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Finally, we are deeply grateful to everyone who has contributed to our final-year project. Their support and encouragement were critical in achieving our goals, and we will always cherish their contribution.

# ABSTRACT

This project is concerned with the detailed design and cost estimation of a road section from Higuwapati road to Baluwapati Bazar. The road has been serving as a major means of connecting the socio-economic activities of the people in that region with the main city area of Nagarkot. Technically, the road falls under class IV with the design speed of 20km/hr. The road section has been designed as intermediate lane road with shoulder width 0.75m on both the sides and minimum radius of 15m and pavement thickness 575mm. For site research and design work, AutoCAD, Google Earth, and the professional version of SWROAD V2 were utilized. Because the route is located in an urban area, slopes were included in a vertical profile while taking grade relaxation into account. Following a general hydrological assessment, longitudinal and cross drainage was installed, and the fill portion's required retaining walls were installed. 17902.59 m3 of earthwork were done in the cut portion and 4698.217 m3 in the fill portion overall. According to cost estimation, the project will cost a total of Rs. 12,99,43,809.46 and Rs. 5,19,77,523.71per kilometers.

# SALIENT FEATURES OF THE PROJECT

|  |  |  |  |
| --- | --- | --- | --- |
| TRIBHUVAN UNIVERSITY | | | |
| INSTITUTE OF ENGINEERING, THAPATHALI CAMPUS | | | |
| DEPARTMENT OF CIVIL ENGINEERING | | | |
|  |  |  |  |
| 1 | Name: |  | |
| i) | Name of the project: | Detailed Engineering Survey, Design and Cost Estimation for the construction, improvement and renovation of the Nagarkot-Higuywapati road section connecting Nagarkot and Banepa | |
| ii) | Name of the road: | Nagarkot-Higuwapati road | |
|  |  |  | |
| 2 | Location: |  | |
| i) | District: | Kavrepalanchowk | |
| ii) | Province: | Bagmati | |
|  |  |  | |
| 3 | Geography: |  | |
| i) | Climate: | Moderate (9-25⁰C) | |
| ii) | Geology: | Loam, lightly cultivated or covered | |
| iii) | Hydrology: | Indrawati River | |
| iv) | Precipitation: | Uneven, mostly during monsoon | |
|  |  |  | |
| 4 | Classification: |  | |
| i) | Road Classification: | Technical Classification: Class IV road (according to NRS 2070) Administrative Classification: District Road | |
| ii) | Existing Surface: | Unpaved surface | |
| iii) | Proposed Surface: | Bituminous Surface | |
|  |  |  | |
| 5 | Road Length: |  | |
| i) | Start Point: | 0+000 | |
| ii) | Final Point: | 2+440.729 | |
| iii) | Road Length (km): | 2.441 | |
|  |  |  | |
| 6 | Geometric Design: |  |  |
| i) | Right of Way (m): | 10 | Both Side |
| ii) | Carriage Way Width (m): | 5.5 | Intermediate lane |
| iii) | Shoulder Width (m): | 0.75 | Both Side |
| iv) | Drain Width (m): | 0.464 | Maximum width |
| v) | Design Speed (Kmph): | 30 |  |
| vi) | Minimum Radius (m): | 15 | Design Requirement: 15m |
| vii) | Maximum Radius (m): | 206 |  |
| viii) | Maximum Gradient (%): | -10.588 | Design Requirement: 10 % |
| ix) | Minimum K for Summit: | 2.227 | Design Requirement: 4 |
| x) | Minimum K for Valley: | 0 | Design Requirement: 6 |
| xi) | Altitude at Start (m): | 1620.713 | at CH: 0+000 |
| xii) | Altitude at Mid (m): | 1526.6 | at CH: 1+220.364 |
| xiii) | Altitude at End (m): | 1479.284 | at CH: 2+440.729 |
| xiv) | Maximum Altitude (m): | 1620.713 | at CH: 0+000 |
| xv) | Minimum Altitude (m): | 1473.513 | at CH: 2+304.561 |
|  |  |  |  |
| 7 | Cross Drainage: |  | |
| i) | Box Culvert (Num): | 0 | |
| ii) | Pipe Culvert (Num): | 5 | |
| iii) | Slab Culvert (Num): | 0 | |
| iv) | Bridge (Num): | 0 | |
| v) | Causeway (Num): | 0 | |
|  |  |  |  |
| 8 | Wall Structures: |  | |
| i) | Gabion Wall (m3): | 2849 | |
| ii) | Masonry Wall (m3): | 671.039 | |
|  |  |  | |
| 9 | Earthwork: |  | |
| i) | Cut (m3): | 17965.482 | |
| ii) | Fill (m3): | 4635.766 | |
| iii) | Structure Cut (m3): | 2509.748 | |
| iv) | Drain Cut (m3): | 1983.7 | |
| v) | Back Fill (m3): | 391.337 | |
|  |  |  | |
| 10 | Project Cost: |  |  |
| i) | Total Cost (NRs.): |  | Exclusive VAT & Contingencies |
| ii) | Cost per km (NRs.): |  | Exclusive VAT & Contingencies |
| iii) | Total Cost (NRs.): |  | Inclusive VAT & Contingencies |
| iv) | Cost per km (NRs.): |  | Inclusive VAT & Contingencies |

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# Introduction

## General Background

Transportation serves as a foundation for the development of all other infrastructures and is a critical driver for the overall growth and prosperity of any nation. A well-planned and efficient transportation system acts as a lifeline for economic advancement and social transformation. In this context, the construction of new roads and the establishment of scientific transport networks are pivotal. The diversity in demographic trends, productivity, and socio-economic conditions across various regions underscores the importance of prioritizing new road alignments, upgrading existing roads, and organizing transport systems more effectively. To address these demands, detailed studies and surveys are conducted to identify and implement the most viable solutions.

Nepal, a predominantly mountainous country, faces unique challenges in transportation infrastructure. Alternative modes such as railways, waterways, ropeways, and airways are less practical due to high costs and geographical constraints. As a result, roads have become the backbone of connectivity in Nepal, especially for rural areas. With agriculture contributing nearly half of the gross national product (GNP) and employing the majority of the population, roads play a crucial role in facilitating access to markets, goods, and services. They significantly impact rural livelihoods and help bridge the gap between remote communities and urban centers. Consequently, road development is not just an infrastructure priority but a fundamental necessity for improving living standards, fostering economic growth, and achieving sustainable national development.

Nepal’s road network is categorized into two primary segments: the Strategic Road Network (SRN) and Rural Roads (RR). The SRN comprises approximately 5,500 kilometers of completed and planned national highways and feeder roads. These roads handle the majority of the country’s traffic, providing critical links between major economic hubs, urban centers, and international borders. Within the SRN, the Core Road Network (CRN) encompasses about 1,500 kilometers of highways with the highest traffic volumes, often exceeding 1,000 vehicles per day. This network facilitates long-distance commercial traffic and strengthens regional and cross-border trade. On the other hand, Rural Roads (RR) include roughly 4,600 kilometers of district roads, trails, tracks, and suspension bridges that serve as lifelines for remote and underdeveloped areas.

Recognizing these realities, the development of a “Detailed Engineering Survey, Design, and Cost Estimation for the Construction, Improvement, and Renovation of the Nagarkot-Higuwapati Road Section Connecting Nagarkot and Banepa” is an urgent and necessary step. This project aims to provide reliable connectivity, reduce travel times, and enhance access to essential services, ultimately improving the quality of life for local residents. Furthermore, the development of this road will stimulate economic activities, create new opportunities for trade, and contribute to the overall development of the region and the nation.

The history of road development in Nepal is relatively recent, beginning systematically with the introduction of planned development programs in 1956. At that time, Nepal had a mere 376 kilometers of roads. Today, thanks to sustained efforts, the total road length has surpassed 2,400 kilometers, encompassing both urban and district roads. This remarkable progress underscores the transformative role of road infrastructure in driving industrialization, regional development, and economic prosperity. As outlined in the National Transport Policy of 2058, the Government of Nepal has placed significant emphasis on developing both road and air transportation to ensure balanced social and economic growth across the nation.

Despite this progress, Nepal’s road density remains one of the lowest globally. As of the SSRN 2009/10 report, the average road density is only 13.77 kilometers per 100 square kilometers, translating to just 1.143 kilometers per 1,000 people. These figures highlight a pressing need to expand the road network, particularly in underserved and remote regions. The challenges ahead include increasing road density, upgrading and modernizing existing roads, completing under-construction projects, and ensuring that all 77 district headquarters have reliable road access. Maintenance and repair are equally critical to sustaining connectivity and ensuring road safety.

In addition to expanding the network, integrating modern technology into road design and construction is essential. Employing sustainable practices, such as using environmentally friendly materials and mitigating the impact of construction on local ecosystems, will help align Nepal’s road development with global sustainability goals. Moreover, strengthening disaster-resilient infrastructure is imperative, given the country’s vulnerability to landslides, floods, and earthquakes.

A well-connected road network not only facilitates the movement of goods and people but also fosters inclusive development. It enables access to education, healthcare, and employment opportunities, particularly for rural and marginalized communities. By prioritizing road infrastructure, Nepal can create a robust foundation for economic growth, improve regional equity, and enhance the overall quality of life for its citizens. Investing in roads is not just about transportation—it’s about empowering communities, unlocking potential, and driving the nation toward a prosperous future.

## Project Background

The track has already been opened using an excavator in our project area. However, the further design of the unpaved road has not been carried out. The construction of road section with optimized gradients, well-planned geometric designs, and appropriately designed pavement thickness has become essential for our project site. The infrastructure development holds the potential to elevate the living standards of the local population, encourage systematic urban growth, and contribute significantly to the nation’s economic advancement. For the design process, the Nepal Road Standard (NRS 2070) has been adopted as the guiding framework.

## Statement of Problem

The following problems caused the need and necessity of the project in the site area:

* Public discomfort and inconvenience due to poorly maintained roads.
* Improper curve radius and curve designs compromise road functionality.
* Insufficient road width in several locations’ limits traffic flow.
* Lack of proper surfacing reduces road durability and usability.
* Absence of adequate drainage structures exacerbates water damage.
* Insufficient retaining structures compromise the stability of the road.
* Limited accessibility during adverse weather isolates the local communities.
* Unstable slope and vegetation loss increases the risk of landslides.
* Insufficient load bearing capacity restricts heavy vehicle movement.
* Frequent maintenance requirements make the track unsustainable and costly.

## Objective

### General Objective

Detailed Engineering Design, Drawing, and Cost Estimation of based on NURS 2076.

Precisely,

1. Assess the current state of urban infrastructure.
2. Study traffic flow and congestion patterns.
3. Create plans to enhance urban transportation.
4. Identify key infrastructure projects for prioritization.
5. Deploy measures to boost road safety.
6. Incorporate environmental factors into planning efforts.
7. Engage with local community members and stakeholders.
8. Conduct evaluations to weigh project costs against benefits.
9. Ensure adherence to regulations in infrastructure endeavors.
10. Enhance skills and knowledge in urban planning and management.

### Specific Objective

* To conduct a thorough engineering survey to establish horizontal and vertical curves, grades, and alignments.
* To carry out detailed design of the road using available design software applications such as SW ROAD v2 by Softwel.
* To prepare detailed drawings, quantity and cost estimation of the project.
* To work out the final Detailed Project Report**.**

## Significance of Study

The proposed road alignment is situated within Mandandeupur Municipality. This roadway has implications for the 31261 residents of Mandandeupur Municipality's ward no.2, along with all individuals who travel through this area. Running primarily from the southern to the eastern boundary of this ward, and located roughly in its center, this road has the potential to serve a significant portion of the ward's population. Enhanced geometric design and transport infrastructure could make this route a preferred choice, attracting a substantial volume of journeys.

## Scope and Limitations of the work

This project includes the road stretch of approximately 2.5 kilometers. This study area was chosen for the improvement of the road network. The following are taken in the scope of work of the proposed road project:

* Detailed survey and geometric design of road
* Design of drainage structures for effective drain management
* Design of retaining structures for road stability
* Estimation of materials
* Cost analysis

The limitations of the project are:

* Unavailability of space for widening of road
* Sharp curves with limited sight distance

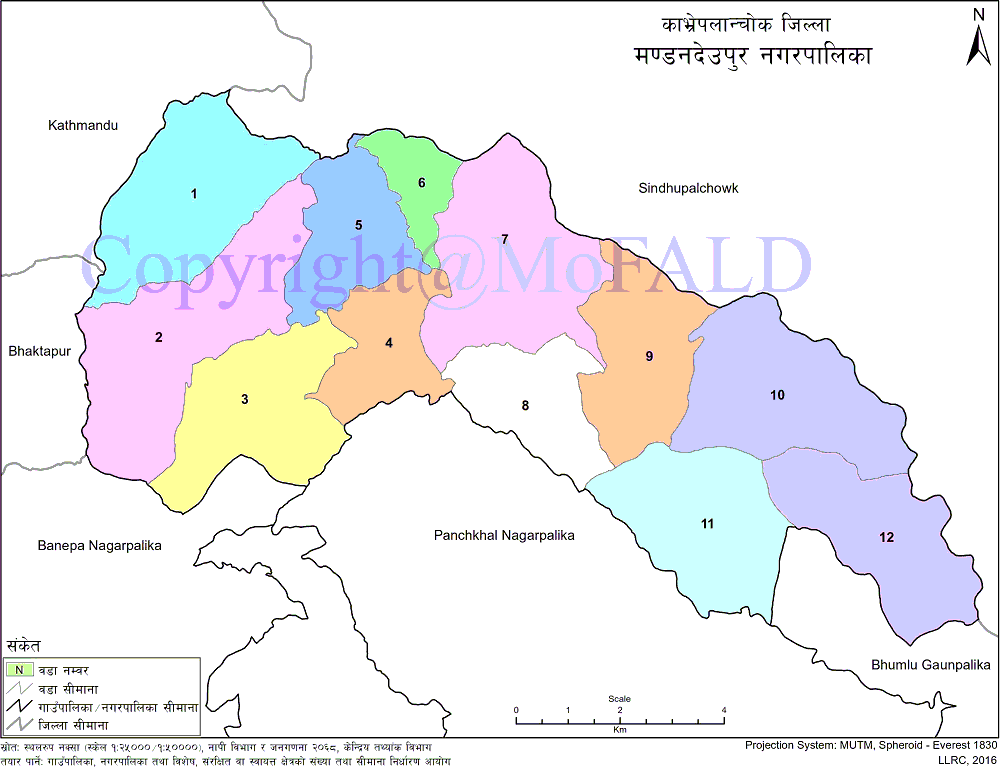
# Study Area

## Project Location

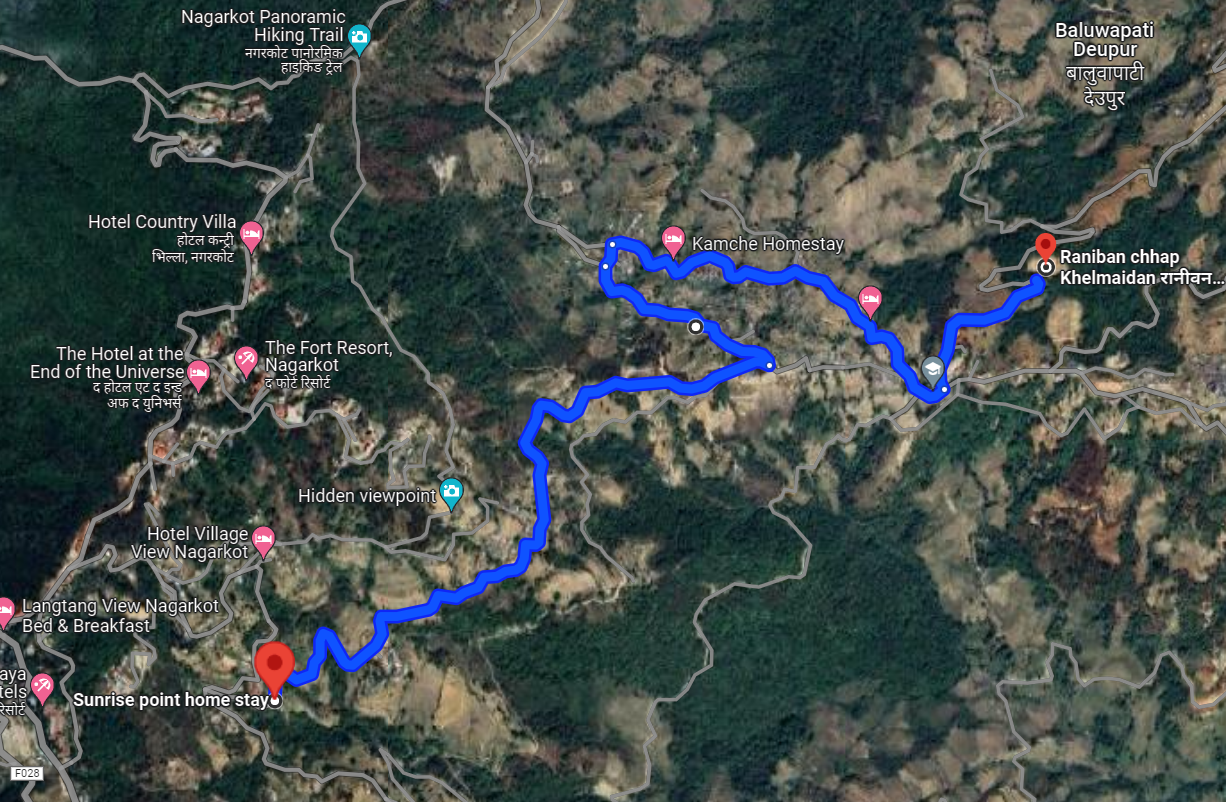
The proposed road alignment lies in Mandandeupur Municipality. Mandandeupur Municipality is located in Kavrepalanchok District under Bagmati Pradesh of Nepal. It is located 55 km northeast of Kathmandu, the capital of Nepal. The municipality covers an area of ​​89 sq. km. The total population is 32,659 of which 15,320 are males and 17,339 are females. The sex ratio is 88.36 and the population density is 367 per sq km of this municipality. The designed alignment of approximately 2.5 km length starts from the Sunrise Point Homestay and ends at Baluwapati Bazaar. The proposed alignment includes the Ward no. of the Mandandeupur Municipality.

The project area in Mandandeupur Municipality is mainly inhabited by Hindus, and Buddhists. Tamangs are in the majority here. The people here have been embracing agriculture, animal husbandry, and trade and tourism business as their main occupations. The proximity of Dhulikhel, Banepa, and Kathmandu Valley has had a direct positive impact on the economic, social, and cultural development of the municipality. Agricultural and livestock products produced here are mostly consumed and sold in the same market area. Geographically, the town has a moderately hilly terrain and is well-suited for human habitation and tourism.

Figure 2.1: Administrative Map of Mandandeupur Municipality

*Source:* [*www.mandandeupurmun.gov.np*](http://www.mandandeupurmun.gov.np)

* Proposed road alignment

Figure 2.2: Proposed Road Alignment

Source: Google Earth

* Starting coordinate: (27.7170939, 85.5242699)
* Ending point coordinates: (27.723100, 85.552619)

## Climate and Hydrology

Mandandeupur Municipality, located in the hilly region of Nepal, experiences a varied climate with distinct seasonal changes. Summers are generally warm, while winters are cooler, with temperatures typically ranging between 9°C and 25°C. The municipality receives the majority of its rainfall during the monsoon season, which spans from June to September. This heavy rainfall often leads to challenges such as landslides and soil erosion, particularly in its steep terrain.

Hydrologically, Mandandeupur relies on both surface and groundwater sources to meet the water demands of the local population. The region’s topography plays a significant role in water flow patterns, influencing agricultural productivity and water availability. However, the increasing impacts of climate change are putting additional pressure on these water resources, with rising concerns about sustainability and food security. Efforts are underway to equip local communities with adaptive practices to manage climate-related risks more effectively.

Understanding the interplay between climate and hydrology in Mandandeupur is essential for devising sustainable development strategies, particularly in addressing water management and mitigating risks associated with extreme weather events. It is also crucial for the proper design of the road section.

## Physical Infrastructure and Economy

The economy of this region is heavily dependent on agriculture. Seasonal farming, which yields a variety of crops, serves as a primary source of income for most of the households. The engineering geological study area covers such as areas with high cut and fill, drainage flow and study, minor landslide.

## Factors Controlling Road Alignment

Mainly, road alignment aims for the most direct and shortest connection between two points. However, this isn't always practical due to physical challenges and obstacles. The shortest route might have prohibitive inclines, and what appears to be an easy route could present significant construction and maintenance problems. Roads are frequently diverted from the straightest path to serve essential points and meet community needs.

The various factors which control the highway alignment in general may be listed as:

1. **Obligatory points**

These are the control points that determine how the road is aligned. These are of two types:

1. Points through which a road has to pass such as

* An industrial area or mine zone to which a highway is to serve additionally
* Quarry
* Hill Pass
* Link with Intermediate towns
* Bridge sites
* Tourist spots

1. Points through which a road should not pass

* Water-logged areas
* Property which is historically and archeologically important
* Restricted zone
* Costly structural elements requiring heavy compensation

1. **Traffic**

Road layouts should be designed with traffic needs as a primary factor. Analyzing the locations where trips originate and terminate is crucial, and desired lines should illustrate how traffic is expected to move. When establishing the highway's path, it's imperative to consider not only current conditions but also future traffic trends, current flow dynamics, and the desired travel corridor

1. **Geometric Design**

The ultimate highway alignment would also be determined by factors including gradient, curve radius, and sight distance. As much as possible, the gradient should be flat and smaller than the design or governing gradient. It is necessary to make adjustments taking into account the horizontal alignment, design speed, maximum permitted super elevation, and lateral friction.

1. **Economics**

The initial cost of the maintenance and vehicle operation should be taken into account. Due to high embankments and deep cutting total cost per kilometers of the road increases. Therefore, there should be balance in cutting and filling with the decrement of high embankment and deep cutting.

1. **Other Considerations**

For Hill Road special consideration needs to be given:

* Drainage of surface as well as sub-surface water flowing from hill side.
* Stability of hill side slope.
* Special Geometric standards of hill roads.
* Composition of traffic.

# LITERATURE REVIEW

## History Of Roads In Nepal

* Nepal's road history has seen a gradual transformation from ancient footpaths to modern highways, shaped by geographical, cultural, and political factors. Traditionally, Nepal's rugged terrain necessitated the creation of foot trails and mule tracks, vital for trade and travel between villages and cities.
* During the mid-19th century Rana regime, the construction of the first modern roads and bridges began, primarily to support trade and administrative control. However, infrastructure development remained constrained, primarily focusing on key routes connecting Kathmandu with major trade centers.
* In the early 20th century, motor vehicles were introduced, initially for military purposes and later for civilian transportation. This era witnessed a slow expansion of road networks due to resource constraints and technological limitations.
* The construction of the Tribhuvan Highway in the 1950s marked a significant milestone, linking Kathmandu with the southern plains and facilitating trade with India. Subsequent years saw gradual road network expansion, connecting remote areas with urban centers.
* Recent efforts have concentrated on enhancing road infrastructure to meet increasing connectivity demands driven by economic growth and urbanization. Major highways such as the Prithvi and Mahendra Highways have been constructed to improve inter-regional connectivity and facilitate transportation of goods and people.
* Furthermore, the government has focused on upgrading existing roads and building new ones to enhance accessibility, boost tourism, and stimulate economic development. Despite advancements, challenges like difficult terrain, natural disasters, and financial limitations persist, hampering the establishment of a robust and resilient road network in Nepal.

## Emerging Innovations in Road Construction

Road construction is an important field that continuously experiences emerging innovations aimed at improving safety, durability, sustainability, and efficiency. Here are some of the emerging innovations in road construction:

1. **Intelligent Compaction:**

Intelligent Compaction (IC) refers to the compaction of pavement materials, such as soils, aggregate bases, or asphalt, using modern vibratory rollers equipped with an integrated measurement system, an onboard computer reporting system, Global Positioning System (GPS) based mapping, and optional feedback control. Researchers have developed new "intelligent compaction" technology, which integrates into a road roller and can assess in real-time the quality of road base compaction. The research, recently published in a peer reviewed journal Engineering Structures, suggests the application of this technology could help build longer-lasting roads that can better withstand severe weather conditions (New Technology to Reduce Potholes, 2022).

1. **LiDAR Survey:**

LiDAR drone survey involves attaching a LiDAR sensor to a drone to map an area and collect point cloud data. From planning to construction and project management, LiDAR has many uses. It helps out in soil work computations, multiple alignment identification, and topographic survey for DPR generation. LiDAR survey has the required accuracy coupled with the ground survey. In areas like hilly terrain, many stretches have to be repeated manually. A high error is there in dense vegetation, U-turns to negotiate steep slopes; a ground survey coupled with LiDAR can avoid repetitions in these cases (Geospatial, 2021).

1. **Recycled aggregates:**

By adopting the usage of recycled materials, the wastage coming out from different industries, factories can be utilized and the total cost of the construction of road can be reduced. Among various materials, cement kiln dust (CKD) is a significant byproduct material of the cement manufacturing process. Over the past several years dramatic advances have been achieved in the management and use of cement kiln dust, thus reducing its dependency on landfill disposal.

Recycled Concrete Aggregates (RCA) can be used as base and subbase materials, in place of Crushed Stone Aggregates (CSA), for supporting a concrete pavement system. Similarly, Construction and Demolition materials (C&D) is the excess or waste material associated with the construction and demolition of buildings and structures, including concrete, brick, steel, timber, plastics, and other building materials and products. Also, it is found that the loadbearing capacity of the recycled (C&D) aggregate was satisfactory (Bakash, 2013).

1. **Scrap tire:**

Studies were conducted by adding different percentages of rubber tire aggregates to M35 mix. From this study it can be concluded that up to 8% of rubber aggregate can be added into concrete mixes without considerable reduction in strength. Based on this study rubber tire aggregates can be added to concrete for structural constructions mainly for rigid pavement constructions. Utilization of rubber tire aggregates, which is a waste product, in rigid pavements is economically viable and environmentally effective (Innovative Research Publications, 2014).

1. **Ground improvement using Fujibeton and Terrazyme as Soil Stabilizing Agent:**

Recently several environmental friendly enzymes have come into the market such Fujibeton, Terrazyme and Renolith etc.The Fujibeton material, developed in Japan, is climatically stable material and suitable for stabilization of all types of soils. Basically, the product is an inorganic polymer that chemically binds with all compounds, where blended with ordinary Portland cement in 1 to 3% by weight of OPC. Fujibeton improves CBR of the sub-grade and does not create shrinkage cracks and is therefore highly effective for clayey/soils. Likewise, Terrazyme is a natural, non-toxic; environmentally safe, bioenzyme product that improves engineering qualities of soil reduces ruts and potholes resulting in more durable and longer lasting roads. It minimizes absorbed water in the soil for maximum compaction, which decreases the swelling capacity of the soil particles and reduces permeability. The application of Terrazyme enhances weather resistance and increases loadbearing capacity of soils especially in clayey/soils. This provides cost effectiveness both in the initial construction cost and maintenance cost. Use of these products indicates minimization, elimination of the use of aggregates and is referred to as Aggregate-Free Pavement Technology (Vedula, M., & Nath, P., 2007). Coconut Shell and Coconut Fiber: Experimental study has been carried out to determine the effectiveness of crushed coconut shell and eggshell powder to act as subgrade stabilizer (Ramli et al., 2019).

1. **Jute Geo Textiles:**

The Jute Geo-textile strengthens the soil sub-grade by preventing intermixing of sub-grade and sub-base by acting as a separation layer and further it prevents migration of fines of a sub-grade by acting as a filtration material (Vedula, M., & Nath, P., 2007). These emerging innovations in road construction are aimed at creating safer, more sustainable, and efficient road networks for the future. As technology continues to advance, we can expect further advancements in this field to address the evolving needs of transportation infrastructure.

## Some Existing Literature Review

1. **Highway Engineering, Khanna and Justo (2018)**

Khanna and Justo (2018) stated the basic requirements of an ideal alignment between two terminal stations be short, easy, safe and economical. Obligatory points, traffic, geometric design, economics and other considerations are the factors controlling highway alignment.

1. **Traffic Engineering and Transport planning, Dr. L.R. Kadiyali**

Dr. L.R. Kadiyali stated that a knowledge of a vehicular volume using a road network is important for understanding the efficiency at which the system works at present and the general quality of service offered to the road users. Volume count indicates the need to improve the transport facilities and can be done manually and by using different mechanical and automatic devices. (Kadiyali)

1. **Soil Mechanics and Foundation Engineering, Dr. K.R. Arora**

K.R. Arora stated that the basic requirements of a good pavement are to provide a stable, non-yielding surface for the movement of heavy vehicles. Wheel load, subgrade, climate, pavement materials, location and other miscellaneous factors affect pavement design. CBR test can be conducted on a prepared specimen in a mold or on the soil in-situ condition. CBR values obtained from CBR test are used to determine the total thickness of the flexible pavement and the thickness of different layers. (Arora)

1. **Bagmati Province, MOPID, “Guidelines for Survey Works Including Preparation of Detailed Project Report (DPR) of Roads”**

It provided a comprehensive framework for conducting surveys and preparing DPRs for road projects. The guidelines cover various aspects of road infrastructure development, including survey methodologies, design considerations, environmental and social impact assessments, cost estimation and quality assurance. By following these guidelines, road construction projects in Bagmati province can be effectively planned, executed and monitored, leading to the development of safe, sustainable and well-designed road infrastructure.

## Documents/Guidelines

1. **Nepal Road Standard (NRS) 2070**

These standards are to be applied for all roads being constructed in Nepal. These standards apply mostly for non-urban roads (in open country outside built-up area.). These requirements can be relaxed in some very difficult situations by the Government of Nepal. The geometric features of roads except cross sectional elements do not lend to stage construction. Geometric deficiencies are costly and sometimes impossible to rectify later on due to subsequent road development. Therefore, it is essential that geometric requirements should be kept in view right in the beginning. (Nepal Road Standard, 2070)

1. **Nepal Rural Road Standards (NRRS) 2071**

These standards set the classification and geometric design standards for the Local Road Network (LRN) to be followed by all those involved in the development of the network. (Nepal Rural Road Standards, 2071)

1. **Nepal Urban Road Standard (NURS) 2076**

Nepal Urban Road Standard, 2076 is introduced with the objective of achieving consistency specifically in urban road design and construction. The focus of this standard is the urban area respecting the volume and composition of traffic focusing on pedestrian and non-motorized vehicle with the requirements for urban services e.g., water supply, sewage, drains, electricity, etc. Some references are drawn from the prevailing road standards to this standard. This standard is applicable to roads or streets in urban areas as well as for small town and suburban areas. This standard does not cover standards for urban express ways, strategic and rural road networks. (Nepal Urban Road Standard, 2076)

1. **DoR Pavement Design Guidelines (Flexible Pavement**)

This guideline explains the approach of designing the flexible pavement in Nepal. It helps in designing suitable pavement structure for any cases of sub-grade soil, traffic scenario and materials available on the site by providing sufficient information. In this guideline the pavements are considered to have bituminous surfacing and granular base. (Pavement Design Guidlines (Flexible Pavement), 2014)

1. **Indian Standard Methods of Test for Soil (IS: 2720 (Part 16)- 1987)**

This standard is established for the determination of the various characteristics of the soil and also for facilitating the comparative study of the results. The CBR value of a soil can thus be considered to be an index which in some fashion is related to its strength. The value is highly dependent on the condition of the material at the time of testing. Recently, attempts have been made to corelate CBR values to parameters like modulus of subgrade reaction, modulus of resilience and plasticity index with considerable success. (Indian Standard Methods of Test for Soil, 1988).

## Road Classification

Roads are classified as:

1. **Administrative Classification:**

For assigning national importance and level of government responsible for overall management and methods of financing administrative classification is need. According to this classification roads are classified into:

1. **National Highway:**

Acting as the core transport infrastructure, National Highways serve as vital links, extending from east to west and north to south across Nepal. These roadways accommodate a significant proportion of longer-distance journeys, ensuring consistently higher speeds and supporting connectivity between communities. These key arterial roads run the full length and width of the nation. Their official label consists of the letter 'H' and a two-digit number.

1. **Feeder Roads:**

Feeder roads are significant routes primarily serving local areas. They cater to the broad needs of the community by providing connections between District Headquarters, major economic hubs, and tourism destinations with either National Highways or other feeder roads. These roads are identified by the letter 'F' followed by a three-digit numerical code.

1. **District Roads:**

District Roads are important roads within a district serving areas of production and markets, and connecting with each other or with the main highways.

1. **Urban Roads:**

Urban Roads are the roads serving within the urban municipalities.

1. Technical Classification

* **Class-I:** Class I roads are the highest standard roads with divided carriageway and access control (Expressways) with ADT of 20,000 PCU or more in 20 yrs perspective period. Design speed adopted for design of this class of roads in plain terrain is120 km/h.
* **Class-II**: Class II roads are those with ADT of 5000-20000 PCU in 20 yrs perspective period. Design speed adopted for design of this class of roads in plain terrain is I00 km/h.
* **Class III:** Class III roads are those with ADT of 2000-5000 PCU in 20 yrs perspective period. Design speed adopted for design of this class of roads in plain terrain is 80 km/h.
* **Class IV:** Class IV roads are those with ADT of less than 2000 PCU in 20 yrs perspective period. Design speed adopted for design of this class of roads in plain terrain is 60 km/h.

Table 3.1: Correlation between administrative and functional classification

|  |  |  |
| --- | --- | --- |
|  | Plain and rolling terrain | Mountainous and steep terrain |
| National Highway | I, II | II, III |
| Feeder Roads | II, III | III, IV |

## Terrain classification

Table 3.2: Terrain classification

|  |  |  |  |
| --- | --- | --- | --- |
| S.No | Terrain Type | Percentage Cross Slope | Degree |
| 1 | Plain | 0-10 | 0°-5.7° |
| 2 | Rolling | >10-25 | >5.7°-14° |
| 3 | Mountainous | >25-60 | >14°-31° |
| 4 | Steep | >60 | >31° |

## Design Speed

Recommended Design Speeds for Different Classes of Urban Roads: (Roads, Nepal Urban Road Standards, 2076)

Table 3.3: Different Classes Urban Road Design Speed

|  |  |
| --- | --- |
| Type of Road | Design speed (km/hr) |
| Arterial Roads | 40-50 |
| Sub Arterial Roads | 30-40 |
| Collector Roads | 20-30 |
| Local Streets | 10-20 |

## Development of Road in Nepal

The Malla era's approach to transportation infrastructure included wide trails built for horse-driven vehicles, with a solid base of lime concrete covered by crushed brick and finished with flat stone slabs. The Tribhuvan Rajpath, marking the first highway between Kathmandu and Birgunj, was constructed in 1956. The Kodari highway linking Kathmandu with Kodari was completed in 1963. Modern road construction increased substantially by the mid-1970’s with the completion of the eastern sector of East West Highway. The state of existing connectivity through road network by the development regions in the country is provided in Table 2.

Table 3.4: Road Connectivity in Nepal by the Development Regions

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Province | Number of  Roads | Constructed  Length  (Km) | Road Length (Km) | | | | Population  Influenced  (Km/1000 persons) |
| Black topped | Gravel  Road | Earthen  Road | Road  density  (Km/sq.  Km) |
| Eastern | 1009 | 9435.737 | 172.507 | 3015.185 | 6248.046 | 33.16 | 1.62 |
| Central | 3072 | 18751.270 | 679.463 | 4976.740 | 13095.067 | 68.41 | 1.93 |
| Western | 1705 | 14282.066 | 646.394 | 2377.426 | 11258.246 | 48.58 | 2.89 |
| Midwestern | 643 | 5593.780 | 77.070 | 2378.030 | 3138.680 | 13.20 | 1.56 |
| Farwestern | 254 | 2880.794 | 0.000 | 1854.540 | 1026.254 | 14.74 | 1.13 |
| Total | 6683 | 5943.647 | 1575.434 | 14601.921 | 34766.293 | 34.61 | 1.91 |

The road network of Nepal, both in terms of total length and density, is substantially below that of other South Asian nations. Accordingly, the development of roads has been prioritized in the country for the last twenty years.

## Design consideration of road

Road design is a complex process influenced by a variety of factors. These include intended design speed, the road's functional classification, the expected amount and type of traffic, existing geographical features and terrain, community and environmental impacts, cost constraints, and the required right-of-way. Successful road design adheres to specific criteria and guidelines, including:

1. **Design Hourly Volume and Capacity:**

Traffic flow on a road fluctuates throughout the day, ranging from low volumes during off-peak periods to high volumes during peak hours. It would be impractical and expensive to design road infrastructure to accommodate the absolute highest peak traffic. Instead, a practical traffic volume, known as the design hourly volume, is chosen for design purposes.

1. **Design Speed:**

Higher design speeds require more stringent design standards to ensure road safety, capacity, and comfort, and they can also reduce vehicle operating costs. However, the selected design speed is determined by factors like the road's classification, traffic volume, budgetary limitations, and the terrain.

1. **Terrain:**

The characteristics of the land the road passes through directly impact the selection of geometric design elements. These include the width of the roadbed, the width of the traveled surface, the right-of-way width, the vertical clearance, the radius of horizontal curves, and the slope of the road.

1. **Environment:**

Road design must also consider environmental aspects. These include aesthetics, landscaping, air and noise pollution, and other local environmental conditions, all of which should influence decisions on road geometry.

## Environmental and Social consideration in Urban Roads

1. **Environmental Considerations:**

The primary goal of environmental considerations in road development is to create the most suitable road possible within existing environmental conditions. This involves utilizing environmentally sound approaches, methods, standards, and techniques to maintain and protect environmental quality. Key environmental factors that must be addressed include the protection of forests and protected areas, mitigation of landslides and erosion in vulnerable regions, management of flood and drainage issues, safeguarding of historical, cultural, religious, or archaeological sites, minimizing impact on population centers, and preservation of valuable environmental features such as wetlands, lakes, and drinking water sources. These factors must be carefully considered during both the planning and development of the road network.

1. **Social Considerations:**

Social considerations in road development are focused on maximizing the broader social benefits of the project while minimizing or avoiding any negative social impacts. Particular attention should be paid to ensuring that the development does not harm poor, landless, and otherwise vulnerable populations. Fair compensation must be provided for any loss of livelihood resources and employment opportunities.

## Road Alignment

Road alignment refers to the planned position or layout of the road's centerline on the ground. This alignment is defined by two components: horizontal and vertical. The horizontal alignment includes straight sections and curves that change the road's direction. The vertical alignment encompasses changes in the road's slope (gradient) and the vertical curves that connect these different gradients. During construction, accurately transferring the centerline from design plans to the ground requires determining the three-dimensional coordinates (X, Y, and Z) of all points along the centerline. Thus, road alignment is physically established on the ground using these horizontal and vertical components. Careful consideration of road alignment is critical because improper alignment can lead to several disadvantages, including:

* Increased construction costs
* Higher vehicle operating expenses
* Greater maintenance requirements
* Elevated accident rates

Modifying a road's alignment after it has been constructed is extremely expensive due to the costs of reconstructing existing structures and acquiring adjacent land. Therefore, the final alignment must be determined through careful planning and evaluation.

## Process of Identifying Best Route Location

An ideal road alignment between two points should primarily meet the following requirements:

1. **Short Distance:**

The road should ideally follow the shortest possible route between the starting and ending points. However, deviations from the most direct path are often necessary due to factors such as terrain (including gradients and mountain passes), the presence of structures or ditches, and the need to connect intermediate population centers.

1. **Easy Construction and Operation:**

The alignment should be straightforward to construct and maintain with minimal complications. Additionally, the road should be designed for easy and efficient vehicle operation, with manageable gradients and curves.

1. **Safe Construction and Operation:**

The alignment should ensure safety during construction and maintenance by considering the stability of natural hill slopes, embankments, cut slopes, and the foundations of embankments. It should also provide safe traffic operation, with appropriate geometric design features to minimize risks.

1. **Economical:**

The most economical road alignment is one that minimizes the total cost, including initial construction, ongoing maintenance, and vehicle operating costs, while also maintaining social, environmental, and safety (SESE) standards. All of these factors must be taken into consideration when evaluating the economic viability of any given alignment. In addition to cost considerations, the alignment that best serves the population and provides maximum overall utility should be selected.

## Geometric Design of Road

### Sight Distance

The distance a driver can clearly see ahead, particularly at horizontal and vertical curves and intersections, is crucial for safe vehicle movement. This visible distance, known as sight distance, is a primary factor in road design. Three specific sight distance scenarios are considered:

1. **Stopping Sight Distance:** The distance required for a vehicle traveling at the design speed to stop safely when encountering an obstruction.
2. **Overtaking or Passing Sight Distance:** The distance needed for a vehicle traveling at the design speed to safely pass a slower vehicle without posing a risk to oncoming traffic.
3. **Intersection Sight Distance:** The distance required for a driver entering an uncontrolled intersection to see and react safely, avoiding collisions with other vehicles.

The standards for sight distance must ensure the following:

1. A driver traveling at the design speed has enough visible distance ahead to safely stop their vehicle before hitting any obstacle in the road.
2. A driver traveling at the design speed has enough visible distance to safely overtake a slower vehicle without causing any obstruction or danger to vehicles traveling in the opposite direction.
3. A driver entering an uncontrolled intersection has sufficient visibility to assess the situation and safely avoid colliding with another vehicle.
4. **Stopping Sight Distance (SSD)**

The stopping sight distance (SSD) is the minimum length of road that should be visible to a driver at any point to allow them to stop their vehicle safely and without colliding with any obstruction when traveling at the road's design speed. The available sight distance on a road depends on:

* The characteristics of the road ahead
* The height of the driver's eyes above the road surface
* The height of any objects on the road surface.

The total stopping distance is the sum of two components: the lag distance and the braking distance. Therefore:

Stopping Distance = Lag Distance + Braking Distance

The formula used to calculate stopping sight distance is:

Stopping Sight Distance (SSD) = Lag Distance + Braking Distance = V x t

Where:

* is the design speed (m/sec)
* t is the perception-reaction time of the driver in seconds, usually taken as 2.5 seconds
* f is the coefficient of friction between tyre and road surface.

Table 3.5: Coefficient of longitudinal friction

|  |  |
| --- | --- |
| Speed(km/h) | ∅ |
| 20 | 0.40 |
| 30 | 0.39 |
| 40 | 0.39 |
| 60 | 0.38 |
| 80 | 0.36 |
| 100 | 0.35 |
| 120 | 0.34 |

1. **Overtaking Sight Distance (OSD)**

Overtaking Sight Distance (OSD), also known as safe passing sight distance, is the minimum distance a driver needs to see ahead to safely overtake a slower vehicle without risking a collision with oncoming traffic.

Several key factors influence the minimum OSD required for a safe overtaking maneuver:

* Speeds:
  + The speed of the vehicle performing the overtake.
  + The speed of the vehicle being overtaken.
  + The speed of any vehicle approaching from the opposite direction.
* **Spacing:** The distance between the overtaking and overtaking vehicles; this minimum spacing depends on speed.
* Driver Factors:
  + The skill and reaction time of the driver performing the overtake.
* **Vehicle Factors:** The rate of acceleration of the overtaking vehicle.
* **Roadway Factors:** The gradient (slope) of the road.

Time components for various maneuvers and corresponding overtaking distances are given below in table:

Table 3.6: Overtaking Distance Calculation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Speed, km/h | Time Components | |  | Overtaking Distance, m |
| For overtaking maneuvers | For opposing vehicles | Total |
| 40 | 9 | 6 | 15 | 165 |
| 60 | 10.8 | 7.2 | 18 | 300 |
| 80 | 12.5 | 8.5 | 21 | 470 |
| 100 | 14 | 9 | 23 | 640 |
| 120 | 16 | 10 | 26 |  |

### Vertical Alignment Details

When designing a highway, the alignment must generally follow the existing terrain. While some areas may be level, the land often has varying slopes. Consequently, a road's vertical profile will include both level sections and sloping sections (grades). To ensure smooth vehicle movement, these changes in grade must be eased with vertical curves.

Key considerations for vertical alignment are:

1. **Design of Vertical Curves:**

Vertical curves are necessary where different grades meet to create a smoother vertical profile. This gradual change in slope prevents abrupt transitions that could be dangerous for fast-moving vehicles, leading to potential loss of control, damage, and injuries. Vertical curves are therefore crucial for safety, comfort, and visual appeal.

1. **Types of Vertical Curves:**

There are two main types of vertical curves:

* **Summit curves:** These are curves that crest upward and are convex in shape.
* **Valley curves:** These are curves that dip downward and are concave in shape.

The length (L) and K-value of a vertical summit curve should be determined based on:

* **Visibility Requirements:** The curve must provide enough visibility for at least the stopping distance. This assumes a driver's eye height of 1.2 meters above the road and a minimum object height of 0.15 meters.
* **Overtaking Requirements:** The curve must provide enough visibility for at least the overtaking distance, or twice the stopping distance (whichever is greater). This also assumes a driver's eye height of 1.2 meters.

The minimum length of a summit curve based on stopping distance can be calculated using the following formulas:

* When the stopping sight distance (S) is less than the curve length (L):
* When the stopping sight distance (S) is greater than the curve length (L):

Where:

* L = Length of the summit curve (m)
* A = Algebraic difference in approach grades (%)
* S = Stopping distance (m)
* h1= Height of the driver's eye above the pavement surface (m), taken as 1.0 m
* h2 = Height of the object above the pavement surface (m), taken as 0.1 m.

The minimum length of a summit curve based on overtaking distance (or twice the stopping distance, whichever is greater) can be calculated using the following formulas:

* When the overtaking distance (S) is less than the curve length (L):

L= (A \* S^2) / 800

* When the overtaking distance (S) is greater than the curve length (L):

L= 2S - (800/A)

### Horizontal Curve

1. Radius of horizontal curve is selected based on the following criteria:
   * The centrifugal force developed on the vehicle negotiating a horizontal curve should not be more than the balancing force of friction and superelevation.
   * The vehicle should be stable against overturning.
   * The road should be visible to a sufficient distance that is illuminated in a horizontal plane by the headlight of the vehicle during night driving time.
   * The visibility of the road ahead should not be obstructed by objects on the inner side of the horizontal curve.
   * The wear and tear of vehicle tires should be minimum.
   * Passengers and drivers of the vehicle should not feel excessive lateral force from the view point of comfort of travel.
2. Among all above criteria the first one usually governs in the road design.
3. Radius of horizontal curves is decided in such a way that the centrifugal force acting on the vehicle is balanced by superelevation and side friction.
4. Basic equation for finding the radius of horizontal curve from the condition of equilibrium of centrifugal force, superelevation and friction is given below:

R = radius of horizontal curve, metres

V = design speed in km/h

e = Superelevation provided

f = coefficient of lateral friction, depends on the speed

Table 3.7: Coefficient of lateral friction

|  |  |
| --- | --- |
| Table No. 4 Speed (km/h) | f |
| 120 | 0.09 |
| 100 | 0.12 |
| 80 | 0.14 |
| 60 | 0.17 |
| 40 | 0.23 |
| 30 | 0.28 |
| 20 | 0.33 |

1. Radius of curve calculated from the above consideration usually gives a very sharp curve. As a consequence, passengers travelling on such curves experience discomfort with high lateral force acting on their body.
2. So, where site conditions permit it is recommended that radius of horizontal curve be decided based on the lateral force acting on the passenger caused by the centrifugal force thereby limiting the ratio of lateral to vertical forces to

0.15.

1. From the consideration of passenger’s comfort

R= Radius of Horizontal Curve, m

V = Design speed in km/h

Elements of horizontal curves are as follows:

* Tangent Length (T): The length between the beginning of the curve or end of the curve and the point of intersection is called the tangent length. It depends on the deflection angle and radius of the curve given by the relation T=R tan (Δ/2).
* Length of Curve (L): The length of curve from the point of commencement to the point of tangency is called length of the curve. If the curve is designated by its degree of curvature, the length of the curve will depend upon the criteria used for the definition of the degree of curve given by relation L= πRΔ/180.
* Length of Chord (l): It is the chord joining the point of curve with the point of tangent or point of curve itself.
* Deflection Angle (Δ): The angle between which a survey line makes with the prolongation of the proceeding line is called deflection angle. It is measured to the clockwise or anticlockwise from the prolongation of the previous line. Its value ranges from 0°-180°.
* Radius of Curve(R): For the certain speed of vehicle, the centrifugal force is dependent on the radius of the horizontal curve. To keep the centrifugal ratio within low limit the radius of the curve should be kept correspondingly high.

According to the NRRS2055, the minimum radius to be adopted is 15m.

A diagram of a triangle with arrows with Great Pyramid of Giza in the background

Description automatically generated

Figure 3.1: Horizontal curve

* Apex Distance (E): It is the distance between the points of intersection to the middle of curve length. It also depends in the deflection angle and radius of the curve.
* Bearing of Line: The bearing of line is the angle made by that line with respect to the magnetic north direction. It is also known as whole circle bearing (WCB).

Radius of Horizontal Curve

For the certain speed of vehicle, the centrifugal force is dependent on the radius of the horizontal curves. To keep the centrifugal ratio within a low limit the radius of the curve should be kept correspondingly high. The centrifugal force which is counteracted by the super elevation and lateral friction is given by the relation,

e + f =0.07 + 0.15 = 0.22

(Where e = 0.07 maximum allowable superelevation rate)

(f = 0.15, design coefficient of lateral friction)

If the design speed is decided for a highway, the minimum radius to be adopted can be found from the above relationship. Thus, the ruling minimum radius of the curve for ruling design speed v m/sec or V, Kmph is given by:

R

Also,

R

Where, v and V = ruling design speeds in m/sec and kmph respectively

e = rate of super-elevation

1. = design value of transverse skid resistance or coefficient of friction taken as 0.15
2. = acceleration due to gravity = 9.8 m/s2

 Widening of Pavement on Horizontal Curve

Especially on horizontally curves, when they are not of very large radii, it is common to widen the pavement slightly more than the normal width. The widening is introduced gradually, sta1ting from the beginning of the transition curve or the tangent point progressively increased at the uniform rate, till the full value of designed widening is reached. Total widening 'We' is reached at the end of transition curve where full value of super elevation is provided.

Mechanical widening (Wm) =

Psychological widening (Wps) =

Total widening (We) = Mechanical widening (Wm) + Psychological widening

(Wps)

= Wm + Wps

Where, n = number of traffic lanes.

l = Length of wheelbase of longest vehicle, m. The value of l is normally taken as 6.1m or 6.0 m for commercial vehicle.

V = design speed, Kmph.

R = radius of horizontal curve.

Transition Curve

A non- circular curve introduced between a straight and a circular curve, is known as transition curve. The curvature of such curves varies from zero as its beginning to a definite value at its junction with the circular curve.

The function of transition curves in the horizontal alignment of the highway may be summed up into the following points:

* To introduce gradually the centrifugal force between the tangent point and the beginning of the circular curve, avoiding a sudden jerk on the vehicle.
* To enable the driver tum the steering gradually for his own comfort and security.
* To enable gradual introduction of the designed super-elevation and extra widening of pavement at the start of the circular curve.
* To improve the aesthetic appearance of the road.

Calculation of the length of transition curve

The length of transition curve is designed to fulfill following three conditions:

* Rate of the change of centrifugal acceleration to be developed gradually.
* Rate of the introduction of the designed super-elevation to be at reasonable rate.
* Minimum length by IRC empirical formula.

Rate of the change of centrifugal acceleration (C)

C = (m/sec3)

The length of transition curve Ls = where, v is in m/s

Ls = where, v is in kmph

Where,

Ls = Length of transition curve, m

R = radius of the circular curve, m

C = allowable rate of change of centrifugal acceleration m/sec3

C = m/sec3 [0.5 < C < 0.08]

Rate of introduction of superelevation

Ls = = (W + We); If the outer edge is rotated about the centre line.

Ls = EN = eN(W+We); If pavement is rotated about the inner edge. Where, Ls = Length of transition curve, m e = rate of superelevation in %

E = e (W+We)

* We = extra widening provided at the circular curve

N = 150 in plain rolling terrain and 60 in hilly terrain

By empirical formula

1. For plain and rolling terrain

.

Ls = where, V= Velocity in Kmph

1. For hilly and steep terrains

Ls = where, V= Velocity in Kmph

Grade Compensation on Horizontal Curves

When a sharp horizontal curve is to be introduced in a certain section of the road, which has already maximum permissible gradient, then the longitudinal gradient should be corrected and reduced to compensate the loss of tractive effort due to various reasons. Some of them are:

* 1. Increased rolling resistance
  2. Increased grade resistance
  3. Increased air resistance

Due to the turning angle of vehicles, the curves resistance is developed at the horizontal curves. When there are horizontal curves in addition to the gradient, there will be increased resistance to traction due to both gradient and curves; it is necessary that in such cases, the total resistance due to grade and curve should not exceed the resistance due to the maximum value of gradient specified. For design purpose, this maximum value may be taken as the ruling gradient and in some special cases as limiting gradient for the terrain. When the sharp horizontal curve is to be introduced on a road, which has already the maximum permissible gradient, the gradient should be decreased to compensate for the loss of tractive effort due to the curves.

This reduction in gradient at the horizontal curve is called grade compensation. This is calculated from the relation:

Grade compensation, % = , subject to a maximum value of

Where,

R = Radius of circular curve, m

The grade compensation is not required for the curves flatter than 4% gradients

### Intersection Elements

Design of road intersection with facilities for safe and efficient traffic movement needs adequate knowledge of traffic engineering.

### Highway Cross Section elements

Cross-sections are run along transverse direction to the longitudinal profile and on other side for the purpose of lateral outline of the ground surface. They provide the data for estimating quantities of earthwork and for other purposes. The scale selected for plotting is equal on both the axes. Cross-sections are plotted for each element of curves. The cross-section consists of the following:

1. **Carriageway**

The standard width of carriageway shall be as shown on the following table. Total width of pavement shall be determined based on the volume of the traffic and capacity of each lane.

Table 3.8: Width of Carriageways, meter

|  |  |  |
| --- | --- | --- |
| Single lane road | Intermediate lane | Multilane pavements width per lane |
| 3.75 (up to 3.0m in difficult terrain) | 5.5 m | 3.5 m |

In case of single lane roads, it is recommended to have two treated shoulders on either side to make a total width of 5.5m of treated surface.

1. **Shoulder**

* The width of shoulders on either side of the carriageway shall be at least 0.75m. Recommended width of shoulder for various classes of roads is given below in Table.
* For protection of pavement from water percolating under it from shoulder it is recommended to treat at least a 0.50-0.75m wide strip of shoulder near the edge of the pavement with impervious to water surfacing.
* If a small gap(<1m) of untreated shoulder is formed between the edge of the pavement and edge of the side drain in hill roads it is recommended to treat this gap with appropriate surface treatment.

Table 3.9: Width of Shoulders, metres

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Road class | Class I | Class II | Class III | Class IV |
| Minimum Shoulder width, m | 3.7 | 2.5 | 2.0 | 1.5 |

* For mountainous and steep terrains, the above values can be reduced to a minimum value for a lower class of the road but not less than 0.75m.
* It is desirable that the color and texture of shoulders be different from those of the carriageway.
* This contrast serves to clearly define the carriage way at all times, particularly at night and during inclement weather, while discouraging the use of shoulders as additional through lanes.
* Very wide shoulders (more than 3.75m wide) are also not desirable due to tendency of vehicles misusing it as a carriageway.

1. **Medians**

* For roads with 4 or more lanes, it is recommended to provide medians or traffic separators.
* Medians should be as wide as possible.
* A minimum median width of Sm is recommended. But a width of 3m can be adopted in areas where land is restricted.
* In mountainous and steep terrains maximum possible width of median dictated by the topography should be provided. In such situations simple barriers may be provided to function as a median or individual carriageways could be designed at different levels.
* On long bridges and viaducts, the width of the median may be reduced to 1.5m, but in no case this should be less than 1.2m.
* The median should be of uniform width in a particular section of the highway. However, where changes are unavoidable, a transition of 1 in 20 must be provided.

1. **Formation or Roadway Width**

Formation width shall be a total of widths of carriageways, medians and shoulders as discussed in previous paragraphs.

1. **Camber**

* All straight sections of roads shall have a camber or cross fall as given on the Table.
* On roads with undivided carriageways the camber shall be on both directions from the center line of the road. On roads with divided carriageways unidirectional camber can be provided.
* However, on some sections of hill roads with undivided carriageway a unidirectional camber can be adopted. In this case the adverse effect of negative camber on movement of vehicles on curves should be properly checked.

Table 3.10: Camber, percentage (%)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Pavement type | Cement Concrete | Bituminous | Gravel | Earthen |
| Camber, % | 1.5 to 2.0 | 2.5 | 4.5 | 5.0 |

![A black background with a black square

Description automatically generated with medium confidence](data:image/png;base64,iVBORw0KGgoAAAANSUhEUgAAADcAAAAnCAYAAACrDdDdAAAAAXNSR0IArs4c6QAAAARnQU1BAACxjwv8YQUAAAAJcEhZcwAAIdUAACHVAQSctJ0AAABNSURBVGhD7c+xCcAwEATBRyU4ce7+E3VoBSpBIO6ZgePiLQCgl+fAxlpb3/6WxKUSl0pcKnGpxKUSl0pcKnGpxKUSd8M8sHcNAO6p+gH/sw/Xe1hO9wAAAABJRU5ErkJggg==) On straight sections of roads, shoulders should have a higher cross fall than that of the carriageway by 0.5%.

1. **Superelevation**

* Superelevation is provided on horizontal curves. Value of superelevation is calculated using following formula: 𝑒 = − 𝑓
* Minimum value of superelevation should be equal to the rate of camber of the pavement.
* The rate of introduction of superelevation (i.e. longitudinal grade developed at the pavement edge compared to through grade along the center line) should be such as not to cause discomfort to travelers or to make the road unsightly.
* Rate of change of the outer edge of the pavement should not be steeper than 1 in 150 in plain and rolling terrain and l in 60 in mountainous and steep terrain in comparison with the grade of the center line.

1. **Side slopes**

* Side slopes of embankment and cuttings depend on the type of fill/cut materials and height/depth of filling/cutting.
* Recommended side slopes for embankments are given below. But wherever possible flatter slopes are recommended for aesthetic reason and traffic safety.

Table 3.11: Embankment side slopes

|  |  |
| --- | --- |
| Height, m | Side slope (vertical: Horizontal) |
| <1.5 | 1:4 |
| 1.5-3.0 | 1:3 |
| 3.0-4.5 | 1:2.5 |
| 4.5-12.0 | 1:2 |
| >12.0 | Design Specially |

* If natural cross slope of the ground is more than 1:5 then the ground should be cut with more than 2m wide horizontal steps.
* Recommended values of side slopes in cutting are given in Table:

Table 3.12: Cutting Side slopes

|  |  |
| --- | --- |
| Table No. 1 Soil Type | Side Slope (vertical: Horizontal) |
| Ordinary Soil | 1:2 to 1:1 |
| Disintegrated rock or conglomerate | 1: 1 to 1: 1 |
| Soft rock, shale | 1: 1 to 1: 1 |
| Medium Rock | 1: 1 to 1: 1 |
| Hard Rock | Almost vertical |

1. **Typical Cross Sections** 
   1. Arterial Road section

A diagram of a car and a car

Description automatically generated with medium confidence

Figure 2 : Arterial Road section option 1

A diagram of a bridge

Description automatically generated

Figure 3: Arterial Road section option 2

* 1. Sub Arterial Road Sections

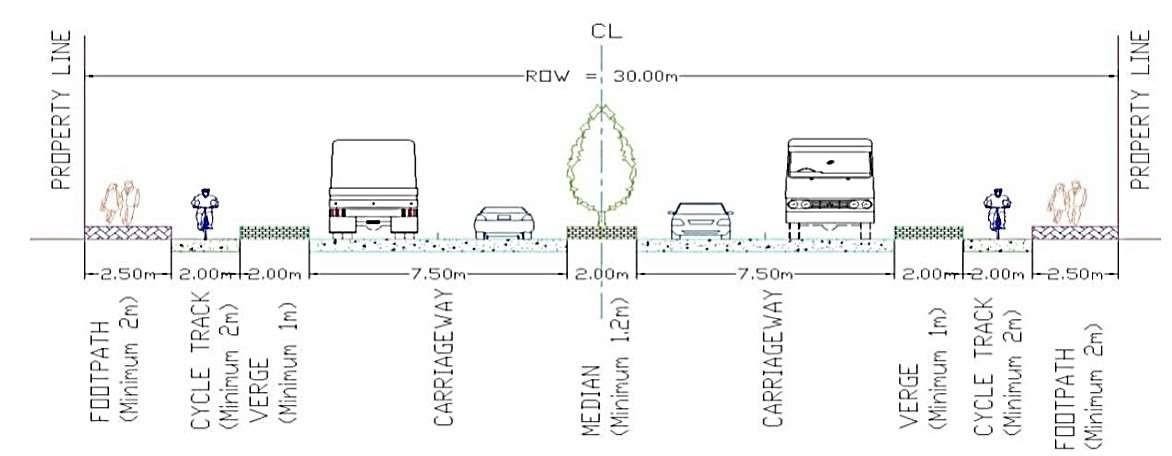


Figure 4: Sub-Arterial Road Option 1

A diagram of a road with cars and a tree

Description automatically generated

Figure 5: Typical Sub-Arterial Road Option 2

* 1. Collector Road Section

A diagram of a bridge

Description automatically generated

Figure 6: Typical Collector Road Section

* 1. Local Road Section

A diagram of a road with cars and text

Description automatically generated

Figure 7: Typical Local Road Section

1. **Right of way and Clearances** 
   1. **Right Of Way**

Right of way for different types of roads shall be as follows:

Table 3.13: Right of way, meters

|  |  |
| --- | --- |
| Road Type | Total Right of way, m |
| Highways | 50 |
| Feeder Roads | 30 |
| District Roads | 20 |

* 1. **Lateral Clearances**
* For a single carriageway road that goes through an underpass, whole width of the roadway (carriageway plus shoulder widths) should be cleared in lateral direction.
* If footpaths are provided minimum lateral clearance should be width of footpath plus 1.0 m.
* On roads with divided carriageway, left hand side lateral clearance should be as given on (a.) and (b.) above.
* Right hand side clearance should be 2.0 m (desirable) with 1.5m minimum.
  1. **Vertical Clearances**
* A vertical clearance of 5.0m measured from the crown of the road surface shall be provided for whole roadway width on all roads. No obstructions shall be made on this space.
* Vertical clearance for high voltage electric cables from the road surface shall be as shown in Table

Table 3.14: Vertical Clearances for Electric wires and cables

|  |  |
| --- | --- |
| Table No. 2 Voltage, kV | Minimum vertical clearance, m |
| 1 | 6 |
| 110 | 7 |
| 132 | 7.5 |
| 220 | 8 |
| 330 | 8.5 |
| 550 | 9 |
| 720 | 16 |

## Highway Drainage

### Introduction

Highway drainage is used to collect and remove the excess sub-surface and surface water within the right of way. Highway drainage is achieved by following two methods:

1. **Surface Drainage**

Surface water must be collected and then released. This is done by first collecting the water in longitudinal drains, generally side drains, and then directing it towards the nearest stream, valley, or water channel. To carry water effectively from the roadside drains, cross-drainage structures like culverts and small bridges may be required.

1. **Sub-Surface Drainage**

The process of sub-surface drainage is designed to eliminate excess moisture from within the soil layers. This involves a range of techniques aimed at: lowering the water table, controlling the movement of seepage water, limiting the upward capillary movement of water, and draining infiltrated water.

### Importance Of Highway Drainage

1. Good drainage preserves the soil's ability to support loads.
2. It ensures the road surface is free from both moving and stagnant water.
3. By preventing water damage, it contributes to the long-term integrity of the pavement.
4. Effective drainage reduces the need for costly repairs and upkeep.
5. It promotes safer conditions, particularly in regions with freezing weather.
6. This also eliminates mud pumping as a factor in pavement failure.

### Side Drains

Side drains are provided on the both sides of carriageway to collect and remove the surface water which is made parallel to the longitudinal alignment of raod.

### Design Of Surface Drainage System

a) Hydrologic Analysis

The peak runoff is calculated by rational formula:

Q = CIA

Where, Q = Runoff in m3/s.

C = Runoff Coefficient, I = Rainfall intensity, mm/hr., A = Catchment area in hectares.

1. Hydraulic Analysis

Once the design discharge is determined hydraulic analysis is done.

Q = A x V

1. = (𝐴𝑅2/3 𝑆 ½)/n …………… (1)

For the rectangular section, select economical section as,

1. = D/2, B= 2D

Solve equation (1) to get B and D

Calculate V by

V = (R2/3xS1/2)/n for the design section which should be within the permissible limit otherwise change lining material and redesign the section

Where,

V= velocity of flow, m/sec

n= Manning’s roughness coefficient

A= Area, m2

R= Hydraulic Radius = A/P, m

P= wetted perimeter, m

S= Longitudinal bed slope of channel

### Cross Drainage Structure

One of the important cross drainage structure in road alignment is culvert.

1. **Culvert**

A culvert is essentially an enclosed channel positioned below a road embankment, designed to convey water from one side to the other. Culverts are often favored over small bridges due to their superior hydraulic efficiency. The Nepal Road Standard of 2027 defines any bridge structure with a span of less than 6 meters as a culvert. Key types of culverts include:

* **Slab Culverts:** These feature a slab supported by masonry abutments, sometimes referred to as box culverts when the span is under two meters.
* **Pipe Culverts:** For smaller discharge volumes, pipes of at least 60 cm in diameter, crafted from steel or pre-cast reinforced concrete, are employed. Standard pipe culvert diameters available on the market include 75 cm, 90 cm, and 120 cm.

1. **Causeway**

These are structures provided in hill road which drains off water flowing over the road surface to the lower level safely. Generally, for stability and durability consideration RCC cause ways are used rather than dry stone cause ways.

## Retaining Structure

### Introduction

A retaining wall is a structure designed to hold back a vertical mass of soil. Its main purpose is to counteract the lateral force exerted by the earth on one side, and sometimes it must also resist the pressure of subsoil, water, or even vertical loads from a structure above, known as surcharge.

Essential requirements for retaining structures include:

* Strength and stability**:** The structure must be able to withstand the forces acting upon it.
* Durability**:** It must be resistant to wear and degradation over time.

Furthermore, retaining structures must not:

* Slide horizontally
* Overturn or topple
* Subject their construction materials to excessive stress
* Exceed the load-bearing capacity of the underlying soil.

### Types Of Retaining Walls

1. Gravity retaining walls
2. Cantilever retaining walls

Designing retaining walls requires consideration of the following:

1. **Active Earth Pressure:** A constant lateral pressure which applies a force pushing outward against the wall, originating from the retained soil wedge and any related hydrostatic groundwater pressure.
2. **Passive Earth Pressure:** A resistance force that develops when soil in front of the wall is compressed, working to impede any forward movement of the wall.
3. **Angle of Repose:** The natural slope assumed by a material, quantified as an angle relative to a horizontal plane. This angle ranges widely from 0 degrees for wet clay up to approximately 30 degrees for common soils and at times up to 45 degrees.
4. **Wedge of Soil:** The volume of soil supported above the angle of repose.
5. **Surcharge Load:** This is the extra weight imposed on a retaining wall by any materials or structural elements located above its top level.

These walls are constructed to secure mountainsides and support roadways on the valley side. They are built to counteract active soil pressure. Toe walls, with a 1 in 10 outer slope and a 1 in 4 bed slope, are examples of retaining structures typically found at the foot of slopes.

The following practical features are important to consider during retaining wall construction:

* Where appropriate, use dry masonry walls. Only use other wall types when increased strength is genuinely required and the additional cost can be justified.
* The top of a stone masonry retaining wall should have a minimum width of 60 cm.
* The back of the wall should be constructed with a rough surface or built in steps to enhance friction with the backfill material.
* Backfill should be placed in layers of 10 to 15 cm, with gentle compaction and a slope away from the wall. This practice, performed once the wall has gained sufficient strength, reduces lateral pressure on the structure.
* The foundation of the wall should be established at a depth to avoid environmental damage, and to be at least h/10 + 30 cm below ground level.
* Any footing projection should not exceed half of the course's depth.
* Careful planning and oversight of foundation construction are crucial.
* During excavation, all waste materials should be moved to a safe location and never discarded down the slope.
* Since drainage problem is major challenge. Therefore, preference should be given to well-drained wall types. Following construction, ensure that the surrounding slopes are properly shaped and treated with suitable bioengineering methods. Excess materials should be removed to prevent erosion.

## 3.14 Miscellaneous Works

### Bio-Engineering

Bioengineering systems function by providing the necessary engineering mechanisms for slope protection and stabilization. While it is not a replacement for civil engineering, it provides a valuable set of complementary tools for addressing various shallow slope challenges. Bioengineering contributes by trapping debris, reinforcing the surface, strengthening the soil, anchoring top layers, providing slope support, or improving drainage. It has a dual purpose: offering techniques to stabilize shallow failures and control erosion, while also enhancing civil engineering structures by protecting them and maximizing their efficiency.

In the specific context of Nepal, bioengineering plays a critical role due to its unique conditions, such as active geological processes, steep mountain slopes, heavy rainfall, and economic limitations. Therefore, bioengineering should be more widely implemented in Nepal, given the difficult terrain and the need for affordable and effective techniques to protect slopes and stabilize superficial failures.

### Traffic Control Device

1. **Traffic sign**

* Regulatory sign
* Warning sign
* Informatory sign

Traffic signs are installed at appropriate distance and appropriate number according to chapter 7 of the Vehicle Road Transportation Management Act 2049

1. **Traffic Signals**

Power operated control device or sign which direct and guide the user are traffic signals. Types of traffic signals are as follows:

* Fixed time signals
* Manually operated signals
* Automatic signals

Traffic signals are not yet necessary for this road section as there is less traffic and busy intersections.

1. **Road Markings**

Lines, symbols, patterns, letters, reflectors to guide and direct the road users are road markings which acts as psychological barrier.

Types of road markings:

* Pavement Marking
* Kerb Marking
* Object Marking
* Reflector Unit Marking

### Maintenance

Maintenance encompasses the actions taken to keep a pavement surface functional and in the best possible condition for as long as practical. Pavement maintenance can be classified into several categories: Routine Maintenance, Recurrent Maintenance, Periodic Maintenance, and Emergency Maintenance. During inspections, various defects are identified, requiring maintenance. However, due to funding limitations, these activities must often be prioritized.

Pavement strengthening involves adding extra thickness to the pavement as needed. When dealing with a partially damaged road, patch repairs should be carried out prior to applying an overlay. For our specific road segment, a flexible overlay on a flexible pavement is a viable option for future strengthening, considering the current damaged state.

# METHODOLOGY

## General

Following the selection of the project area, a detailed survey was conducted using total stations, level machines, and GPS. Socioeconomic, geological, and demographic data of the region were collected. Environmental factors such as temperature, rainfall, vegetation, and climate were studied, as these are crucial for analyzing hydrological data. Once the survey data was fully analyzed, the final road alignment was determined. An engineering survey was then carried out along the proposed alignment, taking into account various geometric parameters as defined by NRS 2070. During this survey, primary data was gathered, including soil types at various points along the route, details of existing buildings, the types of crops being cultivated, and precise three-dimensional coordinates (x, y, z). The cost estimate for the proposed road was developed by considering the different types of work involved in road construction. This estimate was produced with the assistance of road design software, including Autodesk Civil 3D, Autodesk, and Excel programs.

## Tools and Equipment’s used in Survey

The following tools and equipment were utilized during the surveying process:

* **Navigation and Direction:**
  + Compass
  + GPS (Global Positioning System)
* **Distance Measurement:**
  + Measuring tape
* **Elevation Measurement:**
  + Level machine
* **Combined Distance and Angle Measurement:**
  + Total station
  + Reflector (used with the total station)
* **Marking and Setting:**
  + Hammer
  + Concrete blocks
  + Paint and Brush

## Feasibility

This proposed road project involves upgrading an existing road that currently supports traffic and is considered essential for improving the local community's quality of life. The municipality's intention to develop the area, driven by its considerable growth potential, makes this project feasible.

## Engineering Design

Road design parameters were selected based on the NRS (2070) guidelines, prioritizing comfort, safety, and minimizing construction and maintenance costs. The chosen parameters were based on the finalized road classification. The vertical alignment was designed to balance cut and fill volumes while minimizing embankment fill, particularly in plain and rolling terrain, to ensure its stability. The key points of the vertical alignment, including the start, midpoint, and end of curves, as well as high and low points, were precisely defined relative to the designed vertical intersection points. Cross-sectional elements such as extra widening, superelevation, and camber were determined according to NR (2070) standards. Adequate provisions for retaining walls, gabion walls, and both cross and side drains were incorporated to ensure road safety.

Road Design Software (SW Road V2) was used to process field data and facilitated the creation of various design drawings and computations, including:

* **Survey Alignment Plan:** Showing the key structures within the road corridor.
* **Horizontal and Vertical Alignments:** Illustrating all design parameters in accordance with road design standards.
* **Cross Sections:** Displaying the proposed design at specified intervals, including retaining structures and recommended drainage types.
* **Earthwork Quantity Computation:** Calculation of cut and fill volumes to estimate the necessary earthwork.

## Engineering Drawings

The detailed design drawings for this project were created using Autodesk Civil 3D. The following drawings were produced to support the implementation of the road design:

* **Plan View:** A plan view at a scale of 1:5000. This drawing shows the road alignment, curve data, and surrounding features within the road corridor.
* **Profile View:** A profile view at a scale of 1:5000. This drawing illustrates the existing ground conditions, the proposed road design, and includes details about drain lengths and types.
* **Cross-Sections:** Cross-sectional views at a scale of 1:1000. These drawings are created at each centerline peg and include information about existing ground conditions, the proposed design, and data such as existing ground level, cut and fill areas, soil type, and drain types.

## Software used

SW Road V2 is a powerful software tool for road design, offering a simple way to create plans, profiles, and cross-sections of proposed road alignments. It is commonly used in roadway design projects. The software imports survey data, typically collected with a total station and stored in an Excel sheet. Using this data, SW Road V2 generates a longitudinal profile of the existing terrain. This profile allows for adjusting the road alignment in relation to a chosen maximum gradient while considering the balance of cut and fill volumes.

After inputting key design parameters – including coordinates, drain type, drain side slopes, right-of-way, shoulder width, carriageway width, soil type, cross-section interval, and drawing scale – SW Road V2 can produce outputs in the form of cross-sections, plan views, and profiles. The software also calculates quantities needed for structures such as gabion retaining walls and breast walls. Additionally, it generates data for horizontal and vertical curves in Excel sheets. The resulting cross-sections, plans, and profiles can be easily plotted from SW Road V2, making it a valuable tool for roadway design.

# ENGINEERING STUDY AND INVENTORY SURVEY

## General

Following field surveys and investigations have been carried out for the project roads to determine the appropriate outputs for design and project preparation.

* Road Inventory Survey
* Geological and Geo-technical Survey
* Traffic Count Survey
* Hydrological and Meteorological Survey
* CBR test of Soil sample

## Road Inventory Survey

Field surveys have been carried out to record road inventory details of the project roads. The following surveys have been carried out:

* Existing structure survey
* Cross drainage requirement survey
* Retaining work requirement survey

### Land Use Pattern

Table 5.1: Land Use Pattern

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Legend: FA- Forest Area, MA- Market Area, SA- Settlement Area, AL- Agricultural land, IA-  Industry present Area | | | | | | |
| SN | Chainage | | Length | Land Use pattern | | Remarks |
|  | From | To | (m) | Side | FA, MA,  SA, AL,  IA |  |
| 1 | 0+000 | 0+040 | 40 | Left | SA |  |
| 2 | 0+040 | 0+120 | 80 | Left | AL |  |
| 3 | 0+120 | 0+200 | 80 | Left | SA |  |
| 4 | 0+200 | 0+340 | 140 | Left | AL |  |
| 5 | 0+340 | 0+540 | 200 | Left | IA | A factory located adjacent to the road |
| 6 | 0+540 | 0+730 | 190 | Left | AL |  |
| 7 | 0+730 | 0+840 | 110 | Left | IA | Brick factory adjacent to road |
| 8 | 0+840 | 0+960 | 120 | Left | AL |  |
| 9 | 0+960 | 1+120 | 160 | Left | SA |  |
| 10 | 1+120 | 1+470 | 350 | Left | AL |  |
| 11 | 1+470 | 2+220 | 750 | Left | SA |  |
| 12 | 2+220 | 2+560 | 340 | Left | AL |  |
| 13 | 0+000 | 0+040 | 40 | Right | SA |  |
| 14 | 0+040 | 0+130 | 90 | Right | IA | A factory located adjacent to the road |
| 15 | 0+130 | 0+200 | 70 | Right | SA |  |
| 16 | 0+200 | 0+460 | 260 | Right | AL |  |
| 17 | 0+460 | 0+880 | 420 | Right | SA |  |
| 18 | 0+880 | 1+030 | 150 | Right | AL |  |
| 19 | 1+030 | 1+760 | 730 | Right | SA |  |
| 20 | 1+760 | 2+400 | 640 | Right | AL |  |
| 21 | 2+400 | 2+589 | 189 | Right | SA | End point of road site |

### Existing Condition of Road Structures

Table 5.2: Existing Road Site Conditions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.No. | Chainage | Length(m) | Condition | Remarks |
| 1 | 0+100 | 100 | Unpaved | Earthen Road |
| 2 | 0+200 | 100 | Unpaved | Earthen Road |
| 3 | 0+300 | 100 | Unpaved | Earthen Road |
| 4 | 0+400 | 100 | Unpaved | Earthen Road |
| 5 | 0+500 | 100 | Unpaved | Earthen Road |
| 6 | 0+600 | 100 | Unpaved | Earthen Road |
| 7 | 0+700 | 100 | Unpaved | Earthen Road |
| 8 | 0+800 | 100 | Unpaved | Earthen Road |
| 9 | 0+900 | 100 | Unpaved | Earthen Road |
| 10 | 1+000 | 100 | Unpaved | Earthen Road |
| 11 | 1+100 | 100 | Unpaved | Earthen Road |
| 12 | 1+200 | 100 | Unpaved | Earthen Road |
| 13 | 1+300 | 100 | Unpaved | Earthen Road |
| 14 | 1+400 | 100 | Unpaved | Earthen Road |
| 15 | 1+500 | 100 | Unpaved | Earthen Road |
| 16 | 1+600 | 100 | Unpaved | Earthen Road |
| 17 | 1+700 | 100 | Unpaved | Earthen Road |
| 18 | 1+800 | 100 | Unpaved | Earthen Road |
| 19 | 1+900 | 100 | Unpaved | Earthen Road |
| 20 | 2+000 | 100 | Unpaved | Earthen Road |
| 21 | 2+100 | 100 | Unpaved | Earthen Road |
| 22 | 2+200 | 100 | Unpaved | Earthen Road |
| 23 | 2+300 | 100 | Unpaved | Earthen Road |
| 24 | 2+400 | 100 | Unpaved | Earthen Road |
| 25 | 2+500 | 100 | Unpaved | Earthen Road |

## Pavement Design

The stable and non-yielding layer constructed over natural soil is the soil pavement. The objective of laying a pavement is to support the wheel load and transfer load stresses over a wide area on the soil subgrade such that the magnitude of stresses transferred are considerably lower. The pavement is designed such that vehicles can travel at design speed without discomfort. The pavement structure typically consists of the following layers: prepared soil subgrade, granular sub-base course, base course and surface course.

Based on structural behavior, road pavements are generally classified as:

1. **Flexible pavement**

The pavements which have low or negligible flexural strength and are rather flexible in their structural action under the loads are called flexible pavements. The lower layer of flexible pavements reflects the deformation up to the surface of the layer. The typical flexible pavement structure consists of a wearing surface at the top, the base course followed by sub-base course and the lowermost layer of compacted soil.

1. **Rigid Pavement**

The pavement which possesses noteworthy flexural strength or flexural rigidity is rigid pavement. The rigid pavements are made up of plain reinforced or prestressed concrete. The rigid pavement has the ‘slab action’ which transmits the wheel load through a much wider area. Rigid pavement structure consists of a cement concrete slab, below which granular sub-base or base course over the subgrade soil.

### CBR Test

The California Bearing Ratio or CBR test is performed in construction materials laboratories to evaluate the strength of soil subgrades and base course materials. Those who design and engineer highways, airport runways and taxiways, parking lots, and other pavements rely on CBR test values when selecting pavement and base thicknesses.

Standard Proctor Test for determination of Optimum Moisture Content (OMC)

Table 5.3: Sample -1 at Chainage 0+500m

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| S.No | Observations and Calculations | 1 | 2 | 3 | 4 | 5 |
| 1 | Mass of empty mould+ base plate (gm) | 4200 | 4220 | 4180 | 4190 | 4210 |
| 2 | Mass of mould+ base plate+ compacted soil (gm) | 6060 | 6200 | 6110 | 6125 | 6085 |
| 3 | Mass of compacted soil (gm) | 1860 | 1980 | 1930 | 1935 | 1875 |
| 4 | Bulk density (gm/ml) | 1.86 | 1.98 | 1.93 | 1.935 | 1.875 |
| 5 | Water content (%) | 14 | 16.5 | 18 | 20.5 | 23 |
| 6 | Dry density (gm/ml) | 1.63 | 1.67 | 1.7 | 1.65 | 1.61 |
| Water Content | | | | | | |
| 7 | Mass of empty container | 22 | 22 | 22 | 22 | 22 |
| 8 | Mass of container+ soil | 184 | 178 | 162 | 174 | 170 |
| 9 | Mass of soil | 162 | 156 | 140 | 152 | 148 |
| 10 | Mass of container+ dry soil | 160 | 150 | 130 | 134 | 130 |
| 11 | Mass of dry soil | 138 | 128 | 108 | 112 | 108 |
| 12 | Water content (%) | 14 | 16.5 | 18 | 20.5 | 23 |

Figure : OMC vs MDD curve for sample 1

From figure, OMC =17.95% MDD = 1.698 gm/ml

Table 5.4: Sample -2 at Chainage 1+500m

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| S.N. | Observations and Calculations | 1 | 2 | 3 | 4 | 5 |
| 1 | Mass of empty mould+ base plate (gm) | 4080 | 4080 | 4080 | 4080 | 4080 |
| 2 | Mass of mould+ base plate+ compacted soil (gm) | 6020 | 6075 | 6030 | 6020 | 6030 |
| 3 | Mass of compacted soil (gm) | 1940 | 1995 | 1950 | 1940 | 1950 |
| 4 | Bulk density (gm/ml) | 1.94 | 1.995 | 1.95 | 1.94 | 1.95 |
| 5 | Water content (%) | 17.5 | 18.3 | 20.5 | 22.8 | 24.1 |
| 6 | Dry density (gm/ml) | 1.645 | 1.671 | 1.597 | 1.558 | 1.545 |
| Water content | | | | | | |
| 7 | Mass of empty container | 21 | 21 | 21 | 31 | 21 |
| 8 | Mass of container+ soil | 210 | 245 | 247 | 327 | 277 |
| 9 | Mass of soil | 189 | 224 | 226 | 296 | 256 |
| 10 | Mass of container+ dry soil | 178 | 205 | 202 | 261 | 216 |
| 11 | Mass of dry soil | 157 | 184 | 181 | 230 | 196 |
| 12 | Water content (%) | 17.5 | 18.3 | 20.5 | 22.8 | 24.1 |

Figure : OMC vs MDD curve for sample 2

From figure, OMC =17.90% MDD = 1.662 gm/ml

Table 5.5: Sample-3 at Chainage 2+500m

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Observations and Calculations | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Mass of empty mould+ base plate(gm) | 4050 | 4050 | 4050 | 4050 | 4050 | 4050 |
| 2 | Mass of mould+,base plate+ compacted soil (gm) | 5850 | 5920 | 5930 | 5935 | 5940 | 5938 |
| 3 | Mass of compacted soil (gm) | 1783 | 1854 | 1860 | 1862 | 1866 | 1850 |
| 4 | Bulk density (gm/ml) | 1.783 | 1.854 | 1.86 | 1.862 | 1.866 | 1.85 |
| 5 | Water content (%) | 15.78 | 18.75 | 20.47 | 22.36 | 23.91 | 25.69 |
| 6 | Dry density (gm/ml) | 1.5399 | 1.5613 | 1.5439 | 1.5217 | 1.5059 | 1.4718 |
| Water content | | | | | | | |
| 7 | Mass of empty container | 30 | 30 | 20 | 20 | 20 | 22 |
| 8 | Mass of container + soil | 225 | 220 | 254 | 340 | 202 | 315 |
| 9 | Mass of soil | 190 | 192 | 254 | 322 | 184 | 288 |
| 10 | Mass of container + dry soil | 190 | 186 | 222 | 270 | 160 | 236 |
| 11 | Mass of dry soil | 140 | 156 | 202 | 250 | 140 | 214 |
| 12 | Water content (%) | 15.8 | 18.7 | 20.4 | 22.4 | 23.9 | 25.7 |

OMC vs MDD curve for sample 3

From figure, OMC =18.75% MDD = 1.561 gm/ml

CBR test

Table 5.6: Sample-1

|  |  |  |  |
| --- | --- | --- | --- |
| S.N | Penetration (mm) | Load dial gauge | |
|  |  | Dial gauge reading | Load (kg) |
| 1 | 0 | 0 | 0 |
| 2 | 0.5 | 1 | 12.5 |
| 3 | 1 | 1.8 | 22.5 |
| 4 | 1.5 | 3.2 | 40 |
| 5 | 2 | 4.2 | 52.5 |
| 6 | 2.5 | 5.4 | 67.5 |
| 7 | 3 | 7.2 | 90 |
| 8 | 4 | 9.2 | 115 |
| 9 | 5 | 11.2 | 140 |
| 10 | 7.5 | 14.6 | 182.5 |
| 11 | 10 | 16.4 | 205 |
| 12 | 12.5 | 18 | 225 |

0

50

100

150

200

250

0

4

6

8

10

12

14

2

Load (kg)

Penetration (mm)

Figure : Load vs penetration curve for sample 1

From figure,

CBR at 2.5mm penetration = 4.92%

CBR at 5 mm penetration = 6.81%

Table 5.7:Sample-2

|  |  |  |  |
| --- | --- | --- | --- |
| S.N | Penetration (mm) | Load dial gauge | |
| Dial gauge reading | Load (kg) |
| 1 | 0 | 0 | 0 |
| 2 | 0.5 | 1.8 | 22.5 |
| 3 | 1 | 2.8 | 35 |
| 4 | 1.5 | 3.6 | 45 |
| 5 | 2 | 4.6 | 57.5 |
| 6 | 2.5 | 5.4 | 67.5 |
| 7 | 3 | 6.2 | 77.5 |
| 8 | 4 | 7.6 | 95 |
| 9 | 5 | 8.4 | 105 |
| 10 | 7.5 | 10 | 125 |
| 11 | 10 | 11.2 | 140 |
| 12 | 12.5 | 12.4 | 155 |

0

20

40

60

80

100

120

140

160

180

2

4

6

8

10

12

14

0

Load (kg)

Penetration (mm)

Figure: Load vs penetration curve for sample 2

From figure,

CBR at 2.5mm penetration = 4.927%

CBR at 5 mm penetration = 5.109%

Table 5.8: Sample-3

|  |  |  |  |
| --- | --- | --- | --- |
| S.N | Penetration (mm) | Load dial gauge | |
| Dial gauge reading | Load (kg) |
| 1 | 0 | 0 | 0 |
| 2 | 0.5 | 1.6 | 20 |
| 3 | 1 | 2.8 | 35 |
| 4 | 1.5 | 3.4 | 42.5 |
| 5 | 2 | 4.4 | 55 |
| 6 | 2.5 | 5.4 | 67.5 |
| 7 | 3 | 6.4 | 80 |
| 8 | 4 | 8 | 100 |
| 9 | 5 | 10 | 125 |
| 10 | 7.5 | 13 | 162.5 |
| 11 | 10 | 14.8 | 185 |
| 12 | 12.5 | 16.2 | 202.5 |

0

50

100

150

200

250

0

5

10

15

Load (kg)

Penetration (mm)

Figure : Load vs penetration curve for sample 3

From figure,

CBR at 2.5mm penetration = 4.927%

CBR at 5 mm penetration = 6.082%

Table 5.9: CBR value at 87th percentile:

|  |  |  |
| --- | --- | --- |
| S.N. | CBR in descending order | % equal to or greater than |
| 1 | 6.6909 | 33.333 |
| 2 | 5.839 | 66.667 |
| 3 | 5.2311 | 100 |

Figure: Final CBR value

0

1

2

3

4

5

6

7

8

0

40

60

80

100

120

20

Thus, the CBR value is adopted as 5.3% .

### Traffic Count

For highways in Nepal, traffic count surveys are a crucial part of Detailed Project Reports (DPRs). They offer essential information for efficiently organizing, creating, and overseeing transportation infrastructure. To ensure the best possible development and upkeep of road networks, precise traffic count surveys are essential in Nepal due to the country's varied geography and traffic patterns.

The data are as follows:

Table 5.10: Table for Three Days Traffic Count Data

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Type of Vehicle | Day 1 | | | Day 2 | | | Day 3 | | | Average |
| Towards | Outwards | Total | Towards | Outwards | Total | Towards | Outwards | Total |
|  |
|  |
|  |
| Two-Wheeler | 104 | 120 | 224 | 40 | 45 | 85 | 107 | 102 | 209 | 172.67 |  |
| Pickup | 14 | 16 | 30 | 4 | 5 | 9 | 15 | 17 | 32 | 23.67 |  |
| Car/jeep/van/taxi | 20 | 25 | 45 | 10 | 15 | 25 | 22 | 26 | 48 | 39.33 |  |
| Bus Full | 14 | 12 | 26 | 13 | 14 | 27 | 16 | 14 | 30 | 27.67 |  |
| Bus Mini | 8 | 10 | 18 | 9 | 11 | 20 | 12 | 20 | 32 | 23.33 |  |
| Truck(2 axle) | 25 | 22 | 47 | 18 | 17 | 35 | 22 | 24 | 46 | 42.67 |  |
| Water Tanker | 2 | 2 | 4 | 0 | 0 | 0 | 1 | 2 | 3 | 2.33 |  |
| Cycle | 9 | 11 | 20 | 4 | 3 | 7 | 11 | 14 | 25 | 17.33 |  |
| Dozer | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.00 |  |
| Tractor | 4 | 4 | 8 | 3 | 2 | 5 | 3 | 2 | 5 | 6.00 |  |
| Total | 200 | 222 | 422 | 101 | 112 | 213 | 209 | 221 | 430 | 355.00 |  |

* PCU calculation of base year:

Table 5.11: Table for PCU values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.N | Vehicle Type | Equivalency | Traffic | PCU |
| 1 | Motorcycle,Bicycle,porter | 0.5 | 190 | 95 |
| 2 | Car,Auto,Rickshaw, | 1 | 63 | 63 |
| 3 | Tractor,Light Truck,Rickshaw | 1.5 | 6 | 9 |
| 4 | Truck,Bus,Minibus,Tractor with trailer | 3 | 96 | 288 |
|  | Total |  |  | 455 |

* PCU calculation in the design year

Traffic growth rates shall be established for each category of commercial vehicles. In the absence of data for estimation of the annual growth rate of commercial vehicles a minimum annual growth rate of 7 percent shall be used for commercial vehicles for estimating the design traffic.

Table 5.12: Table for PCU in Next 20 years

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| S.N | Vehicle Type | PCU | Growth Rate | PCU in next 20 years |
|  |
| 1 | Motorcycle,Bicycle,porter | 95 | 0.05 | 252.063 |  |
| 2 | Car,Auto,Rickshaw, | 63 | 0.05 | 167.158 |  |
| 3 | Tractor,Light Truck,Rickshaw | 9 | 0.05 | 23.880 |  |
| 4 | Truck,Bus,Minibus,Tractor with trailer | 288 | 0.05 | 764.150 |  |
|  | Total | 455 |  | 1207.250 |  |

After projecting the traffic for next 20 years, PCU was found to be 1990.05 which is less than 2000 PCU so the road lies in class IV.

### Pavement Design methods

This section details the pavement design approach for low-volume traffic roads, incorporating Road Note 31, DOR Guidelines, and IRC-2001. The methodology emphasizes using standard parameters, cumulative axle loads, and subgrade strength to determine the pavement's structural requirements.

#### Design Using Road Note

1. Design Year:20 Years
2. Construction Period:2Years
3. Lane Distribution Factor: 75% (two lane single carriageway)
4. Annual Traffic Growth Rate (r): 7%
5. Axle Load Survey: Not required for small projects; standard Vehicle Damage Factor (VDF) values are used instead.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Traffic Type** | **Total No. (a)** | **ESAL Factor (b)** | **a × b (ESAL/day)** | **Remarks** |
| Two-axle truck | 46 | 4.75 | 218.5 |  |
| Mini truck | 5 | 1.00 | 5 | Tractor |
| Bus (full) | 30 | 0.50 | 15 |  |
| Mini bus | 32 | 0.35 | 11.20 | Mini bus |
| Water Tanker | 3 | 2 | 6 | Tanker |
| TOTAL |  |  | 234.717EAL/DAY |  |

Cumulative no. of standard axle at base period (A) = P(1+r) ^n =268.72ESAL/DAY

Cumulative number of standard axles at the end of design period (N) = 3.O15\*10^6 ESAL/DAY

Cumulative number of standard axles at the end of design period (\*10^6) =3.015msa

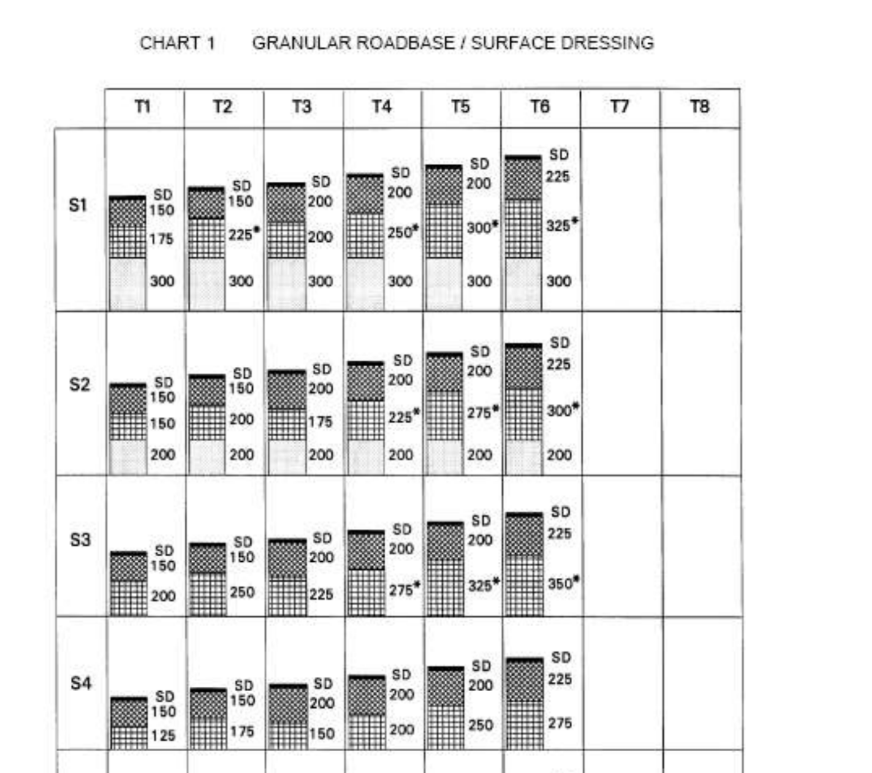
CBR=5.3%

From key to structural catalogue,

Traffic Classes=T5

Subgrade strength classes = S3

|  |  |  |  |
| --- | --- | --- | --- |
| **Total Thickness (mm)** | **Wearing Course (mm)** | **Granular Base (mm)** | **Granular Sub-base (mm)** |
| 575 | **50** | **200** | 325 |



#### Design Using IRC Guidelines 2001

* + Design Year:20 Years
  + Construction Period:2Years
  + Lane Distribution Factor: 75% (two lane single carriageway)
  + Annual Traffic Growth Rate (r): 7%
  + Axle Load Survey: Not required for small projects; standard Vehicle Damage Factor (VDF) values are used instead.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Traffic Type** | **Total No. (a)** | **ESAL Factor (b)** | **a × b (ESAL/day)** | **Remarks** |
| Two-axle truck | 46 | 4.75 | 218.5 |  |
| Mini truck | 5 | 1.00 | 5 | Tractor |
| Bus (full) | 30 | 0.50 | 15 |  |
| Mini bus | 32 | 0.35 | 11.20 | Mini bus |
| Water Tanker | 3 | 2 | 6 | Tanker |
| TOTAL |  |  | 234.717EAL/DAY |  |

Cumulative no. of standard axle at base period (A) = P(1+r) ^n =268.72ESAL/DAY

Cumulative number of standard axles at the end of design period (N) = 3.O15\*10^6 ESAL/DAY

Cumulative number of standard axles at the end of design period (\*10^6) =3.015msa

CBR=5.3%

A table with numbers and text

Description automatically generated with medium confidence

TABLE IRC GUIDELINES -2001

|  |  |  |  |
| --- | --- | --- | --- |
| **Total Thickness (mm)** | **Wearing Course (mm)** | **Granular Base (mm)** | **Granular Sub-base (mm)** |
| 475 | 50 | 200 | 225 |

CONCLUSION:

1. Total Thickness (mm):475mm
2. Wearing Course (mm):50mm
3. Granular Base (mm):200mm
4. Granular Sub-base (mm):225mm

#### Design Using DOR Guidelines

* Design Year:20 Years
* Construction Period:2Years
* Lane Distribution Factor: 75% (two lane single carriageway)
* Annual Traffic Growth Rate (r): 7%
* Axle Load Survey: Not required for small projects; standard Vehicle Damage Factor (VDF) values are used instead.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Traffic Type** | **Total No. (a)** | **ESAL Factor (b)** | **a × b (ESAL/day)** | **Remarks** |
| Two-axle truck | 46 | 4.75 | 218.5 |  |
| Mini truck | 5 | 1.00 | 5 | Tractor |
| Bus (full) | 30 | 0.50 | 15 |  |
| Mini bus | 32 | 0.35 | 11.20 | Mini bus |
| Water Tanker | 3 | 2 | 6 | Tanker |
| TOTAL |  |  | 234.717EAL/DAY |  |

* Cumulative no. of standard axle at base period (A) = P(1+r) ^n =268.72ESAL/DAY
* Cumulative number of standard axles at the end of design period (N) = 3.O15\*10^6 ESAL/DAY
* Cumulative number of standard axles at the end of design period (\*10^6) =3.015msa
* CBR=5.3%

**Using DOR, we get following data**

Table 5.13: **Thickness Distribution:**

|  |  |
| --- | --- |
| Layer | Thickness (mm) |
| Wearing Course | 50AC |
| Binder Course | 50DBM |
| Granular Base | 150mm |
| Granular Sub-base | 310.15mm |
| Total Thickness | 510.525 |

#### Design Using Asphalt Institute Method:

* + Design Year:20 Years
  + Construction Period:2Years
  + Lane Distribution Factor: 75% (two lane single carriageway)
  + Annual Traffic Growth Rate (r): 7%
  + Axle Load Survey: Not required for small projects; standard Vehicle Damage Factor (VDF) values are used instead.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Traffic Type** | **Total No. (a)** | **ESAL Factor (b)** | **a × b (ESAL/day)** | **Remarks** |
| Two-axle truck | 46 | 4.75 | 218.5 |  |
| Mini truck | 5 | 1.00 | 5 | Tractor |
| Bus (full) | 30 | 0.50 | 15 |  |
| Mini bus | 32 | 0.35 | 11.20 | Mini bus |
| Water Tanker | 3 | 2 | 6 | Tanker |
| TOTAL |  |  | 234.717EAL/DAY |  |

* Cumulative no. of standard axle at base period (A) = P(1+r) ^n =268.72ESAL/DAY
* Cumulative number of standard axles at the end of design period (N) = 3.O15\*10^6 ESAL/DAY
* Cumulative number of standard axles at the end of design period (\*10^6) =3.015msa
* CBR=5.3%

**Subgrade Resilient Modulus (M**R):

For a California Bearing Ratio (CBR) of 5.3%

MR=10.3×CBR=53.56MPA

MSA=3.015msa

Full Depth=280mm

Let, Asphalt concrete surface=75mm

Equivalent thickness of bituminous treated base= ((2500/1200) ^1/3) \*205=262mm

Use 150mm thick base course

Equivalent thickness of subbase= ((1200/125) ^1/3) \*112=240mm

So, Use 240mm thick granular subbase.

|  |  |  |  |
| --- | --- | --- | --- |
| **Total Thickness (mm)** | **Asphalt surface(mm)** | **Granular Base (mm)** | **Granular Sub-base (mm)** |
| 465 | 75 | 150 | 240 |

**Final Adopted Pavement Design:**

After calculating the pavement thickness from all above methods, considering the economy the pavement design having the least thickness is chosen which is obtained from road note 31.

1. Total thickness=575mm
2. Wearing Course=50mm
3. Granular Base=200mm
4. Granular Sub-base=325mm

|  |  |  |  |
| --- | --- | --- | --- |
| **Total Thickness (mm)** | **Wearing Course (mm)** | **Granular Base (mm)** | **Granular Sub-base (mm)** |
| 575 | **50** | **200** | 325 |

## Hydrological and Meteorological Study

### Rainfall Data

Maximum rainfall data of the past 16 years are given below:

Table 5.14: Rainfall data of past 16 years

|  |  |
| --- | --- |
| Year | Maximum Rainfall (mm) |
| 2009 | 104.5 |
| 2010 | 109.0 |
| 2011 | 83.4 |
| 2012 | 125.6 |
| 2013 | 71.6 |
| 2014 | 61.0 |
| 2015 | 84.0 |
| 2016 | 70.0 |
| 2017 | 74.0 |
| 2018 | 117.0 |
| 2019 | 83.6 |
| 2020 | 61.0 |
| 2021 | 116.4 |
| 2022 | 65.2 |
| 2023 | 102.2 |
| 2024 | 168. |

For the drainage design, we have taken the return period as 5 years which is feasible for the road project.

Time of concentration (tc)

Kirpich’s equation: tc = 0.01947 L0.77S0.385

Where, tc = time of concentration (minutes)

L= maximum length of travel of water (m) = 980m

ΔH = Difference in elevation between the farthest point and outlet (m)

=270m

S = Slope of catchment = ΔH/L =0.2755102041

Now,

tc = 0.01947\*(980)0.77 \*(0.2755102041)-0.385 = 6.429 minutes

Take tc = 15 minutes

### Calculation of rainfall intensity

1. Gumbel’s Method:

The Gumbel method is a statistical technique used in hydrology to estimate the probability of extreme events such as floods, droughts, and rainfall. According to this method, the value of rainfall X with a recurrence interval T is given by:

XT =x̄ + Kσn-1

Where, x̄ = Mean, σn-1 = Standard deviation of the sample, T = Return period = 1/p

K = frequency factor = (YT - ȳn)/ Sn

YT = Reduced variate = − {𝑙𝑛. (T/T-1)}

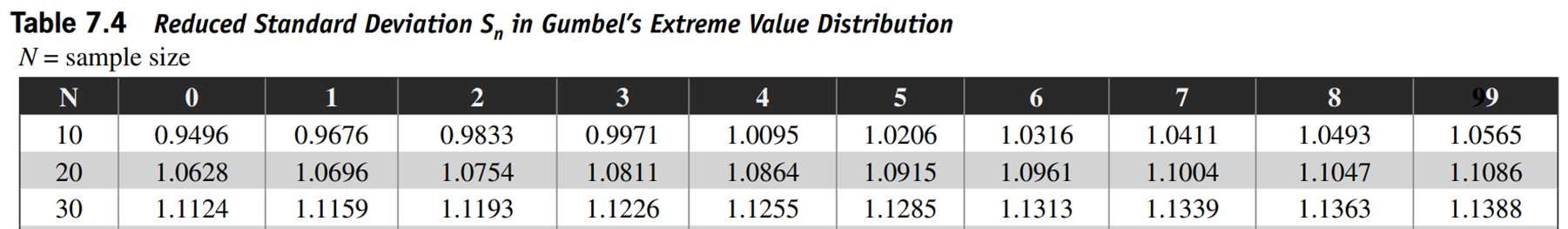
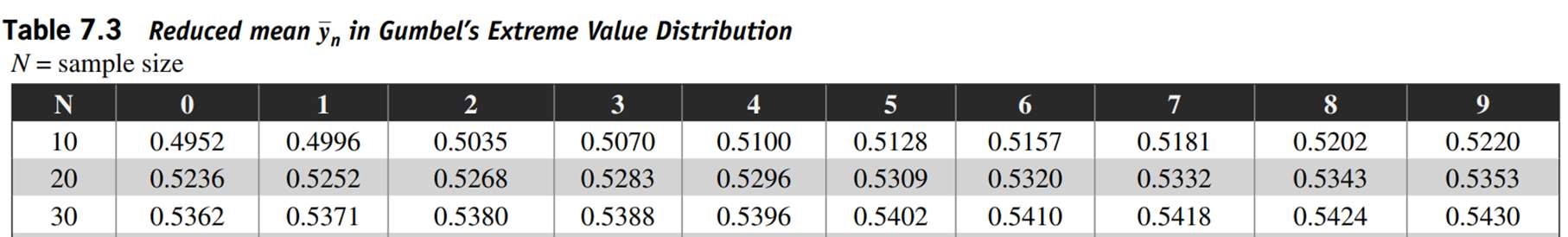
ȳn = Reduced mean in Gumbel’s extreme value distribution

Sn = Reduced standard deviation in Gumbel’s extreme value distribution

Table 5.15: Calculation of T for observed data:

|  |  |  |  |
| --- | --- | --- | --- |
| Order number (m) | Rainfall in Descending Order | Return Period(T) | Probability of Excedence (P=1/T) |
| 1 | 168.8 | 17 | 0.058823529 |
| 2 | 125.6 | 8.5 | 0.117647059 |
| 3 | 117 | 5.666667 | 0.176470588 |
| 4 | 116.4 | 4.25 | 0.235294118 |
| 5 | 109 | 3.4 | 0.294117647 |
| 6 | 104.5 | 2.833333 | 0.352941176 |
| 7 | 102.2 | 2.428571 | 0.411764706 |
| 8 | 84 | 2.125 | 0.470588235 |
| 9 | 83.6 | 1.888889 | 0.529411765 |
| 10 | 83.4 | 1.7 | 0.588235294 |
| 11 | 74 | 1.545455 | 0.647058824 |
| 12 | 71.6 | 1.416667 | 0.705882353 |
| 13 | 70 | 1.307692 | 0.764705882 |
| 14 | 65.2 | 1.214286 | 0.823529412 |
| 15 | 61 | 1.133333 | 0.882352941 |
| 16 | 61 | 1.0625 | 0.941176471 |
| N=16 |  |  |  |

N = 16, x̄ = 93.58125 mm/hr, σn-1 = 29.2458 mm/hr, ȳn = 0.5157 mm/hr and Sn = 1.0316 mm/hr



Calculation of XT for different T years are as follows:

Table 5.16: Table Discharge for different years

|  |  |  |  |
| --- | --- | --- | --- |
| T | Yt= -ln(ln(T/(T-1))) | Kt=(Yt-Yn)/Sn | Xt= X'+ Kt\*SD |
| 1 |  |  |  |
| 2 | 0.366512921 | -0.14462 | 89.3518 |
| 5 | 1.499939987 | 0.954091 | 121.4844 |
| 10 | 2.250367327 | 1.681531 | 142.759 |
| 20 | 2.970195249 | 2.379309 | 163.166 |
| 25 | 3.198534261 | 2.600654 | 169.6394 |

2. Log-Pearson Type III Distribution

The Log-Pearson Type III distribution is another statistical distribution commonly used in hydrology for analyzing extreme events. In this method if X is the rainfall value then, the variate Z for any recurrence interval T is given by,

ZT = z̄ + Kz σz Where, z = log x and z̄ = mean of z values

Kz = Frequency factor, a function of coefficient of skew (Cs) and return period (T)

σz = standard deviation of the sample of z values

Coefficient of skew (Cs)

After calculating zT the corresponding value of xT is calculated by,

XT = antilog (zT)

Calculating z=log x for all the rainfall values:

Table 5.17: Value for rainfall data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Max rainfall (x) | z=log(x) | z-z mean | (z-z mean)^3 |
| 2009 | 104.5 | 2.01911629 | 0.066097774 | 0.00028877 |
| 2010 | 109 | 2.037426498 | 0.084407981 | 0.00060138 |
| 2011 | 83.4 | 1.921166051 | -0.031852466 | -3.2317E-05 |
| 2012 | 125.6 | 2.098989639 | 0.145971123 | 0.00311029 |
| 2013 | 71.6 | 1.854913022 | -0.098105495 | -0.00094423 |
| 2014 | 61 | 1.785329835 | -0.167688682 | -0.00471532 |
| 2015 | 84 | 1.924279286 | -0.028739231 | -2.3737E-05 |
| 2016 | 70 | 1.84509804 | -0.107920477 | -0.00125693 |
| 2017 | 74 | 1.86923172 | -0.083786797 | -0.0005882 |
| 2018 | 117 | 2.068185862 | 0.115167345 | 0.00152752 |
| 2019 | 83.6 | 1.922206277 | -0.030812239 | -2.9253E-05 |
| 2020 | 61 | 1.785329835 | -0.167688682 | -0.00471532 |
| 2021 | 116.4 | 2.06595298 | 0.112934463 | 0.00144038 |
| 2022 | 65.2 | 1.814247596 | -0.138770921 | -0.00267236 |
| 2023 | 102.2 | 2.009450896 | 0.056432379 | 0.00017971 |
| 2024 | 168.8 | 2.227372442 | 0.274353925 | 0.02065064 |
| SUM |  |  |  | 0.01282103 |

Mean (z̄) = 1.95302 , SD (σz)= 0.1275

Coefficient of skew (CS) = 0.47123295451

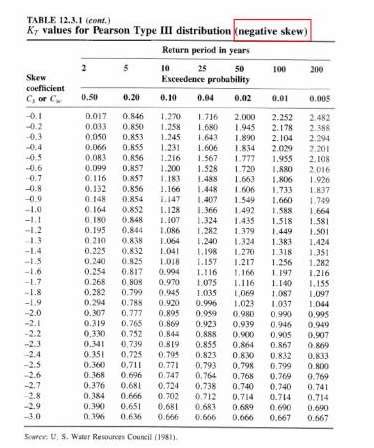
Calculating the frequency factor (K):

Table 5.18: Frequency factor (K) table

|  |  |  |  |
| --- | --- | --- | --- |
| Coefficient  of skew, Cs | Recurrence interval T in years | | |
| 2 | 10 | 25 |
| 0.5 | -0.083 | 1.323 | 1.91 |
| 0.471295451 | -0.07812023 | 1.321278 | 1.901388635 |
| 0.4 | -0.066 | 1.317 | 1.88 |

The values of rainfall for a given T is calculated as below:

|  |  |  |  |
| --- | --- | --- | --- |
| T | Kz | Zt =z mean+Kz\*Sz | Xt |
| 2 | -0.078120227 | 1.943058188 | 87.7118332 |
| 10 | 1.321277727 | 0.639758362 | 4.362730254 |
| 25 | 1.901388635 | 2.195445568 | 156.8359316 |

The values of rainfall for a given T is calculated as below:

Table 5.19: Rainfall value for different return periods using Gumbel’s method

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Rainfall Duration, hr | Return Period, Years | | | | |
| 2 | 5 | 10 | 20 | 25 |
| 0.25 | 78.05599 | 106.1264 | 124.7114 | 142.5387 | 148.1937 |
| 0.5 | 49.17219 | 66.85544 | 78.56329 | 89.79374 | 93.35618 |
| 1 | 30.97654 | 42.11629 | 49.49177 | 56.56651 | 58.81071 |
| 3 | 14.89197 | 20.2474 | 23.79316 | 27.19434 | 28.27324 |
| 6 | 9.381352 | 12.75506 | 14.98875 | 17.13136 | 17.81103 |
| 12 | 5.909881 | 8.035186 | 9.442322 | 10.79208 | 11.22024 |
| 18 | 4.510083 | 6.131994 | 7.205841 | 8.2359 | 8.562648 |
| 24 | 3.722992 | 5.06185 | 5.94829 | 6.798585 | 7.06831 |
| 0.25 (tc) for all  culvert streams | 78.05599 | 106.1264 | 124.7114 | 142.5387 | 148.1937 |

Table 5.20: Rainfall value for different return periods using Log Pearson Type III method

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Rainfall Duration, hr | Return Period, Years | | | |  |
| 2 | 5 | 10 | 25 | 50 |
| 0.25 | 76.62 | 99.46 | 115.55 | 137.01 | 153.87 |
| 0.5 | 48.27 | 62.66 | 72.80 | 86.31 | 96.93 |
| 1 | 30.41 | 39.47 | 45.86 | 54.37 | 61.06 |
| 3 | 14.62 | 18.97 | 22.04 | 26.14 | 29.35 |
| 6 | 9.21 | 11.95 | 13.89 | 16.46 | 18.49 |
| 12 | 5.80 | 7.53 | 8.75 | 10.37 | 11.65 |
| 18 | 4.43 | 5.75 | 6.68 | 7.92 | 8.89 |
| 24 | 3.65 | 4.74 | 5.51 | 6.53 | 7.34 |
| 0.25 (tc) for all  culvert streams | 76.62 | 99.46 | 115.55 | 137.01 | 153.87 |

(Using Log Pearson Type III equation)

Rainfall Intensity: 137.01 mm/hr

### Design calculation of side drain

Calculation of rectangular side drain for chainage 0+000m to 0+830m:

Rational formula:

𝑄 = (CIA)/360

Where,

Q = Peak runoff in m3/s

I = Critical intensity in mm/hr corresponding to time of concentration of catchment

=137.01 mm/hr

A = Catchment area, hectare = 5 ha

C = Runoff coefficient

= 0.4 for Loam, lightly, cultivated or covered

𝑄 = 𝑚3 /𝑠 = 0.7611 m3/s

For well finished concrete, Manning’s coefficient (n) = 0.013

Minimum Longitudinal Drain Slope (S) = 0.50% (NRS 2070)

Let D = 2B and road side slope of drain = 1V:1H

Then, A= B.D = 2B2 , P = B+2D = B+4B= 5B and R=A/P

We know,

𝑄 = 𝐴𝑉

Replacing the values:

On solving the equation with the known values:

D = 0.928m = 928mm

B = 2D = 0.464m = 464mm

Adopt a rectangular channel of width 465 mm and depth 930mm.

Check for safe velocity for side drain:

The velocity should lie within a certain range in order to be safe. =1.769811 m/s (2-2.5 m/s, Safe velocity for lined concrete!)

Calculation of dimension of side drain at different road section:

Table 5.21: Calculated side drain dimension for different chainage :

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Chainage (m) | Side drain | Catchment  Area (ha) | Q(m3/s) | D(m) | B(m) |
| 0+000 to 0+830 | SD1 | 5.0 | 0.7611 | 0.928 | 0.464 |
| 0+830 to 1+000 | SD2 | 1.12 | 0.171 | 0.53 | 0.265 |
| 1+000 to 1+320 | SD3 | 4.0 | 0.6089 | 0.854 | 0.427 |
| 1+320 to 2+150 | SD4 | 3.44 | 0.524 | 0.8064 | 0.4032 |
| 2+150 to 2+300 | SD5 | 3.09 | 0.47 | 0.774 | 0.387 |

### Design of pipe culvert

Calculation of pipe culvert at 0+830m:

Design Discharge (Q) = 0.06793817 m3/s

Manning's coefficient (n) = 0.013

Slope (S) = 1:100 = 0.01

Central angle for maximum discharge (θ) = 302°

Depth of flow for maximum discharge (y) = 0.938D

Area for maximum discharge (A) = = 3.059471219\*r2

Wetted perimeter for maximum discharge (P) = = 5.270894341\*r

Hydraulic radius (R) = A/P

We have,

Now,

Substituting all the available values and solving for the unknown value of radius, we get:

r = 0.492 m

Thus, Diameter = 2\*r = 0.984m

Similarly, the calculations were carried out at four other chainage.

Calculation of pipe culvert at different road sections:

Table 5.22: Pipe culvert sizes as per chainage

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Chainage | Pipe culvert | Catchment area (ha) | Q(m3/s) | r(m) | D(m) |
| 0+830 | PC1 | 5 | 0.7611 | 0.492 | 0.884 |
| 1+000 | PC2 | 1.12 | 0.171 | 0.181 | 0.362 |
| 1+320 | PC3 | 4 | 0.6089 | 0.2914 | 0.583 |
| 2+150 | PC4 | 3.44 | 0.524 | 0.402 | 0.804 |
| 2+300 | PC5 | 3.09 | 0.47 | 0.4082 | 0.816 |

Table 5.23: Cross drainage structures

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Chainage (m) | Length (m) | Diameter (m) | Pipe  Count | Clear Cover Depth (m) | Slope  (1V:mH) | Remarks |
| 0+830 | 10 | 0.9 | 1 | 0.6 | 100 | Proposed pipe culvert |
| 1+000 | 10 | 0.6 | 1 | 0.6 | 100 | Proposed pipe culvert |
| 1+320 | 10 | 0.6 | 1 | 0.6 | 100 | Proposed pipe culvert |
| 2+150 | 10 | 0.9 | 1 | 0.6 | 100 | Proposed pipe culvert |
| 2+300 | 10 | 0.9 | 1 | 0.6 | 100 | Proposed pipe culvert |

SLOPE STABILITY

## Shear Strength Of Soil

Shear strength of soil is the resistance of soil to shear stress. It determines how well soil can withstand forces that try to cause it to slide or fail. Shear strength is crucial in geotechnical engineering for designing foundations, slopes, retaining walls, and other structures.

Shear strength of soil governs:

* Bearing capacity of foundation
* Liquefaction potential
* Slope failure

### Components of Shear Strength

Shear strength (τ) of soil is given by the Mohr-Coulomb equation:

τ= c+σn tan ϕ

where:

* c = Cohesion (internal molecular attraction between particles)
* σn = Effective normal stress (total stress minus pore water pressure)
* ϕ= Angle of internal friction (resistance due to particle interlocking and friction

**Cohesion (c):**

* Represents the bonding force between soil particles.
* Significant in clayey soils due to electrostatic and chemical attraction.
* Exists even without confining pressure.

**Angle of Internal Friction (ϕ):**

* Represents resistance due to interparticle friction and interlocking.
* Higher in granular soils (sands, gravels).
* Depends on grain size, shape, and packing.

**Effective Normal Stress (σ′):**

* Increases contact between soil grains, improving shear strength.
* Controlled by external loads, water table, and pore water pressure.

### Factors Affecting Shear Strength:

* Soil Type – Sand relies more on friction, while clay relies on cohesion.
* Water Content – High water reduces effective stress, decreasing shear strength.
* Compaction – Well-compacted soil has higher shear strength.
* Stress History – Over consolidated soils have higher shear strength.
* Loading Rate – Rapid loading reduces time for drainage, affecting strength.
* Particle Shape and Size – Angular particles interlock better, increasing friction.

### Types of Shear Strength in Soil:

1. **Total Shear Strength**

Includes both cohesion and internal friction components.

Used in short-term conditions (e.g., rapid loading in clay).

1. **Effective Shear Strength**

* Considers effective stress (excluding pore pressure effects).
* Used for long-term stability analysis.

1. **Apparent Shear Strength**

* Temporary strength due to suction in unsaturated soils.
* Can reduce when moisture increases.

### Shear Strength Tests

1. **Direct Shear Test**
   * Simple and widely used.
   * Measures shear strength under controlled normal stress.
   * Suitable for sands and clays.
2. **Triaxial Shear Test**
   * More accurate and versatile.
   * Can simulate different drainage conditions (CD, CU, UU tests).
   * Measures strength under different confining pressures.
3. **Unconfined Compression Test**
   * Used for cohesive soils (like clay) without lateral pressure.
   * Quick and simple but limited to undrained conditions.
4. **Vane Shear Test**
   * Measures in situ shear strength of soft clays.
   * Used in field conditions where samples are difficult to obtain.

Importance of Shear Strength in Geotechnical Engineering

* Slope Stability – Prevents landslides and slope failures.
* Foundation Design – Determines bearing capacity of soil for structures.
* Retaining Walls – Helps in designing walls that resist soil pressure.
* Road and Embankment Design – Ensures stability under traffic loads.
* Earthquake Resistance – Helps assess liquefaction potential in sandy soils.

Diagram of a stress path diagram

Description automatically generated

FIG: Mohr-Coulomb Graph

#### Direct Shear Test:

The Direct Shear Test is a common laboratory test used in geotechnical engineering to determine the shear strength parameters of soil, including the cohesion (c) and angle of internal friction (φ). It helps assess how soil will behave under shear stress, which is critical in the design of foundations, retaining walls, and slopes.

**Test Procedure:**

1. **Sample Preparation:**

* A soil specimen (typically 60 mm × 60 mm in plan and 25 mm thick) is placed inside a shear box.
* The sample may be undisturbed or remolded, depending on the test requirements.
* The box consists of two halves, which can move horizontally relative to each other.

1. **Normal Load Application:**

* A vertical normal load is applied to the specimen to simulate overburden pressure.

1. **Shearing Process:**

* The upper half of the shear box is moved horizontally at a controlled rate.
* The force required to shear the soil is recorded.

1. **Data Collection:**

* The shear stress at failure is calculated using the applied horizontal force and the area of the shear plane.
* The test is repeated for different normal loads.

1. **Result Analysis:**

* A graph of shear stress vs. normal stress is plotted.
* A straight-line trend (Coulomb's failure envelope) gives the shear strength parameters
* Cohesion and angle of internal friction.

**Advantages:**

* Simple and quick.
* Suitable for all soil types.
* Can be performed on saturated or unsaturated samples.

**Limitations:**

* Stress distribution is not uniform.
* Only measures strength along a predefined plane.
* Drainage conditions may not always be well-controlled.

A diagram of a machine

Description automatically generated

**Fig: Direct Shear Test**

In Lab,

We Calculate the value of cohesion and angle of internal friction by following ways:

Weight of soil=179gm

Weight of water=14.8gm

**Calculation of Shear Strength:**

(τ= c+ σn tanϕ)

Using the given shear strength equation:

Using, we calculate shear strength for different normal stress values:

|  |  |  |
| --- | --- | --- |
| **Trial No** | **Normal Stress (kN/m²)** | **Shear Stress (kN/m²)** |
| 1 | 50 | 39.6 |
| 2 | 100 | 69.2 |
| 3 | 150 | 89.8 |

A diagram of a stress diagram

Description automatically generated

Fig: Normal Stress vs Shear Stress Graph

**Conclusion:**

The calculated shear strength parameters are:

* Cohesion (c) = 16 kN/m²
* Angle of Internal Friction (ϕ) = 28°

#### TRIAL AXIAL COMPRESSION TEST:

The Trial Axial Compression Test is an experimental test used to evaluate the compressive strength, stress-strain behavior, and failure characteristics of materials such as soil, rock, and concrete under axial loading. It is commonly performed in geotechnical and structural engineering to assess material performance under compressive forces.

**Objective:**

* The compressive strength of the material.
* The modulus of elasticity (E) to understand deformation characteristics.
* The failure mode (brittle, ductile, or shear failure).

**Test Apparatus**

* Loading Machine: A Universal Testing Machine (UTM) or Compression Testing Machine is used to apply axial load.
* Dial Gauges or LVDTs: Measure axial deformation.
* Specimen Mold: For shaping cylindrical or cubical specimens.

**Test Procedure**

1. **Sample Preparation**

* A cylindrical or prismatic specimen is prepared (standard dimensions depend on the material).
* The sample is placed centrally in the compression testing machine.

1. **Application of Axial Load**

* A uniform axial compressive load is applied at a controlled rate.
* The axial deformation is measured continuously.

1. **Observation of Failure**

* The sample deforms and eventually fails due to excessive stress.
* The maximum load (P\_max) at failure is recorded.

**Results & Analysis:**

1. **Compressive Strength (σc)**

σc=Pmax/A

where:

* Pmax = Maximum load at failure
* A = Cross-sectional area of the specimen

1. **Modulus of Elasticity (E)**

* Determined from the stress-strain curve as the slope of the elastic portion.

1. **Failure Modes:**

* Brittle Failure: Sudden fracture without significant deformation (rock, concrete).
* Ductile Failure: Gradual deformation before failure (soft clay, ductile materials).
* Shear Failure: Formation of diagonal failure planes.

**Applications**

* Assessing soil and rock strength for foundation and slope stability analysis.
* Quality control in construction materials (e.g., concrete blocks, bricks).
* Evaluating load-bearing capacity of different materials.

## Slope Stability:

### Introduction to Slope Stability

Slope stability refers to the ability of a natural or artificial slope to remain intact without undergoing shear failure or collapse. It is an essential consideration in geotechnical engineering, particularly in construction projects involving hills, embankments, excavations, and dams.

**Why Slope Stability is Important?**

* Prevents landslides and soil erosion.
* Ensures safety of structures and human life.
* Maintains stability in highways, railways, and dams.
* Protects natural landscapes from environmental degradation.

### Causes of Slope Instability

Slope failure occurs when the driving forces (such as gravity and water pressure) exceed the resisting forces (such as soil cohesion and friction).

1. **Geological Factors**

* Weak rock formations (e.g., clay, shale, or fractured rock).
* Presence of faults, joints, or bedding planes.
* Erosion due to weathering.

1. **Hydrological Factors**

* Excessive rainfall increases pore water pressure, reducing soil strength.
* Seepage forces cause internal erosion (piping).
* Groundwater fluctuations weaken slopes.

1. **Human Activities**

* Excavation or construction at the base of a slope.
* Overloading due to buildings, roads, or heavy machinery.
* Deforestation reduces soil stability.

1. **External Forces**

* Earthquakes cause ground shaking and liquefaction.
* Wind erosion gradually weakens slope material.

### Types of Slope Failures

Slope failures are classified based on how the failure surface develops and the material movement.

1. **Rotational (Slump) Failure**

* Occurs in cohesive soils (e.g., clay).
* The failure surface is curved.
* The upper portion of the slope moves downward and outward.

1. **Translational Failure**

* Common in layered soils or fractured rock.
* The failure surface is planar (straight).
* Soil/rock mass slides along a weak layer.

1. **Flow Failure**

* Occurs in saturated fine-grained soils (e.g., loose sand, silt).
* The soil behaves like a fluid.
* Common during heavy rainfall or earthquakes.

1. **Toppling Failure**

* Seen in rock slopes with steep layers.
* Blocks of rock tilt and fall forward due to gravity.

A diagram of different types of slip

Description automatically generated

Fig: **Types of Slope Failures**

### Methods for Slope Stability Analysis

Engineers assess slope stability using analytical, empirical, and numerical methods.

1. **Factor of Safety (FOS) Approach**

FOS= (Resisting force/Driving force)

* FOS > 1.5 → Stable slope
* FOS = 1.0 → Critical condition (failure may occur)
* FOS < 1.0 → Unstable slope (imminent failure)

**Diagram of a stable slope

Description automatically generated**

Fig: SLOPE STABILITY

1. **Numerical Methods**

Used for complex slope geometries or when soil properties are highly variable.

* 1. **Finite Element Method (FEM)**
* Divides the slope into small elements to simulate stress-strain behavior.
* Useful for deformation analysis.
  1. **Finite Difference Method (FDM)**
* Solves slope stability problems using numerical iteration.
* Used in dynamic slope analysis (e.g., earthquake effects).

### Slope Stabilization Techniques

If a slope is found to be unstable, engineers implement stabilization measures to enhance safety.

1. **Surface Drainage Control**

Purpose: Prevents water infiltration, reducing pore pressure.

Methods:

* Surface channels & ditches (divert water away).
* Drainage blankets (filter layers to improve drainage).

1. **Subsurface Drainage Control**

Purpose: Controls groundwater flow to reduce slope instability.

Methods:

* Horizontal drains (pipes drilled into slopes).
* French drains (gravel-filled trenches).

1. **Slope Reinforcement**

Purpose: Increases the shear strength of soil.

Methods:

* Soil Nailing: Steel bars inserted into the slope.
* Geosynthetics (Geogrids & Geotextiles): Improve slope stability by providing reinforcement.

1. **Retaining Structures**

Purpose: Provides mechanical support to the slope.

Methods:

* Retaining Walls (gravity, cantilever, or anchored walls).
* Gabion Walls (wire mesh filled with rocks).

1. **Grading & Slope Modification**

Purpose: Reduces the driving forces acting on the slope.

Methods:

* Terracing & Benching (cutting the slope into steps).
* Flattening the slope angle.

1. **Vegetation & Bioengineering**

Purpose: Increases soil cohesion and reduces erosion.

Methods:

* Planting grass, shrubs, or trees.
* Hydroseeding (spraying seed mixtures on slopes).

### Slope Stability in Cohesive Soil

The stability of slopes in cohesive soil is determined using the Formula. The factor of safety (FOS) for a slope is given by:

At Chainage 0+270km and 0+280km, there is presence of critical section so, we have checked the stability of slope:

C tanϕ

FOS = \_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_

γ Z sin θ\*cos θ tan θ

• γ = Unit weight of soil (kN/m³) =18 kN/m³

• Z = Height or depth of the failure surface (m)=5m

• θ = Slope angle (degrees)=50 degree

• ϕ = Angle of internal friction (degrees)=28 degree

16 tan28

FOS = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_\_\_\_\_\_\_

18\*5sin 50\*cos 50 tan50

= 0.807<1(unsafe)

**Conclusion:**

The stability analysis of the slope at Chainage 0+270 km and 0+280 km using the Factor of Safety (FOS) formula indicates that the calculated FOS is 0.807, which is less than 1, classifying the slope as unstable.

Since the slope is unsafe under the given soil conditions, implementing stabilization measures is necessary. A retaining wall is recommended at these chainages to provide additional support and prevent potential slope failure. Other possible reinforcement methods, such as soil nailing or geogrid reinforcement, may also be considered based on site-specific conditions and feasibility.

ESTIMATION AND COSTING

## Quantity Estimation

Quantity estimation was carried out after the detailed engineering design of the road section.

Table 7.1: Abstract of quantity

|  |  |  |
| --- | --- | --- |
| **Abstract of Quantity** | | |
| **Description** | **Quantity** | **Unit** |
| Drain | 1651.768 | M3 |
| Pavement | 796.9578 | M3 |
| Base | 3187.831 | M3 |
| SubBase | 5180.225 | M3 |
| ShoulderLayer-3 | 915.2734 | M3 |
| Shoulder | 5857.75 | L |
| Cut | 17965.48 | M3 |
| Fill | 4635.766 | M3 |
| DrainCut | 1983.7 | M3 |
| StructureCut | 2509.748 | M3 |
| BackFill | 391.3374 | M3 |
| GabionBreastWall | 2199 | M3 |
| MasonryRetainingWall | 650.5388 | M3 |
| MasonryBreastWall | 20.5 | M3 |
| GabionRetainingWall | 650 | M3 |
| PipeCulvert | 5 | Num |

## Engineering Cost Estimate

After the completion of the alignment, comprehensive survey, and engineering design, Nepalese project cost estimation entails a number of meticulous steps. Alignments are carefully chosen to maximize factors including geography, environmental impact, and community desires in order to produce the greatest choice possible. Input from stakeholders is crucial. Detailed surveys help engineers create comprehensive engineering designs that meet stringent safety and regulatory standards by providing precise information on land contours, existing infrastructure, and any impediments. The foundation of Nepalese costing is the government's standard rate analysis, which takes into account district rates in addition to other relevant sources of labor, supplies, and machinery. While most unit prices are developed by extensive research, certain things, such as bridges and finishing works, follow preset standards from related studies. Quantity estimation is based on established procedures and standardized designs, which ensure precise resource allocation. This rigorous technique makes it easier to distribute cash and build budgets that are both effective and adhere to project goals by carefully evaluating project costs and ensuring that they are in line with local norms and laws.

Table 7.2: Summary of Cost

|  |  |  |
| --- | --- | --- |
|  |  |  |
|  |  |  |
|  |  |  |

### Rate Analysis

Rates for various project components, such as earthworks, retaining structures, side drains, and pipe culverts, are carefully examined. To ensure cost uniformity, culverts and road constructions use a fixed unit rate per meter. The costing model takes into account the road's phased construction approach, allowing for gradual development. The prices for bitumen, pipe culverts, and gravel are averaged. This strategy compensates for the fact that some building supplies may not be required until the site is accessible, therefore their costs will be reimbursed later in the project. The combined experience and expertise of engineers and project planners, along with industry norms and lessons from prior projects, are also used to calculate miscellaneous unit rates. This systematic approach to cost estimation guarantees that resources are distributed effectively while accounting for the dynamic nature of construction projects and the reality of on-site logistics.

# CONCLUSION