ends of development length (m/m); +ve when sloping* upwards from the control line; -ve when sloping downwards from the control line
r = rate of rotation of the road crossfall (radians/second)

Note that for the range of crossfalls involved, m/m radians.

$$L_e = 0.278 V (e_2 - e_1) / r \quad L_e = 0.278 * 60 * 0.025 / 0.04 = 16.68\text{m} \quad \text{Criteria 2: Relative Grade}$$

The relative grade is the percentage difference between the grade of the edges of the carriageway and the grade of the axis of rotation[9].

The minimum superelevation development length based on the criteria is given by $L_e =$

$$100W (e_2 - e_1) / Gr$$

where **L_e** = superelevation development length (m)

W = maximum width from axis of rotation to edge of running lane (m)

e₁, e₂= crossfall or superelevation at ends of development length (m/m); +ve when sloping upwards

from the control line; -ve when sloping downwards from the control line.

W= lateral clearance +lane width

$$= 1 + 3.5 = 4.5\text{m}$$

$$L_e = 100 * 4.5 * 0.025 / 0.8 = 14.0625\text{m}$$

4.4.9. Horizontal Curves in the Range of 300m to 440m.

Experience has found that horizontal curves with a radius in the range of 300m to 440m should be avoided for operating speeds greater than 70 km/h. The curves are deceptive to the driver in that they appear to be able to be travelled at higher speeds than is actually possible. As a result, drivers may not slow down appropriately for them. Therefore, these curves should only be used if they are closely preceded by a curve with a design speed not more than 10 km/h (max. 15km/h) above the design speed of the curve in the range 300-440 m.

In practice, this restriction on the use of curves in the range 300m to 440m limits the range of curves suitable for 80km/h, and particularly, 90km/h. design speeds[9].

Depending on the minimum radius, the above restriction, minimum curve length and site constraints we adjusted the radius to meet the requirements.

The radiuses for all three curves are;150m, 250m and 150m. With corresponding deflection angles of 12, 856, 28.635 and 12.0836 respectively. The minimum curve length couldn't be achieved for the second and third, thus cars are obliged to traverse this curve with a design speed of 70 km/hr (posted speed limit of 60 km/hr)[14].

Element of Horizontal Curve

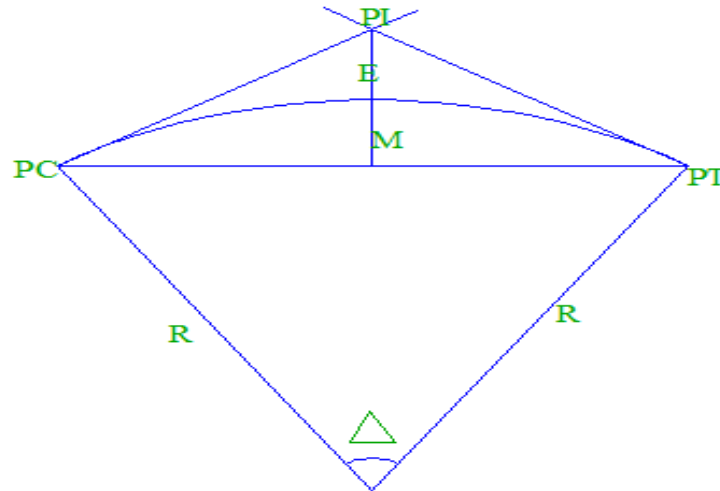


Figure 7. elements of horizontal curve

Where;

Δ : Deflection angle by arc definition (in degrees)

R: Radius of curve by arc definition ECC

T: Tangent distance $T=R \tan \Delta/2$ **Equation 4.13⁽⁸⁾**

E: External distance= $R (\sec \Delta/2 - 1)$ **Equation 4.14⁽⁸⁾**

L: Curve Length $L=\Delta * 2R \pi / 360$ **Equation 4.15⁽⁸⁾**

M: Middle Ordinate $M=R (1 - \cos \Delta/2)$ **Equation 4.16⁽⁸⁾**

C: Chord from P.C to P.T = $2R\sin\Delta/2$ **Equation 4.17⁽⁸⁾**

Point of Curvature (P.C) = P.I-T **Equation 4.18⁽⁸⁾**

Point of Tangency (P.T) =P.C+LC..... **Equation 4.19⁽⁸⁾**

The geometric elements can be calculated each using their formulas or directly taken from Civil 3D (2019).

Curve #1:

$R_{min}=98\text{ m}$, $R_{provided}=150\text{m}$, $e_{max}=5\%$, $e_{prov}=3\%$, $f_{max}=0.24$, $f_{prov}=0.018$

Tangent length (T) = $R*\tan(\Delta/2)$

=16.90m

Curve length (L) = $\frac{\pi R\Delta}{180}$

=33.66m

External distance (E) = $R(\sec\Delta/2 - 1)$

=0.95m

Mid ordinate (M) = $R(1 - \cos\Delta/2)$

=0.94m

Curve #2:

$R_{min}=98$, $R_{prov}=250\text{m}$, $e_{max}=5\%$, $e_{prov}=3\%$, $f_{max}=0.24$, $f_{prov}=0.018$

T=63.81m

L=124.94m

E=8.01m

M=7.77m

Curve #3:

$R_{min}=98\text{m}$, $R_{prov}=150\text{m}$, $e_{max}=5\%$, $e_{prov}=3\%$, $f_{max}=0.24$, $f_{prov}=0.018$

T=16.9m

L=33.66m

E=0.95m

M=0.95

4.5. Vertical alignment

Vertical alignment (referred to as grade line or longitudinal section) consists of straight grades joined by vertical curves. The principal vertical alignment design objectives are to obtain the necessary sight distance and to fit to the natural terrain. In designing the vertical alignment consideration also needs to be

given to the maximum allowable grades, the volume and balancing of the earthworks, the appearance, property acquisition, environmental impacts, and the co-ordination with the horizontal alignment.

The sight distance requirements include obtaining minimum radius vertical curves for stopping sight distance (SSD) and the sight distance to intersections or ramps.

The design criteria which dominate in deciding on the appropriate vertical alignment vary with the type of road being considered. On minor urban roads, obtaining sight distance to property access points and intersections and minimizing the impacts on adjacent property dominate.

On major roads, sight distance to intersections (or ramps) and appearance will tend to dominate other factors such as earthworks balance, but the need to provide an economically sound design cannot be ignored. It may be possible with good design and appropriate co-ordination with the horizontal alignment to achieve all of the design objectives.

On undivided roads, the vertical alignment is designed as the surface of the pavement along the construction center line. On divided roads, the vertical alignment is usually represented by the line along the lane edge against the median (residual median if there are median shoulders).

On divided roads (typically freeways) with a very wide median and independent grading of the carriageways, the vertical alignment is usually designed as the surface of the pavement along the construction Centre line of each carriageway. In urban areas, it is unlikely that the length of such sections will be a significant proportion of the project, and the control lines may be better located on the edge of the residual median for consistency with the rest of the project[9].

Sight distance along a road and to intersecting roads is controlled both by the vertical alignment and by obstructions on the side of the carriageway. Lateral obstructions to sight distance may block intersection sight triangles, and may also block sight distance to the pavement if the road has a horizontal curve. Vertical and horizontal sight distance must be considered together when undertaking route location work and in all subsequent design phases.

On two-way roads, crest vertical curves are not generally designed for overtaking sight distance. The resulting curve is generally too long for practical purposes.

4.5.1. Grades

Maximum Grades

Generally, grades should be as flat as possible consistent with economy. Flat grades permit all vehicles to operate at similar speeds (away from intersections). Steeper grades produce variation in speeds between lighter vehicles and the heavier vehicles both in the uphill and downhill directions. This speed variation leads to higher relative speeds of vehicles producing the potential for higher accident rates and lower traffic capacity. This speed variation also results in increased queuing and overtaking requirements on

single carriageway roads which give rise to further safety problems particularly at higher traffic volumes. In addition, freight costs are increased due to the slow speed of heavy vehicles[13],

Table 18 Maximum Grades (AACRA table 12.2.1-A)

Road Type	Speed Limit or Speed Environment	Minimum Design Speed for Cars	Maximum Grade %	
			Flat Terrain	Hilly Terrain
Suburban Freeway Through Carriageway	100	110	4	6
Suburban Freeway to Freeway Ramp	80	80	5	5
Freeway Collector-Distributor	70-80	80-90	6	8
Inner Urban Freeway Through Carriageway	80	90	4	7
Inner Urban Freeway to Freeway Ramp (excluding loops)	60	60	6	6
Freeway to Arterial Road Exit Ramp	60/70*	60/70	8 up 5 down	
Freeway to Arterial Road Entry Ramp	60/70*	60/70	5 up 7 down	
Freeway Loop Ramps	Truck Advisory Sign 35	40	5 up 5 down	
Continuous Frontage Road	70	80	6	7 desirable 8 max
Arterial Road Controlled Access	70	80	4	6
Discontinuous Frontage Road	60*	60*	6	7 desirable 10max
Arterial and sub-arterial road with frontage access	60	70	4	7 desirable 8 max
Feeder Roads and industrial/commercial access roads (potential bus routes)	60	60	4	7 desirable 8max
Low Volume Residential Feeder Roads (<3000 vpd) no bus routes	50	50	4	7 desirable 10 max
Local Residential Street	30	30	5	7 desirable 12 max
Access place	15	15	5	7 desirable 17 max
Temporary roads (e.g., construction sidetracks)	40-60	40-60	4	8

From the above table depending on terrain type, speed limit and type of road we selected maximum grade of 5%.

Minimum Grades

Very flat grades may make it difficult to provide longitudinal drainage in table drains, curb and channel and medians, where these parallel the road grade. As far as possible, these drainage requirements should not dictate the road grade, rather the drainage facility should be designed to accommodate the road grade. This may require greater recourse to sub-surface drains with closely spaced inlets, or independently graded table drains, or other solutions to suit the circumstances. Care should be taken in cases where a flat grade is combined with superelevated horizontal curves. The rotation of the pavement may create a situation where the flow path crosses from one side of a lane to the other, resulting in undesirable depths of water on the pavement surface[9].

Worse conditions can occur on steep grades combined with successive curves in opposite directions.

The combination of grade and pavement rotation can create a situation where the flow path meanders from one side of the road to the other with the depth of flow becoming excessive.

In both of those cases, pavement contours should be examined to ensure these conditions do not exist. If found to exist, action to change the parameters (e.g. increasing the rate of rotation) must be taken to control the condition.

(a) Cuttings

Generally, the minimum grade in cuttings is 0.5% to allow adequate fall in unlined drains. However, it is permissible to provide flatter grades provided that a minimum grade of 0.5% is retained in the unlined drains. This is done by uniformly widening the drains at their standard slope, thereby deepening them progressively, or alternatively, lining the table drains will permit a flatter grading of table drains to be adopted. In constrained situations, the slope of the drains may be reduced below 0.5% provided that they are lined.

(b) Medians

On divided roads the necessity for median drainage may control the minimum roadway grade. However, where very flat roadway grades are the only practical solution, sag gullies at regular intervals with cross drainage may be provided in the median. This will enable median slopes greater than the roadway slope to be used. The grade considerations given for cuttings also apply to medians.

(c) curb and Channel

Where a curb and channel forms part of the type cross section, for example, a median curb on a divided road, the minimum grade of the channel formed by the pavement edge and curb should not be less than 0.5% except in difficult circumstances, when the absolute minimum shall be 0.2%. This usually influences the grade of the pavement. Where this situation exists on a long flat section of the road, care

must be taken to avoid a wavy grade line, by making grade changes either well-spaced or at the start or end of horizontal curve, so as to disguise the changes of grade.

The use of curb and channel on high-speed alignments is generally undesirable (except in constrained situations and prior to intersections). In addition to the safety problems caused by the curb, separate drainage facilities are required. In these cases, a shallow concrete lined v-drain with subsoil drainage usually provides a better solution.

(d) Bridges

Bridges over roadways should not be provided with scuppers, and pavement drainage will require a minimum grade on the bridge so water can be collected by pits on the lower approach. This will require a minimum grade of 0.3%. Bridges over waterways may be level and fitted with scuppers. However, if roadway runoff is to be channeled to watercourses via pollution control ponds, then these bridges also should be located on a grade of 0.3% minimum.

4.5.2. Curve Geometry

Generally, the type of vertical curve used is a parabolic curve. The parabola is normally used because of its simplicity and because all formulae are exact whereas the same formulae used with the circle would be approximate. The vertical offsets from a tangent are proportional to the square of the distances measured horizontally from the tangent point to the offset point

It is convenient to specify parabolic vertical curves by the length of curve required for a change of grade of 1%, this being a constant for the parabola[9]:

$$K = \frac{L}{A} \dots\dots\dots \text{Equation 4.20}^{(8)}$$

K is used in this manual to designate the limiting curvature required for a given design speed.

K is a single number and is a constant for the curve irrespective of the grades and length of the curve. Large **K** values equate to large radius curves.

The length of curve required for sight distance is given by the following expressions:

$$L = 2D - C/A \dots\dots\dots \text{Equation 4.21}^{(8)}$$

when the length of curve is less than the sight distance and

$$L = D^2A/C \text{ and } K = D^2/C$$

when the length of curve is greater than the sight distance.

The value **C** is a constant that depends on the eye and object heights. and the situation. And A is algebraic difference of grades=3.94+2.78=6.72%: (G1=2.78% and G2=3.94%) For crest vertical curves:

$$C = 200 [\sqrt{h1} + \sqrt{h2}]^2 \dots\dots\dots \text{Equation 4.22}^{(8)}$$

For sag vertical curve headlight sight distance,

$$C = 200 [h + D \tan q]. \dots\dots\dots \text{Equation 4.23}^{(8)}$$

For overhead obstructions over sag vertical curves, $C = 200 [\sqrt{(H-h_1)} + \sqrt{(H-h_2)}]^2$

Our project contains only one crest vertical curve. Hence the value of C is estimated as:

Length of curve for sight distance requirement

$$C = 200 [\sqrt{h_1} + \sqrt{h_2}]^2$$

h₁ is driver eye height and h₂ is object height.

From sight distance requirement for cars $h_1=1.05\text{m}$ and $h_2=0.2\text{m}$ and the corresponding minimum k value is taken from the table below:

Table 19Crest K Values based on SSD for Cars (AACRA table 12.3.2-A)

Speed	Car Stopping Distance		Crest K Value	
	Desirable Min. Ri-2.5sec	<i>Absolute= Min RT= 2.0sec</i>	$h_1 = 1.05\text{m}$ Desirable Min	$h_2=0.20\text{m}$ <i>Absolute= Min</i>
40	39	33	4	3
50	54	47	7	5
60	71	63	12	10
70	91	82	20	16
80	114	103	31	25
90	140	128	46	38
100	170	157	67	57
110	205	190	98	84

Table 23: - Table 20 Crest K Values based on SSD for Trucks (AACRA table 12.3.2-B)

Speed	Truck Stopping Distance		Crest K Value	
	Desirable Min. RT 2.5sec	<i>Absolute min RT 2.0 sec</i>	Desirable Min.h1 = 2.40m	
			absolute=	Min
40	50	44	6	5
50	69	62	9	11
60	91	82	16	19
70	116	106	26	31
80	143	131	40	47
90	173	160	59	69
100	214	197	90	102
110	259	244	140	155

K is then found to be 12. Taking this and substituting gives:

$$C=433.0$$

$$L=2(143)-433.3/6.72=221.52\text{m}$$

Or

$$L=KA \text{ but } K=(D*D)/C=143*143/433.3=47.2>K_{\text{min}}$$

$$L=47.2*6.72=317.184\text{m}$$

From sight distance requirement for trucks $h_1=2.4\text{m}$ and $h_2=0.2\text{m}$

$C=797.13$ the min K values on AACRA are listed in table below

5 CROSSECTIONAL ELEMENTS OF STREET DESIGN

5.1 Designing Streets for Great Cities

Streets lie at the heart of communities, shape human health and environmental quality, and serve as the foundation of urban economies. In many cities, streets make up more than 80% of all public space, and collectively have the potential to foster business activity, serve as front yards for residents, and provide safe places for people to move and spend time. The vitality of urban life demands a design approach sensitive to the multifaceted role streets play in our cities. Shaping great streets is fundamental to shaping great cities[4].

5.1.2 Key Design Principles

The Global Street Design Guide crystallizes a new approach to street design that meets the challenges of today and the demands of tomorrow. Based on the principle that streets are public spaces as well as arteries for movement, the guide foregrounds the role of the street as a catalyst for urban transformation[15].

In an urban context, street design must meet the needs of people walking, cycling, taking transit, doing business, providing city services, and driving, all in a constrained space[4]. The following principles are key to shaping great streets.

Streets for Everyone

Design streets to be equitable and inclusive, serving the needs and functions of diverse users with particular attention to people with disabilities, seniors, and children. Regardless of income, gender, culture, or language, whether one is moving or stationary, streets must always put people first.

Streets are Multidimensional Space

Design the street in space and time. Streets are multidimensional, dynamic spaces that people experience with all their senses. While the ground plane is critical, the edges and the canopy play a large role in shaping a great street environment[15].

Streets for Safety

Design streets to be safe and comfortable for all users. Prioritize the safety of pedestrians, cyclists, and the most vulnerable users among them: children, seniors, and people with disabilities. Safe streets have lower speeds to reduce conflicts, provide natural surveillance, and ensure spaces are safely lit and free of hazards[15],[16].

Streets for Health

Design streets to support healthy environments and lifestyle choices. Street designs that support active transportation and integrate green infrastructure strategies improve air and water quality, can reduce stress levels, and improve mental health.

Streets are Multimodal

Design for a range of mobility choices, prioritizing active and sustainable modes of transport. Safe, efficient, and comfortable experiences for pedestrians, cyclists, and transit riders support access to critical services and destinations and increase the capacity of the street.

Streets as Ecosystems

Integrate contextual green infrastructure measures to improve the biodiversity and quality of the urban ecosystem. All designs should be informed by natural habitats, climate, topography, water bodies, and other natural features.

Great Streets Create Value

Design all streets to be an economic asset as well as a functional element. Well-designed streets create environments that entice people to stay and spend time, generating higher revenues for businesses and higher value for homeowners.

Streets for Context

Design streets to enhance and support the current and planned contexts at multiple scales. A street can traverse diverse urban environments, from low-density neighborhoods to dense urban cores. As the context changes, land uses and densities place different pressures on the street, and inform the design priorities.

Streets Can Change

Design streets to reflect a new set of priorities that ensures appropriate distribution of space among different users. Push boundaries, try new things, and think in creative ways. Implement projects quickly using low-cost materials to help inform public decision making, allowing people to experience and test the street in different ways.

Design streets as quality public spaces, as well as pathways for movement. They play a big role in the public life of cities and communities, and should be designed as places for cultural expression, social interaction, celebration, and public demonstration.

5.1.3. Design Controls and Factors for street design

Design speed is the target speed at which drivers are intended to travel on a street, and not, as often misused, the maximum operating speed. Actively designing for target vehicle speeds is critical to safety. Changing a street's design results in behavior changes. Practitioners must manage speeds by setting clear expectations for drivers[15]. The level of walking, cycling, and activity, as well as the degree to which modes are mixed or separated, is the critical determinant of a safe vehicle speed. Reducing vehicle speeds opens up a range of design options that allow a street to function and feel like part of a city, rather than a highway[17]. Designers must not use highway-based design speed practices in urban areas. Instead, they must be proactive in limiting vehicle speeds, providing frequent pedestrian crossings, limiting the number and width of lanes, using low speeds for turn radii, and introducing trees and furnishings[18].

Every 1 km/h of increased speed results in a 4–5% increased risk of death in case of a crash. Speed on urban streets should be limited to 40 km/h[4].

I. Design Vehicle and Control Vehicle

Designers use a design vehicle or design user to set characteristics of the roadway, transitway, sidewalk, and cycleway. Designing for comfortable use by the occasional large truck often results in overly wide roads or high-speed turns by cars, and opportunities are lost to create space for other, more frequent users such as pedestrians. Select a design vehicle—a routine user for whom the street is designed—as well as a control vehicle—one that only occasionally uses the street — to prevent the overdesign of a facility. Safe design means tailoring elements for the most vulnerable street user rather than the largest possible vehicle. The control vehicle is the least maneuverable vehicle that is ever planned to use a street, but potentially at very low speeds or with multipoint turns[17].

II. Turning Radii.

Accommodate the different turn radii of frequently present Design Vehicle (left) and the occasionally present Control Vehicle (right) at different speeds, using geometric techniques such as advance stop lines, without increasing the turn radius and speed of the Design Vehicle[18],[17].

III. Design Year and Modal Capacity

Cities must make investments that consider the life of major infrastructure investment and account for anticipated future growth and development. Yet, traditional traffic forecasting substantially overestimates traffic growth. Even as trends show otherwise, many transportation models still assume an upward trend in traffic demand, accepting more vehicle kilometers traveled as inevitable. Instead, cities must link design capacity for each mode to the desired mode split and activity on a street. Capacity should be measured based on total person capacity rather than vehicle level of service, using vehicle capacity to understand operational decisions[18].

Design year is applied to a project as the future conditions it should accommodate. If increased traffic is assumed, a self-fulfilling projection of increased traffic will be established.

III. Traffic Evaporation. Research shows that when road capacity is shifted to other modes, some peak-period traffic disappears from the network. Drivers shift to other modes, make trips at other times, or shift destinations[16].

IV. Design Hour

Streets function differently at different times of day, at different times of year, and over longer periods of time. The pace and flow of life varies in each city as does the use of public streets. Streets expand and contract with people, vehicles, vendors, cafés, markets, and crowds throughout the day and week. Design streets to provide comfortable capacity during a typical hour of the day, instead of just the peak hour. The typical hour is often the average between activity levels during peak, late night, midday, and weekend hours. This allows planners to balance safety with the needs and functions of the street at different times[15].

5.2 A Variety of Street Users

In most cities, streets constitute the largest percentage of public property, and this space must be equitably distributed between the needs of the many different users of urban streets[5]. Designs must accommodate people walking, cycling, taking transit, enjoying public spaces, providing city services, doing business, or driving. This identifies design elements and strategies to support safe and inviting spaces for the variety of people using urban streets[4].

I. pedestrians

Pedestrians include people of all abilities and ages, sitting, walking, pausing, and resting within urban streets. Designing for pedestrians means making streets accessible to the most vulnerable users[16]. Design safe spaces with continuous, unobstructed sidewalks. Include visual variety, engage building frontages, design for human scale, and incorporate protection from extreme weather to ensure an enjoyable street experience[15].

II. Cyclists

Cyclists include people on bicycles, cycle-rickshaws, and cargo bikes. Facilities should be safe, direct, intuitive, clearly delineated, and part of a cohesive, connected network to encourage use by people of all ages and confidence levels. Cycle tracks that create an effective division from traffic, are well coordinated with signal timing, and are incorporated in intersection design form the basis of an accessible and connected cycle network[15].

III. Transit Riders

Transit riders are people using collective transport such as rail, bus, or small collective vehicles. This sustainable mode of transportation dramatically increases the overall capacity and efficiency of the street[1]. Dedicated space for transit supports convenient, reliable, and predictable service for riders. Accessible boarding areas promote safe and equitable use. The space dedicated to a transit network should be aligned with demand, meeting service needs without sacrificing streetscape quality[18].

IV. Motorists

are people driving personal motor vehicles for on-demand, point to-point transportation. This includes drivers of private cars, for-hire vehicles, and motorized two-and three-wheelers. Streets and intersections must be designed to facilitate safe movement and manage interactions between motor vehicles, pedestrians, and cyclists.

V. Freight operators and service providers

Are people driving vehicles that move goods or conduct critical city services. These users benefit from dedicated curb access and allocation of space for easy loading and unloading as well as dedicated routes and hours of operation. Emergency responders and cleaning vehicles need adequate space to operate, which must be accommodated while ensuring the safety of all other street users.

VI. People doing business

include vendors, street stall operators, and owners or renters of commercial storefronts. These users provide important services that support vibrant, active, and engaging street environments. Adequate space should be allocated to these uses. Provide regular cleaning, maintenance schedules, power, and water to support commercial activity and improve local quality of life. This pedestrian commercial street has the inherent advantage of attracting walking people.

5.3. Legibility needs

Streets should help people understand where they are and to identify which way they need to go. When people walk around in the city, they need a guide system to figure out where they are. Legible streets have an easy way for people to understand network of routes and junctions with simple, explicit signs and visible, unambiguous features (Burton, 2006).

Signs The objective streets have clear signs. People can figure out where they are by signs in the street. A legible street has sound signs clear and identifiable.



fig. street sight and direction legends

As a result, one can observe that fewer pedestrians can be found in street, and social life is quite restrained compared.

- Safety needs
- Accessibility needs
- Comfort needs
- Legibility needs
- Participation needs

6 EARTH WORK QUANTITY

6.1. Introduction

Earthwork is conversion of natural condition to required section and grade. Earthwork in highway design includes determination of cuts and fills, location of borrow, waste sites, the free haul and over haul distance determination. The quantity of work in embankment and cuts are computed by the cross-sectional end area method. The term earthwork is applied to that portion of highway construction, which is required to convert the right of way from the natural condition and configuration to the section and grades Prescribed by the design. It includes clearing, grubbing, excavation, excavation for structure, borrows, haul and over haul, grading preparation of side slopes.

6.2 Typical earthwork procedures

6.2.1 Site clearance

Clearing and grubbing

Clearing refers to the removal of materials above existing ground surface, and grubbing means the removal of roots, stumps and similar objects to a nominal depth of the ground below the surface.

As mentioned on the standard technical specifications clearing consist of the removal of all the tree, bush, other vegetation, fences and all other unnecessary material including the disposal of all material's resulting from the clearing and grubbing. It includes the removal of structures that can obstruct the work. Clearing of flat surface includes removal of the surface soil up to 15 cm depth. For payment case, the unit of measurement for clearing is taken as the area in hectare and that of grubbing is pay depending on the girth (peripheral perimeter of the tree. so that the unit of notification for clearing is birr per hectare. for one hectare clearing the amount of money charged is 19600.

6.2.2 Excavation

There are mainly three types of excavations in the construction of highway.

1. Road ways and drainage excavation.

This is the excavating and grading of the road way and ditches including the removal of all excavated materials and all work needed for the construction and completion of the cuts, embankments, ditches, approaches, intersections and similar operations of the work.

2. Excavation for structures.

This refers to the excavation of materials in order to permit the construction of pipe culverts, concrete box culverts, foundation for bridges, retaining walls and practically all other structures that may be required in particular work.

3. Borrow excavation

When sufficient materials for the formation of embankments and other elements of the road way Structures is not available for excavation performed within the limit of the right of way, additional suitable materials are generally taken from the borrow pits.

Embankment are used in highway construction when it is required that the grade line of the road way be raised some distance above the level of the existing ground surface to maintain the design Standards or prevent damage to the highway through to the action of surface or ground water.

Measuring earthworks Clearing and Grubbing are measured in m² While, Excavation /embankment Excavation for structure borrows are measured in m³.

Classification of Excavation Excavated materials are usually classified as:

Common excavation: is largely earth, or with detached boulders less than 0.5 yd³.

Loose excavation: usually refers to rock which can be removed pick and bar, also the use of power shovels or blasting may be advantageous. Solid rock excavation: comprises hard rock in place and boulders that can be removed only by the use of drilling and blasting equipment.

6.2.3 Shrinkage and Swell Factors

When earth is excavated and hauled to form an embankment, the freshly excavated material generally increases in volume. However, during the process of building the embankment it is compacted, so that the final volume is less than when in its original condition. This difference in volume is usually defined as “shrinkage”. In estimating earthwork quantities, it is necessary to make allowance for this factor. The amount of shrinkage varies with the soil type and the depth of the fill. An allowance of 10 to 15 percent is frequently made for high fills and 20 to 25 percent for shallow fills. The shrinkage may be as high as 40 or 50 percent for some soils. This generally also allows for shrinkage due to loss of material in the hauling process.

When rock is excavated and placed in the embankment, the material will occupy a larger volume. This increase is called “swell” and may amount to 30 percent or more. For this particular project we used a shrinkage percentage of 20%. Shrinkage factor= $1-0.2=0.8$ Adjusted fill volumes= fill volume/shrinkage factor

The process of excavation breaks up the earth and it occupies more space after excavation this increases in volume is known as swell. After placing the excavated earth in a fill and compacted, it will usually become less than the original volume. This difference between the original volume and the final volume in a fill is defined as shrinkage.

Calculations

$$\text{Percent shrinkage} = (1-(\text{wt. of bank measure})) * 100\% \dots\dots\dots \text{Equation 6.1}$$

Wt. compacted % shrinkage = $(1 - (VB)) * 100\%$

VC Percent swell = $[(wt. \text{ of bank measure}) - 1] * 100\%$

Cross-sections and Template

In order to determine earth excavation and embankment requirements by manual means, a section outline of the proposed highway, commonly referred to as a template section, is placed

On the original ground cross-section, the area in cut and they are in fill are determined; and the Volume between the sections is computed

Estimation of earth work quantity

Both the quantity of earth to be removed from cut sections and the volume of the earth to form

The embankment to the proper grade is involved in calculations of earthwork for highways.

Balancing the two quantities sometimes determines the grade alignment.

Area and volume computation: For the purpose of calculating the quantity of the earthwork, the area of the cross-section and the distance between them must be known. From the data supplied by cross-sections and the design of vertical alignment, areas of cross-section can be

6.3. Mass-Haul Diagram

A mass-haul diagram or curve is drawn subsequent to the calculation of earthwork volumes, its ordinates showing cumulative volumes at specific points along the Centre line. Volumes of cut and fill are treated as positive and negative, respectively. Compensation can be made as necessary, for shrinkage or bulking of the excavated material when placed finally in an embankment.

A mass diagram is a graphical representation of the amount of earthwork and embankment involved in a project and the manner in which the earth is to be moved. Its horizontal or x- axis represents distance and is usually expressed in meters or stations. It is drawn to the same horizontal scale as the profile. The vertical or y-axis represents the cumulative quantity of earthwork in cubic meters. The quantity of excavation on the mass diagram is considered positive, and embankment as negative. Preliminary to drawing the mass curve it is convenient to tabulate the cumulative volumes of cuts and fills at each station.

The mass diagram allows a highway engineer to determine direction of haul and the quantity of earth taken from or hauled to any location. It shows “balance points”, the stations between which the volume of excavation (after adjustment for “shrinkage” or “swell”) and embankment are equal.

Study of mass diagram (curve) will verify the following statements:

- a. The ordinate at any point on the mass curve represents the cumulative volume to that point on the profile.

- b. Within the limits of a single cut, the curve rises from left to right; within the limits of a single fill, it falls from left to right.
- c. Sections where the volume changes from cut to fill correspond to a maximum; sections where the volume changes from fill to cut correspond to a minimum. Evidently the maximum and minimum points on the diagram occur at, or near, grade points on the profile.
- d. Any horizontal line, as AC, cutting off a loop of the mass curve, intersects the curve at two points between which the cut is equal to the fill (adjusted for shrinkage). Such a line is called a balance line.
- e. The loops convex upward indicate that the haul from cut to fill is to be in one direction (to the right in this case); loops concave upward indicate a reverse direction of haul.
- f. The final point on a mass diagram for a given project gives the overall net amount of earthwork for the entire project. This amount, if positive, would indicate a surplus of excavation material and a need to waste that quantity of material. If the final point on the mass diagram is a negative amount, it indicates a net shortage of earthwork for the project and a need to borrow that quantity of earthwork material.

The mass diagram may be used to indicate the most economical procedure for disposing of excavated material, what part of it should be moved forward or backward, and whether borrowing and wasting are advisable.

6.3.1 Balancing Earthwork Using the Mass Haul Diagram

The designer should carefully assess the project before start of design and set certain guidelines for balancing the earthwork. A determination should be made as to the maximum haul distance or distance between balance points, whether tight balances will be used or whether it will be more economical to excavate to spoil in some areas and obtain borrow material in others.

Listed below are a few considerations in determining the best earthwork design:

- a) Right-of-way restrictions may necessitate importing borrow material for the required embankments.
- b) Where large quantities of inferior or deleterious material are encountered in the excavation, it will be necessary to waste this material, which is unsuitable for use as embankment.

- c) Special conditions through deep cuts, such as sloughing, sight distance requirements, or sand drift conditions may require very flat back slopes resulting in large amounts of excavation and no large embankments within a reasonable haul distance. This situation will require that some excavated material will be wasted.
- d) The need to carry the road level considerably above the existing ground for extended distances through flood plain areas will generally require borrow excavation.

After the designer has analyzed all of the above factors and determined how he proposes to balance the earthwork, he is ready to start calculations as previously outlined.

In order to obtain a better perspective of the work the project should be broken down to sections not to exceed 5 kilometers in length. This allows the designer to work with smaller sections, solving the individual problems of each section involving drainage, grades, erosion control, and earthwork distribution. Figure 8 shows three situations where the balance line can be at the top, bottom or at the center of the mass curve. Note that Case 3 where the balance line is located at the center of the mass curve is not necessarily the ideal situation in all cases. The profile grade should be studied along with the mass haul diagram to determine where it will be more economical to haul towards back stations (Case 1), towards forward stations (Case 2), or to haul equally towards back and forward stations (Case 3).

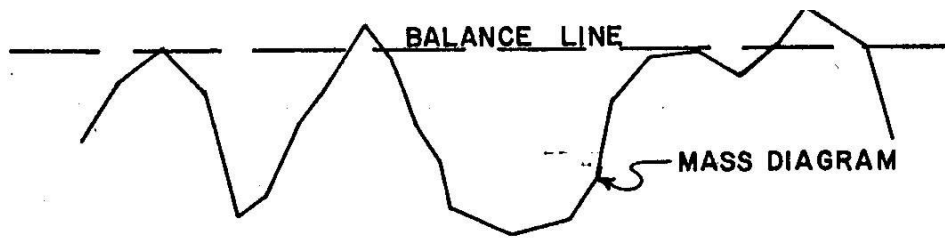
Free haul is defined as the maximum distance through which excavated material may be transported without added cost above the unit bid price. Prior to the use of high-speed pneumatic-tired earth moving equipment, free haul distances were limited to approx. 1000 meters, but distances of up to 2000 meters are not uncommon now. Special conditions on a project may require longer hauls, where restrictions do not allow excavation or borrow in the immediate area.

The economical limit of haul is defined as the distance through which it is more economical to haul excavated material than to waste and borrow. The following formula is presented as a guide to assist the designer in determining the economic limit of haul:

$$E.L.H. = F.H. \text{ distance} + \frac{\text{Unit Price of Borrow}}{\text{Unit Price of Overhaul}}$$

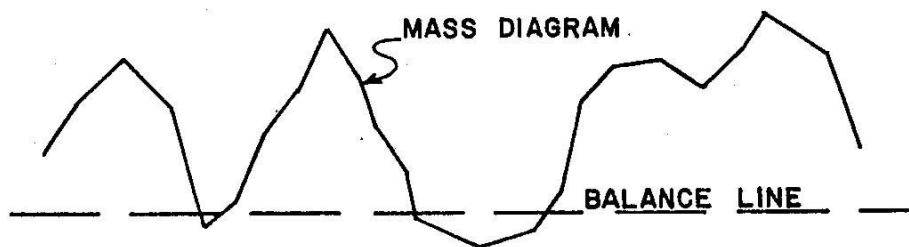
Where:

- E.L.H. = Economic limit of haul
- F.H. = Free haul distance



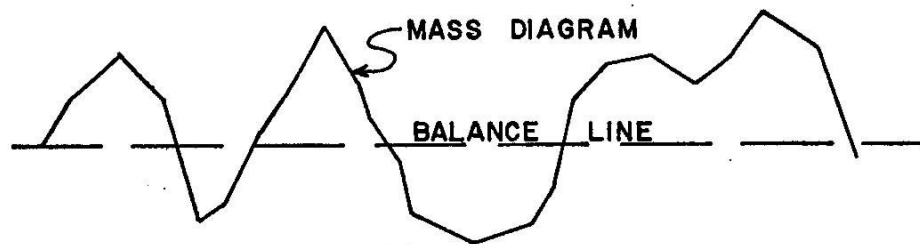
CASE 1

CASE 1: Excavation is hauled mostly to the left or towards back stations. This is recommended for steep grades uphill to produce haul in a downhill direction.



CASE 2

CASE 2: Excavation is hauled mostly to the right or towards forward stations. This is not recommended for steep grades uphill but can be used on downhill grades providing balance distances are not too long.



CASE 3

CASE 3: Excavation is hauled equally to left and right. This is optimum situation for most road construction where grades do not exceed 5%.

Figure 8 Location of Balance Line on Mass Haul Diagram

Overhaul is the product of volume times distance and is represented on the mass haul diagram as the area between the zero-balance line and the curve of the mass after eliminating all free haul. When the mass is

computed using adjusted cut (adjusted for swell), it is necessary to correct overhaul volume to unadjusted excavation by applying the proper correction factor.

Waste and borrow should be avoided on most types of projects by hauling suitable material within economical limits of haul. These terms are defined as follows:

- a) Waste is material excavated from roadway cuts but not required for making the embankments. It must be pointed out that this material is not necessarily wasted as the word implies, but can be used in widening embankments, flattening slopes or filling ditches or depressions for erosion control.
- b) Borrow is material not obtained from roadway excavation but secured by widening cuts, flattening cut back slopes, excavating from sources adjacent to the road within the right-of-way, or from selected borrow pits as may be noted on the plans. Borrow areas should be carefully selected after consideration of the suitability of the material; economic haul; access to the pits, including cost of access roads; drainage problems; and impact on the environment including timber production, fish life, watershed, soil erosion and all multiple land uses present and future.

Table 21 shrinkage percentage for different soil type

Material	% Of shrinkage
Light excavated soil (on ordinary ground)	10 – 20%
Light excavated soil (on swampy ground)	20 – 40%
Heavy Excavated soil	Up to 10%
Excavated Rock (Swell)	5 – 25%

The material in this project site is heavy excavated soil therefore shrinkage factor of 1.0 is adopted (no need of adjustment)

7 Pavement design

7.1 INTRODUCTION TO THE PAVEMENT DESIGN PROCESS

Effective pavement design is one of the more important aspects of project design. The pavement is the portion of the highway which is most obvious to the motorist. The condition and adequacy of the highway is often judged by the smoothness or roughness of the pavement. Deficient pavement conditions can result in increased user costs and travel delays, braking and fuel consumption, vehicle maintenance repairs and probability of increased crashes.

Pavement design is an integral part of the project decision process. The Project Team should discuss, consider, and document the pavement design as it relates to the overall project. The pavement is typically one of the major costs of a project. The pavement design affects maintenance of traffic, constructability, the environment, as well as other aspects of the project.

Pavement Design Engineer (PDE), and Research & Materials. The Designer must also apply sound engineering judgment. Steps in the design process include:

- Review Pavement Management Data to determine the appropriate scope of work and treatment type (i.e., new pavement, reconstruction, reclamation, resurfacing, or pavement preservation);
- Evaluate existing pavement to confirm the scope of work and determine preliminary design and appropriate construction strategy. Research roadway history and traffic data, verify existing pavement materials and structure. Perform field trips to make site inspections, prepare a pavement condition checklist, communicate with engineering and maintenance forces for history of roadway performance, groundwater problems and other background information;
- Evaluate sub-base and sub-grade for drainage characteristics and bearing capacity;
- Make structural calculations. The traffic, soils, and existing pavement data is used to calculate specific pavement course requirements;
- Set specifications. The pavement materials, construction methods, and finished project requirements must be both practical to attain and clearly defined. The Designer must ensure that the plans, specifications, and estimate clearly and unambiguously define the requirements.

For HMA structural resurfacing on Interstate and other controlled access highways, the design procedures contained in the 1993 AASHTO Guide features the following:

Use of statistical reliability instead of the factor of safety design;

- Use of resilient modulus tests for soil support (a dynamic test) vs. CBR (a static test); and
- Introduction of environmental factors to evaluate the effects of spring thaw and frost heave. PAVEMENT TYPES, DEFINITIONS, AND ABBREVIATIONS

Different types of pavements are commonly used in the construction of roadways. There are three different types of pavements. These are:

- Flexible Pavement
- Rigid Pavement
- Composite Pavement

Each of these pavement types is presented below.

FLEXIBLE PAVEMENT

A flexible pavement structure consists of the following layers – the sub-base, base course, intermediate course, surface course, and where determined necessary, a friction course[10].

- The sub-base consists of granular material - gravel, crushed stone, reclaimed material or a combination of these materials.
- The base course is an HMA or concrete pavement layer placed upon the compacted sub-base. A gravel base course can be designed and specified for low volume roadways (<2,000 vehicles per day) depending upon loading and other design considerations.

The intermediate course is an HMA pavement layer placed upon the base course. The surface course is the top HMA pavement layer and is placed upon the intermediate course[11].

- A friction course is a specialized thin-lift wearing course which, when specified, is placed over the surface course.

Friction courses provide improved vehicle skid resistance, but do not provide any structural value to the pavement. Typically, friction courses are placed on high volume limited access roadways.

RIGID PAVEMENT

A rigid pavement is constructed of Portland cement concrete (PCC) placed on a granular sub-base. PCC pavements are either plain and jointed or continuously reinforced. All newly

constructed or rehabilitated rigid pavements shall be designed as directed and approved by the PDE.

Composite Pavement

A composite pavement consists of one or more HMA pavement courses over a PCC base. All newly constructed or rehabilitated composite pavements shall be designed as directed and approved by the PDE[10].

7.2. Pavement materials

This Section defines the physical properties for materials to be used in the pavement structure and forms an essential part of the method for design of new roads and rehabilitation design for existing roads[11].

As far as possible all material types commonly used in our project are included such as natural gravel/soils, processed or crushed materials, materials stabilized with cement or lime and bituminous materials. The design procedures of this Manual permit the use of a wide range of materials, provided pertinent information on their behavior and likely performance is known. The choice of materials for any particular application should be based on considerations of structural requirements, economics, durability, workability and experience. This section is presented based on the following major material types[13]:

- Unbound Granular materials
- Cemented materials
- Bituminous materials
- Asphalt Concrete
- Spray Seals
- Cement Concrete.

For paved roads, the sub base is the lower most layer of a pavement, which separates the sub-grade or the capping layer from the base course. It is an important load spreading part of pavement, which reduces the traffic stress on the subgrade to acceptable level and protects the base course from contamination by highly plastic subgrade material[13].

7.3. Traffic forecasting

For our road segment entrance 2 to 3 in Wolkite University rather than a seven day count the total count is given as local street. Thus, only forecasting will be required. The above given data is for the normal traffic only. But there are other types of traffic to account in the analysis process.

Now the traffic volume at the opening year can now be easily determined as:

$$AADT_n = AADT_0 (1+i)^n, \dots\dots\dots \text{Equation 7.1}^{(12)}$$

where AADT_n: the normal base year (road opening year) traffic volume

AADT0: initial traffic volume as counted

i: growth rate n: the road construction period

$AADT_n = 1500(1+0.055)^2 = 1,669.3 \sim 1670$; only the normal traffic.

The generated and diverted traffic are accounted in percentage to be $= (13\%+6\%) * 1670 = 317.3 \sim 318$

Totally the traffic volume at the base year will be $1,670+318 = 1,988$

The traffic calculation is summarized in table form as follows.

Table 22 traffic forecast to the base year

Vehicle class	Typical percentage(local)	Normal traffic	Generated traffic	Diverted traffic	sum
Cars	97%	1620	211	81	1912
Light	3%	51	7	2	60
Medium	0%	0	0	0	0
Articulated	0%	0	0	0	0

For the purpose of pavement design the traffic volume can further be extended to the end of design period with the respective growth factor and the corresponding load of traffic is calculated. Tasks performed in this chapter

- Normal, diverted and generated traffic estimation
- Design period selection
- Growth rate determination
- Traffic forecasting

7.4. Traffic load calculation

According to AACRA’s pavement design manual the initial daily traffic loading is calculated using the equation;

$$N = N_C EF_C + N_L EF_L + N_M EF_M + N_H EF_H + N_A EF_A \dots\dots\dots \text{Equation 7.2}^{(12)}$$

Where the subscripts C, L, M, H, A stand for the traffic categories car, light, medium, heavy and articulated respectively. N and EF are the corresponding number and equivalency factors of the vehicle classes.

7.4.1. Axle Loads and Equivalency Factors

All design of bitumen surfaced road pavements shall be based on axle load surveys. The damaging effect of an axle passing over the pavement is expressed by the equivalency factor related to an equivalent standard axle (ESA) of 8160 kg load:

$$EF = \left(\frac{\text{axcle loads (Kg)}}{8160} \right)^{4.5} \dots\dots\dots \text{Equation 7.3}^{(12)}$$

In the absence of exact axle load survey results or studies for the specific project, generic values may be used based results from previous studies completed in Addis Ababa.

These are shown in Table 6.3 but caution should be used and sensitivity of design to the use of default values should be used based on the lower and upper values listed in the table.

Table 24. Typical Equivalency Factors for Addis Ababa Traffic (AACRA table 6.3)

Vehicle Class	Typical	Lower	Upper
Car	0.03	0.00	0.10
Ligh	0.73	0.39	1.07
Mediu	1.31	0.73	1.89
Heavy	1.61	1.05	2.18
Articulated	3.15	2.15	4.14

Since axle load survey is not given to be on the safe side, we took the upper equivalency factors put forward by the manual. But first the number of vehicles for each class has to be forecasted to the road opening time (after 2 yrs.');

$N_C = 1912$ (including the diverted and generated traffic), similarly

$N_L = 60$

$N_A = N_M = 0$

Now, $N = (1912 * 0.1) + (60 * 1.07) + (0 * 1.89) + (00 * 4.14)$

$$N = 256$$

For geometric traffic growth throughout the design period, total traffic over the design period is determined by multiplying the total traffic in the first year by the appropriate Cumulative Growth Factor from Table below or calculated exactly using the following equation:

$$GF = (1 + 0.01i) \left(\frac{(1 + 0.01i)^y - 1}{0.01} \right) \dots\dots\dots \text{Equation 7.4}^{(12)}$$

Where i: growth rate in % = 5.5% and

y; design period = 20 yrs.' While using the table interpolation could be done for intermediate values.

Table 23 Cumulative Growth Factors (GF) (AACRA table 6.4)

Design Period (years)	Growth Rate (% pa)					
	0	2	4	6	8	10
5	5	5.2	5.4	5.6	5.9	6.1
10	10	10.9	12.0	13.2	14.5	15.9
15	15	17.3	20.0	23.3	27.2	31.8
20	20	24.3	29.8	36.8	45.8	57.3
25	25	32.0	41.6	54.9	73.1	98.3
30	30	40.6	56.1	79.1	113.3	164.5
35	35	50.0	73.7	111.4	172.3	271.0
40	40	60.4	95.0	154.8	259.1	442.8

Since $i=5.5\%$ falls between 4 and 6 then our growth factor rate GF will be 33.3 (by interpolation).

Because asphalt, cemented materials and subgrades each have different performance relationships it is necessary to determine separately for each material the number of standard axles which will cause the same level of accumulated damage as the actual traffic load spectrum. The design loading is then calculated as the design number of standard axles for:

$$\text{Asphalt} = N_{sa} \times 365 \times GF \dots\dots\dots \text{Equation 7.5}^{(12)}$$

$$\text{Subgrade} = N_{ss} \times 365 \times GF \dots\dots\dots \text{Equation 7.6}^{(12)}$$

$$\text{Cemented materials} = N_{sc} \times 365 \times GF \dots\dots\dots \text{Equation 7.7}^{(12)}$$

Where GF is the cumulative growth factor from the Table or equation and a lane distribution factor of 1 (two-way two-lane road) and direction factor of 0.5(only one direction flow should be considered) has to be introduced in the equation.

$$N_{sa} = 1.1N$$

$$N_{ss} = 1.1N$$

$$N_{sc} = 10.0N \dots\dots\dots \text{Equation 7.8}^{(12)}$$

And N is the initial daily traffic loading. which is 256

$$\text{Thus ESA} = 365 * 1 * 1.1 * 256 * 33.3 = 3,422,707.2 = 3.4227072 * 10^6 \text{ (two-way two-lane road)}$$

$$\text{ESA} = 0.5 * 3.4227072 * 10^6 = 1.71135 * 10^6 \text{ (One direction flow load)}$$

Table 24:- ERA Traffic classes for Flexible Pavement Design

Traffic classes	Range (10 ⁶ ESAs)
T1	< 0.3
T2	0.3 - 0.7
T3	0.7 - 1.5
T4	1.5 - 3.0
T5	3.0 - 6.0
T6	6.0 - 10
T7	10 - 17
T8	17 - 30

Based on the above analysis, the main access road under study would belong to the traffic class **T4** for flexible pavement design.

7.5. SUB-GRADE

The type of subgrade soil is largely determined by the location of the road. However, where the soils within the possible corridor for the road vary significantly in strength from place to place, it is clearly desirable to locate the pavement on the stronger soils if this does not conflict with other constraints. For this reason, the pavement engineer should be involved in the route corridor selection process when choices made in this regard influence the pavement structure and the construction costs.

The strength of the road subgrade for flexible pavements is commonly assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the type of soil, its density, and its moisture content. Direct assessment of the likely strength or CBR of the subgrade soil under the completed road pavement is often difficult to make. Its value, however, can be inferred from an estimate of the density and equilibrium (or ultimate) moisture content of the subgrade together with knowledge of the relationship between strength, density and moisture content for the soil in question. This relationship must be determined in the laboratory. The density of the subgrade soil can be controlled within limits by compaction at a suitable moisture content at the time of construction. The moisture content of the subgrade soil is governed by the local climate and the depth of the water table below the road surface.

7.5.1. Soil property

The next thing to do after load calculation is evaluation of the subgrade. The subgrade is the most important part of a pavement since every other layer is laid on it has to be strong enough to support all the loads from traffic. The subgrade can also be considered as a foundation which provides a level surface for the construction of the road. According to the data we are given the soil type in the area is of very poor strength, CBR value of less than 3% for almost all test pits. Expansive clays which are commonly known

as black cotton soil are present Wolkite university. The material is characterized by its high swelling behavior when saturated and shrinks and cracks when dry. The development of cracks allows water to enter deep in to the sub-grade material causing considerable expansion due to change of volume and causes deformation of the pavement surfaces. This has been causing difficulties in road and airport runway performances in Wolkite university. When black cotton soil is saturated, its volume changes and the bearing value decreases to $\text{CBR} < 2\%$. In the dry state, the black cotton soil becomes fissured and affected by soil falls, which gives way to develop into gullies.

❖ **Low Strength Soils**

Soil with CBR less than 3% are described as Low Strength Soils. Before acceptance as foundation of the pavement within the design depth these soils require special treatment that may include one or more of the following measures:

- removal and replacement of soils.
- chemical stabilization or modification.
- mechanical stabilization.
- raising of the vertical alignment to increase soil cover

Further details on the respective methods for treatment of these soils need to be established in the design at project level and will vary depending on soil properties, site conditions, available equipment, available materials, experience from other sites with similar conditions and construction economy.

❖ **Expansive Soils**

Expansive soils are those that exhibit particularly large volumetric changes (swell and shrinkage) following variations in their in-service moisture contents. Expansive soils shall be assessed also when they occur below design depth. The chosen measures to minimize or eliminate the effect of expansive soils shall be economically realistic and proportionate to the risks of potential pavement damage and increased maintenance costs. The most economical and viable method of treating the expansive soils in Wolkite university area would be excavating and spoiling of the expansive soil and replacing it with suitable fill material[13],[19].

imported from economic hauling distances. For medium and heavy traffic roads it is sufficient to excavate and replace the soil to a depth of about 1m. It is recommended that the backfill material should have minimum CBR of 5% and swelling $< 2\%$, and be impermeable enough not to allow water in to the underlying soil[19],[12].

Tests conducted on Subgrade Soil

It is recommended that laboratory tests should be carried out to determine the particle size distribution and in-situ moisture content for every sample taken[13]. Generally, the tests conducted on the subgrade soil sample are;

- Particle size distribution (Sieve Analysis)
- Moisture content determination
- Atterberg limits
- Proctor Compaction test
- CBR & Swell test

1. Proctor Compaction Test

A. theory:

The purpose of laboratory Compaction test is to determine the optimum amount of mixing water use when compacting the soil in the field and the resulting high degree of denseness, increase shear strength, decrees settlement and decrees permeability which can expected from compaction at this optimum water content[13].

Generally, Procter compaction test is used to determine or obtain the optimum moisture content (OMC) of a soil at which a specified amount of compaction will produce the maximum dry density (MDO). Procter compaction test could be standard Procter test or modified Procter test[12].

Standard Procter test: - it is a test with light compaction for light traffic road construction by using 2.5kg rammer and 3-layer compaction.

Modified Procter test: - heavy compaction for heavy load construction (axel load) by using 4.5kg rammer and 5-layer compaction. In this project the heavy compaction test (modified Procter test) is used because of the design standard of the road.

Table 25 Comparison of 'Standard Proctor' and 'Modified Proctors' Compaction Tests

Type of test	Hammer mass (Kg)	Hammer drop (m)	Blows /layer	Number of layers
Modified proctor	4.5	0.45	25	5
Standard proctor	2.5	0.24	56	3

Standard Procter test is carried out with the following parameter.

- By using diameter of mold which equal to 152mm
- Weights of rammer which equal to 2.5kg
- Height of rammer which equal to 46cm
- No of blows which equal to 75 (25 per layer)
- No of layer which equal to 3

Apparatus that used to perform modified Procter test

- ✓ Mold - measuring cylinder - balance - oven dry
- ✓ Rammer - metal tray - knife - moisture can

Test procedures

1. check then mold that it is clean & dry
2. weight the mold and recorded it
3. prepare samples of soil 6kg it passing 19 mm sieve size
4. adjust the moisture content to desired starting value & mix thoroughly
5. place some sample on the mold for the 1st layer & compacted with 56 blows
6. Repeat it up to 5th layers
7. trim the surface carefully and small fragment at the surface should be filled with fine materials
8. weight the sample+ mold & record it
9. extrude and break up the sample
10. Take small sample and let it oven dry with 24hrs
11. repeat the above all process for the other two samples by increasing the amount of water by 2% of previous sample
12. If decrease in weight not noted, prepare other sample and proceed with the same steps until you get a decrease in weight.

Conclusion

Soil type and gradation heavily affect the density that can be achieved by compaction. From the above test the soil is clays do to that it has low MDD with high OMC in direct granular or well graded soil have high MDD with low OMC.

From the above the maximum dry density and the optimum moisture content of soil are 2.06gm/cm³ and 5.2% respectively. In the cause of sub base material, the sample is divided on to two parts and the half plats is sieved using sieve size 19mm and the retained is weighed. If it is greater than 10% of the sieved sample the retained amount is replaced with similar amount of sample passing sieve size 19mm but retained on sieve size 4.75mm.

7.5.3 California bearing ration (CBR) test

This was developed by the California division of highway it is used to evaluate per penetration strength of sub grade, sub base, base course and surfacing material. In these test material samples compacted in standard CBR mold at OMC are tested to give a relative strength of the material for pavement structure with respect to crushed rock which is consider an extent base cause material. It is developed to measure the resistance of a material to per penetration of a standard plunger under controlled moisture content & density. Three sample of material each 6kg are prepared from either of the following condition. That is: -

- If all pass 19mm sieve
- for sub base and capping it rented on save 19mm is less than 10% no correction is needed for its removal
- if rented on 19mm sieve is gather than 10% it should reply by a similar mass passing sieve size 19mm rented in sieve size 4.75mm

Then 3 sample of mold are prepared with: -

- same amount of water
- same number of laver (5 laver)
- different number of blows plunger for each sample mold number of 10,30 and 65 blows

The graph of CBR is drown with load with KN vertically vs penetration (mm) with horizontally and determined CBR value for penetration of 2.54m & 5.08mm with standard load with km of 13.4KN & 20KN respectably. Then the two values are compared and if CBR value of 2.54mm is greater than

5.08mm that is the value & CBR at 2.54mm < CBR at 5.08mm the test is entirely repeat on fresh specimen[20]. If no change takes the value as it is.

Apparatus used: - mixing tray, mold, rammer, 4.75 & 19mm sieve, balance, dialogite, oven, CBR tester, soaking taker, filter paper, knife & moisture can.

Procedure for CBR test

- ❖ determine the natural moisture content of soil
- ❖ Calculate the amount of water to be added from NMC & OMC (from Procter test) that is

$$M = \frac{(W-WN) \times \text{material}}{(100+W)} \dots\dots\dots\text{Equation 7.9}$$

Where: - W=optimum moisture content

WN= natural moisture co

M= amount of water to be added

- ❖ Weigh 6kg sample & added the amount of water & mix thoroughly
- ❖ Weigh mold & recorded
- ❖ Place the 1st portion of the sample in to the mold & compact it with required blows
 - Mold one = 10 blows
 - Mold two = 30 blows
 - Mold three = 65 blows
- ❖ Weigh mass of mold with sample & recorded it
- ❖ Place a disk of course filter paper on the perforated base plate
- ❖ Invent the mold & place filter paper on it & then surcharge weigh
- ❖ Mount the dial gauge support on top of extension collar. Fix the dial gauge & adjust the level of the stem on the perforated plate, so that the gauge reads zero level or any other convenient value.
- ❖ Immerse the assembled mold in water allowing free access of water in top & bottom.
- ❖ Take the initial measurement for swell immediately & soak it for 4 days take final swell measurement after 4 days soaking

Calculation of swell

$$\% \text{ sell} = (H2-H1) \times 0.0254 \times 100 / H$$

Where: - H= height of specimen

H1= initial dial reading

H2= final dial reading

Diversion of the swelling dial gauge = 0.0254

Perpetration procedure

- ❖ Remove the sample and mold from tank & allow it to drain 15 min
 - ❖ Remove surcharge, perforated plate, extension color & weigh the mold sample weight
 - ❖ Place the mold with base contains the sample centrally on the CBR testing machine
 - ❖ Contact the plunger with the top of the sample surface
 - ❖ Mount the penetration dial gauge on the bracket attached to the plunger
 - ❖ Adjust the penetration dial gauge to read zero or some convenient datum reading
- Switch on the power, record the load ring dial & penetration at 0.64mm, 1.27mm, 1.95mm, 2.54mm, 3.81mm, 4.45mm, 5.08mm, 0.16mm & 12.7 mm.

Sub-Grade Class

For the purpose of pavement design, the sub grade classes of uniform sections are determined by the different manuals used in pavement design. The sub grade categories specified in ERA manual and summary of the subgrade class is shown in table 6-2 presented below.

Table 26 Table 4.3 Subgrade Strength Classes (4)

Class	Range (CBR %)
S1	2
S2	3-4
S3	5-7
S4	8-14
S5	15-29
S6	30+

Since we use an improved soil with CBR value of 5%; the subgrade is classified under class S3.

8.Drainage Design

General

The hydrological study was undertaken in order to compute peak discharges for all watershed areas that crosses the project road[21]. Calculation of these peak discharge values enabled the determination of the hydraulic opening sizes and types of waterways required for all cross-drainage structures and longitudinal drains. There are many methods developed for calculation of the design flood but their applicability depends mainly on the availability of hydrological data[21]. As most of the methods have parameters which depends on climate and morphological condition. The climate data (rainfall data) and morphological condition of the project area were collected and analyzed.

The hydrological analysis was carried out using available maps together with the data acquired from Meteorological Services Agency. Additional information about the project area was collected from site visit and other different sources. For this project, rational method was used for runoff computation depending on the size of catchments area.

8.1 Watershed of the Project Area

Watersheds of the project area are determined from satellite image and field surveys. The area is found to be 0.324sq.km[6].

Likewise, land use and land cover map of the area is revised according to the site visit for their major concerns focus on consequences of land use change and runoff estimation.

The soil group of the project area is black cotton Soils Group Band the majority of the land cover of the area is urban[21],[7]. Topographically the project road is, surrounded by built-up, and flat. In addition, DEM generated using Global Earth Pro software is used to determine and verify the catchment area, watershed shapes, stream length, stream slope, and average slope of watershed which crosses the route.

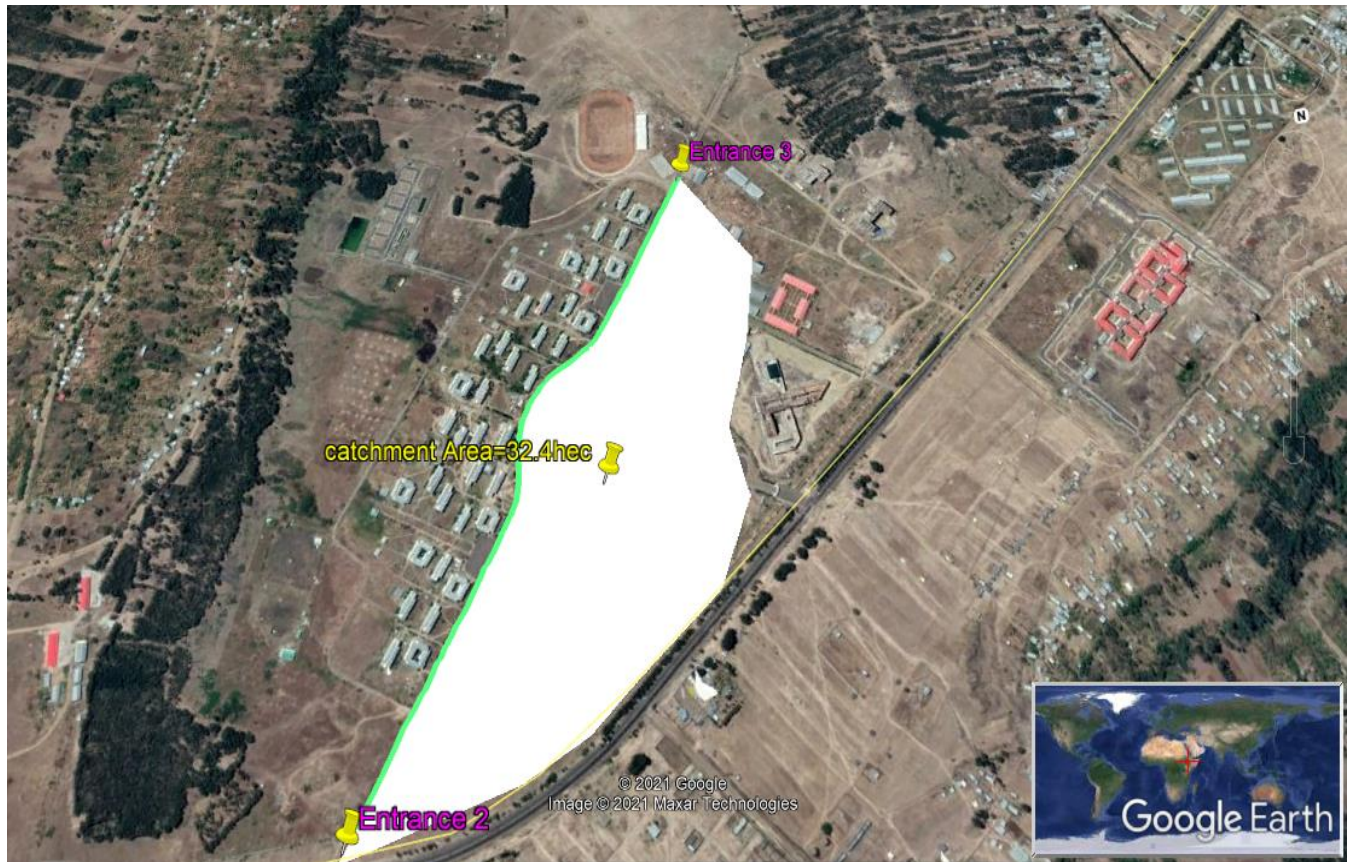


Figure 9 catchment area of in Wolkite near entrance 2 to 3

8.2 General Design Consideration for Hydrological Study

Design Frequency or Return Period AACRA DDM recommends different design frequency based on the road design standards. The subjected road of the project is Street; Hence, the recurrence interval values which are given in the table below are used for hydraulic design of drainage structures[21].

Table 27:- Recurrence interval for drainage structures design

Drainage Structures Type	Return Period
Side ditch	10
Culvert, pipe (span < 2m)	10
Culvert, 2m<span<6m	25

8.2.1 Objectives for Drainage Design

- **To identify Culvert size and shape:** - the culvert size and shape selected is to be based on engineering and economic criteria related to site:

- To come up conditions absolute minimum size to be used to avoid maintenance and clogging. land use requirement can dictate larger or different barrel geometry than required for hydraulics requirement.
- Material selection: concrete is the preferred material for construction of culverts; however, other materials may be more suitable for a particular location, hydraulic roughness, bedding condition or project. In evaluating the suitability of alternate materials, the selection process shall be based on a comparison of total cost of alternate materials over the design life of the structure that is dependent upon:
 - Durability (service life)
 - Cost
 - Availability
 - Construction and maintenance ease
 - Structural strength
 - Traffic delays
 - Abrasion and erosion resistance and
 - Water tightness requirements.

Protection and controls

- **Out let protection and control:** in general, scour holes at culvert out-lets provide efficient energy dissipaters. Out-let protection for the selected culvert design flood shall be provided where the out- let scour hole depth computations indicate:
 - the scour hole will undermine the culvert out- let
 - the expected scour hole may cause costly property damage
 - the scour hole causes a nuisance effect
- **Inlet and out let control**

An exact theoretical analysis of culvert flow is extremely complex because of the following is required:

 - Analyzing non-uniform flow with regions of both gradually and rapidly varying flow.
 - Determining how the flow type changes as flow rate and tail water elevations change.
 - Applying back water and draw down calculations, energy and moment balance.
 - Applying the results of hydraulic model studies and

- Determining if hydraulic jump occur and if they are inside or downstream of the culvert barrel.

Out let velocity: - culvert out let velocities should be calculated to determine the need for erosion protection at the culvert exit. Culverts usually give out-let velocities that are higher than the natural stream velocities. Thus out-let velocities may require flow re-adjustment or energy dissipation to prevent down steam erosion.

8.2.1 Methods of Design Flood Computation

There are many different hydrological calculation methods that may be applied to road drainage. Some of the proven and most suitable methods have been selected for inclusion in this project.

Even though there are two most common design flood estimation methods that presented in AACRA Drainage design manual, the team selects Rational Method which is most appropriate for this project.

The rational method is based on a simplified representation of the processes and variables involved in flood runoff. Rainfall intensity is an important input to the calculations. Because uniform area and time distribution of rainfall have to be assumed, the method is normally only recommended for catchments smaller than 0.5km² in ERA drainage design manual[21].

A. Design discharge computation

There are different methods of determining drainage design discharge; of these methods rational formula method is preferable for our project depending on the catchment area which has contribution for peak discharge. (Area<50ha or 0.5Km²)⁽²⁰⁾

The rational formulas estimate the peak rate of runoff at any location in a catchment area as a function of the catchment area, runoff coefficient, and mean rainfall intensity for a duration equal to the time of concentration (the time required for water to flow from the most remote point of the basin to the location being analyzed). The rational formula is expressed as:

$$Q = 0.00278 CIA \dots \dots \dots (8.1)^{(20)}$$

Where: - Q = maximum rate of runoff, m³/s

C = runoff coefficient representing a ratio of runoff to rainfall⁽²⁰⁾

I = average rainfall intensity for a duration equal to the time of concentration, for a selected return period, mm/hr⁽²⁰⁾

A = catchment area of tributary to the design location, ha

B. Runoff coefficient(c)

Runoff coefficient indicates or tells the permeability or run off generated capacity of a given water shade. The magnitude of the parameters depends on: type of the development with the

catchments area, slope of the catchments area, types of soil, and intensity and duration of the rain fall[19],[12].

Table 28 Recommended Runoff Coefficients for Various Selected Land Uses from AACRA 2013

Type of Area	Run off coefficient
Business down town areas	0.7-0.95
Neighborhood areas	0.5-0.7
Residential –single family areas - Multi units detach	0.3-0.5 0.4-0.6
Multi units attached	0.6-0.75
Sub-urban	0.25-0.4
Residential (0.5 ha or more)	0.3-0.45
Apartment dwelling areas	0.5-0.7
Industrial – light areas	0.5-0.7
Heavy areas	0.5-0.8
Unimproved areas	0.1-0.3

In or case since wolkite university is residential area we use C value for residential area Which is between 0.3-0.45. i.e., average of the two.

This method is the most widely used methods for determining peak flows from small catchments. The peak flow is obtained from equation 8.1 above. And time of concentration is 30mm (assumption)

$$\begin{aligned}
 Q_d &= 0.278CC_pIA, \text{ where } A=0.324\text{km}^2=32.4\text{ha} \\
 &c=0.375 \\
 &I=41.467 \text{ mm/hr} \\
 &= 0.288*0.375*1.0*41.467*32.4 \\
 &= \underline{1.399 \text{ m}^3/\text{sec} \sim 1.40\text{m}^3/\text{s}}
 \end{aligned}$$

8.4 Roadside Drainage

Side ditches are an important part of the drainage system especially in urban section and in cut areas. The major purpose of roadside channels is to collect surface runoff from the road and adjacent areas which drain to the right of way and convey the accumulated runoff to acceptable outlet points.

A. Importance of cross drainage

The adequate functioning of a road depends to a large extent on the effectiveness of cross drainage. The function of the cross-drainage structures is to ensure that the runoff water is discharged across the road from one side to the other, as quickly as possible, without causing undue pounding parallel flow along the road embankment, overtopping of the road embankment or erosion of the portions of the road. Quick drainage prevents water from penetrating the soil in the embankment. A dry sub grade has greater bearing strength than a wet sub grade.

B. Types of cross drainages structures

Cross drainage structures are divided in to the following categories:

1. **culverts** which have a total water way up to 6m
2. **Minor Bridge size**, which have a water way in the range 6- 30 m
3. **Medium Bridge size**, bridges which have a water way in the range 30-100m.
4. **Major Bridges size** which has a water way greater than 100m.
5. **Causeways** which allow the water to flow over the road way.

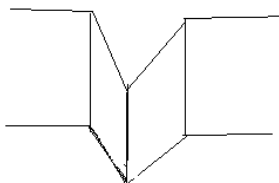
Out of the above structures we selected culvert for this particular project due to:

- Our project road crosses small streams obtained from run off.
- Unavailability of topography of the whole adjoining area to know run off amount.

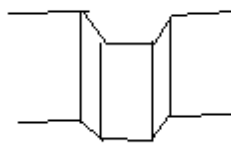
A. The Need- simultaneous to providing protection cover on earth slopes, it is necessary to provide collection of surface water otherwise the water concentrated by roadway surfaces and cut slopes can quickly reach erosive quantities and velocities and cause serious damage. Besides the collection of surface water, another function of roadside ditches is to drain the base course of the road, failing which saturation of the base course and consequent loss on its shear strength can occur resulting in rapid deterioration of the road system.

B. cross- section

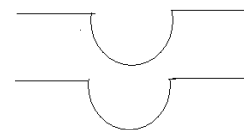
The three main types of x- sections for roadside ditches are shown below. Of the three shapes, the parabolic section is hydraulically the best and most resistant to erosion, even though not as easy in construction as the trapezoidal and triangular shapes.



1. Triangular



2. Trapezoidal.



3. Parabolic

The triangular section although easy to construct is very much susceptible to erosion and gets easily blocked with debris and is generally not recommended.

The most commonly used cross section is the trapezoidal section as it is accepted from both considerations, hydraulic as well as ease of construction.

The side slopes of the ditches as earth slopes should be flat lying in the range 2:1 to 4:1; while the quantity of water to be drained, the length of drain and the gradient will actually determine the width at bottom, it should normally be not less than 0.3m.

8.5 Design of Ditch

Amount of surface water further depends upon intensity of rain fall, amount of rain fall, topography of the area, nature of soil, extent of the area to be drained, etc. Taking all these points into consideration, maximum quantity of water that these ditches or drains have to handle, can be estimated.

Once the quantity of water to be handled is estimated, the next step will be their hydraulic design. Side drains and partially filled culverts are designed for flow through open channel conditions. The following data are to be collected for the design of road side drains:

1. Length of the road and breadth of the land from where rain water will flow on the stretch of the side drain.
2. Fix run off coefficient for the area.
3. Distance from furthest point in the drainage area to the inlet of the side drain.
4. Fix roughness coefficient and thus the velocity of flow in the drains.

To fulfill the requirement of the roadside ditch, the base course of the road pavement, the bottom of the ditch has to be taken at least to a depth 0.3 to 0.6m below the shoulder level.

The side channel design is based on the Manning's formula, given by:

$$Q = 1/nAR^{2/3} S^{1/2}$$

Where:

n = Manning's roughness coefficient

A = Cross sectional area of the ditch

R = Hydraulic Radius

S = Longitudinal slope of the channel

Q = the design discharge

The design discharge has been determined by the rational formula. The discharge computed based on the rainfall intensity 10 years return period for local street. The rainfall duration is based on the time of

concentration. The rainfall intensity is derived from the IDF curve after the project area is identified in rainfall.

The Manning's roughness coefficient for lined channels has been obtained from AACRA Drainage Design Manual and its value is 0.02.

$$\text{From this, } Q = 1/nAR^{2/3} S^{1/2}$$

For most economical section of rectangular channel $b = 2y$

$$Q = 1/n * 2y^2 (2y^2/4y)^{2/3} * .01^{1/2}$$

$$\text{For } Q = 1.399\text{m}^3/\text{s}, n = 0.012, \text{ and } S=0.01$$

By trial and error, the value of $y = 0.468\text{m}$

Implies $b = 0.936\text{m}$

Check for the capacity of the ditch

$$\text{Cross sectional area} = b*y = 0.438\text{m}^2$$

$$\text{Wetted perimeter} = 2y+b = 1.872\text{m}$$

$$\text{Hydraulic radius} = A/P = 0.234$$

$$\begin{aligned} \text{Velocity} &= 1/n * R^{2/3} * S^{1/2} \\ &= 3.164\text{m/s} \end{aligned}$$

$$\text{Ditch capacity} = A*V = 1.386\text{m}^3 \quad \text{not ok! Which less than } Q=1.399\text{m}^3/\text{s}$$

- ❖ But For safety case and for some inconvenience of runoff determination the calculated discharge is increased by 50%

$$Q_d = 1.386\text{m}^3/\text{s} * 1.5 = 2.079\text{m}^3/\text{s}$$

The capacity of ditch = $1.945\text{m}^3/\text{s}$ and it is greater than expected run off (Q_d) i.e., $Q > Q_d$ ($2.079\text{m}^3/\text{s} > 1.386\text{m}^3/\text{s}$).

Therefore, the provided ditch is adequate and the layout of rectangular cross section is drawn as follow;

Check the capacity of the ditch

The capacity of the ditch for the largest cut section is given by

$$Q = A * \left(\frac{1}{n} * R^{2/3} * S^{1/2}\right) \dots\dots\dots (8.3)^{(20)}$$

$$A = (b + my) * y \dots\dots\dots (8.4)^{(20)}$$

$$P = (b + 2y) \sqrt{m^2 + 1} \dots\dots\dots (8.5)^{(20)}$$

$R = y/2$, y for economical trapezoidal section

Let assume the depth of the ditch is 0.6m and side slop is (0.5H: 1V) and also slope of the energy grade line $S = 0.01$ which is the minimum value.

$$A = (b + 0.5 * 0.6) * 0.6 = 0.5b + 0.3 \text{-----eq (a)'}$$

$$P = (b + 2 * 0.6 \sqrt{0.5^2 + 1}) = b + 1.189 \text{ -----eq (b)'} \\ R = 0.6/2 = 0.3, R = A/P \text{ -----eq(c)}$$

By substituting eq (1)' & (eq(b)') in eq(c)

$$0.3 = \frac{0.5b + 0.3}{b + 1.189}$$

It can be simplified as and we get width (b) is 0.489m use b = 0.5m

By substituting the value of b=0.5m in eq(a)' & eq(b)') the area and wetted perimeters is 0.55m² and 1.789m respectively. (i.e., A = 0.55m² and P = 1.789m).

$$Q = \frac{1}{0.025 * 1.12} * 0.25^{2/3} * 0.06^{1/2} \\ Q = 1.945 \text{ m}^3/\text{S}$$

❖ **But for safety factor the ditch capacity is increased by 50%**

$$Q = 1.945 \text{ m}^3/\text{S} * 1.5 = 2.895 \text{ m}^3/\text{S}$$

Hence the capacity of ditch = 2.895m³/S and it is greater than expected run off (Qd)

i.e., Q > Qd ((2.895m³/S > (2.079m³/S)).

Therefore, the provided ditch is adequate and the layout of trapezoidal cross section is drawn as follow;

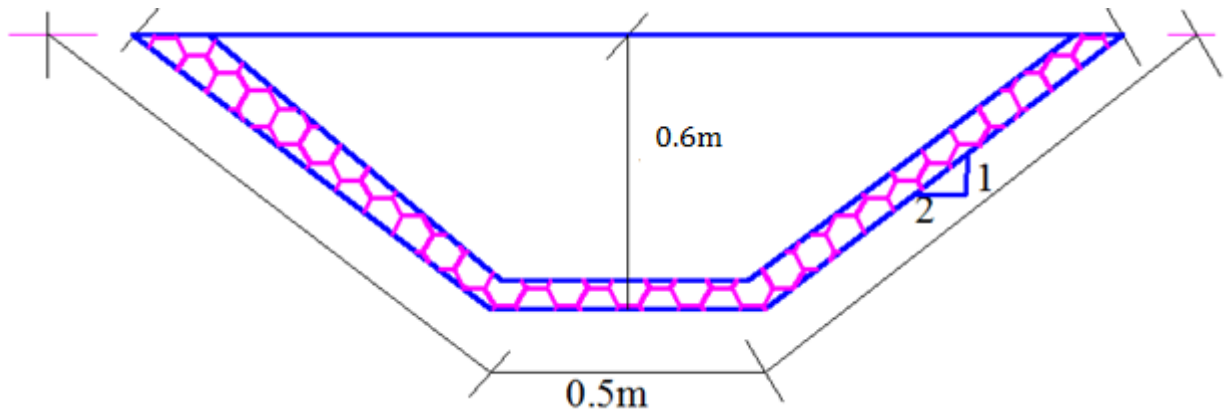


Figure 10. Cross Section of Trapezoidal Ditch

8.6 Culverts

Standard procedure of hydraulic computation was adopted for checking the capacities of the proposed culverts. The most economical culvert is one which utilises all of the available headwater to pass the design discharge, since the discharge increases with increasing head. However, it is not always possible to utilise all of the available headwater, because of constraints which limit the upstream water level in some cases.

In flat terrain, drainage channels are often non-defined and culverts should be located and designed for least disruption of the existing flow conditions. In these locations multiple culverts can be considered at specific interval to have a common headwater elevation, although this will not be precisely so.

The most important consideration in culvert hydraulics is whether the flow is subject to inlet or outlet control. For inlet control two distinct regimes exist, depending on whether the inlet is submerged or not submerged. Outlet control occurs in long culverts, laid on flat grades and with high tail water depths. In designing culverts, the type of control is determined by adopting the greater of the headwater depths calculated for both inlet control and outlet control.

The flow capacity of a culvert is governed by three main criteria, the capacity of the pipe, the hydraulics of the inlet and the downstream water level.

Type of culverts

As stated above across small streams culverts are constructed but in case of large streams or rivers bridges are constructed. Culverts are constructed with various materials and to different designs.

Slab culverts, Box culverts, Arch culverts and pipe culverts are the usual types of culverts most commonly used for cross drainage works.

1. **Pipe culverts:** when the stream carries low discharge and is having high embankment, pipe culverts are considered more suitable. Pipe is laid slightly inclined. For ease inspection minimum diameter of pipe should be 75cm. There should be at least 90 cm cover of soil so that traffic load transmitted on pipe is of small intensity and also without vibrations.

Pipe may be made of stone ware, concrete, R.C.C etc. Pipes should be laid on 15 cm cement concrete bedding.

2. **Slab culvert:** these culverts have masonry abutments with stone slab over them. They are mostly used up to about 2m span. In localities where stone is easily available these culverts are mostly used, where stone patties are not available, R.C.C. slabs are used. R.C.C slabs are designed as simply supported slabs[21].

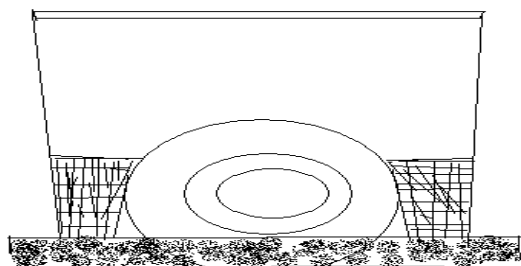


Figure 11:-Pipe culvert

3. **Box culverts.** These culverts are constructed where the nature of the soil below the foundation is not suitable for individual footing under piers and abutments. It is a monolithic rectangular drainage structure. The size of the rectangular passage should not be less than 60x60 cm for easy cleaning of debris. Short span box culverts can be pre-cast[21].
4. **Arch culvert:** This culvert is preferred under the conditions where high fillings are evolved and there are heavier loadings on the culvert. Arches may be built from brick, or stone masonry, or plain cement concrete. Span of each arch should be kept less than 3m. Selection of culvert to be used is done on the basis of availability of construction materials and economic conditions.

Based on these selection criteria as stated below, we selected R.C.C pipe culverts due to:

1. They are economical since a circular section is the most ideal one for withstanding forces from all around.
2. Since the pipes do not need very elaborate bedding, the cost further comes down.
3. Pipe culverts do not demand structural design for individual cases. Pipes are standardized in terms of mix, thickness and reinforcement
4. Pipes can be cast under strictly controlled conditions at a central plant and thus their quality is assured.
5. They generally eliminate the humps in longitudinal profile. The disadvantages with culvert are that they cannot be used for large openings. A minimum cover of at least half the diameter of the pipe is to be ensured over the pipes[12].

Location of Ditch and culvert

Submergence of a culvert outlet may result from a reduced channel slope or an inadequate culvert downstream or an ending densely overgrown channel. Submergence of the outlet is most likely to occur in flat terrain. The total head loss (h_L) can be described as follows[21].

$$h_L = h_e + h_f + h_v \dots\dots\dots (8.6)^{(20)}$$

Where:

h_L = total head loss;

h_e = entrance loss;

h_f = friction loss;

h_v = velocity head in the barrel.

Entrance loss is a function of the velocity head in the culvert. Friction loss may be computed with the Manning formula.[12]

$$h_L = k_e \frac{v^2}{2g} + \frac{n^2 v^2 L}{R^{4/3}} + \frac{v^2}{2g} \dots\dots\dots (8.7) \text{ }^{(20)}$$

The expression can be reduced to:

$$h_l = (K_e + 1 + 2gn^2L/R^{4/3})v^2/2g \dots\dots\dots (8.8) \text{ }^{(20)}$$

$$= \left[1 + k_e + \frac{19.6n^2L}{R^{1.33}} \right] \frac{V^2}{2g} \dots\dots\dots (8.9) \text{ }^{(20)}$$

For this project,

n = Manning's friction coefficient = 0.010-0.013 (Table 7-1 from the manual) [22]

L = Length of the barrel (m) = 15m (assume)

R = Hydraulic radius (m) = A/P

$$= 0.438\text{m}^2/1.872\text{m} = 0.234$$

V = Mean velocity of flow in the culvert barrel, m/s

$$= Q/A = 1.386\text{m}^3/0.438 = 3.164\text{m/sec}$$

$$H_v = \text{Velocity head (exist loss)} = \frac{v^2}{2g} = 0.51$$

$$H_f = \text{friction loss} = \frac{19.6n^2L}{R^{1.33}} \frac{v^2}{2g}$$

$$= 0.104\text{m}$$

$$H_e = \text{Entrance loss} = K_e \frac{v^2}{2g} \quad (\text{Table 7-2 from the manual})$$

K_e = entrance loss coefficient = 0.5

$$H_e = 0.258$$

$$\text{Barrel loss} = 0.517 + 0.104 + 0.258$$

$$= 0.879\text{m}$$

Let the culvert to be used is

Shape = circular

Size = 1200mm in diameter

Interference type = square edge with headwall

Design Discharge Q_d

$$Q_d = \underline{1.405 \text{ m}^3/\text{sec}}$$

Determination of inlet Control Headwater Depth (HW_i)

Using chart 7-1 from ERA DDM -2002 and values of discharge and diameter.

HW _i /D	HW
4.6	5.52

- Determine Outlet Control Headwater Depth at Inlet (HW_{oi})

$$HW_o + (V_u^2/2g) = TW + (V_d^2/2g) + H_L$$

HW_o = headwater depth above the outlet invert, m

V_u = approach velocity, m/s

TW = tailwater depth above the outlet invert, m

V_d = downstream velocity, m/s

H_L = sum of all losses

$$\begin{aligned} TW &= HW_o - V^2/2g + h_l \\ &= 5.52 - 0.517 + 0.924 \\ &= 5.927\text{m} \end{aligned}$$

Calculate critical depth (d_c) using chart 7-3= 1.2

$$= (d_c + D)/2 = 1.2$$

h_o = the larger of TW or (d_c + D/2)

$$= 5.927\text{m}$$

$$HW_{oi} = H + h_o - SoL$$

$$= 0.924 + 5.927 - (0.01 \cdot 15)$$

$$= 6.701 > 1.2D \text{ therefore it is inlet control}$$

- Determination of Controlling Headwater (HW_c)[23].

In comparison of HW_i and HW_{oi}, we use the higher

$$HW_c = HW_i, \text{ if } HW_i > HW_{oi}$$

the culvert is in inlet control

$$HW_c = HW_{oi}, \text{ if } HW_{oi} > HW_i$$

the culvert is in outlet control.

- Computation of Discharge over the Roadway (Q_r)

Computation of depth above the roadway (HW_r)

$$\begin{aligned} \text{HW}_r &= \text{HW}_c - \text{HW}_{ov} \\ &= 6.701 - 2.437 \end{aligned}$$

$$\begin{aligned} \text{HW}_{ov} &= \text{height of road above inlet invert} \\ &= 4.264\text{m} \end{aligned}$$

Compute Total Discharge (Q_t)

$$\begin{aligned} Q_t &= Q_d + Q_r[23] \\ &= 5.917 + 5.367 \\ &= 11.284 \end{aligned}$$

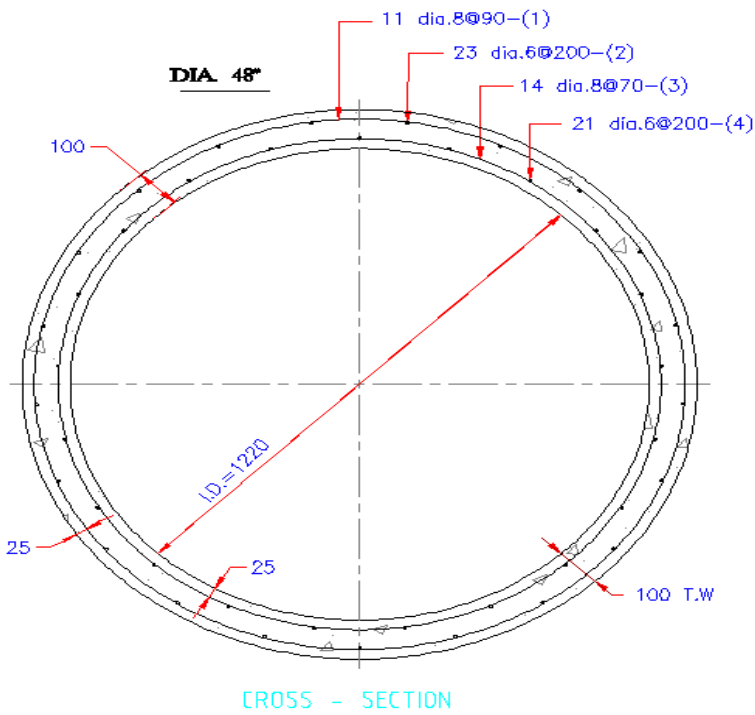
Computation of outlet velocity and normal depth

$$Q = (1/n)A R^{2/3} S^{1/2}$$

$$d_n = 1.256$$

$$\begin{aligned} \text{implies } A &= 1.349 \\ V_0 &= Q/A \\ &= 5.917/1.349 \\ &= 4.386\text{m/sec} \end{aligned}$$

The following figure shows the standard drawing for a pipe culvert recommended for this road project at 400m interval with a diameter of 1220m



9. MISCELLANEOUS DESIGN ASPECTS

9.1 Traffic Control Devices

Street is a form of connectivity creation within the vast space that makes up the society. The conception and creation of roads show human ingenuity at maintaining contacts and links.

In order to control, regulate and guide traffic, it is necessary to have suitable traffic aids or devices which are known as Traffic control devices. The following are the five basic requirements for use of a traffic control devices.

- 1) It must convey clear and simple meaning
- 2) It must command attention
- 3) It must command respect of road users
- 4) It must give adequate time for proper response
- 5) It must justify its necessity

To ensure fulfillment of the above requirements, it is necessary to give proper attention to the design, placement, operation, maintenance and uniformity of all traffic control devices. The uniformity of traffic control device not only means the use of the same control device for similar situations, but also requires the uniformity in application and treatment of similar situations.

The selection and use of traffic control devices should be made only after an Engineering study so that devices are not indiscriminately placed or arbitrarily used.

Following are the three basic traffic control devices;

- I. Road traffic signs
- II. Road traffic marking
- III. Guide posts



Figure 12 street marking and signs

9.2 Street Traffic Signs

The extent to which signs and marking are required depends on: -

- The traffic volume
- The type of road and
- The degree of traffic control required for safe and efficient operation.

The safe and efficiency of a road depends to a considerable degree on its geometric design. However, Physical layout must be supplemented by effective traffic signing as a means of informing and warning drives and controlling drivers. Design of traffic signs and road marking is an intricate part of the design process.

Traffic signs are of three general types: -

- Regulatory signs: indicate legal requirements of traffic movement.
- Warning sign: indicate conditions that may be hazardous to highway users
- Information signs: convey information of use to the driver.

9.3 Street Traffic Marking

The function of road marking is to encourage safe and expeditious operation. Road marking either supplement traffic signs and marker posts or serve independently to indicate certain regulations or hazardous condition. There are three general types of road marking in use pavement marking, object marking and road studs.

9.4 Guide Posts

Marker posts have the function of controlling traffic to encourage safe and expeditious operation.

There are two types of markers posts in use guideposts and kilometer posts.

Guideposts are intended to make drivers aware of potential hazards such as abrupt changes in shoulder width, abrupt changes in the alignment, and approaches to structure etc. for changes in shoulder width and approaches to structures, guide posts should be placed at 50 m intervals.

9.5. Factors Influencing the Provision of Traffic Signals

Traffic signals are usually installed at an intersection:

- to provide traffic control at a site with a traffic capacity or road safety problem;
- to control conflicting movements with high traffic flows;
- to facilitate access to and from local areas in a major/minor road system;
- as part of an area wide system of traffic management.

A side effect of signalization is that the traffic flow on a major road is broken up into platoons. This assists nearby pedestrians to cross the major roads and allows vehicles in nearby streets to cross or enter the major road.

Factors influencing the provision of traffic signals include:

- traffic flows
- traffic conflicts
- crash history
- pedestrian requirements
- access to major roads
- cost of installation

9.6. Pavement Markings

9.6.1. Pedestrian Crosswalks

The pedestrian crosswalk widths should be at least 2m wide. This should be increased when there are heavy pedestrian volumes.

Pedestrian crossings should be located:

- as near as possible to the desire lines of pedestrians;
- as near as possible to and no greater than 20 degrees from the shortest path across the carriageway to minimize clearance times;
- as close to, but at least 0.6m clear of, parallel vehicle movements.



Figure 13 pedestrian markings

8.6.2. Stop Lines

Stop lines should be located:

- so as to minimize intergreen times and clearance times;
 - not less than 3m from conflicting vehicle movements;
 - clear of the swept path of vehicles turning from other approaches;
 - a minimum of 1.0m from parallel pedestrian crossings at intersections;
 - at a desirable 10m in advance of the starting (secondary) lantern for that approach except for mid-block pedestrian crossings; and
 - at a maximum skew of 70 degrees to the direction of travel (over 70°, stop line may be stepped).
- 8.6.3. Longitudinal Lines To control overtaking in the vicinity of the intersection and the position from which left turns are made, a median island, barrier lines or a single unbroken line may be used. The length of barrier line should be 27m minimum from the stop line and further extended if required.

Requirements for curbside parking and access to property entrances adjacent to the barrier line should be considered.

Broken lane lines should be provided where possible for at least 51m on the approach and 27m on the depart side of an intersection. Where necessary to improve lane discipline lane lines may be marked as unbroken lines. Since overtaking is not permitted here broken lines are not provided.

9.6.4. Turn Lines

Turn lines may be used to provide delineation to guide two or more streams of traffic which turn simultaneously in the same direction or provide guidance through intersections with unusual geometry, skewed approaches or lanes not aligned across the intersection.

Turn lines should not be carried through pedestrian crosswalks.

9.6.5. Pavement Arrows

Pavement arrows should be used:

- in auxiliary lanes (left or right) to avoid inadvertent use by through vehicles;
- to allow movements that would not otherwise be allowed under traffic regulations;
- to prohibit movements that would otherwise be allowed under traffic regulations.

Pavement arrows should not be used to reinforce lane usage that is regulated by traffic regulations. If drivers are breaking the law relating to lane usage it may indicate that the existing lane distribution is inappropriate and may need to be changed.

A minimum of three arrows in any lane should be provided.

Pedestrian Protection

Protection for pedestrians should be considered whenever pedestrians are placed at an unnecessarily high risk by the introduction of the pedestrian movement. This includes poorly located crossings, sites with poor visibility, high speed turns, two lane right turns and crossings used by pedestrians with special needs such as children, the aged and the handicapped.

The degree of protection depends on the circumstances and may be:

- no protection;
- timed protection for part of the walk interval;
- timed protection for all of the walk interval;

- full protection for all of the walk and clearance intervals.

As a guide, pedestrian protection is usually unnecessary when all of the following conditions are met:

- the crossing is clearly visible;
- The flow of turning traffic is light;
- The turn only occurs from one lane;
- The speed of the turning traffic is low.

Full protection is necessary when any of the following conditions apply;

- where there is a green arrow controlled conflicting right turn;
- sighting to the pedestrian crossing is restricted;
- the flow of pedestrians is high;
- the speed of the turning traffic is high;
- there is a high proportion of children, aged or handicapped pedestrians;
- there are two or more lanes turning through the pedestrian movement.

Timed protection caters for any other situations. The length of the timed protection depends on the type of pedestrians that are using the crossing, the flow of pedestrians and flow of conflicting vehicles, but it cannot exceed the duration of the walk and clearance display.

In this chapter traffic signs and pavement markings are done at some specific points fulfilling the AACRA recommendations.

10. Conclusions and Recommendations

10.1 Conclusions

The urban living streets account for the greatest proportion of the whole traffic system, and a lively street will enrich leisure activities and contribute to better social life. In considering this, to overcome the idea of safe street and pedestrian-friendship street design we discussed on the design of Local streets in Wolkite University Entrance 2 to 3 Infront of dormitories.

Geometric design of the Street starts from Survey Data by using Total station And Google Earth Pro followed by horizontal and vertical alignment. It includes careful alignments of the given area with the ground profile to reduce the cost of excavation and improves the vehicle comfort safe Street by considering all factors affecting vehicle operating characteristics like, horizontal curves, vertical curves, sight distances, and gradients.

Pavement structure is designed to satisfy all requirements throughout the design life of the Street by considering the effects of traffic loading on pavements from traffic loading and design subgrade strength (from Soil tests like Compaction, Atterberg limit, was conducted and CBR). But CBR has been taken from secondary data as 4% for black cotton Soils Which falls S3 and the calculated traffic class in T4. Based on this form we designed the pavement which has 20 cm,17.5cm, and 20cm thickness.

In addition, safety should get the priority than economy. As a result of local street design, it improves problems associated with assess of marketing system for the Urban to reduce traffic accident by reducing loss of life and property, upgrade the life style of the society (societal), develop comfort and convenience etc.

Most of the Pavements in Ethiopia are deteriorated due to poor drainage. This is due to under estimation of traffic volume, flood and metrological data and also due to design problems. To improve thus problems, establishment of quality control and development of sufficient metrological station should be given attention by the government.

Finally, for safe driving condition and longer life of the road, sufficient collection of data, good design and implementation of the design and good construction are the corner stone in road construction.

9.2 recommendation

We would like to recommend that all the data that are necessary for the design purpose should be collected and accessed practically by the students and all the procedures (survey test, software design and lab test) must be conducted. This used to avoid encounter problems emanating from delay of data and insufficient information of the project area. We used secondary data for CBR value. To keep the efficient and effectiveness of final project work, students try to do the actual work and department should be solve the following problems:

- ❖ Limitation of laboratory equipment's like CBR Plunger machine calibration.
- ❖ lack of computer accesses and internet class and to make the students rich in information there should be free internet access in the computer room
- ❖ the department should propose some titles with the collaboration of the town municipality So as to do the project which gives benefits for the society,
- ❖ It is better to include software courses such as civil 3D, Excel & others in the curriculum so that they facilitate our design.
- ❖ Due Unsuitable weather condition the laboratory test conducted is not so much fit to the point.
- ❖ No enough reading or reference materials are available in the library, especially in accordance with ACCRA, ERA, AASHTO etc...

Besides of this we recommended that, to upgrade this road project there must be the cooperation of government with the society and also government should give great attention for road construction to solve transportation problem in different parts of the country.

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Appendix -A. Earth work volume

<u>Station</u>	<u>Cut Area</u> <u>(Sq.m.)</u>	<u>Cut Volume</u> <u>(Cu.m.)</u>	<u>Reusable Volume</u> <u>(Cu.m.)</u>	<u>Fill Area</u> <u>(Sq.m.)</u>	<u>Fill Volume</u> <u>(Cu.m.)</u>	<u>Cum. Cut Vol.</u> <u>(Cu.m.)</u>	<u>Cum. Reusable Vol.</u> <u>(Cu.m.)</u>	<u>Cum. Fill Vol.</u> <u>(Cu.m.)</u>	<u>Cum. Net Vol.</u> <u>(Cu.m.)</u>
0+020.000	35.77	0	0	0.11	0	0	0	0	0
0+040.000	33.2	689.64	689.64	0.21	3.24	689.64	689.64	3.24	686.4
0+060.000	27.17	603.71	603.71	0.98	11.9	1293.36	1293.36	15.14	1278.22
0+080.000	28.13	552.98	552.98	0	9.8	1846.34	1846.34	24.95	1821.39
0+100.000	26.72	548.44	548.44	0	0	2394.78	2394.78	24.95	2369.84
0+120.000	27.96	546.74	546.74	0	0	2941.53	2941.53	24.95	2916.58
0+140.000	30.61	585.61	585.61	0	0	3527.14	3527.14	24.95	3502.2
0+160.000	27.36	579.69	579.69	0	0	4106.83	4106.83	24.95	4081.88
0+180.000	29.32	566.82	566.82	0	0	4673.65	4673.65	24.95	4648.7
0+200.000	31.68	609.98	609.98	0	0	5283.62	5283.62	24.95	5258.68
0+220.000	30.83	625.13	625.13	0	0	5908.75	5908.75	24.95	5883.81
0+240.000	29.42	602.54	602.54	0	0	6511.29	6511.29	24.95	6486.35
0+260.000	30.66	600.8	600.8	0	0	7112.09	7112.09	24.95	7087.14
0+280.000	30.66	613.2	613.2	0	0	7725.29	7725.29	24.95	7700.34
0+300.000	30.66	613.2	613.2	0	0	8338.49	8338.49	24.95	8313.54
0+320.000	30.66	613.2	613.2	0	0	8951.69	8951.69	24.95	8926.74
0+340.000	30.63	612.92	612.92	0	0	9564.6	9564.6	24.95	9539.66
0+360.000	29.07	597.05	597.05	0.33	3.29	10161.66	10161.66	28.24	10133.42
0+380.000	27.56	566.31	566.31	0	3.31	10727.96	10727.96	31.55	10696.42
0+400.000	27.7	552.52	552.52	0	0.02	11280.49	11280.49	31.57	11248.92
0+420.000	28.84	565.31	565.31	0	0	11845.8	11845.8	31.57	11814.23
0+440.000	29.53	583.7	583.7	0	0	12429.49	12429.49	31.57	12397.93
0+460.000	32.08	616.16	616.16	0	0	13045.65	13045.65	31.57	13014.08
0+480.000	32.29	643.74	643.74	0	0	13689.39	13689.39	31.57	13657.82
0+500.000	32.94	652.29	652.29	0	0	14341.68	14341.68	31.57	14310.11
0+520.000	32.6	658.43	658.43	0	0	15000.11	15000.11	31.57	14968.54
0+540.000	27.3	605.28	605.28	1.99	19.45	15605.39	15605.39	51.01	15554.37
0+560.000	29.59	569.75	569.75	0.35	22.93	16175.14	16175.14	73.94	16101.2
0+580.000	31.05	606.53	606.53	1.2	15.54	16781.67	16781.67	89.48	16692.18
0+600.000	37.53	685.77	685.77	0.73	19.37	17467.44	17467.44	108.85	17358.59
0+620.000	32.25	697.81	697.81	0	7.33	18165.25	18165.25	116.18	18049.08
0+640.000	29.71	617.69	617.69	0	0	18782.94	18782.94	116.18	18666.77
0+660.000	29.57	590.23	590.23	0.31	3.1	19373.17	19373.17	119.28	19253.89

0+680.000	28.64	581.82	581.82	0.3	6.11	19955	19955	125.39	19829.6
0+700.000	25.86	544.56	544.56	0.29	5.92	20499.55	20499.55	131.32	20368.23
0+720.000	31.28	570.42	570.42	0.61	9.09	21069.98	21069.98	140.4	20929.57
0+740.000	28.89	599.09	599.09	0	6.17	21669.07	21669.07	146.58	21522.49
0+760.000	29.94	586.1	586.1	0	0	22255.17	22255.17	146.58	22108.59
0+780.000	35.39	651.59	651.59	0.06	0.58	22906.76	22906.76	147.16	22759.59
0+800.000	36.13	714.05	714.05	0	0.58	23620.8	23620.8	147.74	23473.06
0+820.000	36.34	724.72	724.72	0.07	0.68	24345.52	24345.52	148.42	24197.1
0+840.000	29.72	660.56	660.56	0.12	1.84	25006.08	25006.08	150.26	24855.82
0+860.000	29.44	591.52	591.52	0.03	1.49	25597.6	25597.6	151.75	25445.85
0+880.000	29.97	594.04	594.04	0	0.38	26191.64	26191.64	152.12	26039.51
0+900.000	26.46	567.3	567.3	0	0.04	26758.94	26758.94	152.16	26606.77
0+920.000	33.15	598.54	598.54	0.21	2.02	27357.48	27357.48	154.18	27203.3
0+940.000	29.95	631.04	631.04	0.07	2.72	27988.52	27988.52	156.9	27831.62
0+960.000	35.08	650.32	650.32	0.04	1.09	28638.84	28638.84	157.99	28480.85
0+980.000	41.65	767.29	767.29	0.7	7.42	29406.14	29406.14	165.41	29240.73
1+000.000	34.31	759.6	759.6	0.11	8.08	30165.74	30165.74	173.49	29992.25
1+020.000	33.48	677.87	677.87	0	1.1	30843.61	30843.61	174.58	30669.02
1+040.000	27.01	604.92	604.92	0.33	3.32	31448.53	31448.53	177.9	31270.63
1+060.000	30.55	575.61	575.61	0.93	12.64	32024.14	32024.14	190.54	31833.59
1+080.000	34.04	645.89	645.89	0	9.32	32670.02	32670.02	199.86	32470.16
1+100.000	28.95	629.88	629.88	0	0	33299.9	33299.9	199.86	33100.04
1+120.000	28.76	577.03	577.03	0.02	0.19	33876.93	33876.93	200.04	33676.88
1+140.000	30.11	588.66	588.66	0	0.19	34465.59	34465.59	200.23	34265.36
1+160.000	30.66	607.69	607.69	0	0	35073.29	35073.29	200.23	34873.06
1+180.000	30.66	613.2	613.2	0	0	35686.48	35686.48	200.23	35486.25
1+200.000	30.66	613.2	613.2	0	0	36299.68	36299.68	200.23	36099.45
1+220.000	30.66	613.2	613.2	0	0	36912.88	36912.88	200.23	36712.65
1+240.000	30.66	613.2	613.2	0	0	37526.08	37526.08	200.23	37325.85
1+260.000	27.02	576.77	576.77	0	0	38102.85	38102.85	200.23	37902.62
1+280.000	29.12	561.4	561.4	0	0	38664.25	38664.25	200.23	38464.02
1+300.000	26.38	555	555	0.02	0.25	39219.25	39219.25	200.48	39018.78
1+320.000	22.07	484.46	484.46	1.18	12.04	39703.71	39703.71	212.52	39491.19

APPENDIX B. Alignment Station and Curve Report

<u>Tangent Data</u>			
Description	PT Station	Northing	Easting
Start:	0+00.000	908693.415	368688.037
End:	5+14.371	908265.214	368403.042
<u>Tangent Data</u>			
Parameter	Value	Parameter	Value
Length:	514.371	Course:	S 33° 38' 46.9160" W
<u>Curve Point Data</u>			
Description	Station	Northing	Easting
PC:	5+14.371	908265.214	368403.042
RP:		908182.105	368527.913
PT:	5+62.659	908221.438	368383.162
<u>Circular Curve Data</u>			
Parameter	Value	Parameter	Value
Delta:	18° 26' 40.2531"	Type:	LEFT
Radius:	150.000		
Length:	48.288	Tangent:	24.355
Mid-Ord:	1.939	External:	1.964
Chord:	48.079	Course:	S 24° 25' 26.7895" W
<u>Tangent Data</u>			
Description	PT Station	Northing	Easting
Start:	5+62.659	908221.438	368383.162
End:	6+28.384	908158.012	368365.927
<u>Tangent Data</u>			
Parameter	Value	Parameter	Value
Length:	65.725	Course:	S 15° 12' 06.6630" W
<u>Curve Point Data</u>			
Description	Station	Northing	Easting
PC:	6+28.384	908158.012	368365.927
RP:		908223.568	368124.675
PT:	7+85.510	908028.699	368281.283
<u>Circular Curve Data</u>			
Parameter	Value	Parameter	Value
Delta:	36° 00' 38.5092"	Type:	RIGHT
Radius:	250.000		
Length:	157.126	Tangent:	81.256

Mid-Ord:	12.243	External:	12.874
Chord:	154.553	Course:	S 33° 12' 25.9176" W
<u>Tangent Data</u>			
Description	PT Station	Northing	Easting
Start:	7+85.510	908028.699	368281.283
End:	8+80.032	907969.487	368207.606
<u>Tangent Data</u>			
Parameter	Value	Parameter	Value
Length:	94.522	Course:	S 51° 12' 45.1722" W
<u>Curve Point Data</u>			
Description	Station	Northing	Easting
PC:	8+80.032	907969.487	368207.606
RP:		907852.566	368301.571
PT:	9+22.237	907938.799	368178.836
<u>Circular Curve Data</u>			
Parameter	Value	Parameter	Value
Delta:	16° 07' 15.4482"	Type:	LEFT
Radius:	150.000		
Length:	42.205	Tangent:	21.243
Mid-Ord:	1.482	External:	1.497
Chord:	42.065	Course:	S 43° 09' 07.4481" W
<u>Tangent Data</u>			
Description	PT Station	Northing	Easting
Start:	9+22.237	907938.799	368178.836
End:	13+21.796	907611.865	367949.135
<u>Tangent Data</u>			
Parameter	Value	Parameter	Value
Length:	399.559	Course:	S 35° 05' 29.7240" W

APPENDIX. C. Profile Vertical Curve Report

Vertical Alignment:

Description:

Station Range: Start: 0+000.00, End: 1+320.00

Vertical Curve Information:(sag curve)			
PVC Station:	0+055.99	Elevation:	1,940.057m
PVI Station:	0+061.97	Elevation:	1,940.000m
PVT Station:	0+067.95	Elevation:	1,940.002m
Low Point:	0+067.51	Elevation:	1,940.002m
Grade in:	-0.96%	Grade out:	0.04%
Change:	1.00%	K:	12.000m
Curve Length:	11.963m	Curve Radius	1,200.000m
Headlight Distance:			
Vertical Curve Information:(crest curve)			
PVC Station:	0+646.59	Elevation:	1,940.216m
PVI Station:	0+650.00	Elevation:	1,940.217m
PVT Station:	0+653.41	Elevation:	1,940.199m
High Point:	0+647.03	Elevation:	1,940.216m
Grade in:	0.04%	Grade out:	-0.53%
Change:	0.57%	K:	12.000m
Curve Length:	6.826m	Curve Radius	1,200.000m
Passing Distance:	2,721.922m	Stopping Distance:	1,171.738m
Vertical Curve Information:(sag curve)			
PVC Station:	0+901.57	Elevation:	1,938.879m
PVI Station:	0+903.51	Elevation:	1,938.868m
PVT Station:	0+905.46	Elevation:	1,938.864m
Low Point:	0+905.46	Elevation:	1,938.864m
Grade in:	-0.53%	Grade out:	-0.21%
Change:	0.32%	K:	12.000m
Curve Length:	3.881m	Curve Radius	1,200.000m
Headlight Distance:			

APPENDIX D. Alignment PI Station Report

Alignment Name: Alignment - (1)
 Description:
 Station Range: Start: 0+000.00, End: 1+321.80

PI Station	Northing	Easting	Distance	Direction
0+000.00	908,693.4145 m	368,688.0369 m		
			538.726 m	S33° 38' 47"W
0+538.73	908,244.9400 m	368,389.5478 m		
			171.335 m	S15° 12' 07"W
0+709.64	908,079.6000 m	368,344.6201 m		
			197.020 m	S51° 12' 45"W
0+901.27	907,956.1800 m	368,191.0478 m		
			420.802 m	S35° 05' 30"W
1+321.80	907,611.8654 m	367,949.1349 m		

APPENDIX E. Profile PVI Station & Curve Report

Vertical Description: Station Range: Start: 0+000.00, End: 1+320.00 Alignment:

PVI	Station	Grade Out	Curve Length
0.00	0+000.00	-0.96%	
1.00	0+061.97	0.04%	11.963m
	Vertical Curve Information:(sag curve)		
	PVC Station:	0+055.99	Elevation: 1,940.057m
	PVI Station:	0+061.97	Elevation: 1,940.000m
	PVT Station:	0+067.95	Elevation: 1,940.002m
	Low Point:	0+067.51	Elevation: 1,940.002m
	Grade in:	-0.96%	Grade out: 0.04%
	Change:	1.00%	K: 11.9999999998713
	Curve Length:	11.963m	
	Headlight Distance:		
2.00	0+650.00	-0.53%	6.826m
	Vertical Curve Information:(crest curve)		
	PVC Station:	0+646.59	Elevation: 1,940.216m
	PVI Station:	0+650.00	Elevation: 1,940.217m
	PVT Station:	0+653.41	Elevation: 1,940.199m
	High Point:	0+647.03	Elevation: 1,940.216m
	Grade in:	0.04%	Grade out: -0.53%
	Change:	0.57%	K: 12.0000000003437
	Curve Length:	6.826m	

	Passing Distance:	2,721.922m	Stopping Distance:	1,171.738m
3.00	0+903.51	-0.21%	3.881m	
	Vertical Curve Information:(sag curve)			
	PVC Station:	0+901.57	Elevation:	1,938.879m
	PVI Station:	0+903.51	Elevation:	1,938.868m
	PVT Station:	0+905.46	Elevation:	1,938.864m
	Low Point:	0+905.46	Elevation:	1,938.864m
	Grade in:	-0.53%	Grade out:	-0.21%
	Change:	0.32%	K:	11.9999999999039
	Curve Length:	3.881m		
	Headlight Distance:			
4.00	1+320.00			

Appendix F - Laboratory Test Results

F1- Moisture –density relationship of subgrade soil (AASHTO T265)

a. Objective

To obtain the moisture content-dry density relationship for a soil and hence to determine Its maximum dry density (MDD) and optimum moisture content (OMC).

b. Procedure

1. Select a representative sample of about 18 Kg which passes sieve No 4 and divide in to 5-6 equal parts by weight.
2. Prepare a series of 5-6 specimens with different moisture contents. The moisture content selected shall include the optimum moisture content, thus providing specimens which, when compacted will increases in mass to maximum density and then decrease in density.
3. Place the specimens in separate covered containers and allow standing prior to compaction to insure even distribution of moisture throughout the specimens.
4. Weigh the empty mould with base but without collars.
5. Attach the mould and extension collar, compact the first specimen with 25 blows in three layers of approximately height. Each layer should receive 25 evenly distributed blows.
6. Remove the collar. While removing the collar locate it to break the bond between it and the soil before lifting of the mould. This prevents removing some of the compacted soil when the solar is taken off. If the collar is hard to remove do not risk twisting of the last layers of soil. Take a spatula and trim long the sides of the collar until it comes off easily.
7. Remove the base plate. Carefully strike both the top and the base of the compacted cylinder of soil with a steel edge. Fill any holes in the compacted specimens with soil if the smoothing process removes any small pebbles.
8. Weigh the weight of the mould with base and compacted soil.
9. Remove the soil from the cylinder and obtain a representative sample for water content determination.
10. Repeat steps 6-10 for remaining specimens.

➤ This is the test that shall be conducted upon the soil samples obtained from the site.

Water content of soil is defined as:

$$W = (\text{loss of moisture content/dry mass of soil sample}) * 100$$

Trial No.	1	2	3	4	5
Weight of Mold + Wet soil (g)	4675.3	485	486	485	
Weight of Mold (g)	3246.3	5.2	6.3	9.5	

Weight of Wet soil (g)	1429	160 8.7	161 9.6	161 2.4	
Volume of Mold (cc)					
Wet density (g / cm ³)					
Moisture Content Determination					
Weight of Wet soil + cont. (g)	63.8	69.1	63.4	59.5	
Weight of Dry soil + cont. (g)	56.1	58.2	53.6	48.9	
Weight of Container (g)	25.3	25.5	25.4	25.4	
Weight of water (moisture) (g)	7.7	10.9	9.8	10.6	
Weight of Dry soil (g)	30.60	32.7 0	28.2	23.5	
Moisture content (%)	25.16	33.3 3	34.7	45.1	
Dry Density (g / cm ³)	0.54	0.57	0.57	0.53	
	MDD, g/cc	2.11	OMC, %		9 . 2

F2- Plastic Limit, Liquid Limit & Plasticity Index (AASHTO T89, T90)

ATTERBERG LIMITS TEST

This lab is performed to determine the plastic and liquid limits of a fine grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2in.) when subjected to 25 shocks from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

Test Procedure:

Liquid Limit:

- (1) Take roughly 3/4 of the soil and place it into the porcelain dish. Assume that the soil was previously passed through a No. 40 sieve, air-dried, and then pulverized. Thoroughly mix the soil with a small amount of distilled water until it appears as a smooth uniform paste. Cover the dish with cellophane to prevent moisture from escaping.
- (2) Weigh four of the empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.
- (3) Adjust the liquid limit apparatus by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is 10 mm high and should be used as a gage. Practice using the cup and determine the correct rate to rotate the crank so that the cup drops approximately two times per second.
- (4) Place a portion of the previously mixed soil into the cup of the liquid limit apparatus at the point where the cup rests on the base. Squeeze the soil down to eliminate air pockets and spread it into the cup to a depth of about 10 mm at its deepest point. The soil pat should form an approximately horizontal surface
- (5) Use the grooving tool carefully cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Use extreme care to prevent sliding the soil relative to the surface of the cup.
- (6) Make sure that the base of the apparatus below the cup and the underside of the cup are clean of soil. Turn the crank of the apparatus at a rate of approximately two drops per second and count the number of drops, N; it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 in.). If the number of

drops exceeds 50, then go directly to step eight and do not record the number of drops, otherwise, record the number of drops on the data sheet.

- (7) Take a sample, using the spatula, from edge to edge of the soil pat. The sample should include the soil on both sides of where the groove came into contact. Place the soil into a moisture can cover it. Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours. Place the soil remaining in the cup into the porcelain dish. Clean and dry the cup on the apparatus and the grooving tool.
- (8) Remix the entire soil specimen in the porcelain dish. Add a small amount of distilled water to increase the water content so that the number of drops required closing the groove decrease.
- (9) Repeat steps six, seven, and eight for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Plastic Limit:

1. Weigh the remaining empty moisture cans with their lids, and record the respective weights and can numbers on the data sheet.
2. Take the remaining 1/4 of the original soil sample and add distilled water until the soil is at a consistency where it can be rolled without sticking to the hands.
3. Form the soil into an ellipsoidal mass (See Photo F). Roll the mass between the palm or the fingers and the glass plate. Use sufficient pressure to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position.) The thread shall be deformed so that its diameter reaches 3.2 mm (1/8in.), taking no more than two minutes. When the diameter of the thread reaches the correct diameter, break the thread into several pieces. Knead and reform the pieces into ellipsoidal masses and re-roll them. Continue this alternate rolling, gathering together, kneading and re-rolling until the thread crumbles under the pressure required for rolling and can no longer be rolled into a 3.2 mm diameter thread. Gather the portions of the crumbled thread together and place the soil into a moisture can, then cover it. If the can does not contain at least grams of soil, add soil to the can from the next trial (See Step 6). Immediately weigh the moisture can containing the soil, record its mass, remove the lid, and place the can into the oven. Leave the moisture can in the oven for at least 16 hours.

4. Repeat steps three, four, and five at least two more times. Determine the water content from each trial by using the same method used in the first laboratory. Remember to use the same balance for all weighing.

Analysis:

Liquid Limit:

1. Calculate the water content of each of the liquid limit moisture cans after they have been in the oven for at least 16 hours.
2. Plot the number of drops, N, (on the log scale) versus the water content (w). Draw the best-fit straight line through the plotted points and determine the liquid limit (LL) as the water content at 25 drops.

Plastic Limit:

1. Calculate the water content of each of the plastic limit moisture cans after they have been in the oven for at least 16 hours.
2. Compute the average of the water contents to determine the plastic limit, PL. Check to see if the difference between the water contents is greater than the acceptable range of two results (2.6 %).
3. Calculate the plasticity index, $PI=LL-PL$.

Report the liquid limit, plastic limit, and plasticity index to the nearest whole number, omitting the percent designation.

	Liquid Limit			Plastic Limit	
No. of Blows	32	22	18		
Wt. of cont. + wet soil (g) = (w ₁)	55. 00	46. 20	44. 30	35. 20	25.1 0
Wt. of cont. + dry soil (g.) = (w ₂)	40. 20	39. 40	38. 30	30. 40	27.4 0
Wt. of container (g.) = (w ₃)	17. 50	23. 19	17. 70	27. 80	25.7 0
Mass of moisture (g.) (w ₁ - w ₂) = x	14. 80	6.8 0	6.0 0	4.8 0	- 2.30
Wt. of dry soil (g.) (w ₂ - w ₃) = y	22. 70	16. 21	20. 60	2.6 0	1.70
Moisture Content (%) = (100x/y)	65. 20	41. 95	29. 13	184 .62	- 135. 29
	45			25	
	Plasticity Index			21	

F3-Procedure for CBR test

I. A load is applied by cylindrical metal plunger of 56 mm diameter to penetrate the specimen at a rate of 1.3mm per minute.

II. Depending upon the prevailing climatic conditions of the site, CBR specimens are immersed in water for four days before the test to obtain a saturation condition similar to what may occur in the field.

III. During this period, the sample is loaded with a surcharge load that simulates the estimated weight of pavement layers over the material tested.

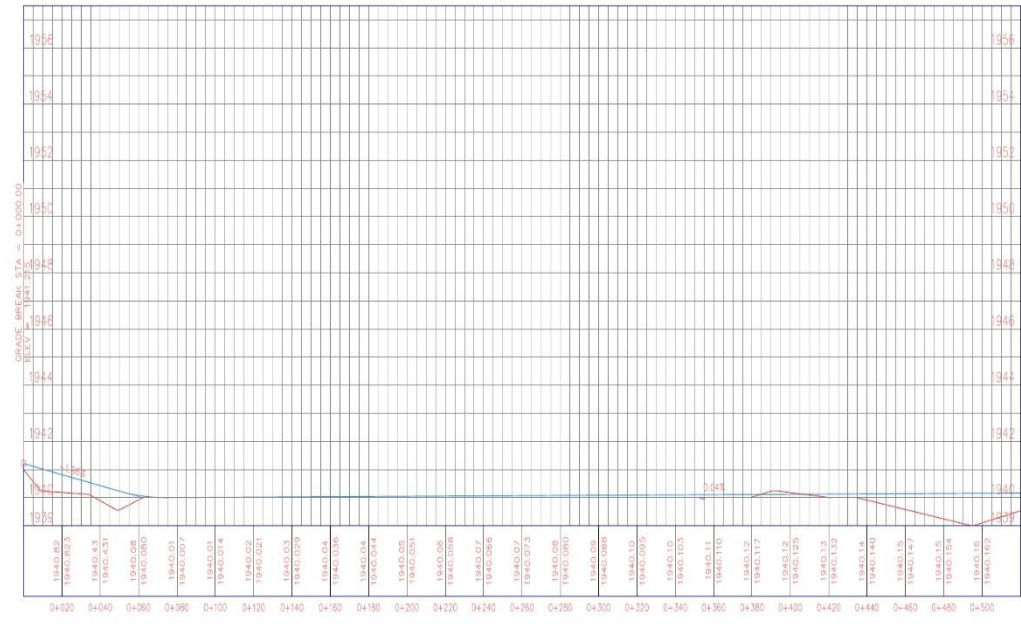
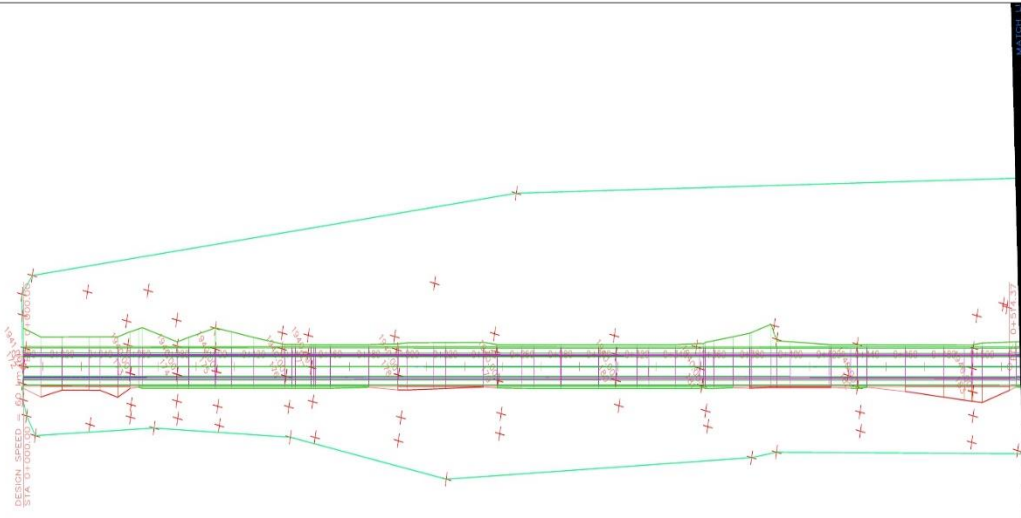
IV. Any swell due to soaking is also measured.

Appendix-G SERVEY DATA

Easting	Northing	Elevation	Description	368330.2	908084.4	1941	l2
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268703.56	908683.75	1940	R2	368277.3	908039.8	1942	L2
368671.72	908639.65	1939	R2	368282.9	908033.2	1941	CL
368664.26	908643.84	1939	R1	368288.7	908030.5	1941	R1
368655.08	908648.42	1940	CL	368296.4	908022.7	1941	R2
368645.65	908654.23	1940	L2	368230	908022.6	1941	L1
368642.07	908656.95	1940	L1	368232.1	908018	1941	L2
368628.09	908636.71	1940	L1	368235.4	908009.7	1941	CL
368633.45	908633.60	1940	L2	368238.1	908001.7	1941	R1
368641.35	908628.31	1940	CL	368242.2	907995	1940	R2
368649.69	908622.62	1940	R1	368175.4	907970.2	1940	L1
368657.55	908617.73	1939	R2	368182.2	907962.6	1939	L2
368643.91	908602.63	1939	R2	368188.5	907957.4	1939	CL
368637.92	908606.82	1940	R1	368194	907953.7	1939	R1
368630.74	908610.71	1940	CL	368199.6	907949.8	1939	R2
368620.14	908616.91	1940	L2	368131	907903.2	1940	L1
368613.95	908620.04	1940	L1	368137.2	907899.2	1939	L2
368590	908591.52	1941	L1	368142.8	907894.8	1939	CL
368599.4	908586.13	1940	L2	368147.5	907890.7	1938	R1
368609.31	908581.34	1940	CL	368153	907887	1938	R2
368618.63	908577.74	1940	R1	368082.3	907828.8	1939	L1
368623.19	908574.45	1940	R2	368087.4	907824.8	1939	L2
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368609.69	908567.27	1940	R1	368097.5	907817.3	1938	R1
368604.62	908568.65	1940	CL	368004.2	907812.1	1938	R2
368594.02	908574.75	1940	L2	368105.3	907862	1940	L1
368582.76	908580.79	1941	L1	368110	907858.9	1939	L2
368557.72	908545.3	1941	L1	368115.8	907855.9	1939	CL
368563.83	908539.55	1941	L2	368121.8	907851.8	1939	R1
368577.11	908532.25	1940	CL	368129.8	907848.3	1938	R2
368585.18	908527.96	1940	R1	36818040	907764.4	1938	L1
368589.68	908526.35	1940	R2	368044.3	907762.8	1938	L2
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368561.61	908482.42	1940	R2	368016.3	907695.2	1938	R1
368596.97	908445.27	1940	L1	368010.1	907700.8	1938	CL
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368526.48	908430.73	1940	R2	367973.5	907661.9	1938	L2
368472.55	908408.11	1940	L1	367981.3	907655.6	1938	CL
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368486.31	908402.62	1940	CL	367990.7	907646.6	1938	R2
368491.92	908400.02	1940	R1	367939.5	907620.1	1938	L1
368499.39	908397.28	1940	R2	367943.8	907613.9	1938	L2
368427.04	908342.68	1941	L1	367949.2	907611.9	1938	CL
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368447.14	908337.09	1940	R1	367962.4	907599	1937	
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368375.06	908256.47	1940	L1	368160.8	907961.9	1940	
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368387.03	908246.19	1940	CL	368202.4	908014.7	1941	
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368397.47	908237.11	1939	R2	368325.1	908111.3	1941	
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APPENDIX- H SOFTWARE OUTPUTS



General Notes

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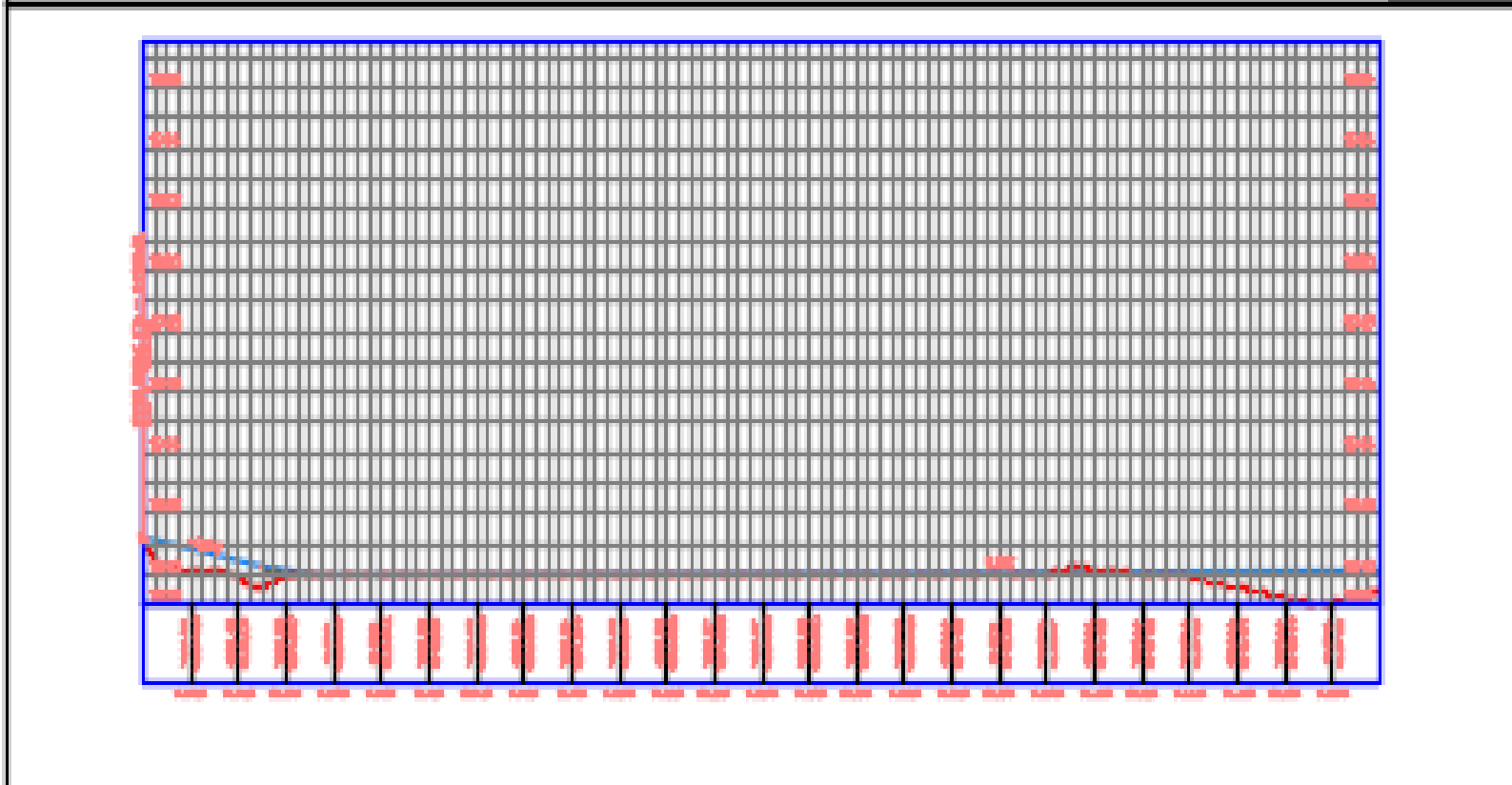
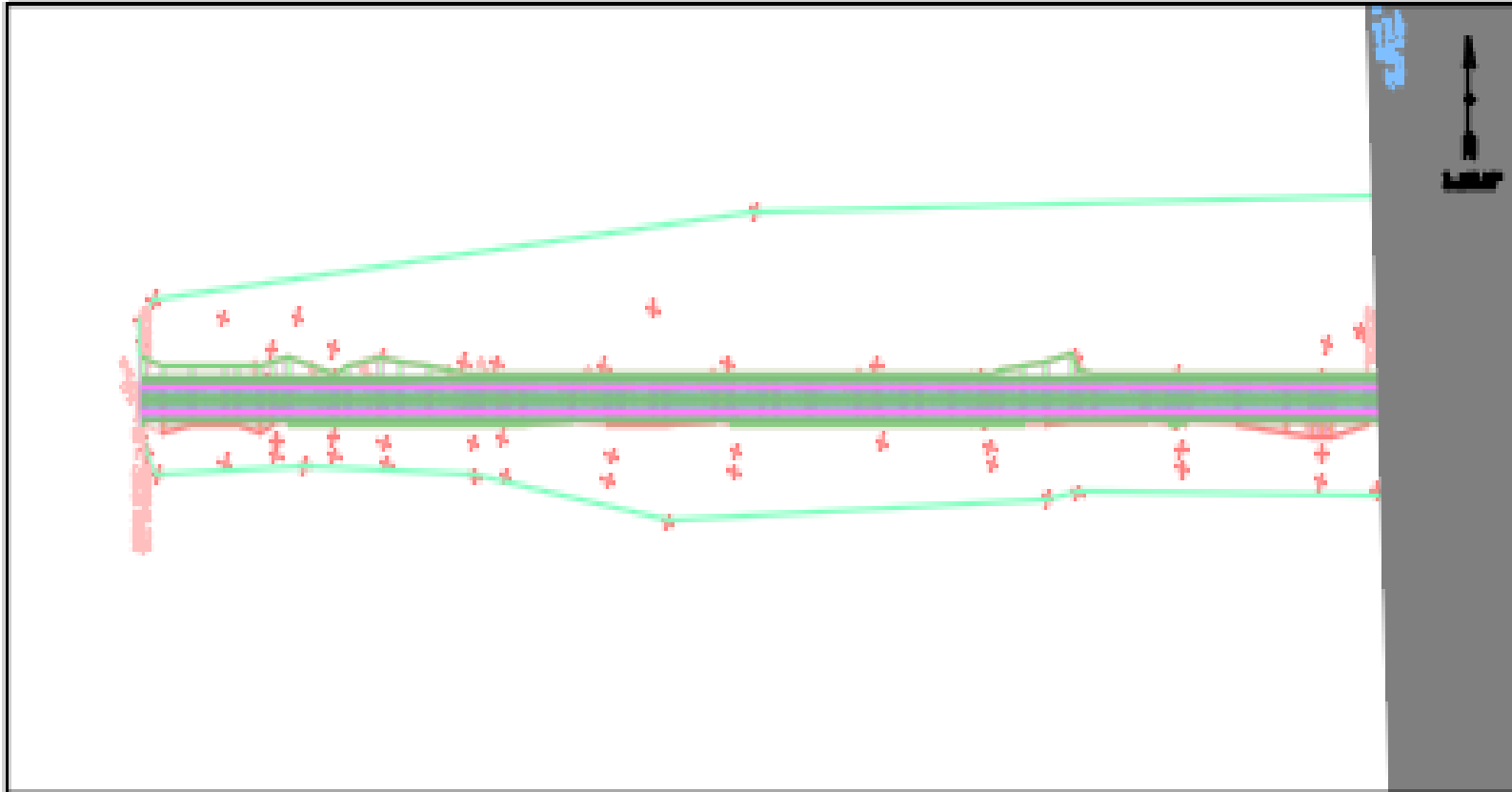
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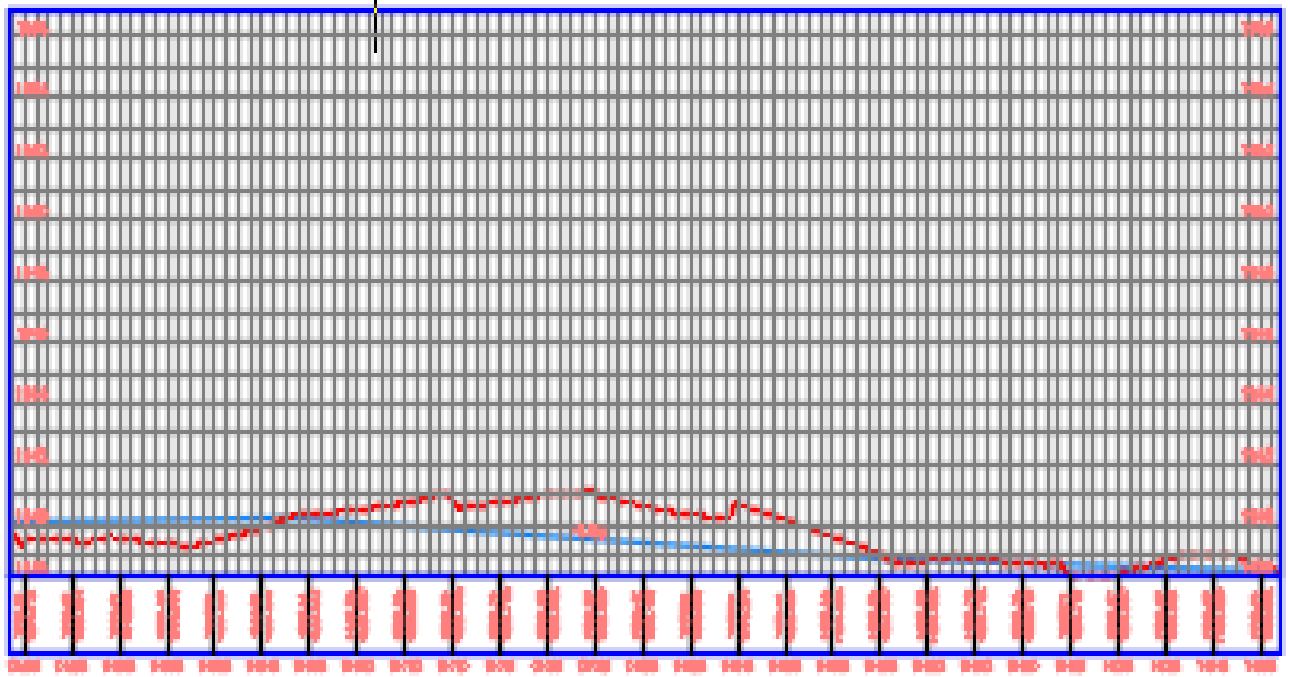
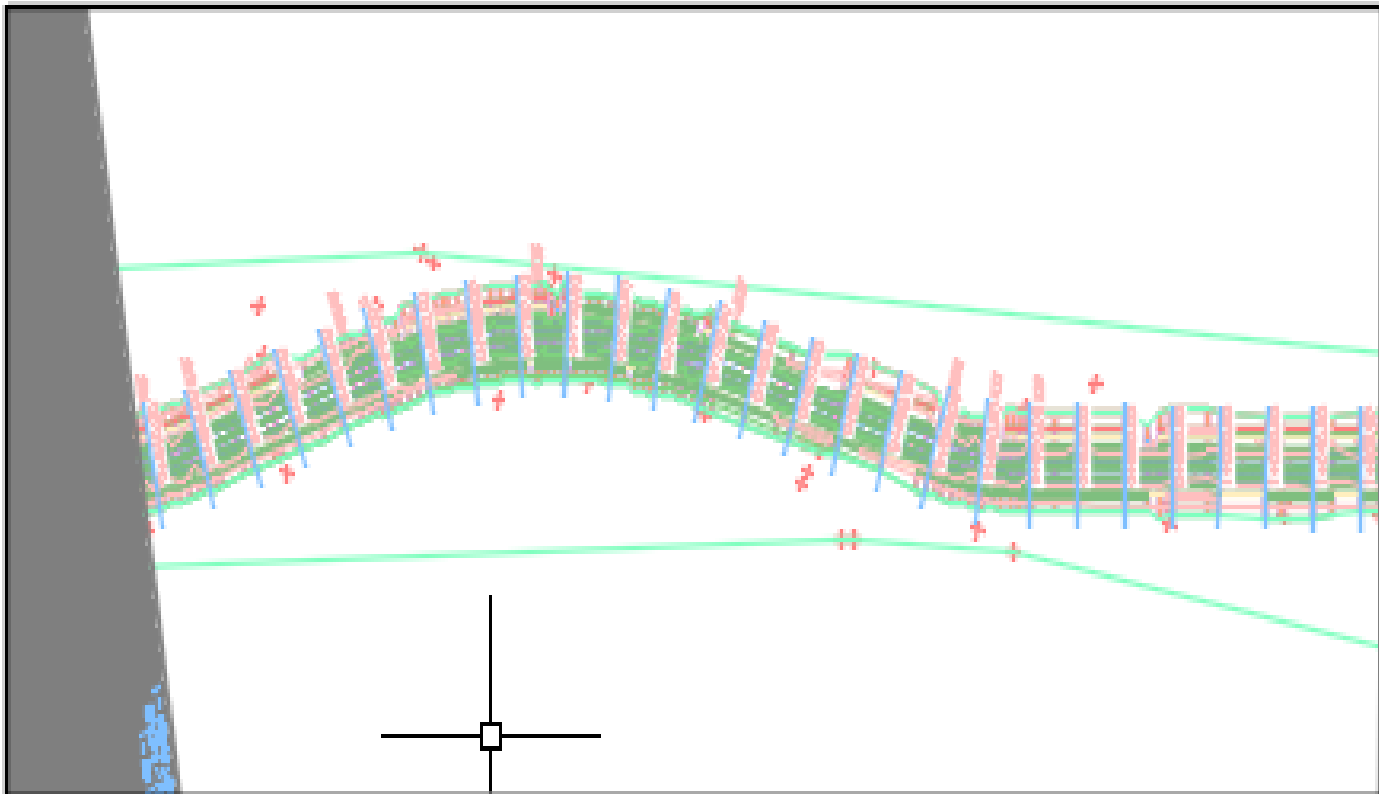
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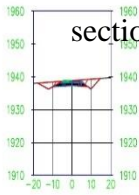




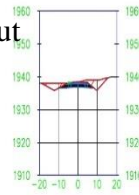
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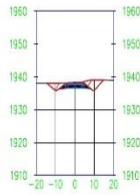
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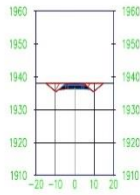
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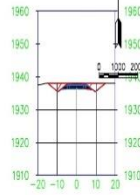
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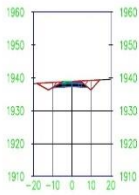
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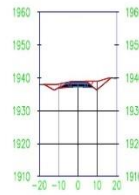
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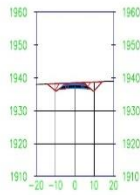
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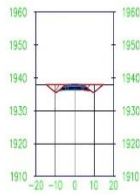
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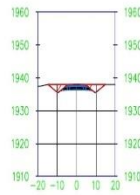
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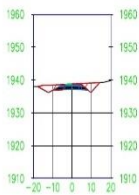
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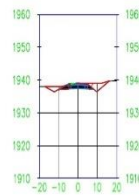
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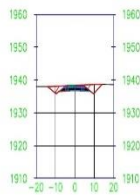
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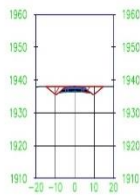
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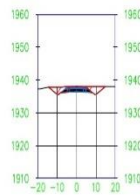
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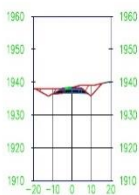
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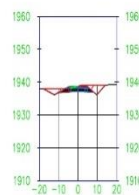
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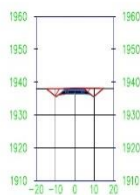
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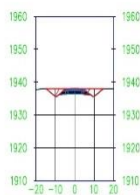
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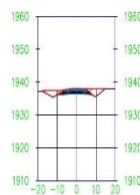
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General Notes

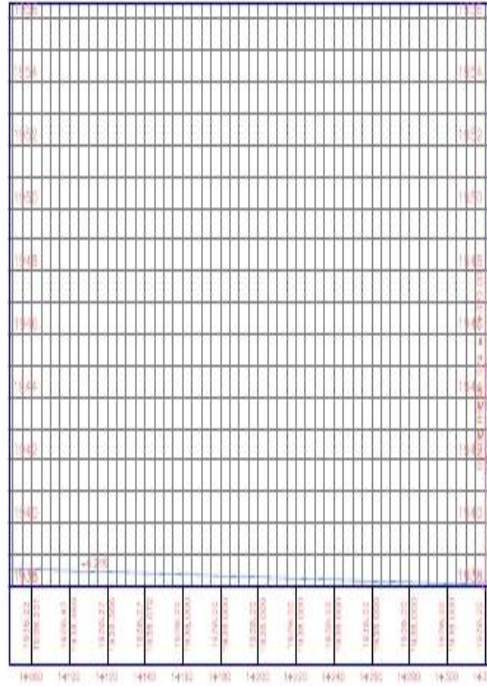
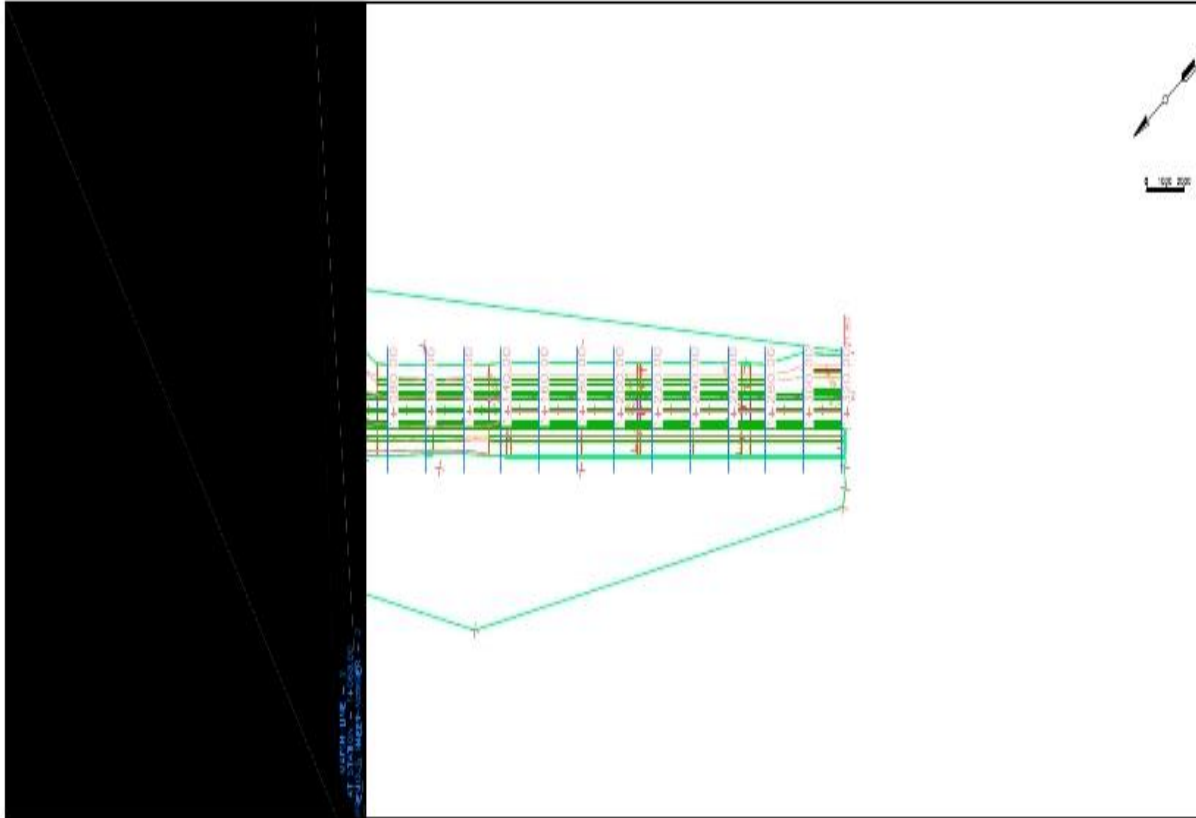
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Sheet 4



General Notes

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For view and other

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Appendix I. Mass-Haul Diagram

