Palestine Polytechnic University

College of Engineering

Design and Rehabilitation Haska Road

By

Anwar Shweiki

Osaid Imar

Supervisor:

Musab Shahin

Submitted to the College of Engineering

in partial fulfillment of the requirements for the

Bachelor degree in Surveying and Geomatics Engineering

Hebron, January 2024

CERTIFICATION

Palestine Polytechnic University

Design and Rehabilitation Haska Road

Team Project

Anwar Shweiki **Osaid Imar**

In accordance with the recommendations of the project supervisors, and the acceptance of all examining committee members, this project has been submitted to the Department of Civil Engineering in the College of Engineering in partial fulfillment of the requirements of the Department for the degree of Bachelor of Engineering.

Project Supervisors **Head of Department**

Name ……………….. **Name:………………..**

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الإهداء

إلى صاحب الفردوس الأعلى وسراج الأمة المنير وشفيعنا النذير البشير محمد (ﷺ)

إلى من سهر الليالي ... وظل سندي الموالي .. وحمل همي غير مبالي ...
والدي الغالي

إلى من اثقلت الجفون سهرا .... وحملت الفؤاد هما ... وجاهدت الأيام صبرا وشغلت البال فكراً ... ورفعت الأيادي دعاءاً ... وأيقنت بالله أملا ... أغلى الغوالي وأحب الأحباب... أمي العزيزة

إلى من عملنا أن النجاح قيمة ومعنى ... وعلمنا كيف يكون التفاني والاخلاص في العمل ... ومن معه أمنا أن لا مستحيل في سبيل الإبداع والرقي ...

إلى ورود المحبة .. وينابيع الوفاء ... إلى من رافقوني في السراء والضراء إلى اصدق الأصحاب ... إخوتي وأخواتي

إلى القلعة الحصينة التي الجا إليها عند شدتي ... أصدقائي الأعزاء

إلى من هم أكرم منا مكانا ... شهداء فلسطين

إلى هذا الصرح العلمي الفتي والجبار جامعة بوليتكنك فلسطين

إلى من احتضنتني كل هذا الكم من السنين ... فلسطين الحبيبة

شكر و تقدير

الحمد لله وحده كما ينبغي لجلال وجهه وعظيم سلطانه الذي خلقنا وأسبغ علينا نعمه ظاهرة وباطنة وانطلاقا من حديث النبي ﷺ :" من لا يشكر الناس لا يشكر الله " وامتثالا له فانه يسرنا ويسعدنا أن نتقدم ونتوجه بشكر الجزيل والعرفان بالجميل لجامعة بوليتكنك فلسطين ممثلة بدائرة الهندسة المدنية ونتقدم بالشكر الجزيل للأستاذ المهندس مصعب شاهين الذي قام بالإشراف على هذا المشروع، ولما منحنى إياه من نصائح وتشجيع.

كما نتقدم بجزيل الشكر لجميع أساتذة دائرة الهندسة المدنية.

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I am writing this acknowledgment to express my sincerest gratitude for your guidance and support throughout my graduation project. Your dedication, expertise, and willingness to share your knowledge with me have been invaluable in helping me complete this project successfully.

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I am truly grateful for the opportunity to work under your supervision and learn from you. Your mentorship has not only helped me complete my graduation project but has also equipped me with skills and knowledge that will be valuable to me in my future endeavor , Eng. Musab Shahin .

Finally, we extended our thank to members in the Civil Engineering Department , especially the part of Surveying Engineering, which help us in designing our project.

Project Team

Abstract

Design and rehabilitation of the road between Halhul Bridge and Haska

Project Team

Anwar Shweiki

Osaid Imar

Supervisor

Eng. Musab Shahin

A road project is the process of planning, designing, and implementing roads, streets. The goal of this project is to provide safe and efficient access to urban and rural areas, as well as industrial and commercial areas. The project involves several stages, including planning, feasibility studies, design, construction, maintenance, and development. This project requires close coordination between the relevant parties, including the government, civil engineers, contractors, suppliers, and end-users. The roads project is considered a vital project that contributes to the development and improvement of the infrastructure of cities and enhances economic and social development.

The project aims to design the road located in the north of Hebron Governorate in the Halhul area, which extends from the glass factory “Halhul Bridge” to Ein Haska and is 1000 meters long.

The most complete way to serve the population and raise the level of public safety.

الملخص

Design and rehabilitation of the road between Halhul Bridge and Haska

Project Team

Anwar Shweiki

Osaid Imar

Supervisor

Eng. Musab Shahin

مشروع الطريق هو عملية تخطيط وتصميم وتنفيذ الطرق والشوارع. الهدف من هذا المشروع هو توفير الوصول الآمن والفعال إلى المناطق الحضرية والريفية، وكذلك المناطق الصناعية والتجارية. ويشتمل المشروع على عدة مراحل، تشمل التخطيط ودراسات الجدوى والتصميم والإنشاء والصيانة والتطوير. يتطلب هذا المشروع تنسيقًا وثيقًا بين الأطراف ذات الصلة، بما في ذلك الحكومة والمهندسين المدنيين والمقاولين والموردين والمستخدمين النهائيين. ويعتبر مشروع الطرق من المشاريع الحيوية التي تساهم في تطوير وتحسين البنية التحتية للمدن وتعزيز التنمية الاقتصادية والاجتماعية.

ويهدف المشروع إلى تصميم الطريق الواقع شمال محافظة الخليل في منطقة حلحول والذي يمتد من مصنع الزجاج "جسر حلحول" حتى عين حسكة ويبلغ طوله 1000 متر.

الطريقة الأكثر اكتمالا لخدمة السكان ورفع مستوى السلامة العامة.

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CHAPTER ONE

INTRODUCTION

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1.1 Over view.

1.2 Problem Statement.

1.3 Aim and Objectives of the project.

1.4 Methodology.

1.5 Study area .

1.6 Project scope.

1.7 Time Table .

1.1 Over view

Road design is the process of determining the shape and specifications of a roadway in a way that ensures the safety and ease of movement on the road, as well as providing comfort and security for users and pedestrians. The road should be designed according to applicable international and local standards to ensure the quality and safety of the road.

A road project involves designing and building roads, streets, intersections , lighting, and everything related to the infrastructure of roads that are used to facilitate traffic and provide safe routes for vehicles and pedestrians.

The road design process includes several stages, including studying the expected load and traffic flow on the road, determining the path and dimensions of the road, identifying deviations, curves, slopes, drops, elevations, and other engineering details. Technical specifications for asphalt, concrete, and other foundations used in road construction should also be taken into account.

Creating a good road requires many stages, including designing the road, studying the foundations and soil, and determining the physical and human requirements needed to construct the road. The road is designed according to the expected load on it, in accordance with applicable international and local standards. Then the road is built using appropriate materials in accordance with the necessary specifications and standards.

The road project is important due to its impact on the economy, social development, trade, and tourism, as well as providing safe and efficient transportation. The creation of roads requires cooperation between the government, the private sector, engineers, contractors, workers, and the local community.

In addition, the road should be designed to preserve the environment and sensitive areas, including agricultural lands and urban areas. The environmental and social effects of the road must be considered, achieving sustainable development and preserving natural resources in the area.

Road design requires many different specialties, including civil engineers, mechanical engineers, electrical engineers, and others, as well as consulting firms that specialize in road design.

1.2 Problem Statement

The roads have become a symbol of progress and prosperity for any city, and therefore cities are highly interested in creating roads that serve the interests of residents, as well as taking care of the cultural aspect of these roads, especially the main roads that are increasingly being used.

1- Vertical and horizontal curves lack many geometric principles, especially the lack of sufficient visibility distance, and this problem can be observed in sharp curves.

2- Rainwater collects in certain areas of the road due to poor drainage resulting from the absence of side channels in some areas that require them.

3- Insufficient lighting and signals that should be placed on the road.

1.3 Aim and Objectives of the project

Road projects are considered one of the most important construction projects in many countries, as they aim to develop and improve the transportation infrastructure in society. The objectives of road projects include the following:

1- Improving access to remote areas: Developing roads helps to improve access to remote areas that are difficult to reach, facilitating transportation and travel and helping to develop those areas.

2- Improving road safety: Expanding and improving roads helps to reduce traffic accidents and improve traffic safety, promoting compliance with safety rules and the administrative and technical procedures necessary to achieve road safety.

3- Improving the country's economy: Road projects help to improve economic growth in the country by providing job opportunities, increasing trade and promoting economic development.

4- Reducing traffic congestion: Significant savings in time and costs can be achieved by improving and expanding roads, reducing traffic congestion and easing pressure on congested roads.

5- Reducing environmental pollution: Improving and updating roads can lead to a reduction in pollution resulting from vehicles and public and private transportation.

In general, road projects are vital and fundamental projects that promote economic, social and environmental development in the country. They also contribute to raising the standard of living for citizens, and improving the quality of life by providing safe and efficient transportation systems.

1.4 Methodology

Phase I : data collection

During this phase, available data and information will be collected from different source.

Moreover, many site visits to both project area and the related local

organization will be conducted. First phase included the following tasks:

1. Collection of aerial topographical maps for the study area.

2. Analyze the work.

Phase II : Site Visit

During this phase, we made a field visit to the site and identified the state of the road and the problems related to the road from side inclinations and vertical curves , where the existing pictures show the road situation .

First stage : The picture represents the situation of the dirt road, which is 4 meters wide

Figure (1. 1): First Stage

Second stage : The picture shows cracks in the street

Figure (1. 2):Second Stage

Third stage : The picture shows the section with asphalt

Figure (1. 3): Third Stage

Phase III : Planning survey

during this phase, designing and organizing the spaces allocated for the road, including traffic lanes, pedestrian and bicycle lanes, parking spaces, traffic signals, and also planning the road itself, including geometric determinations for curves, hills, and slopes. The goal of space planning for roads is to provide safe, smooth traffic flow and efficient use of the road, and increase user safety.

Phase IV : Traffic and Geometric design

during this phase, Traffic and geometric design are two important aspects of transportation engineering that are closely related.

Traffic design involves the planning and design of transportation infrastructure, such as roads, highways, and intersections, to ensure safe and efficient movement of vehicles and pedestrians. It takes into account factors such as traffic flow, capacity, safety, and environmental impact.

Geometric design, on the other hand, focuses on the physical layout and features of the roadway itself, including its alignment, cross-section, and vertical profile. Geometric design considers factors such as sight distance, stopping distance, lane width, and curvature of the roadway.

The goal of traffic and geometric design is to create safe, efficient, and sustainable transportation infrastructure that meets the needs of all users.

Phase V : Pavement Structural design

during this phase, Pavement structural design is the process of designing the layers of a road or pavement that support the traffic loads and distribute them to the subgrade. The structural design of a pavement is critical to ensure that it can withstand the anticipated traffic loads and environmental conditions for its expected lifespan without excessive deformation, cracking, or failure. The main components of pavement structural design include the subgrade, base layer, sub-base layer, and surface layer.

1.5 Study Area

This road is located in the northern region of the city of Hebron, where it serves as a link between Halhul Bridge and Haska.

This makes the road of significant importance and vitality, as its length is 1000 meters and its width on the ground is 3 meters.

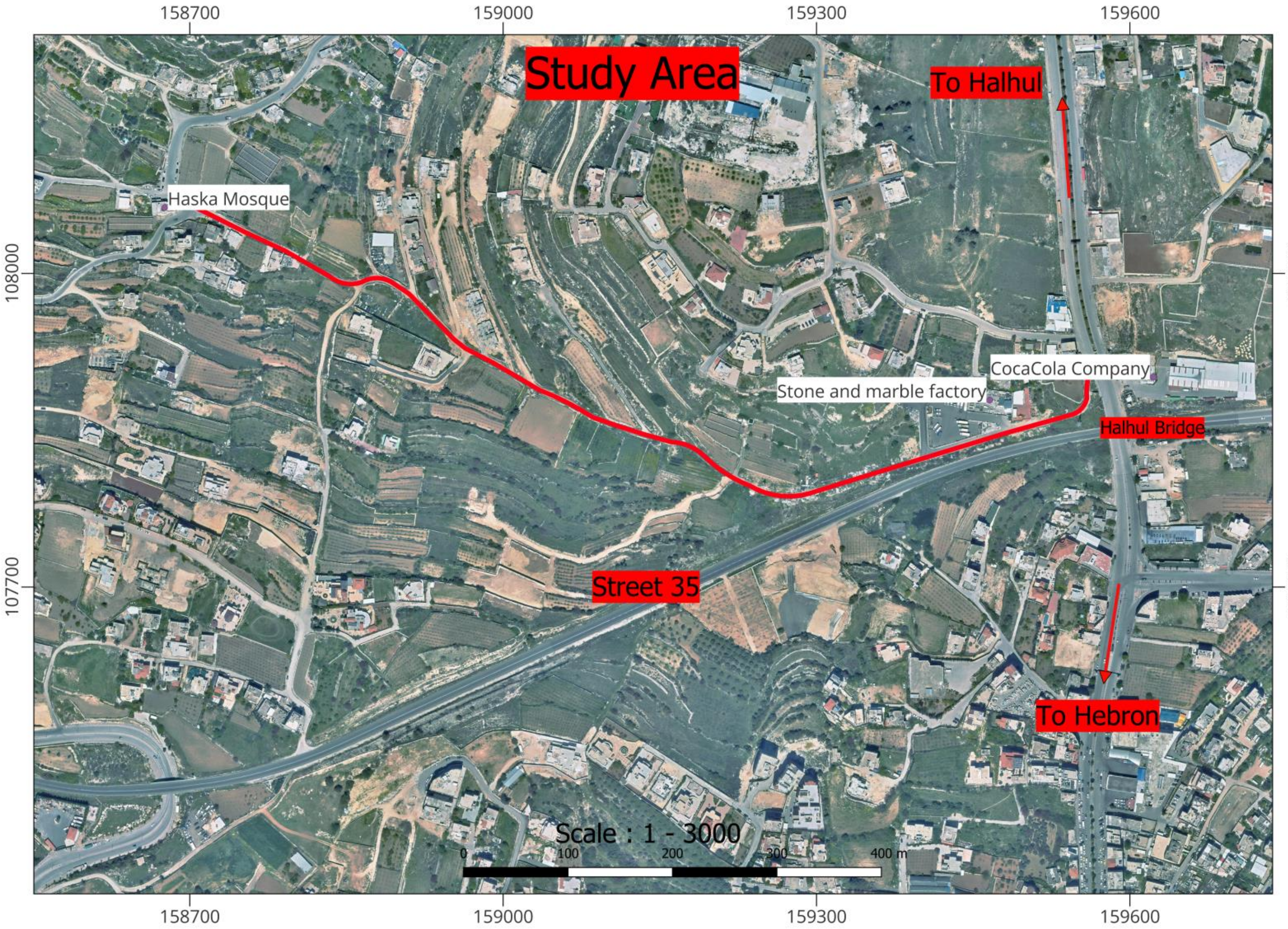


Figure (1. 4): Study Area

1.6 Project Scope

A road project includes surveying and structural design of the road, as well as designing the pavement layers and determining the expected traffic volume. Space planning for roads involves designing traffic lanes, pedestrian and bicycle lanes, parking spaces, and traffic signals, as well as planning the road itself, such as determining engineering specifications for curves, hills.

The structural design of the road aims to ensure that it can withstand the expected traffic loads and environmental conditions for its expected lifespan without excessive deformation, cracking, or failure. The design of the pavement includes the surface, sub-surface, base, and subgrade layers.

Designing pavement layers requires determining the expected traffic volume and evaluating the soil properties to determine its load-bearing capacity, stability, and susceptibility to frost heave, swelling, and shrinkage. Each pavement layer must be designed to consider factors such as expected traffic volume, type of vehicles, weight, climate, soil conditions, and geological formations. Using appropriate materials, thicknesses, and reinforcement strategies to achieve the required structural capacity and durability is essential.

1.7 Time Table

Table (1. 1) : Time table for introduction

Weekly Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project Selection and Information Gathering	■	■													
Survey Space		■	■												
Field Work				■	■	■	■	■							
Office work						■	■	■	■	■					
Computer drawing									■	■	■				
Preparing the initial report for the introduction of the project											■	■	■		
Preparing the final report for the introduction of the project												■	■	■	■

Table (1. 2) : Time table for Project

Weekly Activity	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Laboratory tests	■	■	■	■											
Design and necessary calculations		■	■	■	■	■	■	■	■	■					
Preparing the initial project report								■	■	■	■				
Initial project delivery												■	■		
Final delivery of the project														■	■

CHAPTER TWO

SURVEYING

This chapter contains:

2.1 Survey Works .

2.2 Satellite Positioning System (GNSS) .

2.3 Surveying equipment and tools used .

2.1 Survey Works

2.1.1 Introduction

Surveying works are considered one of the essential aspects of any road project, as they aim to determine and define the site, distances, elevations, terrains, and other details related to the land on which the road is intended to be built.

Surveying works in road projects include several stages, including:

1- Site Surveying.

2- Mapping.

3- Leveling.

4- Conversion operations.

5- Quality Control.

2.1.2 Site Surveying

It is the process of determining the area that will be worked on, including determining the location and defining the boundaries and distances between different sites.

2.1.3 Mapping

Detailed maps are drawn to show the terrain of the area, including horizontal and vertical curves, slopes, inclinations and locations that may be affected by the road.

2.1.4 Leveling

This includes the process of determining elevations, levels, and slopes to determine the levels that the road should be on and the optimal slope of the road.

2.1.5 Conversion operations

These include the process of converting collected survey data into data that can be used in the design process, including drawings, maps, and 3D models.

2.1.6 Quality Control

Quality control processes aim to ensure the accuracy of measurements and calculations, verify the accuracy of data, and ensure that the design conforms to specifications and standard requirements.

2.2 Satellite Positioning System (GNSS)

2.2.1 Introduction

The Global Positioning System (GNSS) is a system used to determine locations and time anywhere on Earth using a set of satellites launched into orbit by the United States National Aeronautics and Space Administration (NASA). Anyone can access these satellites using a GNSS receiver.

The GNSS consists of three main parts: the satellites, the ground stations, and the receiver device. The receiver device analyzes the satellite signals and determines its accurate location on Earth using the triangulation technique.

GNSS is used in many applications, including navigation, mineral exploration, map making, defense, vehicle control, outdoor activity tracking, and many other applications.

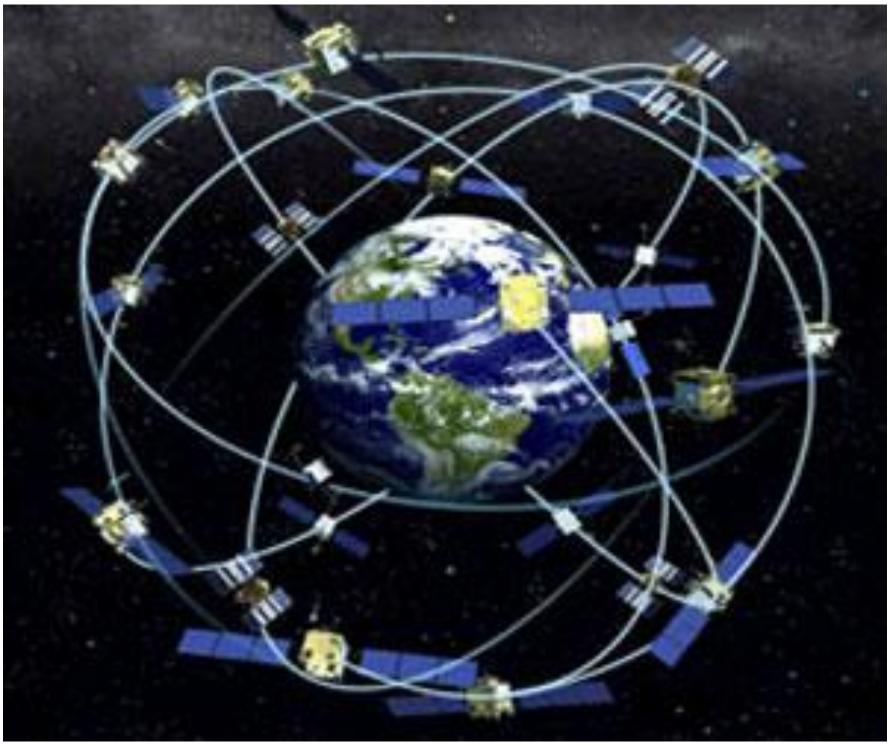


Figure (2. 1) : Satellite system around the Earth

2.2.2 GPS system consists

The (GNSS) consists of three main components:

1- Satellites: The system consists of a constellation of satellites orbiting the earth that transmit signals to the ground. Each satellite determines its position relative to the earth and sends accurate and synchronized signals across space.

2- Ground control stations: Ground control stations track the satellites and adjust their guidance devices to maintain the accuracy of the distance between the satellites and the ground receivers.

3- Receivers: GNSS receivers receive signals from the satellites and use them to calculate the precise location of the user on the ground using the triangulation technique. GNSS receivers differ in accuracy and capabilities, so they can be used in many different applications.

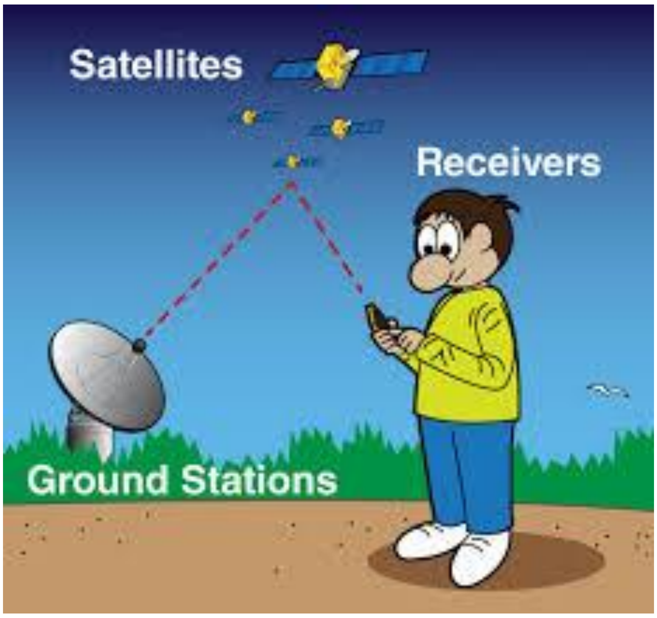


Figure (2. 2) : GPS system consists

2.2.3 How GNSS works

The GNSS is a satellite-based navigation system that uses trilateration to determine the geographic location of any point on the Earth's surface. This system includes Satellites its A network of GNSS satellites that can send radio signals carrying information about location and time with high accuracy. GNSS receiver It receives the radio signals sent by the satellites and analyzes and processes them to determine the geographic location of the receiver. GNSS software It analyzes and processes the data received from the GNSS receiver and converts it into useful information such as maps and directions.

In the process of determining the geographic location using GNSS, the GNSS receiver receives signals from three or more satellites. The GNSS receiver then uses these signals to calculate the distance between the receiver and each of the satellites using trilateration.

After calculating the distance between the receiver and each of the satellites, the geographic location of the receiver is determined by relying on the intersection points of circles of defined distance drawn around each satellite. When the GNSS receiver determines the location of the device, this information is combined with other data to determine the geographic location with high accuracy.

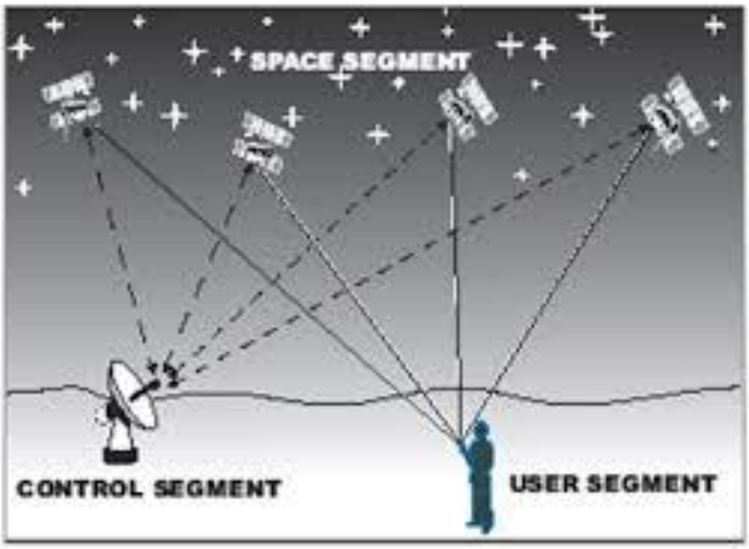


Figure (2. 3) : How GNSS works

2.2.4 Surveying methods using GNSS

The GNSS can be used in surveying to determine the geographic coordinates of specific points in space with high accuracy. Surveying methods using GNSS include:

1- Static Surveying.

2- Rapid Surveying.

3- Static Kinematic Surveying.

4- Mobile Surveying.

Surveying methods using GNSS are used in various fields such as construction, geological and roads. The data resulting from these methods can be analyzed to generate accurate maps and useful information for use in data analysis and making informed decisions.

2.2.4.1 Rapid Surveying

Rapid surveying using GNSS is a technique that involves using a handheld GNSS receiver to quickly obtain highly accurate geographic coordinates of specific points. This technique is commonly used in applications where time is of the essence, such as in emergency response situations, or in instances where a large number of points need to be surveyed quickly.

To perform a rapid survey using GNSS, the user typically moves the GNSS receiver from one point to the next, allowing the receiver to acquire satellite signals and calculate the geographic coordinates of each point. Because the process is relatively quick, it is important to ensure that the GNSS receiver is properly configured and calibrated to provide the highest possible accuracy.

One of the key advantages of rapid surveying using GNSS is that it allows for a large number of points to be surveyed quickly and accurately. This makes it an ideal technique for applications such as mapping, land surveying, and geospatial analysis.

However, there are some limitations to using rapid surveying with GNSS. For example, the accuracy of the GNSS coordinates obtained can be affected by a number of factors, including the quality of the satellite signals, the presence of obstructions such as trees or buildings, and the user's ability to hold the GNSS receiver steady and level.

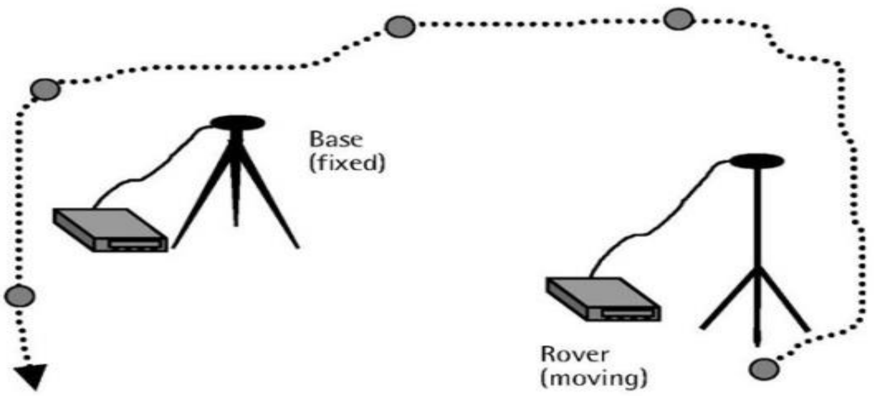


Figure (2. 4) : Rapid Surveying

2.3 Surveying equipment and tools used

- GNSS device (SP 60)
- Civil 3D Program .
- AutoCAD Program .
- ESRI ArcPro 3.0.2 Program .

CHAPTER THREE

TRAFFIC DESIGN

This chapter contains:

3.1 Traffic Volume.

3.2 Traffic Counting.

3.3 Analysis.

3.1Traffic Volume

3.1.1 Introduction

The amount of traffic that passes through a specific road, street, or pathway during a certain period of time. Traffic volume is typically measured in the unit of the number of vehicles that pass in a single time unit, and this data can be used to determine traffic density, speed, and identify traffic flow problems.

Traffic volume can impact many aspects of daily life, including road safety, transportation, traffic congestion, vehicle emissions, transportation costs, trade, and urban development. Therefore, understanding and analyzing traffic volume is crucial in designing and planning roads, pathways, and urban infrastructure.

By analyzing traffic volume data, policymakers and transportation planners can make informed decisions to improve traffic flow and address traffic-related issues. This may include adding new lanes to a road, improving public transportation, or implementing traffic management strategies. Overall, traffic volume plays a critical role in shaping urban mobility and transportation planning.

3.1.2 The aim of studying the traffic volume

The aim of studying traffic volume is to determine traffic density, speed, and identify traffic flow problems such as congestion, accidents, and environmental impacts.

Studying traffic volume helps in designing and planning roads, pathways, and urban infrastructure. It also helps in identifying and developing appropriate solutions to improve traffic flow and solve traffic-related problems. This can be achieved through traffic management, improving public transportation, and promoting alternative modes of transportation.

In general, the purpose of studying traffic volume is to improve road safety and enhance the movement of people and goods in a more efficient, economical, and environmentally friendly way.

3.1.3 Basic concepts

1. Annual Average Daily Traffic (AADT) : The average 24-hour volume at a given location over a full 365-day year, the number of vehicles passing a site in a year divided by 365 days .

2. Average annual weekday traffic (AAWT) : The average 24-hour volume occurring on weekdays over a full 365-day year, the number of vehicles passing 2site on weekdays in a year divided by the number of week days (usually 260).

3. Average daily traffic (ADT) : The average 24-hour volume at a given location over a defined time period less than one year; a common application is to measure an ADT for each month of the year.

4. Average weekday traffic (AWT) : The average 24-hour weekday volume at a given location over a defined time period less than one year; a common application is to measure an AWT for each month of the year.

5. Design hourly traffic volume : the volume of traffic of a particular hour. So for a day, there will be 24 hourly traffic volumes. And for a year there will be 365×24 hourly volumes. The hourly volume which is considered for design purpose is called design hourly traffic volume.

6. future traffic volume : Predicting future traffic volume can be a challenging task, as it depends on a variety of factors such as population growth, urbanization, economic development, and changes in transportation technology. However, transportation planners and policymakers use various methods and tools to forecast future traffic volume.

One method is to analyze current trends and patterns in traffic volume and use statistical models to project future growth.

Overall, predicting future traffic volume is essential for planning and designing transportation infrastructure that can accommodate future demand while promoting safety, efficiency, and sustainability.

7. Road capacity : The maximum amount of traffic that a road or a transportation facility can accommodate while maintaining an acceptable level of service. It is determined by several factors such as the number of lanes, the width of the lanes, the type of intersection, and the design speed.

   Road capacity is an essential consideration in transportation planning and design, as it directly impacts traffic flow and travel time. An inadequate road capacity can lead to traffic congestion, which can result in increased travel time, air pollution, and fuel consumption.

   Transportation planners and engineers use various methods and techniques to determine road capacity, such as traffic flow analysis, capacity analysis, and simulation modeling. These tools help in estimating the maximum traffic flow that a road can handle and identifying the causes of traffic congestion.

Table (3. 1) : Road capacity according AASHTO

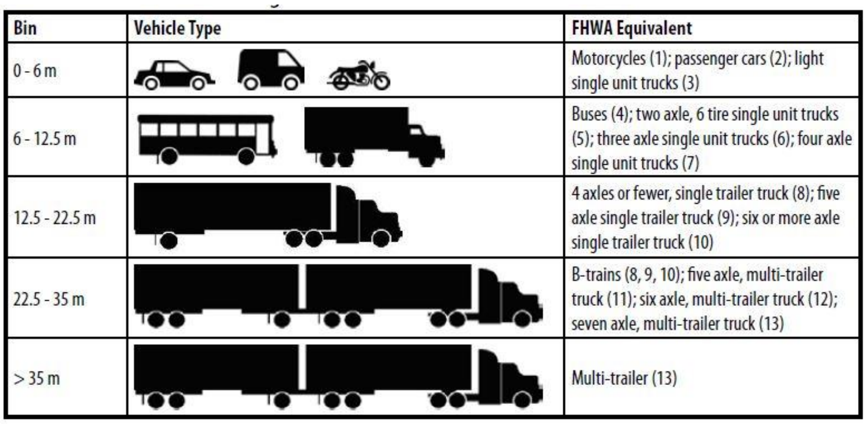
Road Type	**Capacity (Private Car/Hour)**
Highway	**2000 (For each lane)**
Two lane road	**3000 (total in both directions)**
Three lane road	**4000 (total in both directions)**

3.1.4 Design vehicles

There are several types of vehicles that travel on roads, including private cars, public transport buses, small and large trucks. These vehicles differ in their dimensions, sizes, and weights. Therefore, it is necessary to understand their characteristics in order to take them into consideration when designing different parts of the road. It is natural to focus on the most commonly used vehicles on the road during design, as they constitute the majority of traffic volume. These characteristics include:

- The overall length of the vehicle.
- The overall width of the vehicle.
- The height of the vehicle.
- The weight of the vehicle.
- The capacity of the vehicle.
- The distance between the front and rear wheels of the vehicle.
- The distance between the front of the vehicle and the front wheels.
- The distance between the rear of the vehicle and the rear wheels.

Studies have shown that trucks have a significant impact on road pavement, and their impact increases with their weight. Therefore, it was necessary to delve into the study of types of transport vehicles in terms of their dimensions, number of axles, and their impact on road pavement. Figure 3-1 illustrates the loads on the axles, and Table 3-2 shows the main dimensions of private cars and transport vehicles according to AASHTO specifications.



Bin	Vehicle Type	FHWA Equivalent
0 - 6 m		Motorcycles (1); passenger cars (2); light single unit trucks (3)
6 - 12.5 m		Buses (4); two axle, 6 tire single unit trucks (5); three axle single unit trucks (6); four axle single unit trucks (7)
12.5 - 22.5 m		4 axles or fewer, single trailer truck (8); five axle single trailer truck (9); six or more axle single trailer truck (10)
22.5 - 35 m		B-trains (8, 9, 10); five axle, multi-trailer truck (11); six axle, multi-trailer truck (12); seven axle, multi-trailer truck (13)
> 35 m		Multi-trailer (13)

Figure (3. 1) : Vehicle Types

Table (3. 2) : The main dimensions of the vehicle

Dimension	Private Car	Passenger Car	Commercial transport vehicle
length (m)	5.8	12.1	16.7
width (m)	2.1	2.6	2.6
Height (m)	1.3	4.1	4.1
Distance between the front and rear wheels	3.4	7.6	6.1
Distance between the front of the vehicle and the front wheels	0.9	1.2	0.9
Distance between the rear of the vehicle and the rear wheels	1.5	1.8	0.6

3.2Traffic Counting

3.2.1 Introduction

Traffic Count Calculator is a tool used to estimate the volume of traffic that travels through a particular road section. Traffic counts are essential for road planning and design, as well as for evaluating the effectiveness of traffic management strategies.

There are two main types of Traffic Count Calculators: manual and automatic. Manual Traffic Count Calculators involve manually counting the number of vehicles that pass through a road section over a given period. This method is time-consuming and can be subject to human error. Automatic Traffic Count Calculators, on the other hand, use technology such as cameras, radar, or sensors to automatically count the number of vehicles.

Both manual and automatic Traffic Count Calculators provide valuable data for transportation planners and engineers. Traffic counts help to identify traffic patterns, congestion points, and areas where safety improvements may be necessary. Traffic count data can also be used to forecast future traffic volume and plan for future road expansions or improvements.

Overall, Traffic Count Calculators are important tools that provide valuable data for road planning and design, and are crucial for ensuring safe and efficient traffic flow on our roadways.

3.2.2 key aspects of traffic counting

1. **Manual Traffic Counting:**
    - Involves individuals physically counting and recording the number and types of vehicles or pedestrians.
    - Can be time-consuming and may be prone to human error but is useful for small-scale studies.
2. **Automatic Traffic Counting:**
    - Utilizes technology such as video cameras, infrared sensors, radar, or induction loops embedded in the road surface.
    - Provides continuous, accurate, and real-time data, allowing for more comprehensive analysis.
3. **Types of Traffic Counts:**
    - **Volume Counts:** Measure the number of vehicles or pedestrians over a specific period.
    - **Class Counts:** Categorize vehicles into different types (cars, trucks, motorcycles).
    - **Speed Counts:** Measure the speed of vehicles on the road.
4. **Purpose of Traffic Counting:**
    - **Traffic Flow Analysis:** Understand how traffic moves through a particular area.
    - **Capacity Analysis:** Evaluate the efficiency and capacity of roads and intersections.
    - **Safety Assessment:** Identify potential safety issues and accident-prone areas.
    - **Planning and Design:** Assist in planning new roads or modifying existing ones based on observed traffic patterns.
5. **Data Collection Methods:**
    - **Manual Surveys:** Personnel count and record data on-site.

- **Automatic Surveys:** Use technology for continuous data collection over an extended period.

6. **Data Analysis:**

   - Traffic engineers and planners analyze the collected data to derive insights.
   - Statistical techniques and software tools are often employed to interpret the information effectively.

7. **Traffic Counting Technologies:**

   - **Video Cameras:** Record and analyze traffic movements visually.
   - **Induction Loops:** Buried in the road surface to detect the presence and count of vehicles.
   - **Radar and Lidar Sensors:** Use radio waves or laser beams to detect and count vehicles.

3.2.3 Assumption from Hebron municipality

Under the auspices of the Hebron Municipality, and due to the challenging circumstances the country is facing as a result of wars and road closures, we have been unable to conduct traffic counting due to a barrier at the entrance of the street. The data and traffic statistics were collected from the Hebron Municipality, indicating that the number of cars entering Hebron during peak hours was 2953 cars.

As the street serves as an alternative to reduce traffic congestion at the entrance to Hebron heading towards Haska, the proposed road extends from Halhul Bridge to Haska. A 35% proportion of the total cars entering Hebron will be adopted for this new street. Based on this percentage, it is anticipated that the number of cars entering the newly designed street in this project will be 1034 cars.

Please note that this design aims to improve traffic flow and provide an effective alternative route to alleviate pressure on the entrance to Hebron.

3.3 Analysis

Despite the challenges, data and traffic statistics have been collected from the municipality, revealing that the number of cars entering Hebron during peak hours.

The street under consideration, based on the study's data, serves as an alternative to alleviate traffic congestion at the entrance to Hebron, particularly for those heading towards Haska. The proposed road extends from Halhul Bridge to Haska. A strategic decision has been made to adopt a 35% proportion of the total cars entering Hebron for this new street.

It is important to note that the primary objective of this design is to improve traffic flow and provide an effective alternative route. This initiative aims to ease the pressure on the entrance to Hebron, contributing to the overall improvement of traffic management in the area. We will analyze the existing traffic movement using Synchro software.

Figure (3. 2) : Synchro Analysis for Intersection

CHAPTER FOUR

GEOMETRIC DESIGN

This chapter contains:

4.1 Introduction.

4.2 Horizontal Curve.

4.3 Vertical Curve.

4.4 Road Planning.

4.1 Introduction

Geometric design in roads refers to the process of designing the physical layout of a road system, including the alignment, profile, cross-section, and intersection design. The goal of geometric design is to provide a safe and efficient roadway that accommodates the desired traffic volume and speed, while also considering factors such as terrain, environment, and community needs.

Alignment design involves selecting the best path for the road based on factors such as topography, land use, and environmental constraints. The alignment design also considers factors such as sight distance, stopping distance, and turning radii to ensure safe operation.

Profile design determines the vertical shape of the road, including the grades or slopes of the roadway and the location and height of crest and sag vertical curves. The profile design also considers drainage and other factors that affect the comfort and safety of the road.

Cross-section design refers to the shape and dimensions of the roadway and its components, including lanes, shoulders, medians, and curbs. Cross-section design also considers factors such as pavement structure, drainage, and roadside features.

Intersection design involves designing the layout of the intersection where two or more roads meet. Intersection design considers the type of intersection (such as a signalized or roundabout intersection), traffic volume, and turning movements to ensure safe and efficient traffic flow.

4.1.1 Basic concepts

Geometric design is a branch of mathematics that deals with the study of shapes, figures, and their properties. It encompasses various fundamental concepts, including:

1. Points: Basic entities in geometry with no size or dimension. They are represented by dots and have no length, width, or thickness.

2. Lines: A straight path that extends infinitely in both directions. It is defined by two points and has length but no width or thickness.

3. Line segments: A portion of a line with two endpoints. Unlike a line, it has a definite length and is finite.

4. Angles: The space between two intersecting lines or line segments, measured in degrees or radians. They are classified as acute (less than 90 degrees), right (exactly 90 degrees), obtuse (between 90 and 180 degrees), or straight (exactly 180 degrees).

5. Polygons: A closed two-dimensional shape formed by connecting line segments. Common examples include triangles, rectangles, squares, and pentagons.

6. Circles: A perfectly round shape with all points on its boundary equidistant from its center. It is defined by its radius (the distance from the center to any point on the circle) and diameter (twice the radius).

7. Coordinate system: A system that uses a set of numbers or coordinates to locate points in a plane or space. Common coordinate systems include the Cartesian coordinate system (with x and y axes) and the polar coordinate system (with a distance and angle).

These concepts form the foundation of geometric design and are used to analyze, describe .

4.1.2 Fundamentals of design processes

The road design process is a complex engineering operation that involves numerous steps and stages to ensure the construction of effective and safe roadways. Here are the fundamentals of road design operations:

1. **Feasibility Study:**
    - Identifying the need for the road and analyzing traffic patterns and potential user requirements.
2. **Site Study:**
    - Evaluating the targeted area for road construction, including topography and environmental considerations.
3. **Traffic Analysis:**
    - Collecting data on traffic volume and speed distribution to estimate the capacity.
4. **Terrain Analysis:**
    - Examining the surrounding terrain to identify challenges and opportunities in road design.

5. **Path Selection:**
   - Determining the optimal road path based on topography, environmental needs, and economic considerations.

6. **Engineering Design:**
   - Defining basic dimensions, curves, slopes, and other requirements for the road.
7. **Traffic Control Design:**
   - Developing a traffic control system, including signals and signs, to safely guide traffic.
8. **Construction:**
   - Executing the project and building the road according to the engineering designs.

Road design requires collaboration between different engineers, including road engineers, civil engineers, and engineering design specialists, to ensure comprehensive and effective project implementation.

4.2 Horizontal Curve

In geometric design, a horizontal curve refers to a curve or bend along a roadway or a linear profile in the horizontal plane. It is used to transition from one straight section of the road to another while maintaining a constant radius of curvature. Horizontal curves are essential for safely navigating changes in direction and are commonly found in highways, roads, and railway tracks.

Here are some key aspects of horizontal curves in geometric design:

1. Design Speed .
2. Super elevation .
3. Minimum Radius .
4. Sight Distance .

4.2.1 Design speed

The design speed in the context of road design refers to the speed that is considered or specified as the maximum allowable speed on the road. The selection of design speed is based on a set of factors, including:

1. Road Type:
   - Highways typically have higher design speeds compared to secondary roads or urban roads. This reflects the fast nature of traffic flow on highways.
2. Road Design:
   - The road design and incorporated engineering features, such as road curves and surface irregularities, are taken into consideration when choosing the design speed.
3. Traffic Volume:
   - Roads with higher traffic volumes may require higher design speeds to ensure the effectiveness of traffic flow.
4. User Safety:
   - The design speed should be chosen to be safe for users, considering factors that impact their safety.

The design speed plays a crucial role in defining the characteristics of the road and its impact on vehicle behavior and user safety. Careful consideration of design speed contributes to achieving a balance between traffic flow efficiency and road safety.

Table (4. 1) : Design Speed

Road classification	Minimum speed (Km/h)	Desired speed (Km/h)
Local road	30	5
Collector road	50	60
Arterial road	80	100
Less disturbance road	70	90
palpable disturbance road	50	60
EXPRESSWAT	90	120

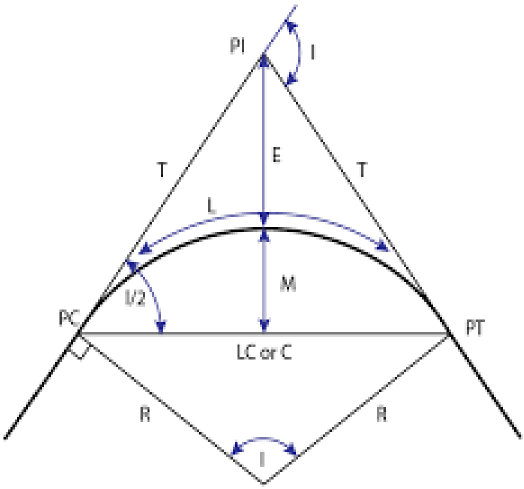


Figure (4. 1) : Horizontal Curve

Simple circular curve calculation equations

- Tangent length (T)

$$T = R\tan\frac{\Delta}{2} \tag{4.1}$$

- External distance (E)

$$E = R\left(\sec\left(\frac{\Delta}{2}\right) - 1\right) \tag{4.2}$$

- Bow arrow (M)

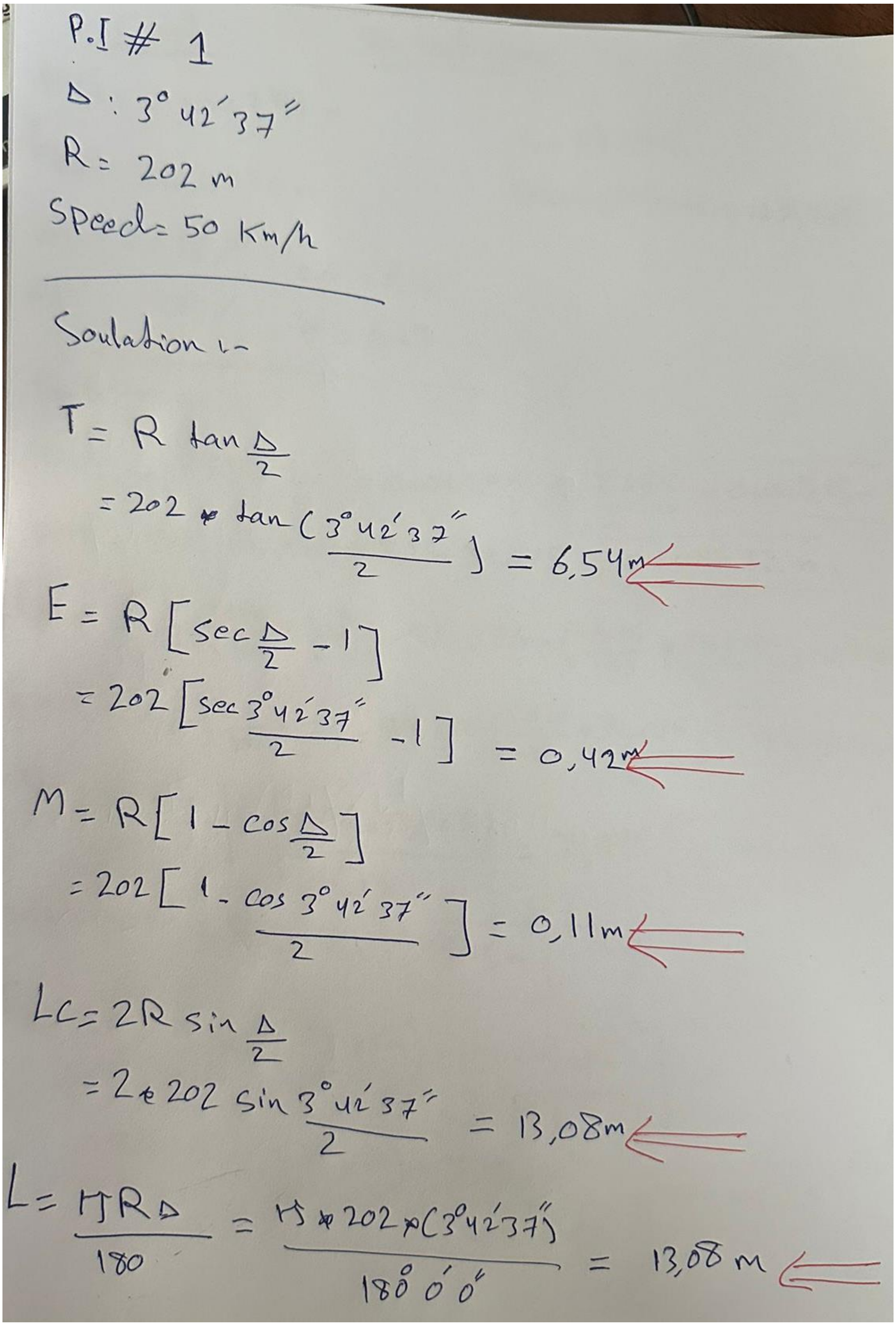
$$M = R\left(1 - \cos\frac{\Delta}{2}\right) \tag{4.3}$$

- Long string (LC)

$$LC = 2R\sin\frac{\Delta}{2} \tag{4.4}$$

- Curve length (L)

$$L = \frac{\pi\, R\, \Delta}{180} \qquad (4.1)$$



P.I # 1

$\Delta : 3^\circ 42' 37''$

R = 202 m

Speed = 50 Km/h

Soulation :-

$T = R \tan \frac{\Delta}{2}$

$= 202 * \tan \left(\frac{3^\circ 42' 37''}{2} \right) = 6,54m$

$E = R \left[\sec \frac{\Delta}{2} - 1 \right]$

$= 202 \left[\sec \frac{3^\circ 42' 37''}{2} - 1 \right] = 0,42m$

$M = R \left[1 - \cos \frac{\Delta}{2} \right]$

$= 202 \left[1 - \cos \frac{3^\circ 42' 37''}{2} \right] = 0,11m$

$Lc = 2R \sin \frac{\Delta}{2}$

$= 2 * 202 \sin \frac{3^\circ 42' 37''}{2} = 13,08m$

$L = \frac{\pi R \Delta}{180} = \frac{\pi * 202 * (3^\circ 42' 37'')}{180^\circ 0' 0''} = 13,08 m$

Figure (4. 2) : Calculate horizontal curve

4.2.2 Super elevation

In geometric design, superelevation It is designed to counteract the centrifugal force acting on vehicles as they travel through the curve, enhancing their stability and reducing the risk of skidding or overturning.

Here are the key aspects of superelevation in geometric design:

1. Centrifugal Force: When a vehicle travels around a curve, a centrifugal force is generated due to the vehicle's inertia. This force tends to push the vehicle outward, away from the curve's center. Super elevation helps counterbalance this force and keeps the vehicle on a safe and stable path.

2. Cross Slope: Super elevation is achieved by providing a cross slope, which is the slope or incline of the roadway from the inner edge of the curve to the outer edge. The cross slope is typically measured as a ratio or percentage, indicating the rise or fall in the road surface over a specified horizontal distance.

3. Critical Speed: The critical speed is the speed at which a vehicle can safely traverse a curve without relying on friction between the tires and the road surface to maintain stability. Super elevation is designed based on the critical speed, which is determined by factors such as curve radius, coefficient of friction between tires and pavement, and desired level of safety.

4. Design Criteria: Designing super elevation involves considering various factors, including the design speed, curve radius, and side friction factor (a measure of the road surface's ability to provide lateral friction). Design guidelines and standards provide specific criteria and formulas to determine the appropriate super elevation for a given curve.

5. Transition Lengths: To ensure a smooth transition between the straight section of the roadway and the curved section, super elevation is gradually introduced

over a transition length. Transition lengths are designed to avoid sudden changes in cross slope and provide a comfortable transition for drivers.

Super elevation is typically implemented on high-speed roadways, such as highways and expressways, where vehicles travel at higher speeds. It improves the safety and handling characteristics of vehicles, allowing them to negotiate curves more efficiently and with reduced risk.

Engineers use mathematical calculations, computer simulations, and design standards to determine the appropriate super elevation and transition lengths based on the specific roadway conditions, design speed, and desired level of safety.

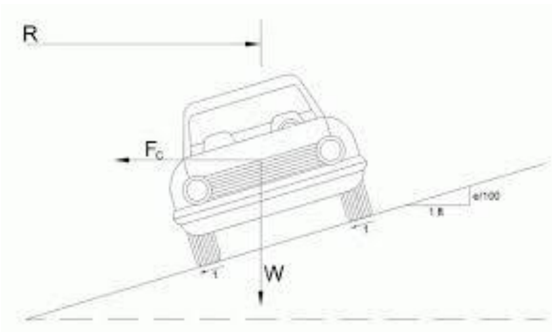


Figure (4. 3) : Superelevation

4.2.3 Minimum Radius

The minimum radius in a horizontal curve refers to the smallest radius of curvature that a road can have in a curved section. This radius is critical in determining the sharpness of the curve and is a crucial factor in road design, ensuring safe and efficient traffic flow.

The minimum radius in a horizontal curve depends on various factors, including the design speed of the road, the type of road, the terrain, and the desired level of comfort and safety for drivers or passengers. Generally, larger radii are preferred for higher design speeds and to accommodate larger vehicles.

It's important to note that the minimum radius is not only determined by geometric considerations but also considers factors like superelevation, sight distance, and lateral friction between tires and the road surface.

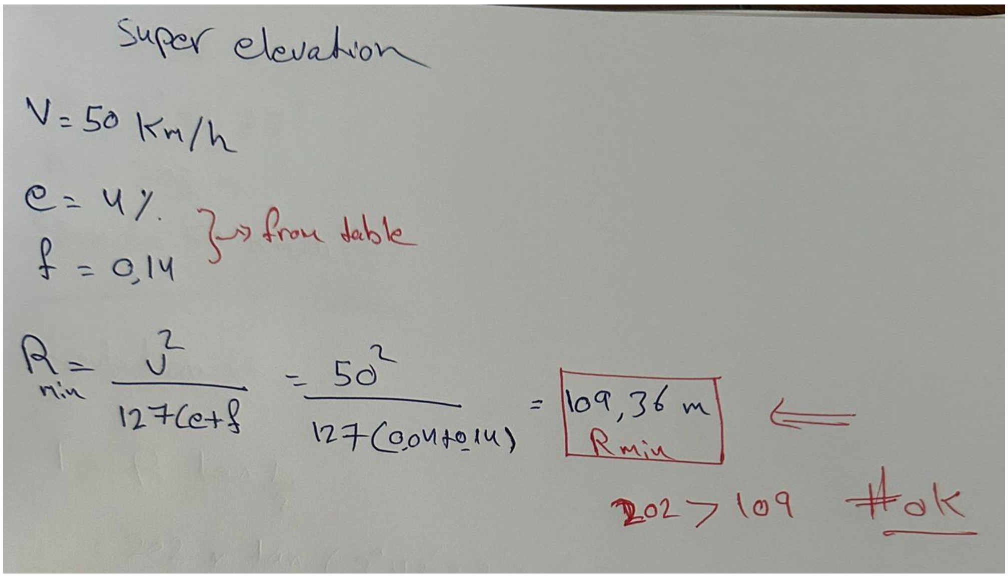


Figure (4. 4) : Calculate R min in super elevation

4.3 Vertical Curve

In geometric design, a vertical curve refers to a curve or transition along a roadway or a linear profile that connects two different grades or slopes. It is used to provide a smooth and safe transition for vehicles traveling along the road, particularly when there is a change in elevation.

Vertical curves are essential for several reasons:

1. Safety: When there is a significant change in the road's gradient, abrupt transitions can lead to driver discomfort, reduced visibility, and potential loss

of control. Vertical curves help to minimize these issues by gradually transitioning between different slopes, ensuring a smoother driving experience and improved safety.

2. Sight Distance: Vertical curves are designed to provide adequate sight distance for drivers. The curve's length and shape are determined to ensure that drivers have a clear view of the road ahead, including any potential hazards or oncoming traffic.

3. Drainage: Vertical curves help facilitate proper drainage along the road. By incorporating a gradual slope change, water can flow smoothly off the roadway without causing pooling or erosion issues.

4. Vehicle Performance: Vertical curves consider the performance capabilities of vehicles. They are designed to accommodate the safe and efficient movement of vehicles, taking into account factors such as acceleration, deceleration, and braking capabilities.

4.3.1 Sag Curve

A sag curve is used when transitioning from an uphill slope to a downhill slope. It is concave upwards, resembling a "U" shape. A sag curve helps drivers adjust their speed and maintain vehicle control as they descend.

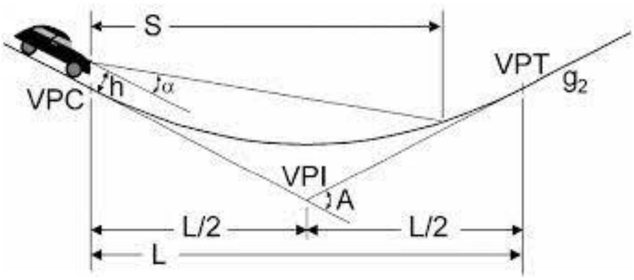


Figure (4. 5) : Sag Curve

Table (4. 2) : K Value for Sag Curve

Design Speed (mi/h)	Stopping Sight Distance (ft)	Rate of Vertical Curvature, K^a	
		Calculated	Design
15	80	9.4	10
20	115	16.5	17
25	155	25.5	26
30	200	36.4	37
35	250	49.0	49
40	305	63.4	64
45	360	78.1	79
50	425	95.7	96
55	495	114.9	115
60	570	135.7	136
65	645	156.5	157
70	730	180.3	181
75	820	205.6	206
80	910	231.0	231

4.3.2 Crest Curve

A crest curve is used when transitioning from a downhill slope to an uphill slope. It is concave downwards, resembling an inverted "U" shape. A crest curve allows drivers to adjust their speed and maintain vehicle stability as they ascend.

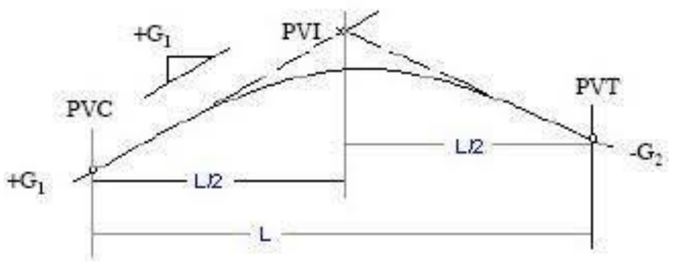


Figure (4. 6) : Crest Curve

Table (4. 3) K Value for Crest Curve

Design Speed (mi/h)	Stopping Sight Distance (ft)	Rate of Vertical Curvature, K^a	
		Calculated	Design
15	80	3.0	3
20	115	6.1	7
25	155	11.1	12
30	200	18.5	19
35	250	29.0	29
40	305	43.1	44
45	360	60.1	61
50	425	83.7	84
55	495	113.5	114
60	570	150.6	151
65	645	192.8	193
70	730	246.9	247
75	820	311.6	312
80	910	383.7	384

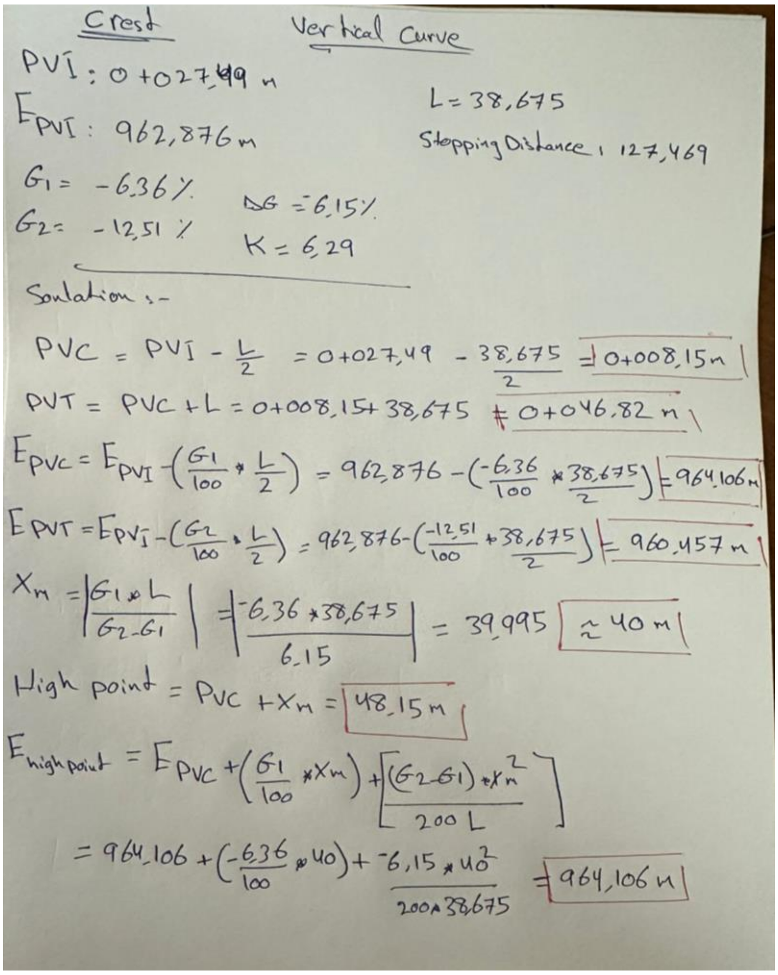


Figure (4. 7) : Calculate Crest Curve

4.3.3 Vertical Curve at Grade

This type of vertical curve is used when transitioning between two different slopes of the same grade. It is generally a straight line and provides a smooth transition without any noticeable curve.

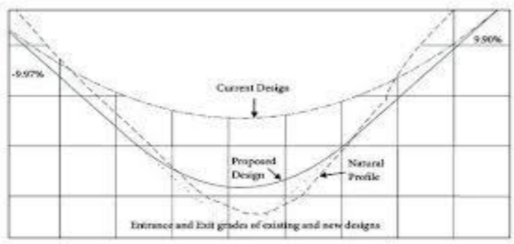


Figure (4. 8) : Vertical Curve at Grade

4.3.4 Stopping side distance

The stopping sight distance for a vertical curve in roadway design is the distance required for a driver to come to a stop when there is an obstacle or condition on the road that necessitates stopping. This sight distance is crucial for ensuring the safety of drivers and passengers.

The stopping sight distance for a vertical curve is influenced by various factors, including the design speed of the road, the gradient of the vertical curve, the height of the driver's eye above the road surface, and the deceleration rate of the vehicle.

Table (4. 4) : Stopping Sight Distance

Metric					US Customary				
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance Calculated (m)	Stopping sight distance Design (m)	Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance Calculated (ft)	Stopping sight distance Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

4.4 Road Planning

4.4.1 Introduction

Road planning is a crucial aspect of urban and regional development that involves the systematic design, construction, and maintenance of road networks to ensure efficient and safe transportation. The process encompasses various stages, including surveying, feasibility studies, design, and implementation. Effective road planning plays a pivotal role in enhancing connectivity, reducing congestion, promoting economic growth, and ensuring the overall well-being of communities.

Key components of road planning include:

1. Surveying and Data Collection: Gathering accurate data on existing road conditions, traffic patterns, and land use is essential. This information helps planners make informed decisions about the design and alignment of roads.

2. Design: Based on collected data and feasibility studies, engineers create detailed designs for the road network. This includes considerations for road geometry, traffic flow, safety features, and environmental sustainability.

3. Land Acquisition: Acquiring the necessary land for road construction is often a complex process. Planners must navigate legal, social, and economic considerations while minimizing disruptions to existing communities.

4. Construction and Maintenance: Once the planning and design phases are complete, road construction can commence. Regular maintenance is also crucial to ensure the longevity and safety of the road network.

Effective road planning is essential for creating a sustainable and interconnected transportation infrastructure that meets the needs of growing populations. It contributes to economic development, environmental conservation, and improved quality of life for residents. As cities and regions continue to evolve, strategic road planning remains a cornerstone for fostering progress and connectivity.

4.4.2 Location

The location of road planning can refer to both the geographical area or region where road planning is taking place and the specific administrative and organizational context within a government or planning agency. Let's explore both aspects:

1. Geographical Location:
    - Urban Areas: In urban settings, road planning is often focused on addressing the transportation needs of a city or metropolitan region. Planners consider factors such as population density, land use, existing infrastructure, and anticipated growth when designing and improving road networks.
    - Rural Areas: In rural settings, road planning may involve connecting remote communities, improving transportation links for agriculture, and ensuring access to essential services. The emphasis may be on creating efficient and reliable transportation routes in less densely populated regions.
    - Regional and National Levels: At broader scales, road planning can occur at the regional or national level to enhance connectivity between cities, states, or countries. This involves strategic planning to facilitate economic development, trade, and tourism.

2. Organizational and Administrative Location:

- Government Agencies: Road planning is typically undertaken by government agencies responsible for transportation and infrastructure. These agencies may operate at different levels of government, such as municipal, county, state, or national departments of transportation.

- Planning Departments: Within government structures, specific planning departments or divisions may be dedicated to road and transportation planning. Planners in these departments collaborate with engineers, environmental experts, and other professionals to develop comprehensive road plans.

- Public-Private Partnerships: In some cases, road planning may involve collaboration between government entities and private organizations. Public-private partnerships (PPPs) can bring together expertise and resources from both sectors to implement road projects.

- International Organizations: For large-scale projects that cross national borders, international organizations and collaborations may play a role in road planning. These entities work to harmonize standards, improve cross-border infrastructure, and facilitate regional development.

- Local Communities: Local communities and stakeholders often have a say in the road planning process. Community input is crucial for identifying local needs, addressing concerns, and ensuring that road projects align with the priorities and values of the people who live in the affected areas.

The location of road planning, therefore, encompasses a broad spectrum, ranging from specific geographic locations to the administrative and organizational contexts in which planning activities take place. It involves a multidisciplinary approach that considers social, economic, environmental, and engineering factors to create sustainable and effective road networks.

4.4.3 Right of way

The road verge is the area surrounding the road or main roadway that must remain free of elements and structures to enhance user safety and ensure road safety. The road verge is an essential part of road design and engineering infrastructure planning. Properly determining the road verge size and design is vital for enhancing overall safety and effectiveness of roads. The size and design of the road verge depend on several factors, including:

1. **Road Type:**
    - The road verge may vary depending on the type of road. For example, highways may require a larger verge than secondary roads.
2. **Traffic Volume:**
    - Road verge requirements are influenced by the volume of traffic and expected traffic movements.
3. **Permissible Speed:**
    - The permissible speed on the road plays a role in determining the road verge size, as higher speeds may necessitate a larger verge.
4. **Safety and Visibility:**
    - The size of the road verge is related to ensuring good visibility for drivers and providing sufficient distance for emergency reactions.
5. **Soil and Environment:**
    - The design of the road verge should consider the environmental and geographical characteristics of the surrounding soil.
6. **General Planning:**
    - The determination of the road verge is part of the overall planning for the area and development guidelines.

Effectively determining the road verge contributes to maintaining the overall safety of roads, enhances traffic organization, and contributes to the long-term sustainability of road infrastructure.

Table (4. 5) : Right of way

Road type	Right-of-way width (m)
Two-lane road	22 - 36
Three-lane road	30 - 42
Four-lane road	37 - 93

4.4.4 Lane width

Lane width refers to the total horizontal distance of an individual traffic lane on the road. It is a crucial factor in road design and traffic planning, influenced by several factors including:

1. **Road Type:**
    - Lane width may vary depending on the type of road. Highways typically have wider lanes compared to local roads.
2. **Traffic Density:**
    - Traffic density affects lane width, with high-traffic roads often requiring wider lanes.
3. **Speed Limits:**
    - The allowed speed on the road influences lane width. Higher speeds may necessitate wider lanes.
4. **Presence of Additional Features:**
    - The existence of features such as shoulders or bike lanes can impact lane width.

5. **User Safety:**
    - Lane width is chosen to ensure the safety of users, including drivers and cyclists.

Lane width plays a crucial role in determining how traffic is organized and ensuring the safety of road users , the lane width from AASHTO 2.75 – 3.65 .

4.4.5 Crossing element

A crossing element in road design refers to any infrastructure or feature that allows pedestrians, cyclists, or vehicles to traverse a road safely. Crossings are essential components of transportation planning and urban design, as they facilitate the movement of people and goods while ensuring the safety of users. There are various types of crossing elements, each designed to accommodate different modes of transportation. Here are some common crossing elements:

1. **Pedestrian Crosswalk:**
    - Zebra Crossings: Marked with distinct white stripes on the road, zebra crossings are designated areas where pedestrians can cross safely. They often include painted lines, and sometimes pedestrian crossing signs or signal lights.

2. **Traffic Signals:**
    - Pedestrian Signals: These are traffic lights specifically designed for pedestrians. They provide signals such as "Walk," "Don't Walk," and countdowns to indicate the time remaining to cross the road safely.
    - Signalized Crosswalks: Some pedestrian crossings are equipped with traffic signals to regulate the flow of both pedestrian and vehicular traffic, ensuring a safe crossing experience.

3. **Crossing Islands and Medians:**
    - Pedestrian Islands: Raised or lowered islands placed in the middle of the road provide pedestrians with a refuge, allowing them to cross one direction of traffic at a time.
    - Raised Medians: Central medians with physical barriers or landscaping can create safer crossing points for pedestrians and also help manage turning movements for vehicles.
4. **Crossing Signs and Markings:**
    - Crosswalk Signs: Informative signs alerting drivers to the presence of pedestrian crosswalks and indicating the need to yield to pedestrians.
    - Road Markings: Painted lines and symbols on the road surface, such as pedestrian crosswalk lines and symbols, guide pedestrians and drivers.
5. **Cyclist Crossings:**
    - Bike Lanes and Crossings: Designated lanes for cyclists with accompanying markings and crossings to facilitate safe passage across roads.
6. **Uncontrolled Crossings:**
    - Unmarked Crossings: Locations where pedestrians are legally allowed to cross but may not have designated markings. Drivers are still required to yield to pedestrians.

Proper planning and implementation of crossing elements are critical for creating a safe and efficient transportation network. Consideration of factors such as traffic volume, pedestrian activity, and the surrounding environment helps determine the most appropriate type of crossing element for a given location. Integrating these elements into road design contributes to overall traffic safety and improves the accessibility of urban and suburban areas.

4.4.6 Alignment selection

Alignment selection in road design refers to the process of choosing the horizontal and vertical alignment for a road. Horizontal alignment refers to the layout of the road in plan view, while vertical alignment involves the profile or elevation of the road along its length. The goal is to create a safe, efficient, and economically viable road that accommodates the topography and meets the intended purpose. Here are key considerations in alignment selection:

1. **Topography and Terrain:**
   - The natural topography of the land influences alignment selection. Engineers strive to minimize earthwork and cut-and-fill operations by aligning the road with the contours of the terrain.
2. **Geometric Design Standards:**
   - Adherence to established geometric design standards ensures that the road provides safe and comfortable travel for users. Standards include criteria for curve radii, superelevation (banking of curves), sight distance, and lane widths.
3. **Traffic Conditions:**
   - The expected traffic volume and types of vehicles using the road influence alignment selection. Highways designed for faster-moving traffic may have different alignment requirements than local roads with lower speeds and traffic volumes.
4. **Land Use and Development Plans:**
   - Alignment should consider existing and future land use. Roads must integrate with development plans, providing access to residential, commercial, and industrial areas while minimizing disruption to existing communities.
5. **Safety:**
   - Safety is paramount in alignment selection. Engineers must consider sight distance, clear zones, and other factors to minimize the risk of

accidents. Proper alignment ensures good visibility for drivers and safe turning radii at intersections.

6. **Environmental Impact:**
    - Minimizing the environmental impact of road construction is essential. Alignment selection should consider avoiding ecologically sensitive areas, wetlands, and habitats, and incorporating measures to protect the environment.
7. **Economic Considerations:**
    - The cost of construction and maintenance is a crucial factor. Engineers aim to minimize construction costs by selecting alignments that require reasonable earthwork, avoid costly structures, and utilize existing infrastructure where possible.
8. **Aesthetic and Cultural Considerations:**
    - In some cases, alignment selection may consider aesthetic and cultural factors. Roads passing through scenic areas or near historical sites may be designed to enhance the overall experience and preserve the cultural landscape.
9. **Accessibility:**
    - The road must be accessible to all users, including pedestrians and cyclists. Alignment selection should include provisions for sidewalks, crosswalks, and bike lanes where appropriate.
10. **Future Expansion and Upgrading:**
    - Planning for future growth and the potential need for road expansion or upgrading is essential. Alignment should allow for future widening or improvements to accommodate changing traffic patterns and needs.

The alignment selection process involves a comprehensive analysis that considers a range of technical, economic, and environmental factors. It requires collaboration between engineers, planners, environmental specialists, and other stakeholders to ensure that the chosen alignment aligns with the overall goals of the transportation system and the community it serves.

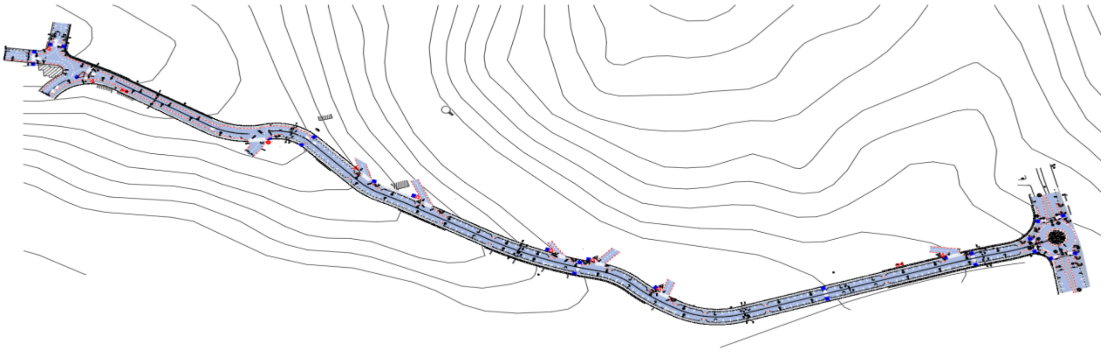


Figure (4. 9) : Alignment selection for project

4.4.7 Profile

In geometric design, a profile refers to a cross-sectional view or representation of an object or shape. It provides a detailed description of the shape's outline or contour at a specific point or along a specific line. Profiles are commonly used in engineering.

A profile typically includes the following aspects:

1. Outline or Boundary: The outermost boundary or silhouette of the shape. It defines the shape's overall form and can be represented by a continuous curve or a series of line segments.

2. Dimensions: Measurements and specifications related to the size and proportions of the profile. This may include lengths, widths, heights, angles, and radii, depending on the specific requirements of the design.

3. Curvature: The curvature of the profile, which describes how the shape's contour changes along its length or at specific points. Curvature can be uniform, varying, or include specific sections with specific curvature properties.

4. Features: Any additional details or features that are integral to the design or function of the object. These could include holes, slots, notches, fillets, chamfers, or other geometric elements.

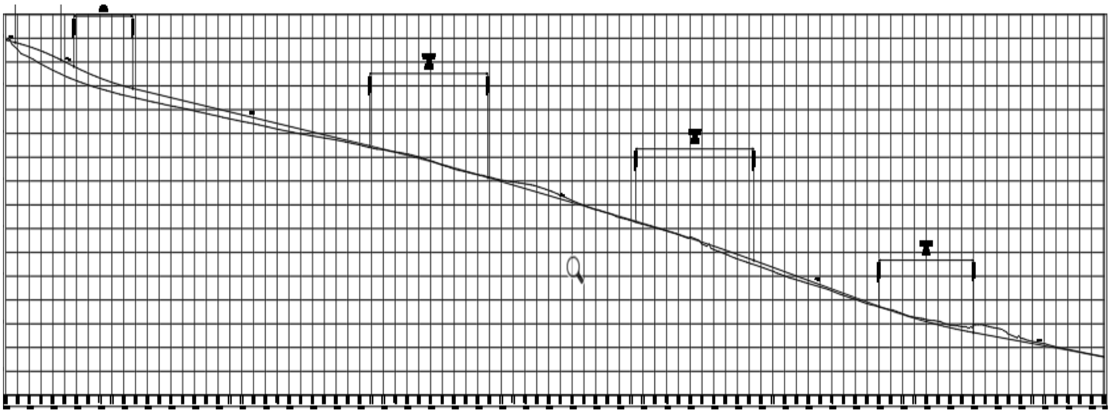


Figure (4. 10) : Profile selection for project

4.4.8 Cross - Section

In geometric design, a cross-section refers to a two-dimensional representation or view of a roadway or any linear infrastructure project taken perpendicular to its alignment. It provides a detailed illustration of the shape, dimensions, and features of the roadway or structure at a specific location along its length. Cross-sections play a crucial role in the design, analysis, and construction of roads, highways, railways, canals, and other linear projects.

Here are the key aspects of cross-sections in geometric design:

1. Geometry: A cross-section depicts the geometric properties of the roadway or structure, including the width, height, slopes, curvatures, and transitions. It represents the shape of the road surface, cuttings, ditches, medians, shoulders, and any other elements present.

2. Grading: Cross-sections show the grading or slope of the terrain and the roadway itself. This includes the slopes of embankments (fill sections) or cuttings (excavated sections) and any necessary transitions between different grades.

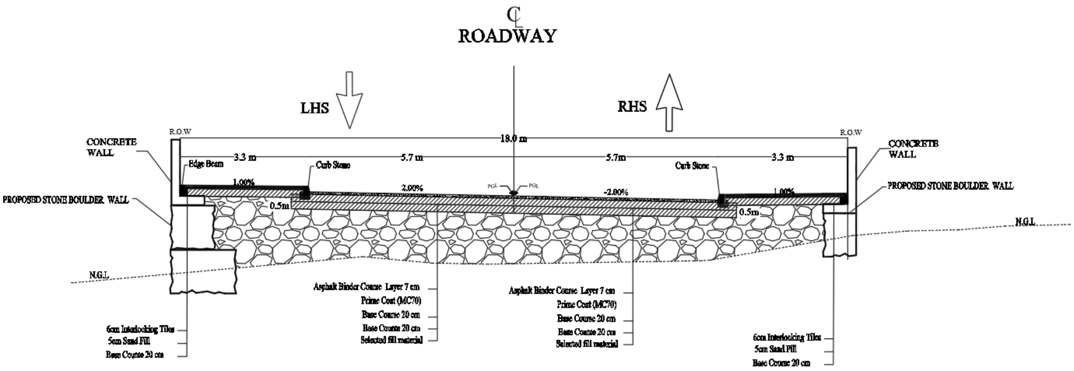
3. Profiles: Cross-sections often include profiles that display the vertical variation of the roadway, showing the elevations and grades at specific points along the cross-section. Profiles are essential for assessing the vertical alignment, including changes in elevation, vertical curves, and vertical clearances.

4. Features and Elements: Cross-sections illustrate various features and elements of the roadway, such as lanes, shoulders, curbs, sidewalks, medians, traffic barriers, drainage structures, signage, and utilities. These elements are typically represented with different symbols, colors, or linetypes to provide clarity.

5. Dimensions: Cross-sections include measurements and dimensions that are essential for construction and analysis purposes. These dimensions may include widths of lanes, shoulders, and other features, as well as slopes, curvatures, and clearances.

6. Construction Details: Cross-sections can show construction details, such as pavement layers, subbase materials, and typical cross-sectional configurations at specific locations. These details help in the construction and quality control processes.

By examining cross-sections at multiple locations along the alignment, designers can ensure consistency, identify potential issues, and optimize the design for safe and efficient transportation or infrastructure projects.



TYPICAL CROSS SECTION NO.01

From STA 0+000m To STA 0+190m

GENERAL NOTE:
CROSS SECTIONS CONTAINED HEREIN ARE PROVIDED FOR INFORMATION ONLY. EXISTING GRADE LINE MAY DIFFER FROM THE ACTUAL FIELD CONDITION. THE CONTRACTOR SHALL VERIFY EXISTING GROUND LINE PERIODICALLY AND NOTIFY THE ENGINEER OF ANY DISCREPANCIES THAT SIGNIFICANTLY IMPACT CONSTRUCTION OF THE PROPOSED FEATURES. DESIGN FEATURES DEPICTED ON CROSS SECTIONS MAY DIFFER FROM WHAT IS SHOWN ON THE PLAN AND PROFILE SHEETS. CONTRACTOR SHALL REFER TO THE PLAN AND PROFILE SHEETS TO DETERMINE THE LOCATION, DIMENSIONS, LIMITS AND EXTENTS OF PROPOSED DESIGN FEATURES.

Figure (4. 11) : Cross – Section

CHAPTER FIVE

PAVMENT STRUTURE DESIGN

This chapter contains:

5.1 Introduction

Pavement structure design is a critical aspect of civil engineering that focuses on creating a durable and safe road surface capable of supporting the traffic loads and environmental conditions to which it will be exposed. The design of a pavement structure involves a systematic approach to ensure the longevity and functionality of roads. Here is an introduction to pavement structure design:

1. Definition and Purpose:

   Pavement structure design refers to the process of determining the composition and specifications of the layers constituting the road surface. The primary purpose is to create a structure that can withstand the stresses imposed by traffic loads and environmental factors over an extended period.

2. Functional Layers:

   A typical pavement structure comprises multiple layers, each serving a specific function. These layers often include the surface course, base course, sub-base course, and subgrade. The design of each layer considers its role in distributing loads, providing support, and resisting environmental effects.

3. Traffic Analysis:

   The design process begins with a thorough analysis of the expected traffic conditions, including the volume, type, and weight of vehicles using the road. This analysis helps determine the appropriate thickness and composition of each pavement layer to ensure sufficient strength and durability.

4. Material Selection:

Pavement designers must carefully select materials for each layer based on factors such as strength, flexibility, and resistance to environmental conditions. The choice of materials significantly influences the overall performance and lifespan of the pavement.

5. Structural Design:

The structural design involves determining the thickness and composition of each layer to achieve the required load-bearing capacity. This process ensures that the pavement can effectively distribute stresses and prevent premature failure.

6. Environmental Considerations:

Pavement structure design takes into account the impact of environmental factors such as temperature variations, moisture, and freeze-thaw cycles. Proper design considers these elements to prevent deterioration and extend the life of the pavement.

7. Sustainability and Cost-Effectiveness:

Designers strive to balance sustainability and cost-effectiveness by selecting materials and techniques that minimize environmental impact while optimizing the economic aspects of construction and maintenance.

8. Quality Control and Assurance:

Throughout the design and construction phases, quality control measures are implemented to ensure that the pavement structure meets specified standards. This includes testing materials, monitoring construction processes, and conducting performance assessments.

In conclusion, pavement structure design is a multifaceted process that integrates engineering principles, material science, and environmental considerations to create road surfaces capable of withstanding the challenges posed by traffic and the surrounding environment. A well-designed pavement structure contributes to the safety, efficiency, and sustainability of transportation infrastructure.

5.2 Soil

Soil is a vital component of the Earth's surface, serving as the foundation for terrestrial ecosystems and playing a crucial role in supporting life. It is a complex mixture of minerals, organic matter, water, air, and living organisms that forms the top layer of the Earth's crust. Soil provides a habitat for plants, animals, and microorganisms, and it plays a fundamental role in various ecological processes.

Key Components of Soil:

1. **Mineral Particles:** Soil is composed of mineral particles, including sand, silt, and clay. The proportions of these particles determine the soil texture. Sandy soils have larger particles, while clayey soils have smaller particles.
2. **Organic Matter:** Organic matter in soil consists of decomposed plant and animal residues. It contributes to soil fertility by providing essential nutrients for plant growth and improving soil structure.
3. **Water:** Soil acts as a reservoir for water, holding moisture that is essential for plant growth. The water-holding capacity of soil depends on its texture and organic matter content.
4. **Air:** Spaces between soil particles contain air, which is crucial for the respiration of plant roots and soil organisms. Adequate soil aeration ensures the supply of oxygen to support biological activities.
5. **Microorganisms:** Soil hosts a diverse community of microorganisms, including bacteria, fungi, protozoa, and nematodes. These organisms

contribute to nutrient cycling, decomposition of organic matter, and other essential soil functions.

Functions of Soil:

1. **Engineering Support:** Soil properties influence construction and engineering activities, such as building foundations, road construction, and agricultural practices.

Soil Types:

Different regions exhibit various soil types based on factors like climate, parent material, topography, and vegetation. Major soil classifications include sandy, loamy, clayey, and peaty soils, each with unique characteristics.

Understanding soil properties is essential for agriculture, environmental management, and sustainable land use planning. Soil science, or pedology, is the scientific discipline dedicated to studying the formation, classification, and mapping of soils to optimize their use for various purposes while ensuring conservation and environmental sustainability.

5.3 Traffic count for asphalt

When designing roads and selecting the type of asphalt, the expected traffic load and the weights of the vehicles that will use the road are considered. Traffic count and vehicle loads are crucial factors that must be taken into account to determine the thickness and quality of the asphalt used. Here are some important points in this context:

1. **Traffic Study:**
    - Traffic flow analysis is conducted to estimate the number of vehicles and expected loads over time.
2. **Load Determination:**
    - The expected loads of vehicles are determined using average and standard weights for vehicles passing on the road, with consideration of additional loads in some cases.

3. **Asphalt Design Factors:**

   - The type and thickness of the asphalt are selected based on the traffic load and vehicle weights. Asphalt design equations, such as those from the American Association of State Highway and Transportation Officials (AASHTO), are used to estimate the required asphalt thickness.

4. **Subgrade Evaluation:**

   - The subgrade soil is evaluated to ensure that it can accommodate the expected loads effectively. In some cases, soil improvement techniques, such as fiber reinforcement or lime stabilization, may be used.

5. **Maintenance Considerations:**

   - Future maintenance needs should also be considered. In some cases, specific types of asphalt are chosen to provide good resistance to wear and extend the road's lifespan.

6. **Distortion and Rutting:**

   - The impact of vehicle weights on asphalt distortion and rutting is considered, and the asphalt design is determined to withstand these effects.

Determining traffic counts and vehicle loads requires collaboration between road and traffic engineers and experts in asphalt design. The engineering approach is used to ensure that the road can withstand the expected traffic loads over the long term without damage or deterioration.

5.4 Pavement Design

5.4.1 Introduction

Highway pavements are divided into two main categories:

1. Rigid pavement; The wearing surface of a rigid pavement is usually constructed of Portland cement concrete such that it acts like a beam over any irregularities in the underlying supporting material.

2. Flexible Pavement; the wearing surface of flexible pavements, on the other hand, is usually constructed of bituminous materials such that they remain in contact with the underlying material even when minor irregularities occur.

Flexible pavements usually consist of a bituminous surface under laid with a layer of granular material and a layer of a suitable mixture of coarse and fine materials. Traffic loads are transferred by the wearing surface to the underlying supporting materials through the interlocking of aggregates, the frictional effect of the granular materials, and the cohesion of the fine materials.

Flexible pavements are further divided into three subgroups:

1. High type
2. Intermediate type
3. Low type

1. High-type : pavements have wearing surfaces that adequately support the expected traffic load without visible distress due to fatigue and are not susceptible to weather conditions.

2. Intermediate-type pavements have wearing surfaces that range from surface treated to those with qualities just below that of high-type pavements.

3. Low-type pavements are used mainly for low-cost roads and have wearing surfaces that range from untreated to lose natural materials to surface-treated earth.

5.4.2 Structural Components Of A Flexible Pavement

Figure 5.1 shows the components of a flexible pavement: the subgrade or prepared road- bed, the subbase, the base, and the wearing surface. The performance of the pavement depends on the satisfactory performance of each component, which requires proper evaluation of the properties of each component separately.

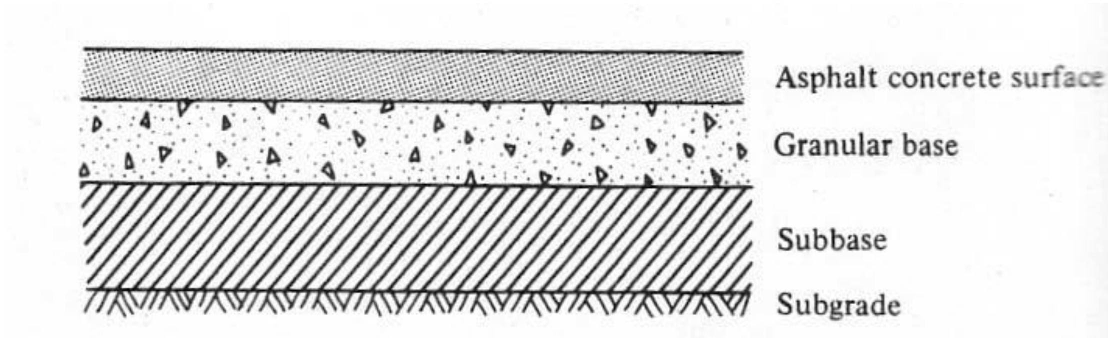


Figure (5. 1) : Components of a flexible pavement

1. Subgrade (Prepared Road Bed) :

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

2. Subbase course :

Located immediately above the subgrade, the subbase component consists of material of superior quality to that which generally is used for subgrade construction. The requirements for subbase materials are usually given in terms of the gradation plastics, and strength. When the quality of the subgrade material meets the requirements of the subbase material, the subbase component may be omitted.

3. Base course :

The base course lies immediately above the subbase or subgrade. It is placed immediately on a subgrade if a subbase course is not used. This course usually consists of granular such as crushed stone, crushed or uncrushed slag, crushed or uncrushed gravel. The specifications for base course materials usually include stricter requirement those for subbase materials, particularly with respect to their plasticity, gradation strength. Materials that do not have the required properties can be used as base material if they are properly stabilized with Portland cement, asphalt, or lime.

4. Surface course :

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

5.4.3 General Principles Of Flexible Pavement Design

In the design of flexible pavements, the pavement structure is usually considered as a multilayered elastic system, with the material in each layer characterized by certain physical properties that may include the modulus of elasticity, the resilient and the Poisson ratio.

It is usually assumed that the subgrade layer is infinite in both the horizontal and vertical directions, whereas the other layers are finite in the vertical direction and infinite the horizontal direction. The application of a wheel load causes a stress distribution which can be represented as shown in Figure 5.2.

The maximum vertical stresses are compressive and occur directly under the wheel load. These decrease depth from the surface. The maximum horizontal stresses also occur under the wheel load but can be either tensile or compressive as shown in Figure 5.2(C) .when load and pavement thickness are within certain ranges, horizontal compressive will occur above the neutral axis, whereas horizontal tensile stresses will occur below the neutral axis. The temperature distribution within the pavement stricter 5.2(d), will also have an effect on the magnitude of the stresses.

The availability of highly sophisticated computerized solutions systems, coupled with recent advances in materials evaluation, has led to of several design methods that are based wholly or partly on theoretical analysis more commonly used design methods are :

1. ASPHALT INSTITUTE METHOD
2. AMERICAN ASSOCIATION OF STATE HIGHWAY.

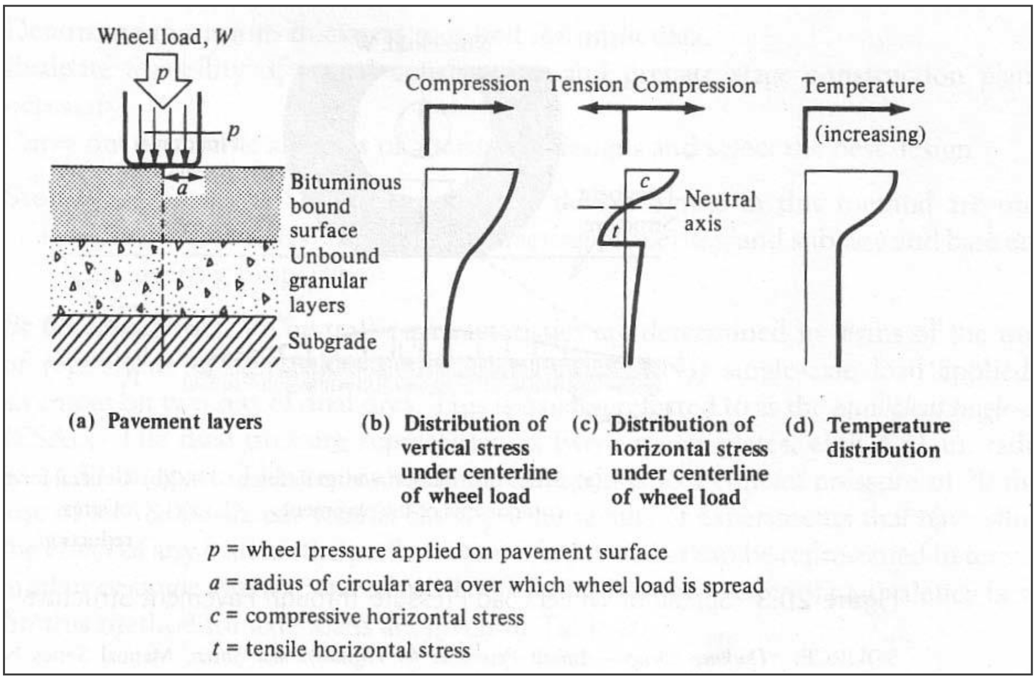


Figure (5. 2) : Typical Stress and Temperature Distributions in a Flexible Pavement Under a wheel load

- **Asphalt Institute Design Method**

In the Asphalt Institute design method, the pavement is represented as a multilayered elastic system. The wheel load W is assumed to be applied through the tire as a uniform vertical pressure p0, which is then spread by the different components of the pavement structure and eventually applied on the subgrade as a much lower stress pv This is shown in Figure 5.3. Experience, established theory, and test data are then used to evaluate two specific stress-strain conditions.

The first, shown in Figure 5.3(b), is the general way in which the stress p0 is reduced to px within the depth of the pavement structure and the second, shown in Figure 5.4, is the tensile and compressive stresses and strains imposed on the asphalt due to the deflection caused by the wheel load.

- **Design Procedure**

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

Design charts have been prepared for a range of traffic loads. This range is usually adequate for normal traffic volumes encountered in practice. However, when this range is exceeded, computer version should be used.

The procedure consists of five main steps:

1. Select or determine input data.
2. Select surface and base materials
3. Determine minimum thickness required for input data.
4. Evaluate feasibility of staged construction and prepare stage construction plan, if necessary.
5. Carry out economic analyses of alternative designs and select the best design.

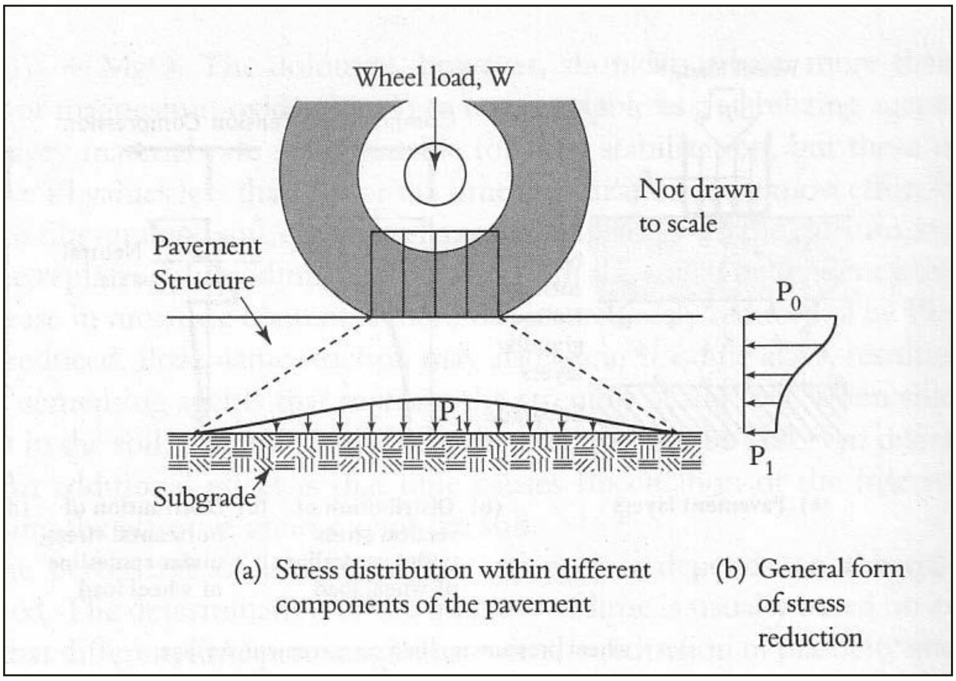


Figure (5. 3) : Spread of Wheel Load Pressure through Pavement Structure

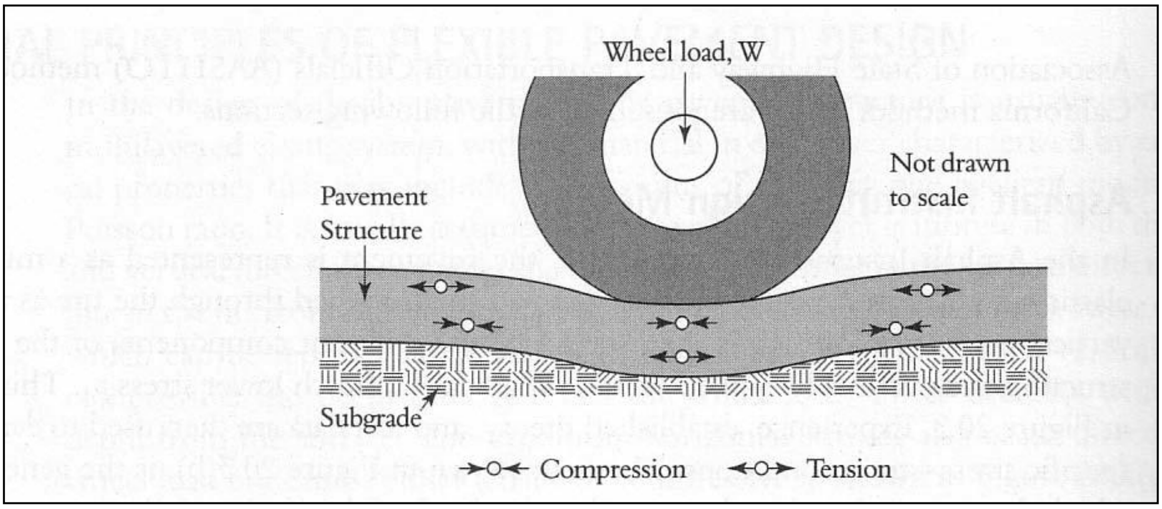


Figure (5. 4) : Schematic of Tensile and Compressive Stresses in Pavement Structure

Step 1. Determine Design Inputs. The design inputs in this method are traffic characteristics, subgrade engineering properties, and subbase and base engineering properties.

Traffic Characteristics. The traffic characteristics are determined in terms of the number of repetitions of an 18,000-lb ((80) kilo-Newton's (KN)) single-axle load applied to the pavement on two sets of dual tires.

This is usually referred to as the equivalent single-axle load (ESAL). The dual tires are represented as two circular plates, each 4.51 in. radius, spaced 13.57 in. apart. This representation corresponds to a contact pressure of 70 lb/in. The use of an 18,000-lb axle load is based on the results of experiments that have shown that the effect of any load on the performance of a pavement can be represented in terms of the number of single applications of an 18,000-lb single axle. A series of equivalency factors used in this method for axle loads are given in Table 5.1.

Table (5. 1) : Load Equivalency

Gross Axle Load		*Load Equivalency Factors*		
kN	*lb*	*Single Axles*	*Tandem Axles*	*Tridem Axles*
4.45	1,000	0.00002		
8.9	2,000	0.00018		
17.8	4,000	0.00209	0.0003	
26.7	6,000	0.01043	0.001	0.0003
35.6	8,000	0.0343	0.003	0.001
44.5	10,000	0.0877	0.007	0.002
53.4	12,000	0.189	0.014	0.003
62.3	14,000	0.360	0.027	0.006
71.2	16,000	0.623	0.047	0.011
80.0	18,000	1.000	0.077	0.017
89.0	20,000	1.51	0.121	0.027
97.9	22,000	2.18	0.180	0.040
106.8	24,000	3.03	0.260	0.057
115.6	26,000	4.09	0.364	0.080
124.5	28,000	5.39	0.495	0.109
133.4	30,000	6.97	0.658	0.145
142.3	32,000	8.88	0.857	0.191
151.2	34,000	11.18	1.095	0.246
160.1	36,000	13.93	1.39	0.313
169.0	38,000	17.20	1.70	0.393
178.0	40,000	21.08	2.08	0.487
187.0	42,000	25.64	2.51	0.597
195.7	44,000	31.00	3.00	0.723

Gross Axle Load		Load Equivalency Factors		
kN	*lb*	*Single Axles*	*Tandem Axles*	*Tridem A*
204.5	46,000	37.24	3.55	0.868
213.5	48,000	44.50	4.17	1.033
222.4	50,000	52.88	4.86	1.22
231.3	52,000		5.63	1.43
240.2	54,000		6.47	1.66
249.0	56,000		7.41	1.91
258.0	58,000		8.45	2.20
267.0	60,000		9.59	2.51
275.8	62,000		10.84	2.85
284.5	64,000		12.22	3.22
293.5	66,000		13.73	3.62
302.5	68,000		15.38	4.05
311.5	70,000		17.19	4.52
320.0	72,000		19.16	5.03
329.0	74,000		21.32	5.57
338.0	76,000		23.66	6.15
347.0	78,000		26.22	6.78
356.0	80,000		29.0	7.45
364.7	82,000		32.0	8.2
373.6	84,000		35.3	8.9
382.5	86,000		38.8	9.8
391.4	88,000		42.6	10.6
400.3	90,000		46.8	11.6

Note: kN converted to lb are within 0.1 percent of lb shown.
SOURCE: *Thickness Design—Asphalt Pavements for Highways and Streets,* Manual Series No. 1, The Asphalt In
Lexington, Ky., February 1991.

To determine the ESAL, the number of different types of vehicles such as cars, buses, single-unit trucks, and multiple-unit trucks expected to use the facility during lifetime must be known. The distribution of the different types of vehicles expected to the proposed highway can be time from results of classification counts that are of highway agencies at regular intervals.

In cases where these data are not available can be made from Table 5.2, which gives representative values for the united states when the axle load of each vehicle type is known, these can then be convened to equivalent 18,000-lb loads using the equivalency factors given in Table 5.1. 18,000-lb load can also be determined from the vehicle type, if the axle load is unknown by using a truck factor for that vehicle.

The truck factor is defined as the number of 18,000-lb single-load applications caused by a single passage of a vehicle. These have been determined for each class of vehicle from the expression

$$\text{truck factor} = \frac{\sum(\text{number of axles} \times \text{load equivalency factor})}{\text{number of vehicles}}$$

Table (5. 2) : Distribution of Trucks on different classes of Highways

Truck Class	Percent Trucks – Rural Systems: Interstate	Rural: Other Principal	Rural: Minor Arterial	Rural: Collectors Major	Rural: Collectors Minor	Rural: Range	Urban Systems: Interstate	Urban: Other Freeways	Urban: Other Principal	Urban: Minor Arterial	Urban: Collectors	Urban: Range
Single-unit trucks												
2-axle, 4-tire	43	60	71	73	80	43–80	52	66	67	84	86	52–86
2-axle, 6-tire	8	10	11	10	10	8–11	12	12	15	9	11	9–15
3-axle or more	2	3	4	4	2	2–4	2	4	3	2	<1	<1–4
All single-units	53	73	86	87	92	53–92	66	82	85	95	97	66–97
Multiple-unit trucks												
4-axle or less	5	3	3	2	2	2–5	5	5	3	2	1	1–5
5-axle**	41	23	11	10	6	6–41	28	13	12	3	2	2–28
6-axle or more**	1	1	<1	1	<1	<1–1	1	<1	<1	<1	<1	<1–1
All multiple units	47	27	14	13	8	8–47	34	18	15	5	3	3–34
All trucks	100	100	100	100	100		100	100	100	100	100	

* Compiled from data supplied by the Highway Statistics Division, Federal Highway Administration.
**Including full-trailer combinations in some states.
SOURCE: *Thickness Design—Asphalt Pavements for Highways and Streets,* Manual Series No. 1, The Asphalt Institute, Lexington, Ky., February 1991.

Table 5.5 gives values of truck factors for different classes of vehicles. However, advisable, when truck factors are to be used, to collect data on axle loads for the types of vehicles expected to use the proposed highway and to determine realistic ; truck factors from that data.

The total ESAL applied on the highway during its design period can be determined only after the design period and traffic growth factors are known. The design period is the number of years the pavement will effectively continue to carry the traffic load without requiring an overlay.

Flexible highway pavements are usually designed for 20 year period. Since traffic volume does not remain constant over the design period of the pavement, it is essential that the rate of growth be determined and applied when calculating total ESAL. Annual growth rates can be obtained from regional planning agencies or state highway departments. These are usually based on traffic volume counts over several years.

It is also advisable to determine annual growth rates separately for trucks and passenger vehicles since these may be significantly different in some cases. The overall growth rate in the United States is between 3 percent and 5 percent per year, although growth rates of up to 10 percent per year have been suggested for some interstate highways.

Table 5.4 shows growth factors (Gf) for different growth rates (J) and design periods (t).which can be used to determine the total ESAL over the design period. The portion of the total ESAL acting on the design lane (fd) is used in the determination of pavement thickness. Either lane of a two-lane highway can be considered design lane, whereas for multilane highways, the outside lane is considered. The identification of the design lane is important because in some cases more trucks will travel in one direction than in the other, or trucks may travel heavily loaded in one direction and empty in the other direction. Thus, it is

necessary to determine the relevant proportion on the design lane. When data are not available to make this determination percentage given in Table 5.7 can be used.

$$ESAL_i = f_d \times G_{jt} \times AADT_i \times 365 \times N_i \times F_{Ei}$$

where

$ESAL_i$ = equivalent accumulated 18,000-lb (80 kN) single-axle load for category i

f_d = design lane factor

G_{jt} = growth factor for a given growth rate j and design period t

$AADT_i$ = first year annual average daily traffic for axle category i

N_i = number of axles on each vehicle in category i

F_{Ei} = load equivalency factor for axle category i

When truck factors are used, the ESAL for each category of truck is given as

$$ESAL_i = AADT_i \times 365 \times f_i \times G_{jt} \times f_d$$

Table (5. 3) : Distribution of Truck Factors (TF) for Different Classes of Highways and Vehicles-United States

	Truck Factors											
	Rural Systems						Urban Systems					
Vehicle Type	Interstate	Other Principal	Minor Arterial	Collectors Major	Collectors Minor	Range	Interstate	Other Freeways	Other Principal	Minor Arterial	Collectors	Range
Single-unit trucks												
2-axle, 4-tire	0.003	0.003	0.003	0.017	0.003	0.003–0.017	0.002	0.015	0.002	0.006	—	0.006–0.015
2-axle, 6-tire	0.21	0.25	0.28	0.41	0.19	0.19–0.41	0.17	0.13	0.24	0.23	0.13	0.13–0.24
3-axle or more	0.61	0.86	1.06	1.26	0.45	0.45–1.26	0.61	0.74	1.02	0.76	0.72	0.61–1.02
All single units	0.06	0.08	0.08	0.12	0.03	0.03–0.12	0.05	0.06	0.09	0.04	0.16	0.04–0.16
Tractor-semitrailers												
4-axle or less	0.62	0.92	0.62	0.37	0.91	0.37–0.91	0.98	0.48	0.71	0.46	0.40	0.40–0.98
5-axle**	1.09	1.25	1.05	1.67	1.11	1.05–1.67	1.07	1.17	0.97	0.77	0.63	0.63–1.17
6-axle or more**	1.23	1.54	1.04	2.21	1.35	1.04–2.21	1.05	1.19	0.90	0.64	—	0.64–1.19
All multiple units	1.04	1.21	0.97	1.52	1.08	0.97–1.52	1.05	0.96	0.91	0.67	0.53	0.53–1.05
All trucks	0.52	0.38	0.21	0.30	0.12	0.12–0.52	0.39	0.23	0.21	0.07	0.24	0.07–0.39

Note: Compiled from data supplied by the Highway Statistics Division, Federal Highway Administration.
*Including full-trailer combinations in some states.
**For values to be used when the number of heavy trucks is low, see original source.
SOURCE: *Thickness Design—Asphalt Pavements for Highways and Streets,* Manual Series No. 1, The Asphalt Institute, Lexington, Ky., February 1991.

Table (5. 4) : Growth Factor

Design Period, Years (n)	Annual Growth Rate, Percent (r)							
	No Growth	2	4	5	6	7	8	10
1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2	2.0	2.02	2.04	2.05	2.06	2.07	2.08	2.10
3	3.0	3.06	3.12	3.15	3.18	3.21	3.25	3.31
4	4.0	4.12	4.25	4.31	4.37	4.44	4.51	4.64
5	5.0	5.20	5.42	5.53	5.64	5.75	5.87	6.11
6	6.0	6.31	6.63	6.80	6.98	7.15	7.34	7.72
7	7.0	7.43	7.90	8.14	8.39	8.65	8.92	9.49
8	8.0	8.58	9.21	9.55	9.90	10.26	10.64	11.44
9	9.0	9.75	10.58	11.03	11.49	11.98	12.49	13.58
10	10.0	10.95	12.01	12.58	13.18	13.82	14.49	15.94
11	11.0	12.17	13.49	14.21	14.97	15.78	16.65	18.53
12	12.0	13.41	15.03	15.92	16.87	17.89	18.98	21.38
13	13.0	14.68	16.63	17.71	18.88	20.14	21.50	24.52
14	14.0	15.97	18.29	19.16	21.01	22.55	24.21	27.97
15	15.0	17.29	20.02	21.58	23.28	25.13	27.15	31.77
16	16.0	18.64	21.82	23.66	25.67	27.89	30.32	35.95
17	17.0	20.01	23.70	25.84	28.21	30.84	33.75	40.55
18	18.0	21.41	25.65	28.13	30.91	34.00	37.45	45.60
19	19.0	22.84	27.67	30.54	33.76	37.38	41.45	51.16
20	20.0	24.30	29.78	33.06	36.79	41.00	45.76	57.28
25	25.0	32.03	41.65	47.73	54.86	63.25	73.11	98.35
30	30.0	40.57	56.08	66.44	79.06	94.46	113.28	164.49
35	35.0	49.99	73.65	90.32	111.43	138.24	172.32	271.02

Note: Factor = $[(1+r)^n - 1]/r$, where $r = \frac{\text{rate}}{100}$ and is not zero. If annual growth is zero, growth factor = design period.

SOURCE: *Thickness Design—Asphalt Pavements for Highways and Streets,* Manual Series No. 1, The Asphalt Institute, Lexington, Ky., February 1991.

Table (5. 5) : Percentage of total truck on design lane

Number of Traffic Lanes (Two Directions)	*Percentage of Trucks in Design Lane*
2	50
4	45 (35–48)*
6 or more	40 (25–48)*

*Probable range.
SOURCE: Adapted from *Thickness Design—Asphalt Pavements for Highways and Streets,* phalt Institute, Lexington, Ky., February 1991.

5.4.4 AASHTO Design Method

The AASHTO method for design of highway pavements is based primarily results of the AASHTO road test that was conducted in Ottawa, Illinois. It was a cooperative effort carried out under the auspices of 49 states, the District of Cc Puerto Rico, the Bureau of Public Roads, and several industry groups. Tests west ducted on short-span bridges and test sections of flexible and rigid pavement constructed on A-6 subgrade material. The pavement test sections consisted of loops and four larger ones, each being a four-lane divided highway.

Design Considerations

The factors considered in the AASHTO procedure for the design of flexible pavement as presented in the 1993 guide are

1. Pavement performance
2. Traffic
3. Roadbed soils (subgrade material)
4. Materials of construction
5. Environment
6. Drainage
7. Reliability

Pavement Performance: The primary factors considered under pavement performance are the

1. Structural :

Structural performance is related to the physical condition of the pavement with respect to factors that have a negative impact on the capability of the pavement to carry the traffic load. These factors include cracking, faulting, raveling, and so forth. Functional performance is an indication of how effectively the pavement serves the user.

2. Functional performance of the pavement:

The main factor considered under functional performance is riding comfort.

Traffic: The treatment of traffic load in the AASHTO design method is similar to that presented for the Asphalt Institute method, in that the traffic load application is terms of the number of 18,000-lb single-axle loads (ESALs). The procedure presented earlier is used to determine the design ESAL. The equivalence factors used in case however, are based on the terminal serviceability index to be used in the design and the structural number (SN) .

Roadbed Soils (subgrade material): The 1993 AASHTO guide also uses the resilient modulus (Mr) of the soil to define its property. However, the method allows conversion

of the CBR or R value of the soil to an equivalent (Mr) value using the following

conversion factors:

Mr. (lb/in.2) = 1500 CBR (for fine-grain soils with soaked CBR of 10 or less) Mr (lb/in.2) = 1000 + 555 x R value (for R < 20)

Table (5. 6) : Axle Load Equivalency Factors for Flexible Pavements, Single Axles

Axle Load (kips)	*Pavement Structural Number (SN)*					
	1	*2*	*3*	*4*	*5*	*6*
2	.0004	.0004	.0003	.0002	.0002	.0002
4	.003	.004	.004	.003	.002	.002
6	.011	.017	.017	.013	.010	.009
8	.032	.047	.051	.041	.034	.031
10	.078	.102	.118	.102	.088	.080
12	.168	.198	.229	.213	.189	.176
14	.328	.358	.399	.388	.360	.342
16	.591	.613	.646	.645	.623	.606
18	1.00	1.00	1.00	1.00	1.00	1.00
20	1.61	1.57	1.49	1.47	1.51	1.55
22	2.48	2.38	2.17	2.09	2.18	2.30
24	3.69	3.49	3.09	2.89	3.03	3.27
26	5.33	4.99	4.31	3.91	4.09	4.48
28	7.49	6.98	5.90	5.21	5.39	5.98
30	10.3	9.5	7.9	6.8	7.0	7.8
32	13.9	12.8	10.5	8.8	8.9	10.0
34	18.4	16.9	13.7	11.3	11.2	12.5
36	24.0	22.0	17.7	14.4	13.9	15.5
38	30.9	28.3	22.6	18.1	17.2	19.0
40	39.3	35.9	28.5	22.5	21.1	23.0
42	49.3	45.0	35.6	27.8	25.6	27.7
44	61.3	55.9	44.0	34.0	31.0	33.1
46	75.5	68.8	54.0	41.4	37.2	39.3
48	92.2	83.9	65.7	50.1	44.5	46.5
50	112.0	102.0	79.0	60.0	53.0	55.0

Where A varies from 772 to 1155 and B varies from 369 to 555. The Asphalt Institute uses the maximum values of A and B, whereas AASHTO suggests using 1000 and 555, respectively.

Materials of Construction: The materials used for construction can be classified under three general groups:

1. Subbase construction
2. Base construction
3. Surface construction

Subbase Construction Materials: The quality of the material used is determined in terms of the layer coefficient, a3, which is used to convert the actual thickness of the subbase to an equivalent SN. The sandy gravel subbase course material used in the AASHTO road test was assigned a value of 0.11. Layer coefficients are usually assigned based on the description of the material used. Note, however, that due to the widely different environmental, traffic, and construction conditions, it is essential that each design agency develop layer coefficients appropriate to the conditions that exist in its own environment.

Charts correlating the layer coefficients with different soil engineering properties have been developed. Figure 5.5 shows one such chart for granular subbase materials.

Base Course Construction Materials: Materials selected should satisfy the general requirements for base course materials. A structural layer coefficient, a2, for the material used should also be determined. This can be done using Figure 5.6.

Surface Course Construction Materials: The most commonly used material is a hot plant mix of asphalt cement and dense-graded aggregates with a maximum size of 1 in. The procedure discussed in Chapter 19 for the design of asphalt mix can be used. The structural layer coefficient (a1) for the surface course can be extracted from Figure 5.7.

which relates the structural layer coefficient of a dense-grade asphalt concrete surface course with its resilient modulus at 68°F.

Table (5. 7) : Axle Load Equivalency Factors for Flexible Pavements, Tandem Axles

Axle Load (kips)	Pavement Structural Number (SN) 1	2	3	4	5	6
2	.0001	.0001	.0001	.0000	.0000	.0000
4	.0005	.0005	.0004	.0003	.0003	.0002
6	.002	.002	.002	.001	.001	.001
8	.004	.006	.005	.004	.003	.003
10	.008	.013	.011	.009	.007	.006
12	.015	.024	.023	.018	.014	.013
14	.026	.041	.042	.033	.027	.024
16	.044	.065	.070	.057	.047	.043
18	.070	.097	.109	.092	.077	.070
20	.107	.141	.162	.141	.121	.110
22	.160	.198	.229	.207	.180	.166
24	.231	.273	.315	.292	.260	.242
26	.327	.370	.420	.401	.364	.342
28	.451	.493	.548	.534	.495	.470
30	.611	.648	.703	.695	.658	.633
32	.813	.843	.889	.887	.857	.834
34	1.06	1.08	1.11	1.11	1.09	1.08
36	1.38	1.38	1.38	1.38	1.38	1.38
38	1.75	1.73	1.69	1.68	1.70	1.73
40	2.21	2.16	2.06	2.03	2.08	2.14
42	2.76	2.67	2.49	2.43	2.51	2.61
44	3.41	3.27	2.99	2.88	3.00	3.16
46	4.18	3.98	3.58	3.40	3.55	3.79
48	5.08	4.80	4.25	3.98	4.17	4.49
50	6.12	5.76	5.03	4.64	4.86	5.28
52	7.33	6.87	5.93	5.38	5.63	6.17
54	8.72	8.14	6.95	6.22	6.47	7.15
56	10.3	9.6	8.1	7.2	7.4	8.2
58	12.1	11.3	9.4	8.2	8.4	9.4
60	14.2	13.1	10.9	9.4	9.6	10.7
62	16.5	15.3	12.6	10.7	10.8	12.1
64	19.1	17.6	14.5	12.2	12.2	13.7
66	22.1	20.3	16.6	13.8	13.7	15.4
68	25.3	23.3	18.9	15.6	15.4	17.2
70	29.0	26.6	21.5	17.6	17.2	19.2
72	33.0	30.3	24.4	19.8	19.2	21.3
74	37.5	34.4	27.6	22.2	21.3	23.6
76	42.5	38.9	31.1	24.8	23.7	26.1
78	48.0	43.9	35.0	27.8	26.2	28.8

Environment: Temperature and rainfall are the two main environmental factors used in evaluating pavement performance in the AASHTO method. The effects of temperature on asphalt pavements include stresses induced by thermal action, changes in the creep properties, and the effect of freezing and thawing of the subgrade soil, as discussed in Chapters 17 and 18. The effect of rainfall is due mainly to the penetration of the surface water into the underlying material. If penetration occurs, the properties of the underlying materials may be significantly altered. In Chapter 17, different ways of preventing water penetration were discussed. However, this effect is taken into consideration in the design procedure, and the methodology used is presented later under "Drainage."

The effect of temperature, particularly with regard to the weakening of the underlying material during the thaw period, is considered a major factor in determining the strength of the underlying materials used in the design.

Test results have shown that the normal modulus (that is, modulus during summer and fall seasons) of materials susceptible to frost action can reduce by 50 percent to 80 percent during the thaw-Also, resilient modulus of a subgrade material may vary during the year, even when no

specific thaw period. This occurs in areas subject to very heavy rains during periods of the year. It is likely that the strength of the material will be affected A periods of heavy rains.

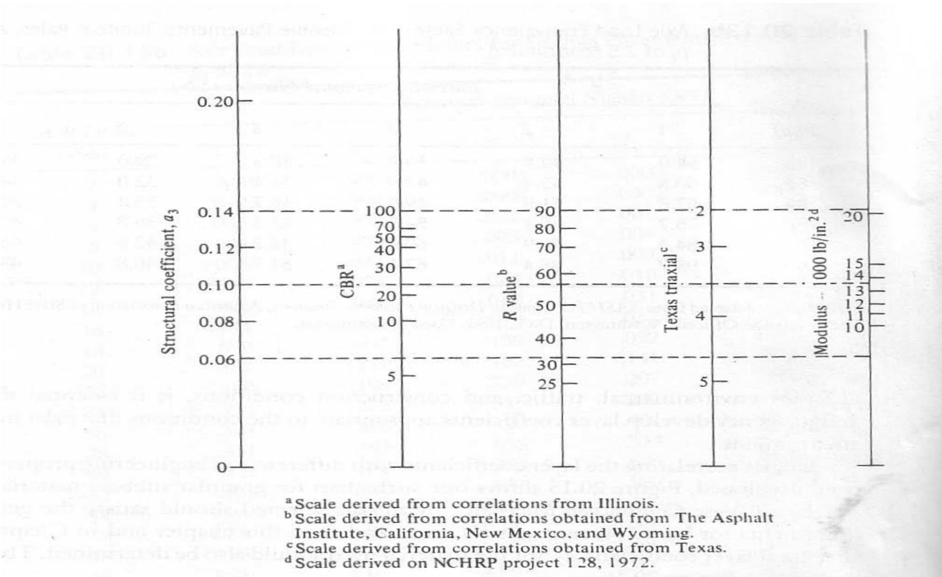


Figure (5. 5) : Variations in Granular Subbase Layer Coefficient, a3, with Various Subbase Strength Parameters

Susceptible to frost action can reduce by 50 percent to 80 percent during the them Also, resilient modulus of a subgrade material may vary during the year, even no specific thaw period. This occurs in areas subject to very heavy rains dur periods of the year. It is likely that the strength of the material will be affected & periods of heavy rains.

The procedure used to take into consideration the variation during d resilient modulus of the roadbed soil is to determine an effective annual resilient modulus. The change in the

PSI of the pavement during a full 12-will then be the same if the effective resilient modulus is used for the full the appropriate resilient modulus for each season is used. This means that resilient modulus is equivalent to the combined effect of the different during the year.

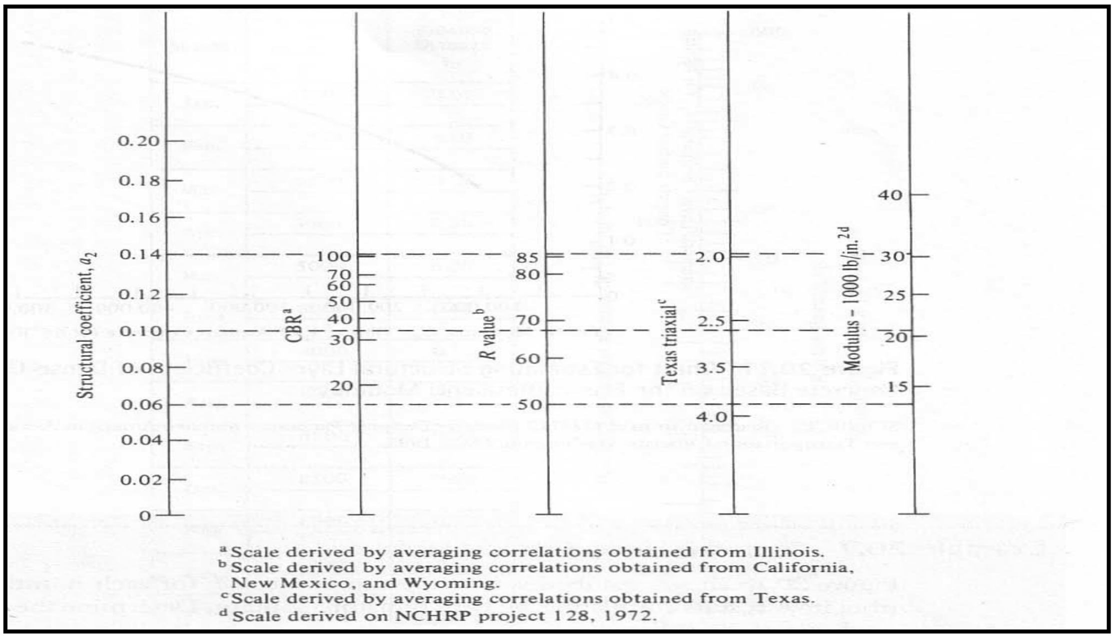


Figure (5. 6) : Variation in Granular Base Layer Coefficient a2, with Various Subbase Strength Parameters

The AASHTO guide suggests two methods for determining the effective resilient modulus. Only the first method is described here. In this method, a relationship between resilient modulus of the soil material and moisture content is developed using laboratory test results. This relationship is then used to determine the resilient modulus for each season based on the estimated in situ moisture content during the season being considered. The whole year is then divided into the different time intervals that correspond with the different seasonal resilient moduli. The AASHTO guide suggests that it is not necessary to use a time interval less than one-half month. The relative damage Uj for each time period is then determined from the

chart in Figure 20.18, using the vertical scale, or the equation given in the chart. The mean relative damage

Uj is then computed, and the effective subgrade resilient modulus is determined using the chart and the

value of ***Uj.***

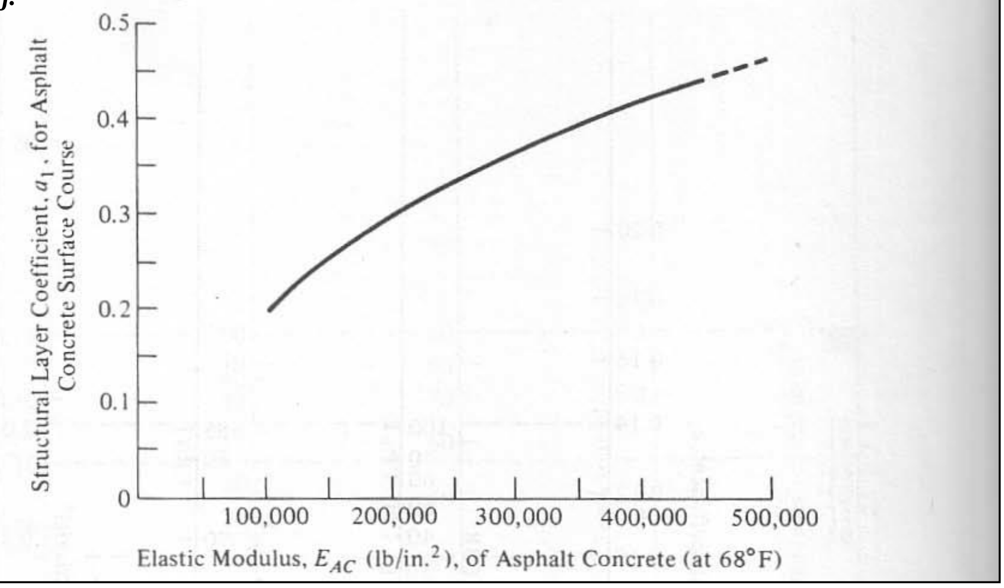
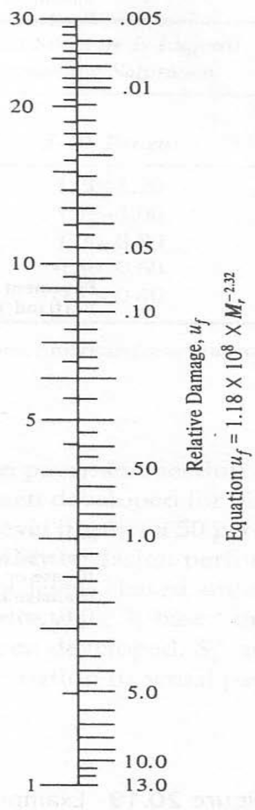


Figure (5. 7) : Chart for Estimating Structural Layer Coefficient of Dense-Graded/Asphalt Concrete Based on the Elastic (Resilient) Modulus

Drainage. The effect of drainage on the performance of flexible pavements is consider in the 1993 guide with respect to the effect water has on the strength of the base mat and roadbed soil. The approach used is to provide for the rapid drainage of the free * (no capillary) from the pavement structure by providing a suitable drainage layer, shown in Figure 5.8 , and by modifying the structural layer coefficient. The modification is carried out by incorporating a factor w, for the base and subbase layer coefficients (a2: a3). The mi factors are based both on the percentage of time during which the pavement structure will be nearly saturated and on the quality of drainage, which is dependent on time it takes to drain the base layer to 50 percent of saturation. Table 5.8 gives the gem definitions of the different levels of drainage quality, and Table 5.9 gives recommence mi values for different levels of drainage quality.

Month	Roadbed Soil Modulus M_r (lb/in.^{2})	Relative Damage u_f
Jan.	22000	0.01
Feb.	22000	0.01
Mar.	5500	0.25
Apr.	5000	0.30
May	5000	0.30
June	8000	0.11
July	8000	0.11
Aug.	8000	0.11
Sept.	8500	0.09
Oct.	8500	0.09
Nov.	6000	0.20
Dec.	22000	0.01
Summation: $\Sigma u_f =$		1.59



Average $\bar{u}_f = \frac{\Sigma u_f}{n} = \frac{1.59}{12} = 0.133$

Effective Roadbed Soil Resilient Modulus, M_r (lb/in.^{2}) = 7250 (corresponds to $\bar{u}_f$)

Figure (5. 8) : Chart for Estimating Effective Roadbed Soil Resilient Modulus for Flexible Pavements Designed Using the Serviceability Criteria

Reliability. It has been noted that the cumulative ESAL is an important input to any pavement design method. However, the determination of this input usually is based on assumed growth rates, which may not be accurate. Most design methods do not consider this uncertainty, but the 1993 AASHTO guide proposes the use of a reliability factor that considers the possible uncertainties in traffic prediction and performance prediction. A detailed discussion of the development of the approach used is beyond the scope of this book; however, a general description of the methodology is presented to allow the incorporation of reliability in the design process, if so desired by a designer. Reliability design

Table (5. 8) : Definition of drainage Quality

Quality of Drainage	*Water Removed Within**
Excellent	2 hours
Good	1 day
Fair	1 week
Poor	1 month
Very poor	(water will not drain)

*Time required to drain the base layer to 50 percent saturation.
SOURCE: Adapted with permission from *AASHTO Guide for Design of Pavement Structures,* American Association of State Highway and Transportation Officials, Washington, D.C., 1993.

Table (5. 9) recommended mi Values

Quality of Drainage	*Percent of Time Pavement Structure Is Exposed to Moisture Levels Approaching Saturation*			
	Less Than 1 Percent	*1–5 Percent*	*5–25 Percent*	*Greater Than 25 Percent*
Excellent	1.40–1.35	1.35–1.30	1.30–1.20	1.20
Good	1.35–1.25	1.25–1.15	1.15–1.00	1.00
Fair	1.25–1.15	1.15–1.05	1.00–0.80	0.80
Poor	1.15–1.05	1.05–0.80	0.80–0.60	0.60
Very Poor	1.05–0.95	0.95–0.75	0.75–0.40	0.40

SOURCE: Adapted from *AASHTO Guide for Design of Pavement Structures,* American Association of State Highway and Transportation Officials, Washington, D.C., 1993. Used by permission.

levels *(R%)*, which determine assurance levels that the pavement section designed using the procedure will survive for its design period, have been developed for different types of highways. For example, a 50 percent reliability design level implies a 50 percent chance for successful pavement performance—that is, the probability of design performance success is 50 percent. Table 5.11 shows suggested reliability levels, based on a survey of the AASHTO pavement design task force. Reliability factors, *FR* > 1, based on the reliability level selected and the overall variation, have also been developed. accounts for the chance variation in the traffic forecast and the chance variation in actual pavement performance for a given design period traffic, *Wl8.* The reliability factor *FR* is given as

Table (5. 10) : Suggested Levels of Reliability for Various Functional Classifications

	Recommended Level of Reliability	
Functional Classification	*Urban*	*Rural*
Interstate and other freeways	85–99.9	80–99.9
Other principal arterials	80–99	75–95
Collectors	80–95	75–95
Local	50–80	50–80

Table (5. 11) : Standard Normal Deviation *(Z_R)* Values Corresponding to Selected Levels of Reliability

Reliability (R%)	*Standard Normal Deviation, Z_R*
50	−0.000
60	−0.253
70	−0.524
75	−0.674
80	−0.841
85	−1.037
90	−1.282
91	−1.340
92	−1.405
93	−1.476
94	−1.555
95	−1.645
96	−1.751
97	−1.881
98	−2.054
99	−2.327
99.9	−3.090
99.99	−3.750

5.5 Structural Design

The objective of the design using the AASHTO method is to determine a flexible pavement SN adequate to carry the projected design ESAL. It is left to the designer to select the type of surface used, which can be either asphalt concrete, a single surface treatment, or a double surface treatment. This design procedure is used for ESALs greater than 50,000 for the performance period. The design for ESALs less than this is usually considered under low-volume roads.

The 1993 AASHTO guide gives the expression for SN as

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

where

m_i = drainage coefficient for layer i

a_1, a_2, a_3 = layer coefficients representative of surface, base, and subbase course, respectively

D_1, D_2, D_3, = actual thickness in inches of surface, base, and subbase courses, respectively

The basic design equation given in the 1993 guide is

$$\log_{10} W_{18} = Z_R S_o + 9.36 \log_{10}(SN + 1) - 0.20 + \frac{\log_{10}[\Delta PSI/(4.2 - 1.5)]}{0.40 + [1094/(SN + 1)^{5.19}]} + 2.32 \log_{10} M_r - 8.07 \qquad (20.13)$$

where

W_{18} = predicted number of 18,000-lb (80 kN) single-axle load applications

Z_R = standard normal deviation for a given reliability

S_o = overall standard deviation

SN = structural number indicative of the total pavement thickness

$\Delta PSI = p_i - p_t$

p_i = initial serviceability index

p_t = terminal serviceability index

M_r = resilient modulus in lb/in.^{2}

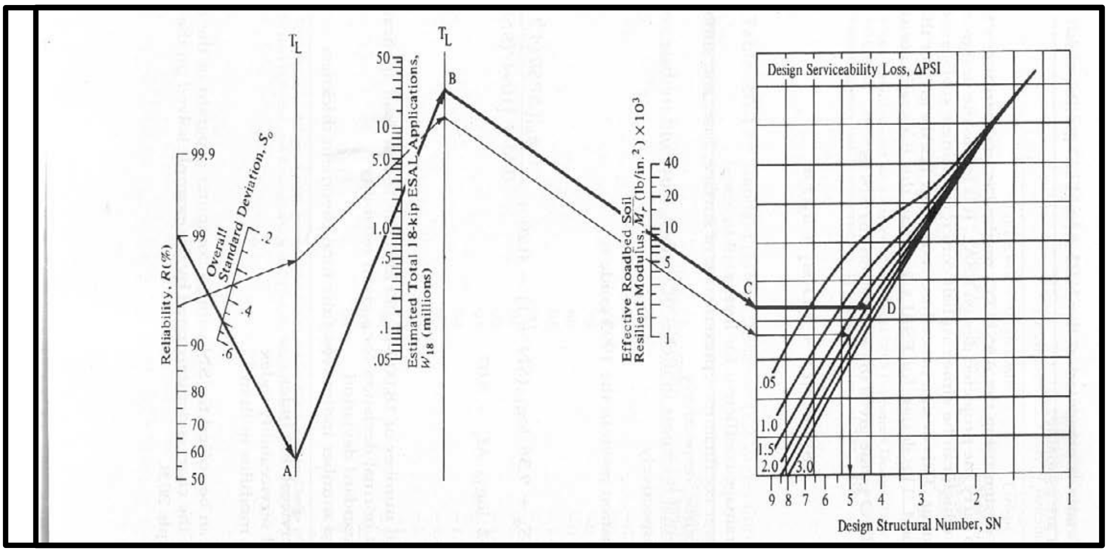


Figure (5. 9) : Design Chart for Flexible Pavements Based on Using Mean Values for Each Input

ESAL = 2 * 10^6

Mr for asphalt = 450000 lb/in^2

CBR of basecourse = 100 , Mr = 31000 lb/in^2

CBR of subbase = 22 , Mr = 13500 lb/in^2

CBR of subgrade = 6

---

* Mr of subgrade = 6 * 1500 = 9000 lb/in^2
* R = 99 % (from table 5.11)
* S_o = 0.49
* Pi = 4.5
* Pt = 2.5

$\Delta psi = P_i - P_t = 4.5 - 2.5 = 2$

Mr for asphalt = 450000 ⟹ $a_1 = 0.44$ from figure (5.7)

CBR of base course = 100 ⟹ $a_2 = 0.14$ from figure (5.6)

CBR of subbase = 22 ⟹ $a_3 = 0.1$ from figure (5.5)

$$SN = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$$

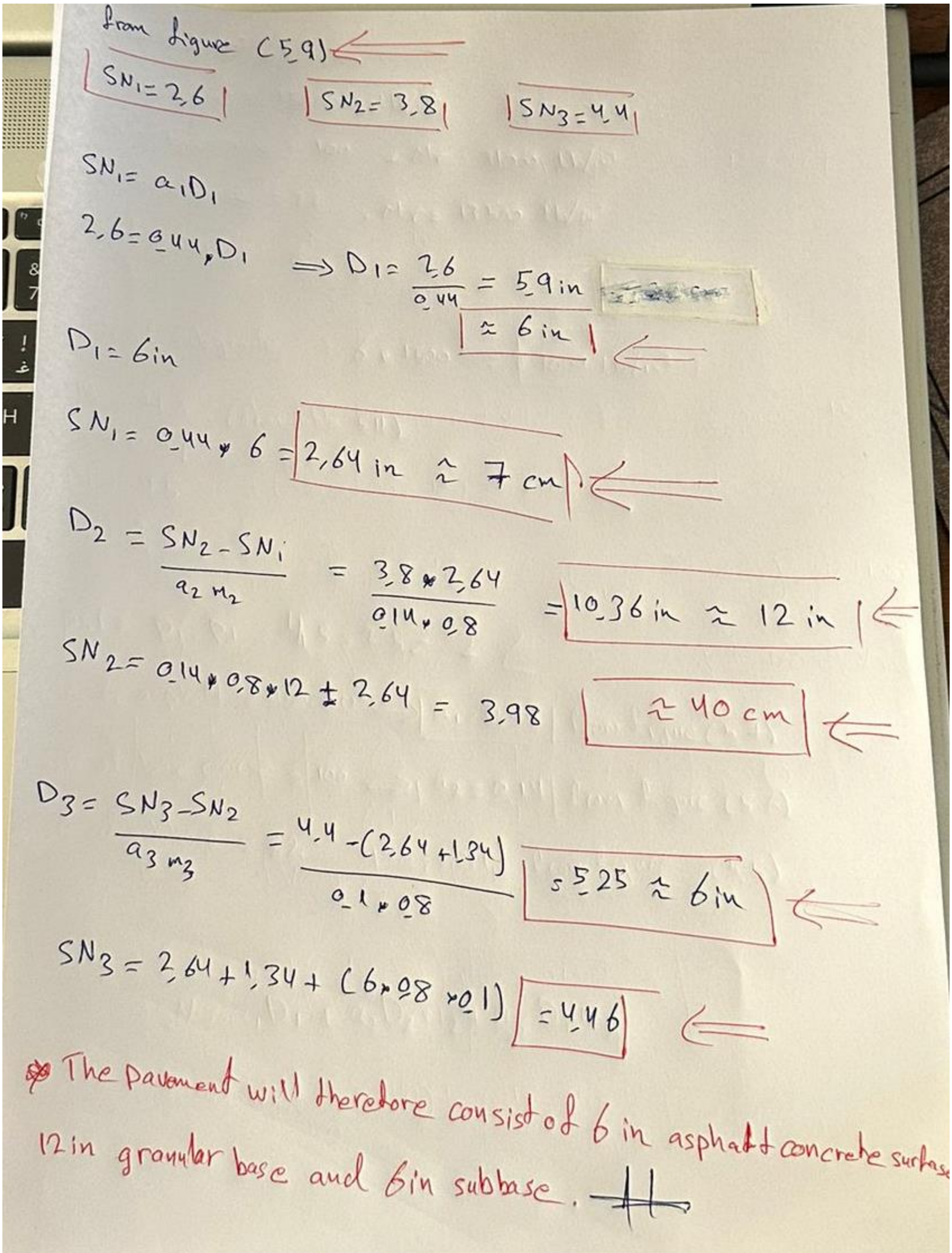


Figure (5. 10) : Calculate Pavement Structural

CHAPTER SIX

RESULTS & RECOMMENDATUIONS

This chapter contains:

6.1 Introduction

This chapter discusses and contains the set of findings reached in the design process for this road

A set of recommendations that will give a good impression when implementing this project and help in other ways.

6.2 Results

After carrying out the complete monitoring process and designing this road, a set of results were reached:

The most important of them are:

1. Raise the road completely and obtain detailed plans of the road.

2. All horizontal and vertical designs and all the necessary information were prepared for signing, and maps were prepared related to that.

3. Implementing this method is important because it saves time and effort for the user.

4. The importance of studying road design and linking it with other knowledge.

5. The result was an engineering design based on (AASHTO 2011) specifications with a design speed of 50 km/h .

6. The results of the layers after performing all the necessary calculations were as follows:

    - Asphalt layer: 7 cm
    - Base Course layer : 40 cm

7. The design was made on the D3 Civil program and the results were displayed on the attached drawings .

6.3 Recommendations

1. The asphalt layer is paved in a stage with a thickness of 7 cm according to specifications.

2. The base layer is spread and compacted in two layers, each layer 20 cm thick, according to specifications.

3. Vehicles are prohibited from driving on the asphalt layer before 24 hours have passed from the time it is spread so that this layer does not collapse.

4. Taking into account the amount of excavation and backfilling resulting from the project so as to reduce costs to the lowest possible.

5. We urge the university to constantly communicate with governmental and non-governmental institutions to improve the general level
For graduates and for suitable projects.

6. Inviting the university to conduct training courses for students to reach a higher level, especially from a technological standpoint
And modern programs.
7. Ensuring the existence of joint projects between the various departments in the College of Engineering to achieve integration
the appropriate

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