University of Jordan

School of Engineering

# Integrated Geometric Design, Pavement Design , and Construction Management of a Minor Arterial Road in Irbid.

A capstone project report submitted in partial fulfillment of the requirement

for the degree of

B. Sc. in civil engineering

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# Executive summary

Due to high traffic loads and the high truck percentage on Irbid-Mafraq Road near Al-Bowaida town, the pavement could not handle the loads and many cracks occurred. Additionally, travelers usually spend 70 Kilometers (Km) going from Al-Bowaida town to Amman through Irbid-Mafraq Road, and nearly 65 Km going to the same destination from Amman-Irbid Road. Finally, the area contains towns that were not directly served by major roads, and they were not easily accessible.

The project aims to transfer the traffic to a minor arterial road which is prepared to handle the current and estimated future loads, decrease the traveling distance, and provide accessibility for empty lands to be developed and existing towns to be served.

The project includes a detailed geometric design of a 70 km/h four-lane minor arterial road with two carriageways divided by a 4-meter median. The design also contains outer shoulders which are 2.5 m and inside 1.5 m shoulders. Also, there are three intersections, two of which are T-intersections, and the other is a four-leg intersection. The road contains 5 horizontal curves with a maximum superelevation of 6% and 5 vertical curves with a minimum slope of 0.34% and a maximum of 2.19%.

The pavement design calculations showed that the surface thickness should be 23 cm with a base of 20.5 cm. Regarding the subbase, the calculations showed that it was not required so we used the minimum thickness of 15.25 cm.

# Table of Contents

# List of Figures

# List of tables

# Chapter 1: Introduction

## 1.1 Background

Highway engineering is part of the civil engineering discipline that intricately involves planning, design, construction, operation, and sustained maintenance of extensive road networks and transportation infrastructure. This field seamlessly integrates diverse principles from civil engineering such as transportation engineering, and urban planning to optimize the functionality and safety of the roadways.

In order to make a successful infrastructure system we need to focus on pavement, a fundamental component that serves as the durable surface covering that accommodates various vehicular loads and transfers to what is known as subgrade. Pavement design is an important process, which takes into account dynamic factors such as traffic loads, soil characteristics, climatic conditions, and materials. These materials, ranging from the resilient properties of asphalt to the enduring strength of concrete, play a pivotal role in creating surfaces that withstand the rigors of constant usage.

Furthermore, the success of pavement design is intricately linked to the implementation of sophisticated techniques, including drainage solutions and good subgrade preparation. The interplay of these elements contributes significantly to the development of resilient and long-lasting pavements within the intricate tapestry of highway projects.

It is worth mentioning that highway engineering and pavement design are inextricably linked, requiring a harmonious synergy of engineering expertise and meticulous planning to create transportation infrastructure that not only facilitates efficient mobility but also stands the test of time in terms of durability and safety.

In conclusion, the highway engineering and pavement design depend on the right application of scientific principles, planning, and sound engineering decisions. The new goal for this industry is to make it more intelligent by utilizing new technologies, sustainable by taking into consideration the environmental impact, and efficient by making the roads safe and durable.

## 1.2 Project Description

The project’s aim is to transfer the traffic that passes through Bowaida town to Amman to a minor arterial road which is prepared to handle the current and estimated future loads, decrease the traveling distance, and provide accessibility for empty lands to be developed and existing towns to be served. The road’s location and general design parameters can be found below.

### 1.2.1 Working Location

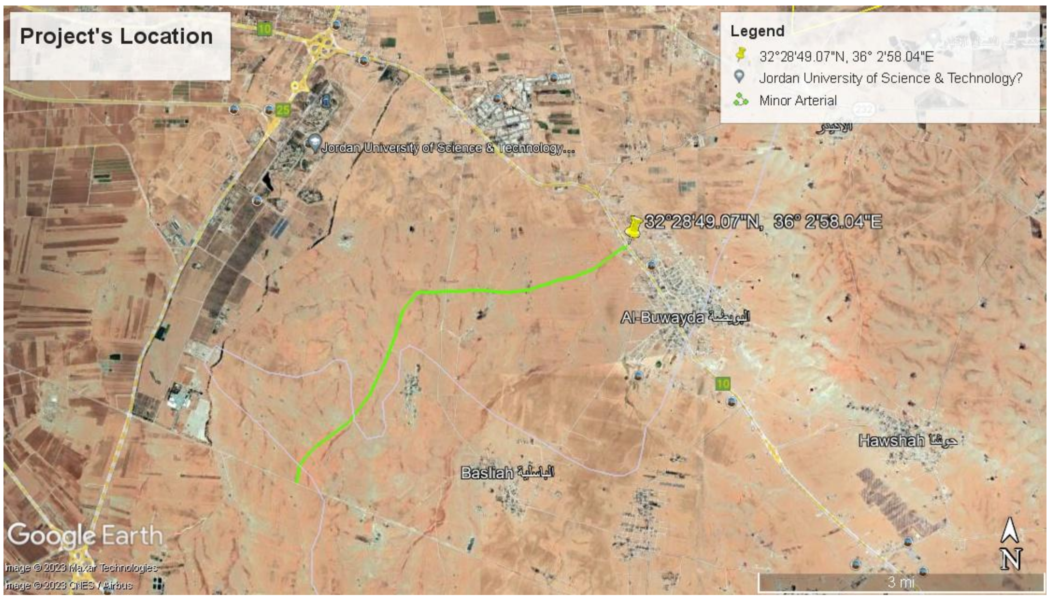



*Figure 1: Works Location*

### 1.2.2 Area Topography

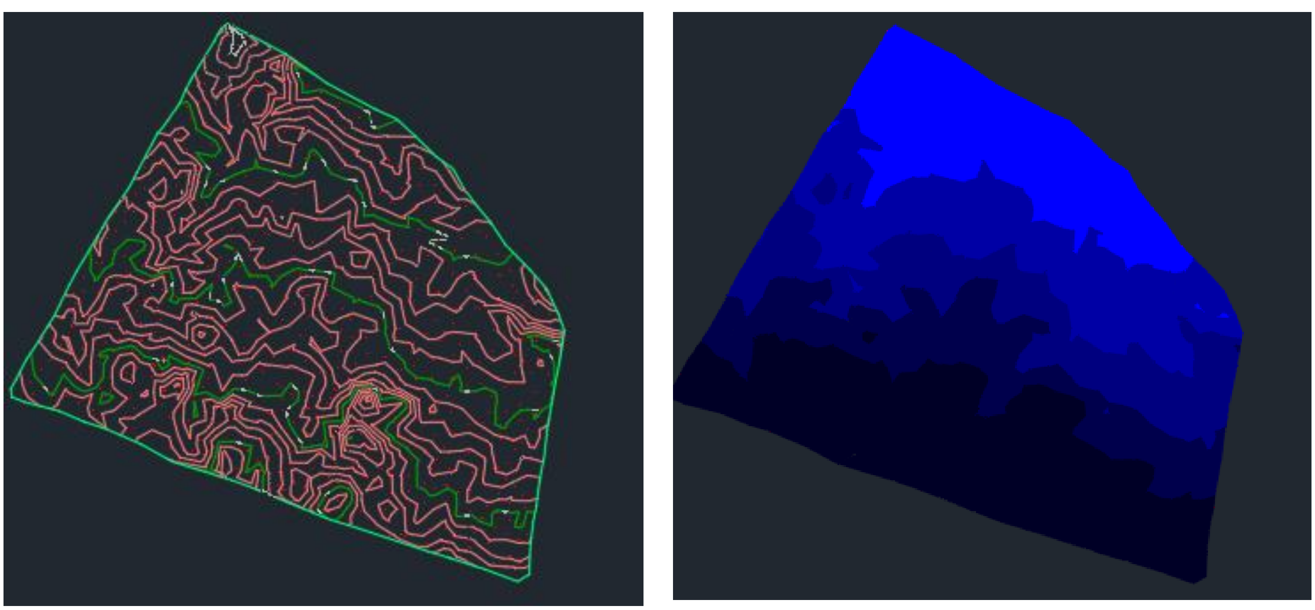


*Figure 2: Contour and Elevation Maps*

In figure 2 we can see the elevation map, which represents the highest point (Darker blue) to the lowest (Lighter blue).

| ID | Minimum Elevation | Maximum Elevation | Color Scheme |
|---|---|---|---|
| 1 | 545.119m | 576.955m | |
| 2 | 576.955m | 593.409m | |
| 3 | 593.409m | 604.990m | |
| 4 | 604.990m | 618.569m | |
| 5 | 618.569m | 632.995m | |
| 6 | 632.995m | 661.007m | |

*Figure 3: Elevation Rates*

### 1.2.3 Soil Parameters

According to actual studies made from official companies in Jordan, the parameters of the soil are:

- CBR: 9.4%
- Mr (since CBR < 10) = 14100 PSI

In addition to the area characteristics, we followed the AASHTO, FHWA, and HCM codes to assure that our design meets the standards. Consequently, we got the following parameters:

### 1.2.4 Road Design Parameters (Calculations can be found in the appendix)

- $ADT_0$ = 8863 vehicle
- Design Speed: 70 km/h
- Number of lanes: 4
- Design Vehicle: SU – 12
- Superelevation = 6% with changing rate of 0.6

### 1.2.5 Pavement Design Parameters (More details in pavement design chapter)

- ESALS = 26 * $10^6$ ESALS
- Surface HMA (E = 450,000 PSI)
- Aggregate base (E = 30,000 PSI)
- Aggregate subbase (E=15,000 PSI)
- Base and subbase to be saturated 5% of the time with good drainage in 1 day.

## 1.3 Objectives

The objective of this project is to make a geometric design that can efficiently drain water, serve the rural towns and give access to empty areas to be developed easily. Furthermore, the pavement design must be able to accommodate the loads that are coming from different trucks type. Finally, to decrease the travel distance as much as possible. The project is focusing on two main streams, highway/pavement design and constucion management.

## 1.4 Scope of work.

As mentioned in the project's description, the project's aim is to design a minor arterial road with its full geometric and pavement design that follows the Jordanian and universal standard. On the other hand, in the management part we aim to construct the road in less time than the average duration of similar projects, which usually takes 10 months.

Finally, traffic analysis is out of the project's scope, but due to the lack of traffic information from official departments, we made a site investigation to estimate the average daily traffic ($ADT_0$), determine the truck's percentage, and determine the design vehicle which will be used for the design of the intersections.

## 1.5 Standards and Codes.

- AASHTO Design of Pavement Structures 1993.
- AASHTO 2018 7$^{th,}$ A Policy on Geometric Design of Highways and Streets Edition.
- HCM
- FHWA (Federal Highway Administration)

## 1.6 Software used:

- Autodesk Civil 3D
- Autodesk AutoCAD
- Primavera
- Google earth
- Excel

# Chapter 2: Planning

The figure below shows the work breakdown structure (WBS) and it illustrates our planning and activities for the project.

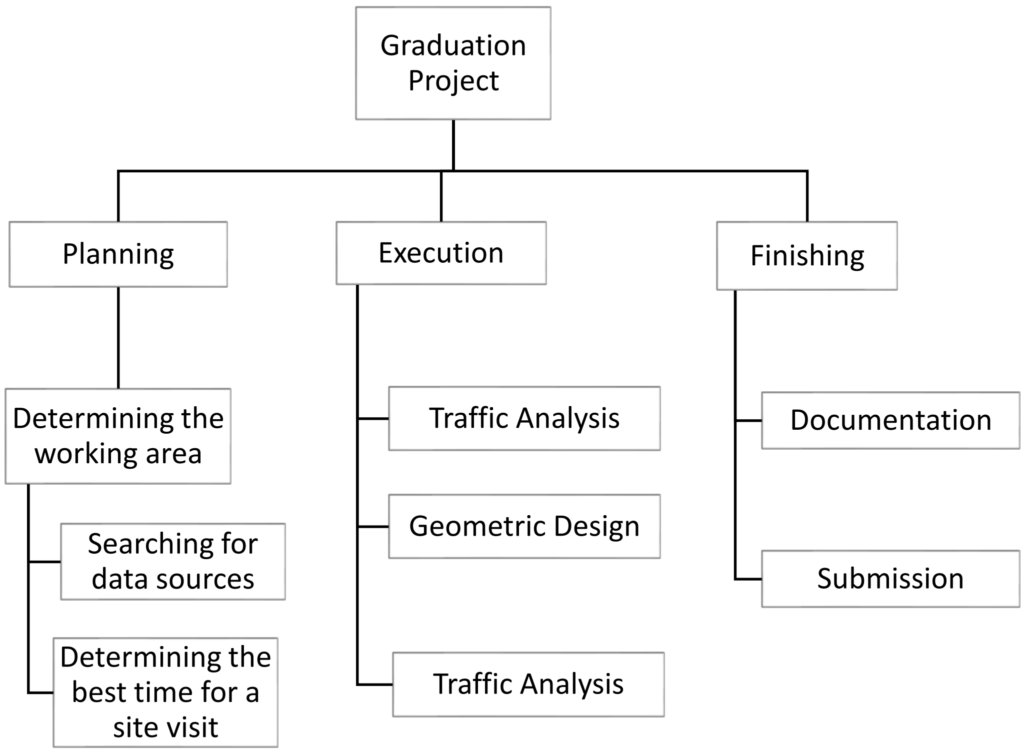



*Figure 4: Work Breakdown Structure for the project in total*

# Chapter 3: Designs & Alternatives

## 3.1 Geometric Design

### 3.1.1 Conceptual Design

The road path was chosen to pass through the empty land passing near towns and avoiding valleys, which will help in serving some towns, give the area a chance to be developed, and decrease the travel path from Bowaida town to Amman. It's design gives a good drainage for water and appropriate stopping/passing sight distance

The road length was 7km in length, with 27 m right of way (ROW) as shown in Figure5.

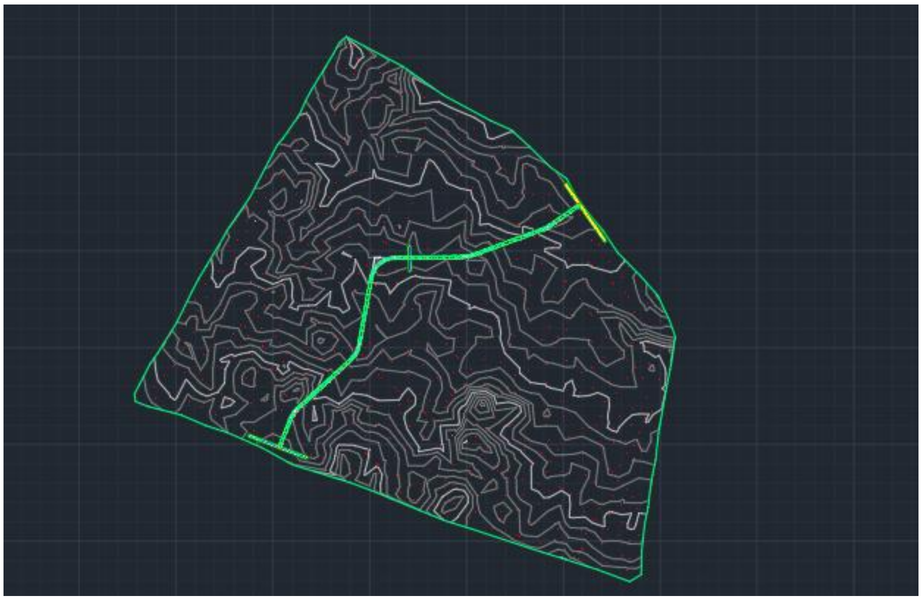


*Figure 5: Road Path*

### 3.1.2 Preliminary Analysis

With the help of GPS technology and google earth software we could determine that the terrain type is considered level with a slope between the highest point and lowest point to be nearly 1%. Thus, the cut fill volumes were approximately the same, which helps us to use the cut volumes to do the filling parts. Check figure 6.

| Cut(adjusted)(Cu. ... | Fill(adjusted)(Cu. ... | Net(adjusted)(Cu. ... | Net Graph |
|---|---|---|---|
| 189422.27 | 195537.91 | 6115.64<Fill> | |
| | | | |

*Figure 6: Cut/Fill Volume Ratio*

## 3.2 Pavement Design Alternative 1 (Flexible Pavement)

### 3.2.1 Conceptual Design

This design follows the most common pavement type in Jordan. It is known for its lower cost, durability, and the ability to carry heavy loads. Unlike rigid pavements, it is created from three layers and materials like hot mix asphalt (HMA). Also, many parameters affect the design like environmental factors, traffic, and drainage. Our goal is to design a pavement that is durable and can last long.

### 3.2.2 Preliminary Analysis

Based on the number of ESALS (26 $*10^6$ ESAL) which were calculated based $ADT_0$, trucks percentage, Mr, it is estimated that the different layers' thickness would be around 8 inches.

## 3.3 Pavement Design Alternative 2 (Rigid Pavement)

### 3.3.1 Conceptual Design

The rigid pavement is not a common type used in Jordan, but it is known for its longer lifespan compared with the flexible and it is more durable than the flexible pavement. On the other hand, rigid pavement is made from one single layer of concrete, and it takes more time to construct than flexible pavement since the concrete needs time to cure. Our goal is to design a rigid pavement and find if it is more efficient in terms of time and cost than the first alternative.

### 3.3.2 Preliminary Analysis

Since we have a high truck percentage, most probably the thickness will be around 9-12 inches with a subbase. The Mr value will not be affected by variation in weather. Also, since there will be no bedrock in our area it might be acceptable to put a subbase 12 inches in depth.

## 3.4 Selection and decision making

In this project, there were two alternatives, rigid pavement, and flexible pavement. The alternative was chosen based on these factors:

**Cost:**

Depending on the cost of each alternative, the choice of pavement was chosen, since the rigid pavement's estimated cost was higher than the flexible pavement, the project proceeded with the flexible where the estimated cost of the rigid pavement according to certified companies was around 5,555,000 JD, and the estimated cost of the flexible pavement was around 1,800,000.

**Time:**

The estimated time for the project was about ten months, since the project had to be completed in four months, clustering had to be done.

Rigid pavements, typically made of concrete, often require more time for curing and setting compared to flexible pavements. The construction process involves placing and finishing the concrete, followed by a curing period during which the concrete gains strength.

As for Flexible pavements, they are usually made of asphalt, may have a faster construction time compared to rigid pavements. Asphalt can be laid and compacted relatively quickly, and it sets faster than concrete.

So, for this project flexible pavement was chosen according to the time and cost factors.

# Chapter 4: Project Design

## 4.1 Geometric Design

In this section, all the elements and procedures used to design geometrically the road will be illustrated. All the constraints will be listed for each part. It is worth noting that economical, legal, and operational constraints were taken into consideration while designing this project.

### 4.1.1 Design Speed, Design Vehicle, and Typical Cross Section.

The design vehicle was chosen to be SU-12 so other vehicles can move through the intersections and make a U-turn. This decision was based on the sight visit we made to the location.

For the **design speed it was chosen to be 70 km/h** since our design took a place in a rural town context area, and this speed was determined by AASHTO for safety reasons.

Regarding the number of lanes and their dimensions, **Table 1** from the AAHSTO shows that if the traffic exceeds 2000 v/d and with a design speed of 70km/h the minimum width for the travel way must be 6.6 meters. Consequently, our road consists of 4 lanes with inner and outer shoulders divided by a median for safety reasons, and a lanes width of 3.65 meters. On the other hand, the width of the inner shoulders was 1.5 m, and for the outer shoulders 2.5m. Finally, the median's total width was 4 m. Thus, the right of way (ROW) is 27 m.

*Table 1: Minimum Width of Traveled Way and shoulders*

| Metric | | | |
|---|---|---|---|
| Design Speed (km/h) | Minimum Width of Traveled Way (m) for Specified Design Volume (veh/day) | | |
| | Under 400 | 400 to 2000 | over 2000 |
| 30 | 6.0[a] | 6.0 | 6.6 |
| 40 | 6.0[a] | 6.0 | 6.6 |
| 50 | 6.0[a] | 6.0 | 6.6 |
| 60 | 6.0[a] | 6.6 | 6.6 |
| 70 | 6.0 | 6.6 | 6.6 |

| All Speeds | Width of Shoulder on Each Side of Road (m) | | |
|---|---|---|---|
| | 0.6 | 1.5 | 2.4 |

### 4.1.2 Horizonal Alignment

When it comes to horizontal alignment, multiple factors affect its design from the radius of curves to super elevation. In our design we focused on passing near unserved towns and the empty area to help in its future development. Regarding the curves, all of them are simple curves. Figure 8 shows the path of the road.

*Figure 7: Path of the road*

The horizontal curves design was based on AASHTO standards, a superelevation maximum rate of 6% was used to design the curves since 4% rates are preferrable in urban areas only. **Table 2** shows the superelevation rate with their corresponding minimum radius.

The minimum radius for horizontal curves with superelevation rate must be 360 m. In our design all the horizontal curves satisfied this point as shown in figure 9.
(sample of curve calculations are available in appendix A)

| No. | Type | Parameter C... | Length | Transition Length Table | Radius |
|---|---|---|---|---|---|
| 1 | Line | Two points | 576.406m | | |
| 2 | Curve | Radius | 164.120m | 4 Lane | 629.838m |
| 3 | Line | Two points | 1172.849m | | |
| 4 | Curve | Radius | 186.915m | 4 Lane | 550.000m |
| 5 | Line | Two points | 1080.710m | | |
| 6 | Curve | Radius | 553.126m | 4 Lane | 400.000m |
| 7 | Line | Two points | 1061.786m | | |
| 8 | Curve | Radius | 325.855m | 4 Lane | 500.000m |
| 9 | Line | Two points | 1137.687m | | |
| 10 | Curve | Radius | 224.920m | 4 Lane | 500.000m |

*Figure 8: Horizontal Curves Data*

*Table 2: Minimum Radius*

| Metric | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $e$ (%) | $V_d$ = 20 km/h | $V_d$ = 30 km/h | $V_d$ = 40 km/h | $V_d$ = 50 km/h | $V_d$ = 60 km/h | $V_d$ = 70 km/h | $V_d$ = 80 km/h | $V_d$ = 90 km/h | $V_d$ = 100 km/h | $V_d$ = 110 km/h | $V_d$ = 120 km/h | $V_d$ = 130 km/h |
| | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) | $R$ (m) |
| NC | 184 | 443 | 784 | 1090 | 1490 | 1970 | 2440 | 2970 | 3630 | 4180 | 4900 | 5360 |
| RC | 133 | 322 | 571 | 791 | 1090 | 1450 | 1790 | 2190 | 2680 | 3090 | 3640 | 4000 |
| 2.2 | 119 | 288 | 512 | 711 | 976 | 1300 | 1620 | 1980 | 2420 | 2790 | 3290 | 3620 |
| 2.4 | 107 | 261 | 463 | 644 | 885 | 1190 | 1470 | 1800 | 2200 | 2550 | 3010 | 3310 |
| 2.6 | 97 | 237 | 421 | 587 | 808 | 1080 | 1350 | 1650 | 2020 | 2340 | 2760 | 3050 |
| 2.8 | 88 | 216 | 385 | 539 | 742 | 992 | 1240 | 1520 | 1860 | 2160 | 2550 | 2830 |
| 3.0 | 81 | 199 | 354 | 496 | 684 | 916 | 1150 | 1410 | 1730 | 2000 | 2370 | 2630 |
| 3.2 | 74 | 183 | 326 | 458 | 633 | 849 | 1060 | 1310 | 1610 | 1870 | 2220 | 2460 |
| 3.4 | 68 | 169 | 302 | 425 | 588 | 790 | 988 | 1220 | 1500 | 1740 | 2080 | 2310 |
| 3.6 | 62 | 156 | 279 | 395 | 548 | 738 | 924 | 1140 | 1410 | 1640 | 1950 | 2180 |
| 3.8 | 57 | 144 | 259 | 368 | 512 | 690 | 866 | 1070 | 1320 | 1540 | 1840 | 2060 |
| 4.0 | 52 | 134 | 241 | 344 | 479 | 648 | 813 | 1010 | 1240 | 1450 | 1740 | 1950 |
| 4.2 | 48 | 124 | 224 | 321 | 449 | 608 | 766 | 948 | 1180 | 1380 | 1650 | 1850 |
| 4.4 | 43 | 115 | 208 | 301 | 421 | 573 | 722 | 895 | 1110 | 1300 | 1570 | 1760 |
| 4.6 | 38 | 106 | 192 | 281 | 395 | 540 | 682 | 847 | 1050 | 1240 | 1490 | 1680 |
| 4.8 | 33 | 96 | 178 | 263 | 371 | 509 | 645 | 803 | 996 | 1180 | 1420 | 1610 |
| 5.0 | 30 | 87 | 163 | 246 | 349 | 480 | 611 | 762 | 947 | 1120 | 1360 | 1540 |
| 5.2 | 27 | 78 | 148 | 229 | 328 | 454 | 579 | 724 | 901 | 1070 | 1300 | 1480 |
| 5.4 | 24 | 71 | 136 | 213 | 307 | 429 | 549 | 689 | 859 | 1020 | 1250 | 1420 |
| 5.6 | 22 | 65 | 125 | 198 | 288 | 405 | 521 | 656 | 819 | 975 | 1200 | 1360 |
| 5.8 | 20 | 59 | 115 | 185 | 270 | 382 | 494 | 625 | 781 | 933 | 1150 | 1310 |
| 6.0 | 19 | 55 | 106 | 172 | 253 | 360 | 469 | 595 | 746 | 894 | 1100 | 1260 |

The following figure shows the alignment with all the stations.

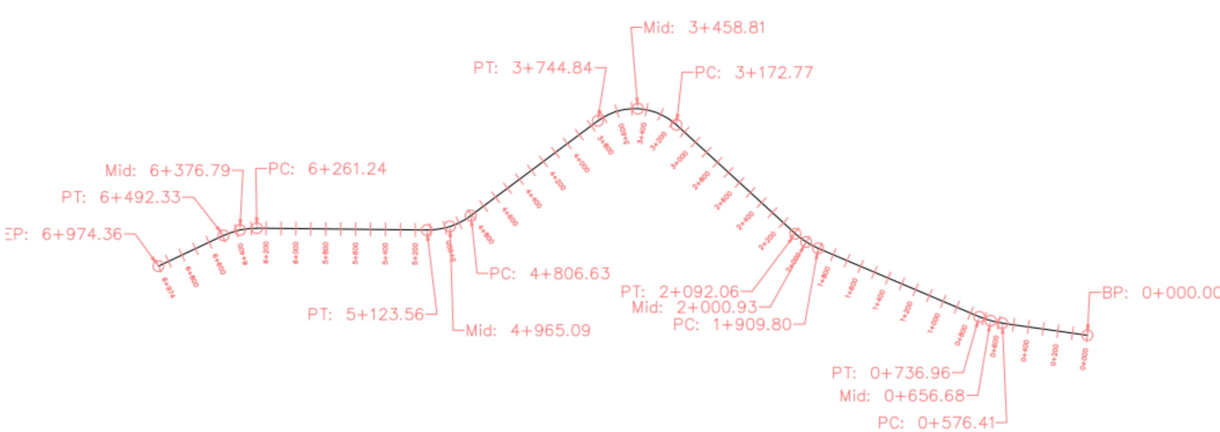



*Figure 9: Horizontal Alignment stations.*

Regarding superelevation, two important concepts determine its efficiency. Runoff and Runout which are the tangent length in which the pivoting around the median takes place. It is worth noting that 66.67% of the runoff distance took place on the tangent and the remaining was on the horizontal curve. This decision was based on AASHTO recommendation for safety reasons. **Table 3** show the minimum length for runoff and runout, based on design speed and superelevation.

*Table 3: Runoff and Runout length*

| | | | | | | | | | | | | Metric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $e$ (%) | $V_d$ = 20 km/h | | $V_d$ = 30 km/h | | $V_d$ = 40 km/h | | $V_d$ = 50 km/h | | $V_d$ = 60 km/h | | $V_d$ = 70 km/h | |
| | Number of Lanes Rotated. Note that 1 lane rotated is typical for a 2-lane hi | | | | | | | | | | | |
| | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 2 |
| | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) | $L_r$ (m) |
| 1.5 | 7 | 10 | 7 | 11 | 8 | 12 | 8 | 13 | 9 | 14 | 10 | 15 |
| 2.0 | 9 | 14 | 10 | 14 | 10 | 15 | 11 | 17 | 12 | 18 | 13 | 20 |
| 2.2 | 10 | 15 | 11 | 16 | 11 | 17 | 12 | 18 | 13 | 20 | 14 | 22 |
| 2.4 | 11 | 16 | 12 | 17 | 12 | 19 | 13 | 20 | 14 | 22 | 16 | 24 |
| 2.6 | 12 | 18 | 12 | 19 | 13 | 20 | 14 | 22 | 16 | 23 | 17 | 26 |
| 2.8 | 13 | 19 | 13 | 20 | 14 | 22 | 16 | 23 | 17 | 25 | 18 | 27 |
| 3.0 | 14 | 20 | 14 | 22 | 15 | 23 | 17 | 25 | 18 | 27 | 20 | 29 |
| 3.2 | 14 | 22 | 15 | 23 | 16 | 25 | 18 | 27 | 19 | 29 | 21 | 31 |
| 3.4 | 15 | 23 | 16 | 24 | 17 | 26 | 19 | 28 | 20 | 31 | 22 | 33 |
| 3.6 | 16 | 24 | 17 | 26 | 19 | 28 | 20 | 30 | 22 | 32 | 24 | 35 |
| 3.8 | 17 | 26 | 18 | 27 | 20 | 29 | 21 | 32 | 23 | 34 | 25 | 37 |
| 4.0 | 18 | 27 | 19 | 29 | 21 | 31 | 22 | 33 | 24 | 36 | 26 | 39 |
| 4.2 | 19 | 28 | 20 | 30 | 22 | 32 | 23 | 35 | 25 | 38 | 27 | 41 |
| 4.4 | 20 | 30 | 21 | 32 | 23 | 34 | 24 | 37 | 26 | 40 | 29 | 43 |
| 4.6 | 21 | 31 | 22 | 33 | 24 | 35 | 25 | 38 | 28 | 41 | 30 | 45 |
| 4.8 | 22 | 32 | 23 | 35 | 25 | 37 | 27 | 40 | 29 | 43 | 31 | 47 |
| 5.0 | 23 | 34 | 24 | 36 | 26 | 39 | 28 | 42 | 30 | 45 | 33 | 49 |
| 5.2 | 23 | 35 | 25 | 37 | 27 | 40 | 29 | 43 | 31 | 47 | 34 | 51 |
| 5.4 | 24 | 36 | 26 | 39 | 28 | 42 | 30 | 45 | 32 | 49 | 35 | 53 |
| 5.6 | 25 | 38 | 27 | 40 | 29 | 43 | 31 | 47 | 34 | 50 | 37 | 55 |
| 5.8 | 26 | 39 | 28 | 42 | 30 | 45 | 32 | 48 | 35 | 52 | 38 | 57 |
| 6.0 | 27 | 41 | 29 | 43 | 31 | 46 | 33 | 50 | 36 | 54 | 39 | 59 |

As it is shown the minimum value for the runoff and runout values must be 59m and 20 m, respectively. But we must maintain a typical value for the changing rate in slope which is 0.06. Thus, the runoff and runout values we used in our design were 100 m and 40 m, in the same order. Figure 9 represents a sample of our values.

(Sample of calculations are in appendix B)

| | | | | | | |
|---|---|---|---|---|---|---|
| Curve.1 | | | | | | |
| Transition In Region | 140.000m | | | | | |
| Runout | 40.000m | | | | | |
| End Normal Crown | | -2.00% | -0.004 | 0.000 | -2.00% | -0.004 |
| Level Crown | | 0.00% | 0.050 | 0.000 | 0.00% | 0.050 |
| Runoff | 100.000m | | | | | |
| Level Crown | | 0.00% | 0.050 | 0.000 | 0.00% | 0.050 |
| Reverse Crown | | 2.00% | 0.060 | 0.000 | 2.00% | 0.060 |
| Begin Curve | | | | | | |
| Begin Full Super | | 6.00% | 0.060 | 0.000 | 6.00% | 0.060 |

*Figure 10: Horizontal Alignment Curves*

In addition, all the results for the curves designed in this project are illustrated in the next figure.

Circular Curve Data

| | | | |
|---|---|---|---|
| Delta: | 14° 55' 47.3605" | Type: | RIGHT |
| Radius: | 629.838 | | |
| Length: | 164.120 | Tangent: | 82.527 |
| Mid-Ord: | 5.338 | External: | 5.384 |
| Chord: | 163.656 | Course: | S 62° 20' 38.3641" W |

Circular Curve Data

| | | | |
|---|---|---|---|
| Delta: | 19° 28' 18.1952" | Type: | RIGHT |
| Radius: | 550.000 | | |
| Length: | 186.915 | Tangent: | 94.368 |
| Mid-Ord: | 7.921 | External: | 8.037 |
| Chord: | 186.017 | Course: | S 79° 32' 41.1420" W |

Circular Curve Data

| | | | |
|---|---|---|---|
| Delta: | 79° 13' 46.1388" | Type: | LEFT |
| Radius: | 400.000 | | |
| Length: | 553.126 | Tangent: | 331.082 |
| Mid-Ord: | 91.860 | External: | 119.245 |
| Chord: | 510.098 | Course: | S 49° 39' 57.1702" W |

Circular Curve Data

| | | | |
|---|---|---|---|
| Delta: | 37° 20' 24.8900" | Type: | RIGHT |
| Radius: | 500.000 | | |
| Length: | 325.855 | Tangent: | 168.950 |
| Mid-Ord: | 26.311 | External: | 27.773 |
| Chord: | 320.119 | Course: | S 28° 43' 16.5458" W |

Circular Curve Data

| | | | |
|---|---|---|---|
| Delta: | 25° 46' 25.9683" | Type: | LEFT |
| Radius: | 500.000 | | |
| Length: | 224.920 | Tangent: | 114.395 |
| Mid-Ord: | 12.594 | External: | 12.919 |
| Chord: | 223.028 | Course: | S 34° 30' 16.0066" W |

*Figure 11: Horizontal Curves Data*

### 4.1.3 Vertical Alignment

In the vertical alignment design our goals were to avoid low points, offer a good water drainage, and attain the least cut/fill volumes for economic reasons. Furthermore, two types of curves can occur in the vertical alignment the crest and sag curves. It is worth mentioning that the curves' design and alignment grades are governed by multiple factors such as terrain type, speed, and stopping sight distance (SSD).

Table 4 shows the maximum allowable grades for a level terrain. Also, based on practical experience AASHTO code suggested that a minimum grade value must be between 0.3% _ 0.5% to attain good water drainage.

*Table 4: Max grades based on terrain and design speed*

| Type of Terrain | Maximum Grade (%) for Specified Design Speed (mph) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 and above |
| Level | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 |
| Rolling | 8 | 8 | 7 | 7 | 6 | 6 | 5 | 5 | 4 | 4 |
| Mountainous | 10 | 9 | 8 | 8 | 8 | 7 | 7 | 6 | 6 | 5 |

| Type of Terrain | Maximum Grade (%) for Specified Design Speed (km/h) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 and above |
| Level | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 3 | 3 |
| Rolling | 8 | 8 | 7 | 6 | 6 | 5 | 5 | 4 | 4 |
| Mountainous | 10 | 9 | 8 | 8 | 7 | 7 | 6 | 6 | 5 |

In our design for the vertical alignment, we faced crests and sags, and we designed them based on appropriate rate of curvature values (K) which are based on SSD. The values of K are shown below.

| Metric | | | |
|---|---|---|---|
| Design Speed (km/h) | Stopping Sight Distance (m) | Rate of Vertical Curvature, Ka | |
| | | Calculated | Design |
| 20 | 20 | 0.6 | 1 |
| 30 | 35 | 1.9 | 2 |
| 40 | 50 | 3.8 | 4 |
| 50 | 65 | 6.4 | 7 |
| 60 | 85 | 11.0 | 11 |
| 70 | 105 | 16.8 | 17 |
| 80 | 130 | 25.7 | 26 |

Consequently, figure 11 shows the K values for our vertical curves which shows that the design is safe and following the standards and shows the slopes of the road.

| No. | PVI Station | PVI Elevation | Grade In | Grade Out | A (Grade Change) | Profile Curve Type | Profile Curve Length | K Value |
|---|---|---|---|---|---|---|---|---|
| 1 | 0+000.00m | 561.975m | | 1.65% | | | | |
| 2 | 1+594.46m | 588.206m | 1.65% | 0.34% | 1.30% | Crest | 258.729m | 198.832 |
| 3 | 3+463.30m | 594.633m | 0.34% | 1.53% | 1.18% | Sag | 115.781m | 98.019 |
| 4 | 4+216.34m | 606.117m | 1.53% | 0.40% | 1.13% | Crest | 184.048m | 163.445 |
| 5 | 4+960.85m | 609.088m | 0.40% | 2.15% | 1.75% | Sag | 140.380m | 80.000 |
| 6 | 6+100.69m | 633.637m | 2.15% | 0.87% | 1.28% | Crest | 239.762m | 187.070 |
| 7 | 6+966.41m | 641.187m | 0.87% | | | | | |

*Figure 12: K values for the designed road.*

Finally, figure 12 shows the whole vertical alignment (green) and how it is built on the existing ground (red) level to attain low and equal cut/full volumes.

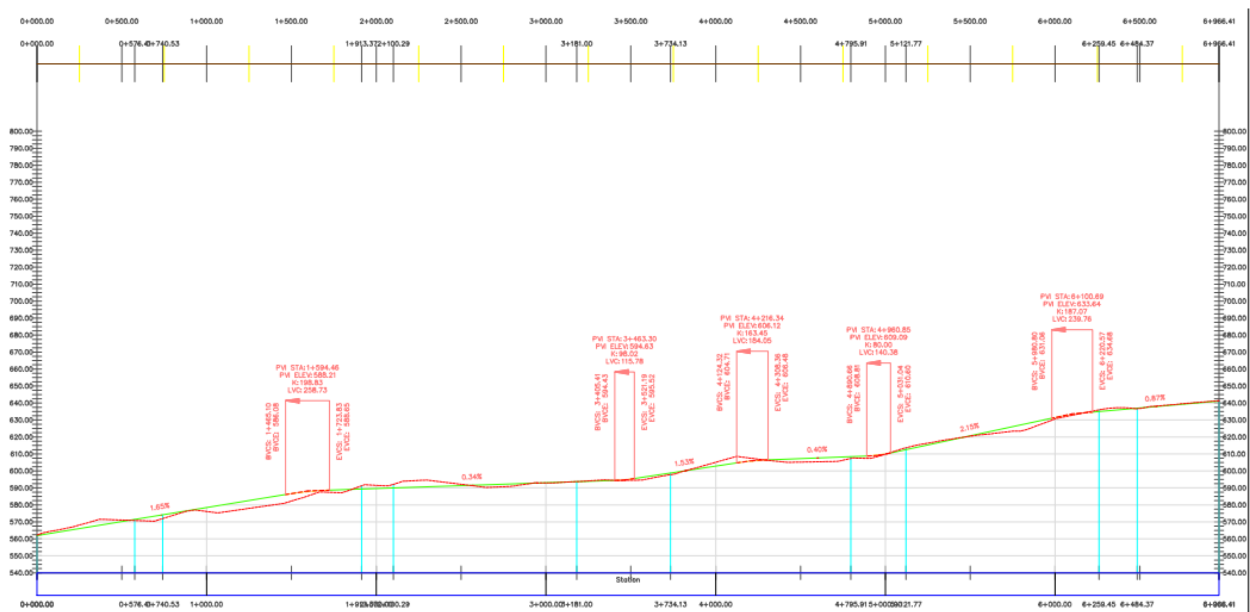


*Figure 13: Vertical Alignment Stations*

Finally, in the following figure all the vertical curves design data are illustrated.

Vertical Curve Information:(crest curve)

| | | | |
|---|---|---|---|
| PVC Station: | 4+124.32 | Elevation: | 604.714m |
| PVI Station: | 4+216.34 | Elevation: | 606.117m |
| PVT Station: | 4+308.36 | Elevation: | 606.484m |
| High Point: | 4+308.36 | Elevation: | 606.484m |
| Grade in: | 1.53% | Grade out: | 0.40% |
| Change: | 1.13% | K: | 163.445m |
| Curve Length: | 184.048m | Curve Radius | 16,344.515m |
| Passing Distance: | 1,465.282m | Stopping Distance: | 682.205m |

Vertical Curve Information:(crest curve)

| | | | |
|---|---|---|---|
| PVC Station: | 1+465.10 | Elevation: | 586.078m |
| PVI Station: | 1+594.46 | Elevation: | 588.206m |
| PVT Station: | 1+723.83 | Elevation: | 588.651m |
| High Point: | 1+723.83 | Elevation: | 588.651m |
| Grade in: | 1.65% | Grade out: | 0.34% |
| Change: | 1.30% | K: | 198.832m |
| Curve Length: | 258.729m | Curve Radius | 19,883.241m |
| Passing Distance: | 1,317.738m | Stopping Distance: | 640.088m |

Vertical Curve Information:(sag curve)

| | | | |
|---|---|---|---|
| PVC Station: | 4+890.66 | Elevation: | 608.808m |
| PVI Station: | 4+960.85 | Elevation: | 609.088m |
| PVT Station: | 5+031.04 | Elevation: | 610.599m |
| Low Point: | 4+890.66 | Elevation: | 608.808m |
| Grade in: | 0.40% | Grade out: | 2.15% |
| Change: | 1.75% | K: | 80.000m |
| Curve Length: | 140.380m | Curve Radius | 8,000.000m |
| Headlight Distance: | 34,941.709m | | |

Vertical Curve Information:(sag curve)

| | | | |
|---|---|---|---|
| PVC Station: | 3+405.41 | Elevation: | 594.433m |
| PVI Station: | 3+463.30 | Elevation: | 594.633m |
| PVT Station: | 3+521.19 | Elevation: | 595.515m |
| Low Point: | 3+405.41 | Elevation: | 594.433m |
| Grade in: | 0.34% | Grade out: | 1.53% |
| Change: | 1.18% | K: | 98.019m |
| Curve Length: | 115.781m | Curve Radius | 9,801.948m |
| Headlight Distance: | | | |

Vertical Curve Information:(crest curve)

| | | | |
|---|---|---|---|
| PVC Station: | 5+980.80 | Elevation: | 631.055m |
| PVI Station: | 6+100.69 | Elevation: | 633.637m |
| PVT Station: | 6+220.57 | Elevation: | 634.683m |
| High Point: | 6+220.57 | Elevation: | 634.683m |
| Grade in: | 2.15% | Grade out: | 0.87% |
| Change: | 1.28% | K: | 187.070m |
| Curve Length: | 239.762m | Curve Radius | 18,706.980m |
| Passing Distance: | 1,326.402m | Stopping Distance: | 638.403m |

*Figure 14: Vertical Curves Data*

### 4.1.4 Intersections

In our project we had to design three intersections, in which two of them were three legs intersection (T-Intersections) and the other was a four legs intersection.

Before diving into the details of the design it is worth mentioning that our design of the vertical alignment of the road was built about the existing roads level. Thus, the difference between our proposed road and the existing roads was less than 1m. Also, the proposed road intersects the existing roads with nearly 90 degrees based on AASHTO recommendation.

Regarding the design, the first thing we had to determine is the design vehicle which its turning radius allow all the vehicles to turn smoothly. After our sight investigation and based on the design vehicle that is used in Jordan, we determined that the design vehicle is SU-12. All of the details of turning values for this type of vehicle are shown in following table.

*Table 5: Turning Radius*

| Design Vehicle Type | Passen-ger Car | Single-Unit Truck | Single-Unit Truck (Three Axle) |
|---|---|---|---|
| Symbol | P | SU-9 | SU-12 |
| Minimum Design Turning Radius (m) | 7.26 | 12.73 | 15.60 |
| Center-lineb Turning Radius (CTR) (m) | 6.40 | 11.58 | 14.46 |
| Minimum Inside Radius (m) | 4.39 | 8.64 | 11.09 |

After finding the turning values, we linked the start and the end of the proposed road with the existing roads and connected the curb return with the profile of both roads to make sure that the intersection is designed good. The next figures show the procedure for the first T-Intersection.

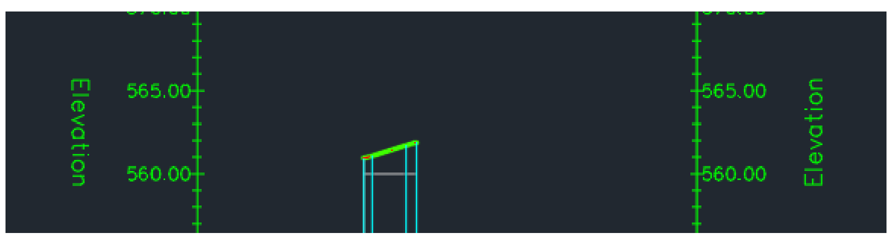
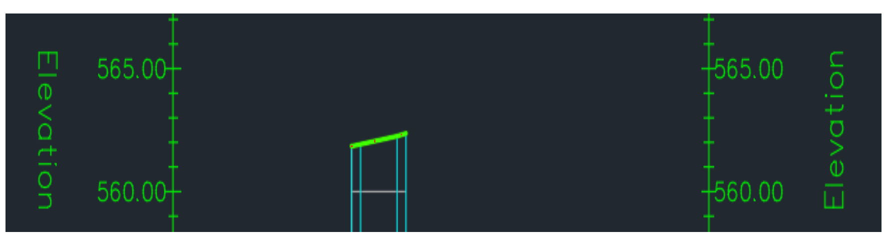



*Figure 15 Connection of curbs.*



After connecting the curb return with both of the proposed road and the existing road elevation, the intersection was ready, and it is showed in the figure below.

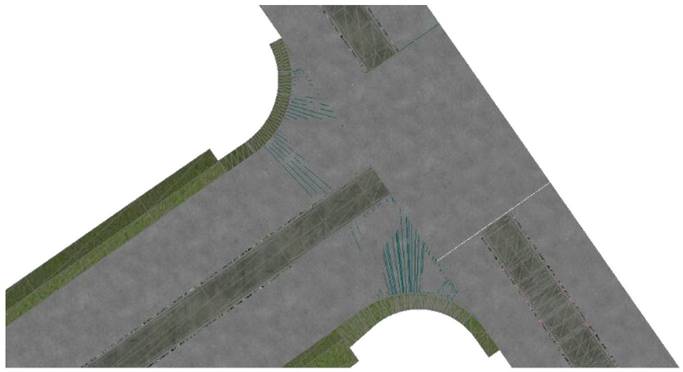


Figure 16: First T-intersection

In the following figure, the four leg and the last T intersections are shown.

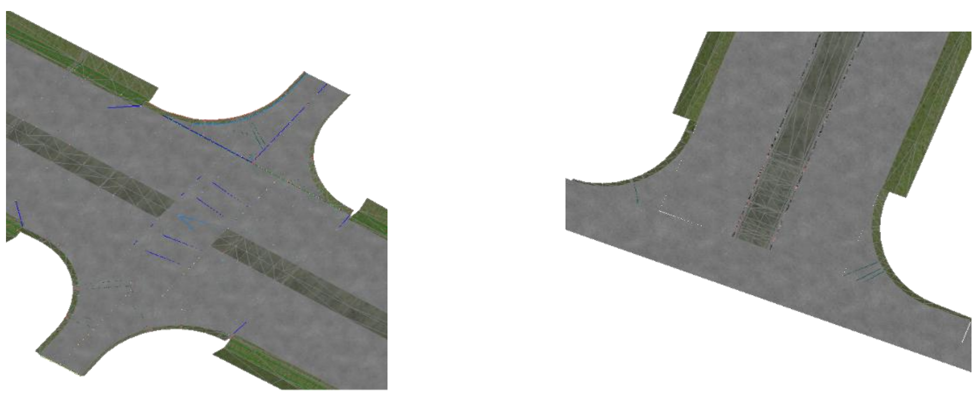


Figure 17: Fourlegs and T-intersection

Finally, all the intersection’s legs must have an adequate SSD which equals 130 m. All the intersection legs are designed with more than this value.

### 4.1.5 Typical Cross-Section

After finishing the design, the typical cross-section is shown below.

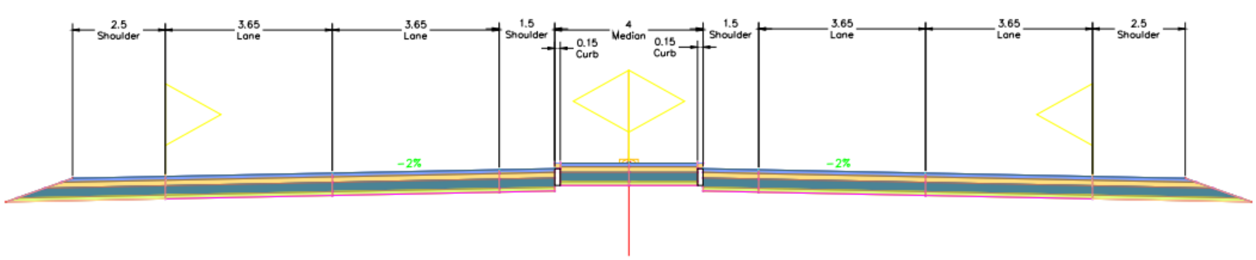



Figure 18: Typical Cross Section

## 4.2 Design Alternative 1 (Flexible Pavement)

When it comes to pavement, two main types are focused on. The first one is the flexible pavement. To design the flexible pavement, we to know the ADT and the trucks percentage in order to find the equivalent single load axle (ESAL). We already know that our ADT = 8863 vehicles.

### 4.2.1 ESALS

Following AASHTO and assuming SN=5 and Pt =2.5 we will do the following:
Our peak hour consists of 12.4% trucks percentage with different types of trucks:

- Single Unit_2 axles as 9.4% of the trucks
- Single Trailer _4 axles as 0.8% of the trucks
- Single Trailer_5 axles as 0.4% of the trucks
- Single Trailer _6 axles as 0.16% of the trucks

After contacting the Ministry of public works, we were able to know each truck's gross weight and following the FHWA bridge constraints, we knew the load distribution on the axles for each truck. Consequently, using the following table we could find the ESAL/truck for each type of truck.

*Table 6: Pavement Structural Number (SN)*

**Table D.6. Axle Load Equivalency Factors for Flexible Pavements, Triple Axles and $p_t$ of 2.5**

| Axle Load (kips) | Pavement Structural Number (SN) | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| 2 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 4 | .0002 | .0002 | .0002 | .0001 | .0001 | .0001 |
| 6 | .0006 | .0007 | .0005 | .0004 | .0003 | .0003 |
| 8 | .001 | .002 | .001 | .001 | .001 | .001 |
| 10 | .003 | .004 | .003 | .002 | .002 | .002 |
| 12 | .005 | .007 | .006 | .004 | .003 | .003 |
| 14 | .008 | .012 | .010 | .008 | .006 | .006 |
| 16 | .012 | .019 | .018 | .013 | .011 | .010 |
| 18 | .018 | .029 | .028 | .021 | .017 | .016 |
| 20 | .027 | .042 | .042 | .032 | .027 | .024 |
| 22 | .038 | .058 | .060 | .048 | .040 | .036 |
| 24 | .053 | .078 | .084 | .068 | .057 | .051 |
| 26 | .072 | .103 | .114 | .095 | .080 | .072 |
| 28 | .098 | .133 | .151 | .128 | .109 | .099 |
| 30 | .129 | .169 | .195 | .170 | .145 | .133 |
| 32 | .169 | .213 | .247 | .220 | .191 | .175 |
| 34 | .219 | .266 | .308 | .281 | .246 | .228 |
| 36 | .279 | .329 | .379 | .352 | .313 | .292 |
| 38 | .352 | .403 | .461 | .436 | .393 | .368 |
| 40 | .439 | .491 | .554 | .533 | .487 | .459 |
| 42 | .543 | .594 | .661 | .644 | .597 | .567 |
| 44 | .666 | .714 | .781 | .769 | .723 | .692 |
| 46 | .811 | .854 | .918 | .911 | .868 | .838 |
| 48 | .979 | 1.015 | 1.072 | 1.069 | 1.033 | 1.005 |

The following values will represent the truck factor for each type.

- **Single Unit_2:** 3.02 LEF
- **Single Trailer _4:** 5.1 LEF
- **Single Trailer_5:** 4.68 LEF
- **Single Trailer _6:** 4.18 LEF

Now, since we are designing flexible pavement, we are going to design for 20 years. Also, we need to know the growth rate in Jordan. After contacting the department of statistics in Jordan we could find the value to be 2%. Finally, we need to find the value of Gy which can be found from the following table.

*Table 7: Growth Rate and Analysis Period*

**Table D.20. Traffic Growth Factors***

| Analysis Period Years (n) | Annual Growth Rate, Percent (g) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No Growth | 2 | 4 | 5 | 6 | 7 | 8 | 10 |
| 1 | 1 0 | 1 0 | 1 0 | 1 0 | 1 0 | 1 0 | 1 0 | 1 0 |
| 2 | 2 0 | 2 02 | 2 04 | 2 05 | 2 06 | 2 07 | 2 08 | 2 10 |
| 3 | 3 0 | 3 06 | 3 12 | 3 15 | 3 18 | 3 21 | 3 25 | 3 31 |
| 4 | 4 0 | 4 12 | 4 25 | 4 31 | 4 37 | 4 44 | 4 51 | 4 64 |
| 5 | 5 0 | 5 20 | 5 42 | 5 53 | 5 64 | 5 75 | 5 87 | 6 11 |
| 6 | 6 0 | 6 31 | 6 63 | 6 80 | 6 98 | 7 15 | 7 34 | 7 72 |
| 7 | 7 0 | 7 43 | 7 90 | 8 14 | 8 39 | 8 65 | 8 92 | 9 49 |
| 8 | 8 0 | 8 58 | 9 21 | 9 55 | 9 90 | 10 26 | 10 64 | 11 44 |
| 9 | 9 0 | 9 75 | 10 58 | 11 03 | 11 49 | 11 98 | 12 49 | 13 58 |
| 10 | 10 0 | 10 95 | 12 01 | 12 58 | 13 18 | 13 82 | 14 49 | 15 94 |
| 11 | 11 0 | 12 17 | 13 49 | 14 21 | 14 97 | 15 78 | 16 65 | 18 53 |
| 12 | 12 0 | 13 41 | 15 03 | 15 92 | 16 87 | 17 89 | 18 98 | 21 38 |
| 13 | 13 0 | 14 68 | 16 63 | 17 71 | 18 88 | 20 14 | 21 50 | 24 52 |
| 14 | 14 0 | 15 97 | 18 29 | 19 16 | 21 01 | 22 55 | 24 21 | 27 97 |
| 15 | 15 0 | 17 29 | 20 02 | 21 58 | 23 28 | 25 13 | 27 15 | 31 77 |
| 16 | 16 0 | 18 64 | 21 82 | 23 66 | 25 67 | 27 89 | 30 32 | 35 95 |
| 17 | 17 0 | 20 01 | 23 70 | 25 84 | 28 21 | 30 84 | 33 75 | 40 55 |
| 18 | 18 0 | 21 41 | 25 65 | 28 13 | 30 91 | 34 00 | 37 45 | 45 60 |
| 19 | 19 0 | 22 84 | 27 67 | 30 54 | 33 76 | 37 38 | 41 45 | 51 16 |
| 20 | 20 0 | 24 30 | 29 78 | 33 06 | 36 79 | 41 00 | 45 76 | 57 28 |
| 25 | 25 0 | 32 03 | 41 65 | 47 73 | 54 86 | 63 25 | 73 11 | 98 35 |
| 30 | 30 0 | 40 57 | 56 08 | 66 44 | 79 06 | 94 46 | 113 28 | 164 49 |
| 35 | 35 0 | 49 99 | 73 65 | 90 32 | 111 43 | 138 24 | 172 32 | 271 02 |

From the table, we can see that the value of **Gy = 24.3**

To find ESALS we must use the AASHTO rule below:

**ESALs =** ESAL * T% * Gy* ADT * 365 * Lane Distribution (0.815 in our case)

1) **For Single Unit:**
   ESALs= 3.02*.094*8863*365*24.3*.815 = 18.9 * $10^6$

2) **For 4-**axles:
   ESALs=5.1*.008*8863*365*24.3*.815 = 2.6 * $10^6$

3) **For 5-**axles:
   ESALs=4.68*.004*8863*365*24.3*.815= 1.19 * $10^6$

4) **For 6-**axles:
   ESALs=4.18*.016*8863*365*24.3*.815 = 4.28 * $10^6$

**Now, we can find that the total ESALs = 26 * $10^6$**

### 4.2.2 Geotechnical Parameters:

We have reached out to a well-known geotechnical company in Jordan and got some important information about the subgrade.

- CBR = 9.4%
- Then, the modulus of resilient Mr = 1500 * 9.4 = 14100 PSI

After designing our road, we can assume that our drainage is good, and the water can be removed in 1 day. Also, due to insufficient data, we assumed that the pavement structure would be saturated for 5% of the year. **Thus, the drainage coefficients $m_1$ and $m_2$ will be 1.15.** The next table shows the AASHTO table that recommends these values.

*Table 8: Drainage coefficients*

**TABLE 11.20** Recommended Drainage Coefficients for Untreated Bases and Subbases in Flexible Pavements

| Quality of drainage | | Percentage of time pavement structure is exposed to moisture levels approaching saturation | | | |
|---|---|---|---|---|---|
| Rating | Water removed within | Less than 1% | 1–5% | 5–25% | Greater than 25% |
| Excellent | 2 hours | 1.40–1.35 | 1.35–1.30 | 1.30–1.20 | 1.20 |
| Good | 1 day | 1.35–1.25 | 1.25–1.15 | 1.15–1.00 | 1.00 |
| Fair | 1 week | 1.25–1.15 | 1.15–1.05 | 1.00–0.80 | 0.80 |
| Poor | 1 month | 1.15–1.05 | 1.05–0.80 | 0.80–0.60 | 0.60 |
| Very poor | Never drain | 1.05–0.95 | 0.95–0.75 | 0.75–0.40 | 0.40 |

### 4.2.3 Materials Used:

The materials that will be used are HMA for the surface, crushed stone for base and subbase. The mentioned materials will have some characteristics that will be used in the design of the flexible pavement.

Surface layer
E (Modulus of Elasticity) = 450,000, $a_1$ (Structural layer) = 0.44

Base
E (Modulus of Elasticity) = 30,000, $a_2$ (Structural layer) = 0.14

Subbase
E (Modulus of Elasticity) = 15,000, $a_3$ (Structural layer) = 0.11

The structural layer coefficients are used in the design, and they can be found from the following figure.

| Pavement component | Coefficient |
|---|---|
| Wearing surface | |
| Sand-mix asphaltic concrete | 0.35 |
| Hot-mix asphaltic (HMA) concrete | 0.44 |
| Base | |
| Crushed stone | 0.14 |
| Dense-graded crushed stone | 0.18 |
| Soil cement | 0.20 |
| Emulsion/aggregate-bituminous | 0.30 |
| Portland cement/aggregate | 0.40 |
| Lime-pozzolan/aggregate | 0.40 |
| Hot-mix asphaltic (HMA) concrete | 0.40 |
| Subbase | |
| Crushed stone | 0.11 |

*Figure 19: Structural Coefficient*

### 4.2.4 Structural numbers and Layer thicknesses:

After finding all the parameters, we can summarize them in the following points to make it easier for us to design the pavement.

**Design Parameters:**

- **Surface:** a=0.44, E=450,000 (HMA)
- **Base:** a=0.14, E=30,000 (crushed stone)
- **Subbase:** a=0.11, E=11,000 (crushed stone)
- **Subgrade:** CBR=9.4%, Mr=14100 psi
- **Drainage coefficients:** $m_1=m_2=1.15$
- **ESALs** = $26 * 10^6$
- **We also are going to use reliability of 95% for better results, Zr = -1.645.**
- **Standard deviation of 0.45 will be good for flexible pavement.**
- **Pt = 2.5 and Pi = 4.2 (for flexible)**

Now, we must find the structural number for each coefficient and find the depth for each later using the monograph in the next page and the rules below.

**Rules:**

- $D_1$ = SN1/a1
- $D_2$= (SN2 - (a1*D1))/($a_2$*$m_2$)
- D3 = (SN3 - (a1*D1) – ($a_2$*$m_2$*D2))/($a_3$*$m_3$)

Now, following AASHTO equation:

$\log(W_{18}) = Zr * S + 9.36L = \log(SN+1) – 0.2 + \log(PSI/2.7)/(0.4+1094/(SN+1)^{5.19} + 2.32\log(Mr) - 8.07$

Using the equation, we can get SN for the first layer to be 3.795, for the base layer the SN is approximately 5.206. Finally, for the subbase SN = 4.86.

Applying these values to the rules, we will get the results below.

- D1 (surface) = 9 inches = 22.86 cm =23 cm
- D2 (Base) = 8 inches = 20.3 cm = 20.5 cm
- D3 (Subbase) = -1.5 inches (Which indicates that we don’t need the subbase layer). But we are going to use the minimum value of 6 inches = 15.25 cm.

## 4.3 Design Alternative 2 (Rigid Pavement)

### 4.3.1 Introduction

Rigid pavement refers to a type of pavement structure that is stiff or rigid in nature, providing a hard and durable surface for roadways. It is commonly used in the construction of highways, airports, and industrial areas where heavy loads and traffic are expected. Rigid pavements are contrasted with flexible pavements, which are more elastic and deform under load.

**Structure of Rigid Pavement:**

- Subgrade Soil
- Frost Protection layer
- Granular Subbase or Stabilized Subbase course
- Granular base or stabilized base course.
- Concrete slab or surface course

## 4.3.2 Design

**Step 1 - find the modulus of subgrade reaction**

Since the road is subjected to a high traffic load, subbase will be added to the layers of the rigid pavement.

Assume subbase thickness is 12 in.

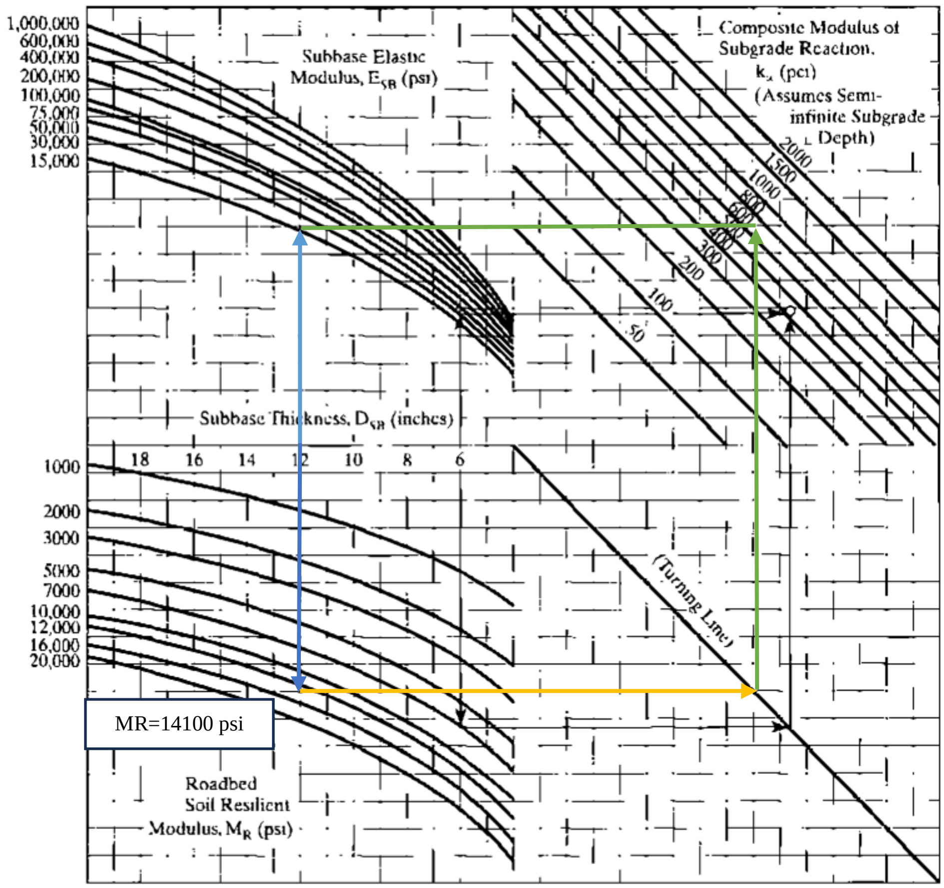



*Figure 20: Chart 1 for Rigid*

K= 700 PCI

**Step 2 - Modify the modulus of subgrade reaction (k)**

There was no rigid foundation that lies 10 ft below the subgrade, so there won't be any modifying.

**Step 3 – Effective Modulus of Subgrade Reaction (k) Assuming no seasonal variation**

No adjustments required|

**Step 4 – Effective Modulus of Subgrade Reaction (k) – Loss of Support**

**TABLE 12.18** Typical Ranges of LS Factors for Various Types of Materials

| Type of material | Loss of support (LS) |
|---|---|
| Cement-treated granular base ($E = 1 \times 10^6$ to $2 \times 10^6$ psi) | 0.0 to 1.0 |
| Cement aggregate mixtures ($E = 500{,}000$ to $1 \times 10^6$ psi) | 0.0 to 1.0 |
| Asphalt-treated bases ($E = 350{,}000$ to $1 \times 10^6$ psi) | 0.0 to 1.0 |
| Bituminous-stabilized mixture ($E = 40{,}000$ to $300{,}000$ psi) | 0.0 to 1.0 |
| Lime-stabilized materials ($E = 20{,}000$ to $70{,}000$ psi) | 1.0 to 3.0 |
| Unbound granular materials ($E = 15{,}000$ to $45{,}000$ psi) | 1.0 to 3.0 |
| Fine-grained or natural subgrade materials ($E = 3000$ to $40{,}000$ psi) | 2.0 to 3.0 |

*Note.* $E$ in this table refers to the general symbol of the resilient modulus.
*Source.* After AASHTO (1986).

*Figure 22: Typical Ranges pfLS factors*

Assuming that the cement aggregate mixtures (E=500,000 to 1x10^6 psi), loss of support will be 0.0-1.0.

Loss of support = 1.0

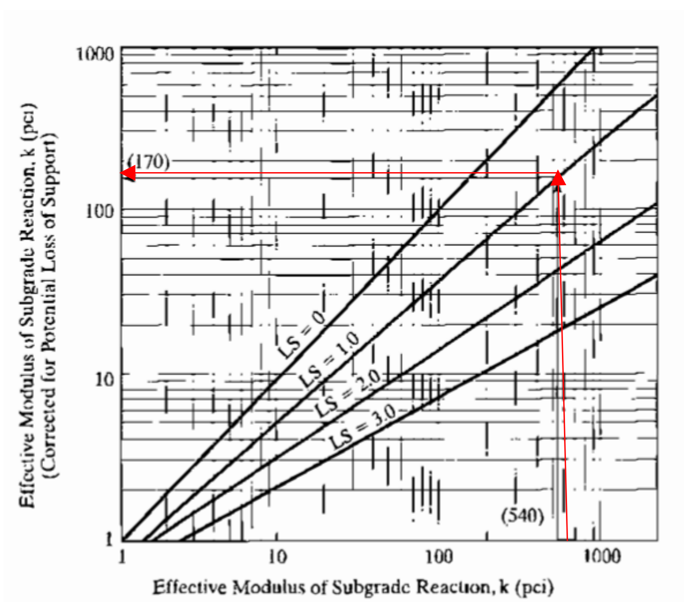



*Figure 21: Effective Modulus for subgrade*

K effective = 180 PCI from figure 26

**Step 5 – find thickness of the slab**

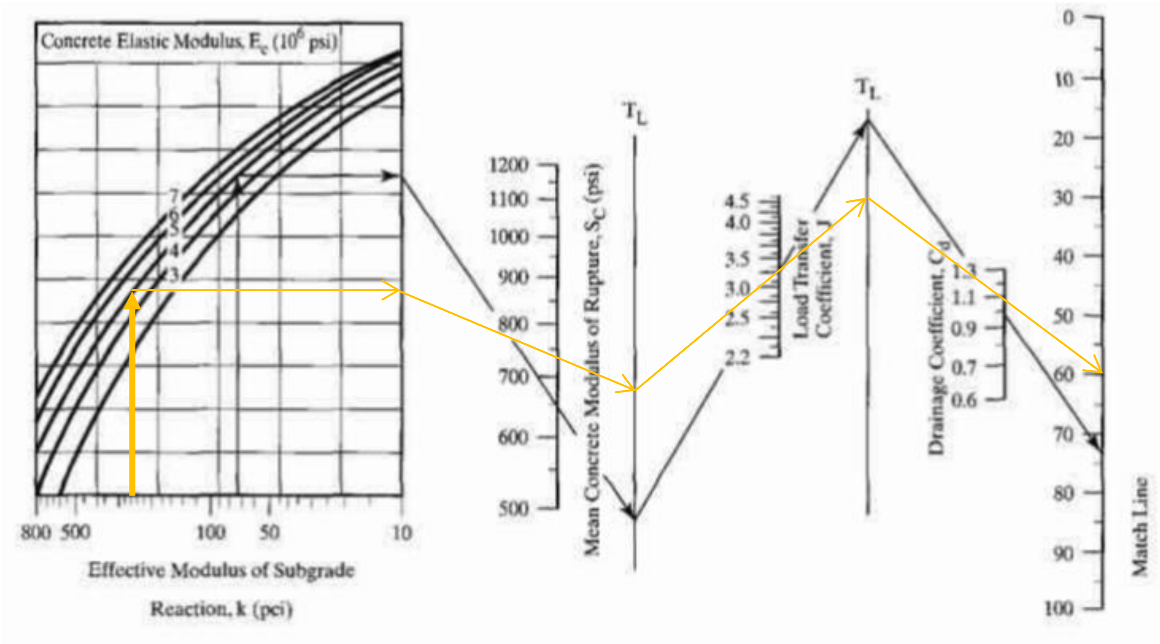



*Figure 22: Chart 3 for Rigid Pavement*

- Concrete elastic modulus (Ec) = 5 x 10^6 psi
- Mean Concrete Modulus of rapture, Sc (psi) = 740
  Where Ec = 6750 x Sc
- Load transfer coefficient (J) = 3.2

TABLE 12.19 Recommended Load Transfer Coefficient for Various Pavement Types and Design Conditions

| Type of shoulder | Asphalt | | Tied PCC | |
|---|---|---|---|---|
| Load transfer devices | Yes | No | Yes | No |
| JPCP and JRCP | 3.2 | 3.8–4.4 | 2.5–3.1 | 3.6–4.2 |
| CRCP | 2.9–3.2 | N/A | 2.3–2.9 | N/A |

*Source.* After AASHTO (1986).

*Figure 23: Recommended Load Transfer*

- Drainage Coefficients (Cd) for Rigid Pavements = 1.1

**TABLE 12.20** Recommended Values of Drainage Coefficients $C_d$ for Rigid Pavements

| Quality of drainage | | Percentage of time pavement structure is exposed to moisture levels approaching saturation | | | |
|---|---|---|---|---|---|
| Rating | Water removed within | Less than 1% | 1–5% | 5–25% | Greater than 25% |
| Excellent | 2 hours | 1.25–1.20 | 1.20–1.15 | 1.15–1.10 | 1.10 |
| Good | 1 day | 1.20–1.15 | 1.15–1.10 | 1.10–1.00 | 1.00 |
| Fair | 1 week | 1.15–1.10 | 1.10–1.00 | 1.00–0.90 | 0.90 |
| Poor | 1 month | 1.10–1.00 | 1.00–0.90 | 0.90–0.80 | 0.80 |
| Very poor | Never drain | 1.00–0.90 | 0.90–0.80 | 0.80–0.70 | 0.70 |

*Source.* After AASHTO (1986).

*Figure 24: Recommended Values of drainage*

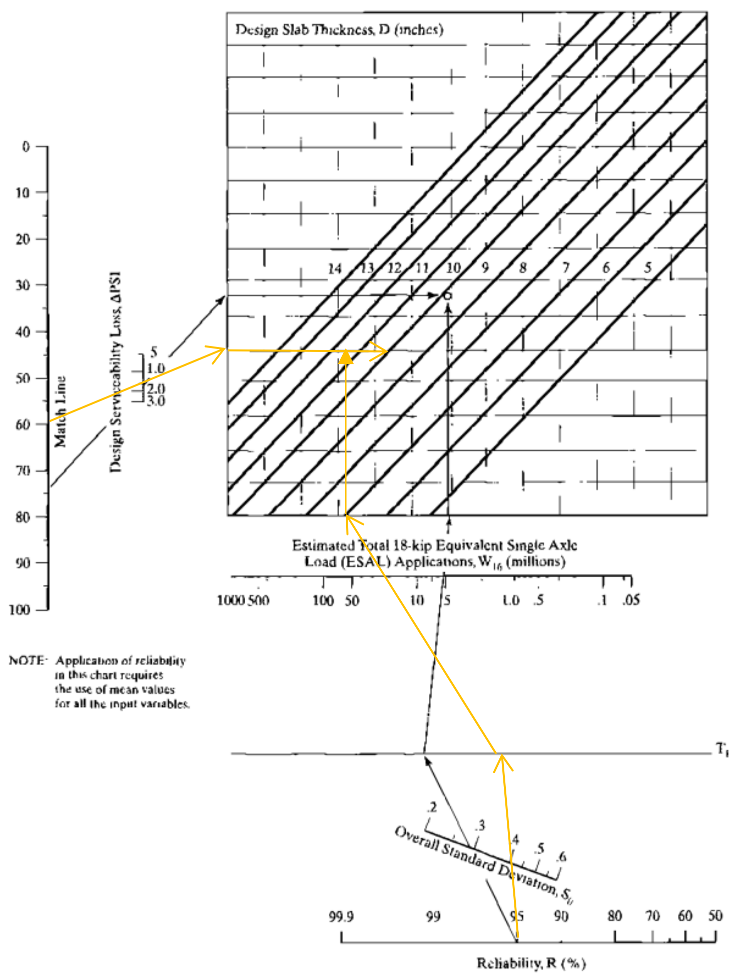



*Figure 25: Chart 4 of rigid*

- Reliability (R %) = 95
- Overall standard deviation = 0.4 ( Due to uncertainty of some factors)
- ESALs = 26 x 10^6
- Design serviceability loss (Δ psi) = 2 …… D= 11.5 inches

# Chapter 5: Project Management

## 5.1 Introduction

### 5.1.1 General Overview

Project management is the discipline of planning, organizing, and managing resources to bring about the successful completion of specific project goals and objectives. A project is a temporary endeavor with a defined beginning and end, undertaken to create a unique product, service, or result.

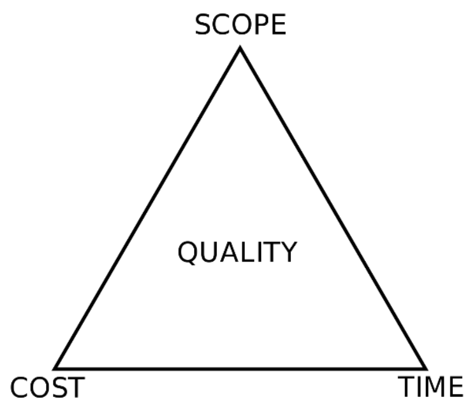



*Figure 26: Quality*

For this project, Primavera P6 was used to carry out the managemental study. Oracle Primavera P6 is one of the most useful and operative project management software available on the market. It is designed to plan and manage all kinds of projects. This software provided all the necessary tools and features that helped to manage the project's entire lifetime cycle, Critical path analysis, resource, and cost management are some of the basic features of this software.

### 5.1.2 Constraints

In this project, the estimated time to finish is 10 months, assuming that the owner demanded that the project must be finished in 4 months.

## 5.2 Project Management

### 5.2.1 Calendar

In this project, assumptions include six working days, 9 hours per day from 7 AM to 5 PM, and a break to all labor and non-labor from 12 PM to 1 PM, while Fridays are non-working days during the project lifetime.


*Figure 27: Calendar*

| Holidays | Date |
|---|---|
| Christmas | Dec-25-2023 |
| New year | Jan-1-2024 |
| Al Isra’ wal Miraj | Feb-7-2024 |

### 5.2.2 Work Breakdown Structure

The purpose of WBS is to outline the project and break it down into smaller parts, more manageable parts.

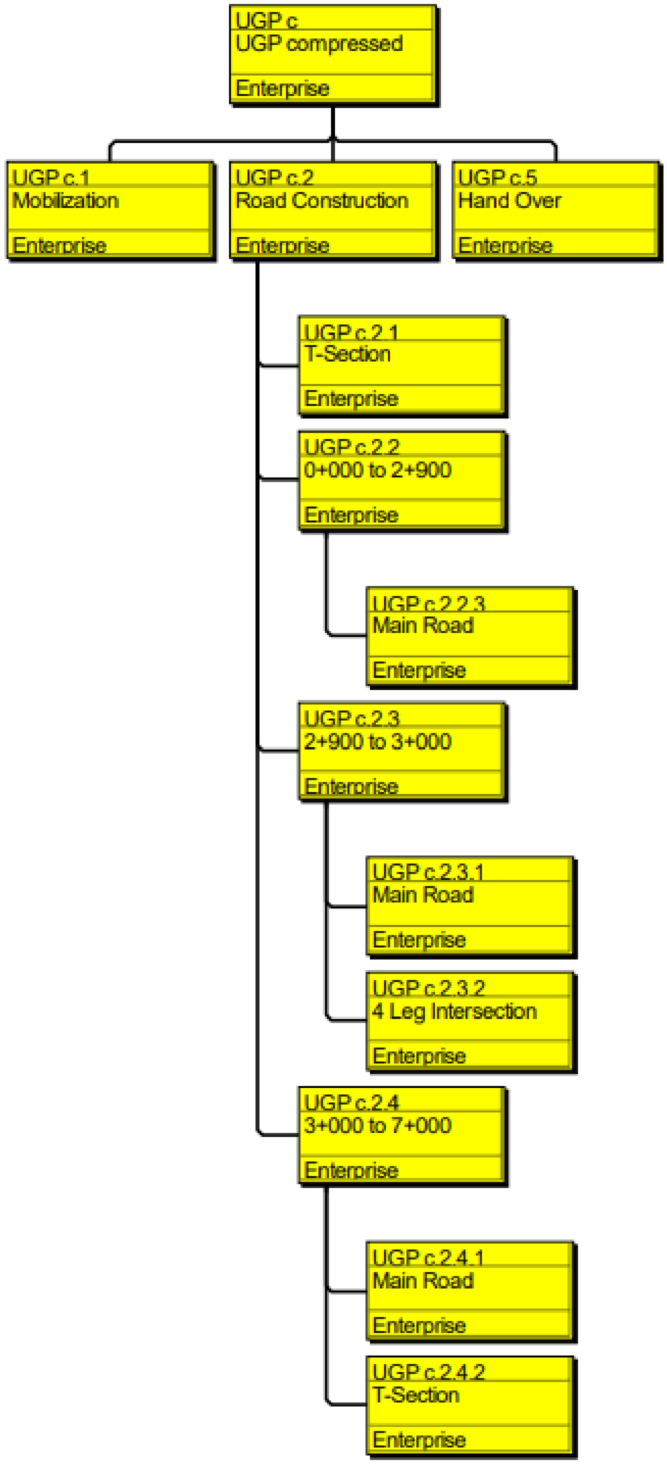



*Figure 28: Work Breakdown Structure for the construction*

Layout: WBS

| WBS Code | WBS Name | Total Activities |
|---|---|---|
| UGP c | UGP compressed | 77 |
| UGP c.1 | Mobilization | 4 |
| UGP c.2 | Road Construction | 71 |
| UGP c.2.1 | T-Section | 13 |
| UGP c.2.2 | 0+000 to 2+900 | 12 |
| UGP c.2.2.3 | Main Road | 12 |
| UGP c.2.3 | 2+900 to 3+000 | 22 |
| UGP c.2.3.1 | Main Road | 12 |
| UGP c.2.3.2 | 4 Leg Intersection | 10 |
| UGP c.2.4 | 3+000 to 7+000 | 24 |
| UGP c.2.4.1 | Main Road | 12 |
| UGP c.2.4.2 | T-Section | 12 |
| UGP c.5 | Hand Over | 2 |

*Figure 29: WBS codes*

In this project, the WBS was divided into 3 subunits, Mobilization, Construction, and Handover. Subsequently, the Construction part was carried out as repetitive tasks assigned at each station, therefore, reducing the time for each task by utilizing the learning curve theory for the laborers, in addition, stations were assigned as a start-to-start relation with lag which was caused by variance of duration of the activities.

### 5.2.3 Logical Relationships

The concept of a logical relationship in the project management scheme refers specifically to an established and existing reliance or dependency between two elements of the project.

There are four main types of relationships:

- Start To Start (SS)
- Start To Finish (SF)
- Finish To Start (FS)
- Finish To Finish (FF)

In this project, there are two relationships used; (SS) as shown in Figure 26, and (FS) as shown in Figure 27.

| WBS | Activity ID | Activity Name | Relationship Type |
|---|---|---|---|
| UGP c.1 | A101 | Installation of Equipments | SS |

*Figure 30: SS relationship*

| WBS | Activity ID | Activity Name | Relationship Type |
|---|---|---|---|
| UGP c.2. | A105 | Close existing road , transfer traffi | FS |

*Figure 31: FS relationship*

### 5.2.4 Activities and Gantt Chart

An activity in project management is a stage of the project management plan. It is the lowest level of the project work breakdown structure and is a sub-division of work packages. An Activity contains a list of tasks or actions to be taken in a particular order to convert an input into the appropriate output. Figure 28 shows a sample of activities in the project.

| Activity ID | Activity Name | Planned Duration |
|---|---|---|
| UGP c | UGP compressed | 119 |
| UGP c.1 | Mobilization | 5 |
| A100 | Install detour signs & barriers | 5 |
| A101 | Installation of Equipments | 5 |
| A102 | Site office installation | 5 |
| A103 | Sybmit Approval for material | 5 |
| UGP c.2 | Road Construction | 106 |
| UGP c.2.1 | T-Section | 12 |
| A104 | Surveying works | 1 |
| A105 | Close existing road , transfer traffic & add barriers | 1 |
| A106 | Road excavation | 1 |
| A107 | Road Fill and compact | 1 |
| A108 | Construction of Sub base layer | 1 |
| A109 | Construction of Base course layer | 1 |
| A110 | Construction of Median | 1 |
| A111 | MC Binder Concrete | 1 |
| A112 | RC & Wearing course | 1 |
| A113 | Street Lighting | 1 |
| A114 | Road marking | 1 |
| A115 | Traffic signs | 1 |
| A116 | Flooring & moving the barriers | 2 |
| UGP c.2.2 | 0+000 to 2+900 | 71 |

*Figure 32: Sample of activities in the project*

Most of the activities are repetitive, the activities will be shown in detail in the appendix.

A Gantt chart is a commonly used graphical depiction of a project schedule. It's a type of bar chart showing the start and finish dates of a project's elements such as resources, planning, and dependencies. Figure 29 will show a sample of the Gantt chart used.

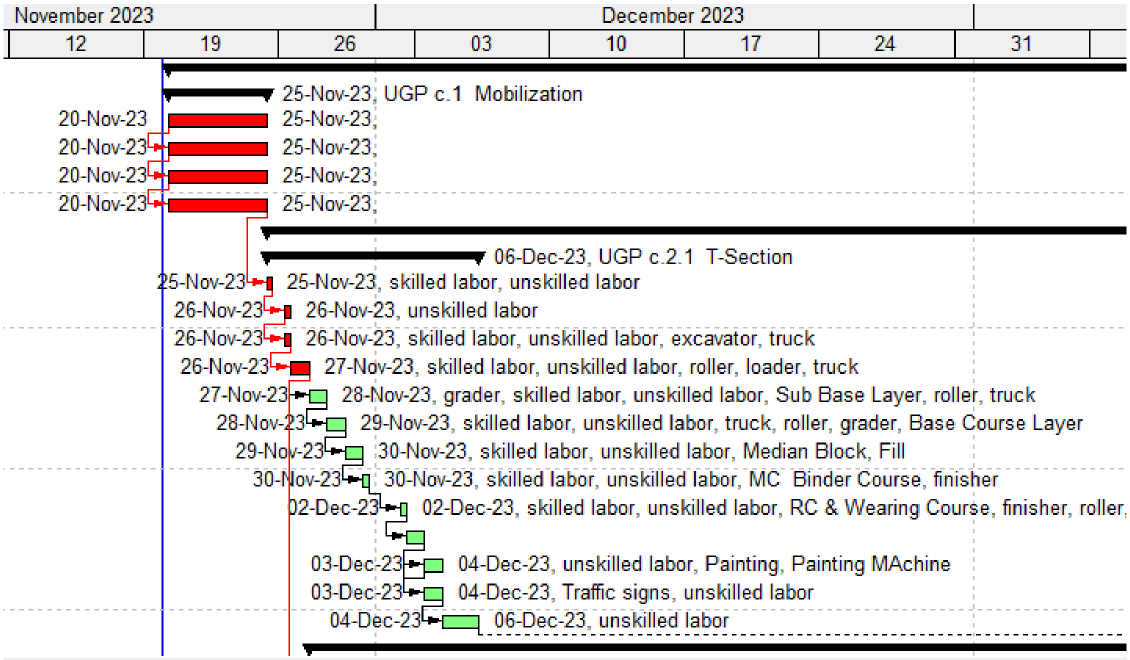



*Figure 33: Gantt Chart*

In Figure 29, the critical path is represented by the red bars and lines.

The critical path in project management refers to the sequence of tasks or activities that must be completed on time for the entire project to finish according to its planned schedule. In other words, it represents the longest path through the project, and any delay in activities along this path will directly impact the project's overall timeline.

**The project's critical path is:**

A100 – A101 – A102 – A103 – A104 – A105 – A106 – A107 – A117 – A118 – A119 – A129 – A141 – A142 – A143 – A144 – A151 – A152 – A153 – A154 – A155 – A156 – A157 – A158 – A159 – A160 – A161 – A175 – A176

(Activities will be shown in the appendix)

### 5.2.5 Quantity and Specifications

quantity and specifications in project management are critical for defining, planning, executing, and controlling a project. They provide the necessary details and criteria to ensure that the project meets its objectives while managing resources, time, and costs effectively.

**Part A - Laborers and Machines**
For this project, we have two types of laborers, skilled and Unskilled. Regardless of the type of project, laborers often work under the supervision of skilled tradespeople or project managers. Their contributions are essential to the successful completion of projects, as they perform the hands-on, physically demanding tasks necessary for project progress. Safety protocols and adherence to project specifications are crucial aspects of their responsibilities.

As for machines, the project used these machines:

- Truck
- Loader
- Roller
- Finisher
- Excavator
- Grader
- Painting machine

**Part B – Materials**
Different types of materials were used for the construction part of the project, and each material has its specifications and cost. Each specification is used according to the Ministry of Business in Jordan.

The cost of the materials depends on the amount used, that’s why the cost of certain materials was related to the compaction level and percentage of the laboratory air voids, where these factors vary from one material to another.

compaction level of materials:

- Subgrade: 90%
- Sub-base: around 98%
- Base course: around 98%
- Air void percentage is Asphalt: 5%

Depending on these factors, the price of the mentioned materials was chosen, as for the other materials used, prices were taken from certified companies.

**Bill of Quantities**

*Table 9: Bill of Quantities*

| Material | Unit Of Measure | Price/Unit | Quantity | Cost jd |
|---|---|---|---|---|
| Fill | $m^3$ | 0.85 jd / $m^3$ | 49385 | 41977.25 |
| Subbase layer | $m^2$ | 1. 5 jd / $m^2$ | 163316 | 244974 |
| Base course layer | $m^2$ | 1. 5 jd / $m^2$ | 163316 | 244974 |
| MC Binder Course | $m^2$ | 1.8 jd / $m^2$ | 163316 | 293968.8 |
| RC and wearing course | $m^2$ | 2.0 jd / $m^2$ | 163316 | 326632 |
| Street light | One unit | 1400 / no | 203 | 284200 |
| painting | m | 0.03 jd / m | 34355 | 1030.65 |
| Tiles | $m^2$ | 6.0 jd / $m^2$ | 25200 | 151200 |
| Median block | m | 2.2 jd / m | 14000 | 30800 |
| Cement paste | $m^2$ | 0.4 jd / $m^2$ | 25200 | 10080 |
| Traffic signs | One unit | 10.0 jd / m | 26 | 260 |

Table 12 shows the bill of quantity (BOQ), which is a document used in project management and construction projects to provide a detailed list of quantities and descriptions of the materials, components, and work required to complete a project. The Bill of Quantities is an essential part of the tendering process and serves several purposes throughout the project lifecycle.

# Chapter 6: Summary

In this project our aim was to make a road that can accommodate a high traffic load and give accessibility to the empty area to be developed, another goal was serve the existing towns with a minor road.

For the geometric design we focused on following the AASHTO standards in terms of intersections, drainage, superelevation, and horizontal alignment. On the other hand, pavement design was a crucial part since it is directly related to our first goal. We took the soil data from official companies and made a basic traffic analysis in order to design two types of pavements which are flexible and rigid pavements.

Regarding construction management, we used primavera for Project Planning and Scheduling, Resource Management, Cost Management and Critical Path Analysis.

The project had two design alternatives, Flexible Pavement and Rigid pavement, since the project had to be done in four months instead of ten, the price of the project increased in each alternative due to clustering.

The flexible pavement cost was 1,775,000 JD including all the finishings, as for the price of the rigid pavement, cost was estimated by asking companies due to the lack of information, since most roads in Jordan use flexible pavement .

# Chapter 7: References


- AASHTO Design of Pavement Structures 1993.
- AASHTO 2018 7th, A Policy on Geometric Design of Highways and Streets Edition.
- HCM ( Highway Capacity Manual)
- FHWA (Federal Highway Administration)
- https://pavementinteractive.org/

# Appendices

## Appendix A

**Sample of calculations: ESALS**

Since we couldn't find the required traffic data from official departments, we made a site visit in a typical day (Tuesday) and counted the traffic for three different hours, then used the peak hour volume to find the ADT based on the HCM values.

| Traffic Data | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Time | PC | Trucks | Two Ax. | Three Ax. | Four Ax. | Five Ax. | Six Ax. | Notes | Truck % |
| 9:00 - 10:00 | | | | | | | | | |
| 9:00 - 9:15 | 86 | 23 | 16 | 3 | 2 | 2 | 0 | | 21.1 |
| 9:15 - 9:30 | 90 | 31 | 19 | 1 | 1 | 2 | 8 | | 25.6 |
| 9:30 - 9:45 | 84 | 24 | 16 | 0 | 2 | 2 | 4 | | 22.2 |
| 9:45 - 10:00 | 83 | 21 | 14 | 3 | 3 | 1 | 0 | | 20.2 |
| avg truck% = 22.3% …. Peak Hour = 484 …. PHF=0.91 | | | | | | | | | |
| 11:00 - 12:00 | | | | | | | | | |
| 11:00 - 11:15 | 88 | 28 | 16 | 6 | 2 | 1 | 3 | | 24.1 |
| 11:15 - 11:30 | 86 | 27 | 17 | 4 | 3 | 0 | 3 | | 23.9 |
| 11:30 - 11:45 | 80 | 28 | 15 | 5 | 4 | 2 | 2 | | 25.9 |
| 11:45 - 12:00 | 83 | 21 | 14 | 3 | 3 | 1 | 0 | | 20.2 |
| avg truck% = 23.5% …. Peak Hour = 432 …. PHF=1.1 | | | | | | | | | |
| 3:00 - 4:00 | | | | | | | | | |
| 3:00 - 3:15 | 205 | 29 | 22 | 0 | 2 | 1 | 4 | | 12.4 |
| 3:15 - 3:30 | 169 | 15 | 12 | 2 | 0 | 0 | 1 | | 8.2 |
| 3:30 - 3:45 | 172 | 20 | 9 | 0 | 0 | 4 | 7 | | 10.4 |
| 3:45 - 4:00 | 168 | 21 | 15 | 1 | 0 | 3 | 2 | | 11.1 |
| avg truck% = 10.5% …. Peak Hour = 936 …. PHF=0.85 | | | | | | | | | |

We took the three hours and found the weekly vehicle count,

=((442*18.8)+(441*18.52)+(799*14.77))/3 = 9426 veh (Weekly)

Then to find the ADT we multiplied by 6.582 and divided by 7:

The ADT = 8863 veh/day

**Sample of calculations: Horizontal Curves (Curve 1)**

For the design parameters we can find them from the figure that shows the data about curve 1 in chapter 4.

- I (central angle) = 14.9
- Superelevation (e) = 6%, f=0.15
- Length = 164.12
- Chord= 163.35

Please note that the minimum radius that was taken from the previous table was based on two (e and f) distributions which is illustrated in AASHTO chapter 3. Thus, the minimum radius yielded was bigger than the $R_{min}$ provided from the following equation.

1) To find minimum radius use:

$$Rmin = \frac{V^2}{127(0.01e + f)}$$

Thus, $R_{min}$= $70^2$/(127*(.01*6 + 0.15) = 184 m

2) For minimum length of curve:

$$Lmin = R * I * \frac{2\pi}{360}$$

Length = 184 * 14.9 * 2PI/360 = 48 m let's say 50 m.

3) For chord length:

$$LC = 2 * R * \sin\left(\frac{I}{2}\right)$$

LC = 48 m

From these values, we can see that our values are above the minimum standards.

4) For the SSD:

Stopping sight distance is needed to make sure that drivers have enough time to act when something urgent happen or when they need to make a decision. Thus, AASHTO provided us with minimum values based on intersections and grades. In this part, we will focus on the intersections part.

$$SSD = 0.278tV + \frac{V^2}{254f}$$

Using this rule and assuming t=2.5 s, we can find that SSD = 177 m. Our design shows that the distance before intersections and curves are sufficient.

**Sample of calculations: Vertical Curves (Curve 1)**

From vertical curve 1 figure previously, we can see that our curve is a crest curve and its parameters are:

- A=1.13%
- Length = 184 m
- SSD = 682
- PSD = 1465m

To know the minimum length of the curve we will use:

K which is a standard and = 51

K = L/A

Then the minimum length = 57 m. Our design is following the standards.

Since K is based on the SSD and PSD there is no need to find the SSD and PSD values manually.

**Sample of calculations: Superelevation values.**

We increased the values of runoff to be 100 and runout to 40 meters. Then 66.7 meters was on tangent and 33.3 meter on the curves.

The distance from the normal crown to level cross section equals runoff/3 = 33.3 meters and from level cross section to all elevated 2% also equals 33.3 meters and the remaining distance will be to superelevated cross section.

The values will be shown in the next tables for all the curves:

| Superelevation Region | Station | Description | Left Outside Lane | Left Inside Lane | Right Outside Lane | Right Inside Lane |
|---|---|---|---|---|---|---|
| | 0+000.00m | Begin Alignment | 0.00% | 0.00% | 0.00% | 0.00% |
| **1** | 0+493.30m | End Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **1** | 0+533.30m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **1** | 0+566.60m | Reverse Crown | 2.00% | 2.00% | -1.99% | -1.99% |
| **1** | 0+633.30m | Begin Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **1** | 0+667.00m | End Full Super | 6.00% | 6.00% | -5.97% | -5.97% |
| **1** | 0+733.70m | Reverse Crown | 2.00% | 2.00% | -2.00% | -2.00% |
| **1** | 0+767.00m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **1** | 0+807.00m | Begin Normal Crown | -2.00% | -2.00% | -1.99% | -1.99% |
| **2** | 1+793.30m | End Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **2** | 1+833.30m | Level Crown | 0.00% | 0.00% | -1.98% | -1.98% |
| **2** | 1+866.60m | Reverse Crown | 2.00% | 2.00% | -1.99% | -1.99% |
| **2** | 1+933.30m | Begin Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **2** | 2+067.00m | End Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **2** | 2+133.70m | Reverse Crown | 2.00% | 2.00% | -2.00% | -2.00% |
| **2** | 2+167.00m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **2** | 2+207.00m | Begin Normal Crown | -2.00% | -2.00% | -1.98% | -1.98% |
| **3** | 3+093.30m | End Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **3** | 3+133.30m | Level Crown | 0.00% | 0.00% | -1.98% | -1.98% |
| **3** | 3+166.60m | Reverse Crown | 2.00% | 2.00% | -1.97% | -1.97% |
| **3** | 3+233.30m | Begin Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **3** | 3+666.70m | End Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **3** | 3+733.40m | Reverse Crown | 2.00% | 2.00% | -3.33% | -3.33% |
| **3** | 3+766.70m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |

| | | | | | | |
|---|---|---|---|---|---|---|
| **3** | 3+806.70m | Begin Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **4** | 4+693.30m | End Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **4** | 4+733.30m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **4** | 4+766.60m | Reverse Crown | 2.00% | 2.00% | -2.00% | -2.00% |
| **4** | 4+833.30m | Begin Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **4** | 5+066.70m | End Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **4** | 5+133.40m | Reverse Crown | 2.00% | 2.00% | -2.00% | -2.00% |
| **4** | 5+166.70m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **4** | 5+206.70m | Begin Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **5** | 6+152.75m | End Normal Crown | -2.00% | -2.00% | -2.00% | -2.00% |
| **5** | 6+192.75m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **5** | 6+226.05m | Reverse Crown | 2.00% | 2.00% | -2.00% | -2.00% |
| **5** | 6+292.75m | Begin Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **5** | 6+466.70m | End Full Super | 6.00% | 6.00% | -6.00% | -6.00% |
| **5** | 6+533.40m | Reverse Crown | 2.00% | 2.00% | -3.33% | -3.33% |
| **5** | 6+566.70m | Level Crown | 0.00% | 0.00% | -2.00% | -2.00% |
| **5** | 6+606.70m | Manual station | -2.00% | -2.00% | -2.00% | -2.00% |
| | 6+966.41m | End Alignment | 0.00% | 0.00% | 0.00% | 0.00% |

**Superelevation Cross-Section Views (Curve 1)**

The cross-section views are shown in the following pages. Please follow up with curve one values to confirm the shown values.

Management .

Activities sample of calculations .

UGP compressed | Classic WBS Layout | 23-Dec-23 16:03

| Activity ID | Activity Name | Planned Duration | Start | Finish | Free Float | Total Float |
|---|---|---|---|---|---|---|
| UGP c UGP compressed | | 119 | 20-Nov-23 A | 18-Mar-24 | 0 | 0 |
| UGP c.1 Mobilization | | 5 | 20-Nov-23 | 25-Nov-23 | 0 | 0 |
| A100 | Install detour signs & barriers | 5 | 20-Nov-23 | 25-Nov-23 | 0 | 0 |
| A101 | Installation of Equipments | 5 | 20-Nov-23 | 25-Nov-23 | 0 | 0 |
| A102 | Site office installation | 5 | 20-Nov-23 | 25-Nov-23 | 0 | 0 |
| A103 | Sybmit Approval for material | 5 | 20-Nov-23 | 25-Nov-23 | 0 | 0 |
| UGP c.2 Road Construction | | 106 | 25-Nov-23 A | 10-Mar-24 | 0 | 0 |
| UGP c.2.1 T-Section | | 12 | 25-Nov-23 A | 06-Dec-23 | 0 | 94 |
| A104 | Surveying works | 1 | 25-Nov-23 | 25-Nov-23 | 0 | 0 |
| A105 | Close existing road , transfer traffic & add barriers | 1 | 26-Nov-23 | 26-Nov-23 | 0 | 0 |
| A106 | Road excavation | 1 | 26-Nov-23 | 26-Nov-23 | 0 | 0 |
| A107 | Road Fill and compact | 1 | 26-Nov-23 | 27-Nov-23 | 0 | 0 |
| A108 | Construction of Sub base layer | 1 | 27-Nov-23 | 28-Nov-23 | 0 | 94 |
| A109 | Construction of Base course layer | 1 | 28-Nov-23 | 29-Nov-23 | 0 | 94 |
| A110 | Construction of Median | 1 | 29-Nov-23 | 30-Nov-23 | 0 | 94 |
| A111 | MC Binder Concrete | 1 | 30-Nov-23 | 30-Nov-23 | 0 | 94 |
| A112 | RC & Wearing course | 1 | 02-Dec-23 | 02-Dec-23 | 0 | 94 |
| A113 | Street Lighting | 1 | 05-Dec-23 A | 03-Dec-23 | 0 | 94 |
| A114 | Road marking | 1 | 03-Dec-23 | 04-Dec-23 | 0 | 94 |
| A115 | Traffic signs | 1 | 03-Dec-23 | 04-Dec-23 | 0 | 94 |
| A116 | Flooring & moving the barriers | 2 | 04-Dec-23 | 06-Dec-23 | 94 | 94 |
| UGP c.2.2 0+000 to 2+900 | | 71 | 27-Nov-23 | 06-Feb-24 | 0 | 32 |
| UGP c.2.2.3 Main Road | | 71 | 27-Nov-23 | 06-Feb-24 | 0 | 32 |
| A117 | Surveying works | 4 | 27-Nov-23 | 30-Nov-23 | 0 | 0 |
| A118 | Road excavation | 8 | 02-Dec-23 | 09-Dec-23 | 0 | 0 |
| A119 | Road fill & compact | 8 | 09-Dec-23 | 17-Dec-23 | 0 | 0 |
| A120 | Construction of Sub base layer | 8 | 17-Dec-23 | 24-Dec-23 | 0 | 32 |
| A121 | Construction of Base course layer | 8 | 26-Dec-23 | 03-Jan-24 | 0 | 32 |
| A122 | Construction of Median | 4 | 03-Jan-24 | 07-Jan-24 | 0 | 32 |
| A123 | MC Binder Concrete | 6 | 08-Jan-24 | 13-Jan-24 | 0 | 32 |
| A124 | RC & Wearing course | 6 | 14-Jan-24 | 18-Jan-24 | 0 | 32 |
| A125 | Street Lighting | 12 | 20-Jan-24 | 30-Jan-24 | 0 | 32 |
| A126 | Road marking | 2 | 31-Jan-24 | 01-Feb-24 | 0 | 32 |
| A127 | Traffic signs | 1 | 01-Feb-24 | 03-Feb-24 | 0 | 32 |
| A128 | Flooring | 4 | 03-Feb-24 | 06-Feb-24 | 32 | 32 |
| UGP c.2.3 2+900 to 3+000 | | 16 | 17-Dec-23 | 03-Jan-24 | 0 | 67 |
| UGP c.2.3.1 Main Road | | 16 | 17-Dec-23 | 03-Jan-24 | 0 | 67 |
| A129 | Surveying works | 2 | 17-Dec-23 | 18-Dec-23 | 0 | 0 |
| A130 | Road excavation | 1 | 19-Dec-23 | 19-Dec-23 | 0 | 67 |
| A131 | Road fill & compact | 1 | 19-Dec-23 | 20-Dec-23 | 0 | 67 |
| A132 | Construction of Sub base layer | 1 | 20-Dec-23 | 21-Dec-23 | 0 | 67 |
| A133 | Construction of Base course layer | 1 | 21-Dec-23 | 23-Dec-23 | 0 | 67 |

Remaining Level of Effort · Remaining Work · Actual Level of Effort · Critical Remaining Work · Actual Work · ◆ Milestone | Page 1 of 6 | TASK filter: All Activities | © Oracle Corporation

UGP compressed | Classic WBS Layout | 23-Dec-23 16:03

| Activity ID | Activity Name | Planned Duration | Start | Finish | Free Float | Total Float |
|---|---|---|---|---|---|---|
| A134 | Construction of Median | 2 | 23-Dec-23 | 24-Dec-23 | 0 | 67 |
| A135 | MC Binder Concrete | 1 | 26-Dec-23 | 26-Dec-23 | 0 | 67 |
| A136 | RC & Wearing course | 2 | 26-Dec-23 | 28-Dec-23 | 0 | 67 |
| A137 | Street Lighting | 1 | 28-Dec-23 | 30-Dec-23 | 0 | 67 |
| A138 | Road marking | 1 | 30-Dec-23 | 31-Dec-23 | 0 | 67 |
| A139 | Traffic signs | 1 | 31-Dec-23 | 31-Dec-23 | 0 | 67 |
| A140 | Flooring | 2 | 02-Jan-24 | 03-Jan-24 | 67 | 67 |
| UGP c.2.3.2 4 Leg Intersection | | 10 | 17-Dec-23 | 27-Dec-23 | 0 | 73 |
| A141 | Surveying works | 2 | 17-Dec-23 | 18-Dec-23 | 0 | 0 |
| A142 | Close existing road , transfer traffic & add barriers | 1 | 19-Dec-23 | 19-Dec-23 | 0 | 0 |
| A143 | Road excavation | 1 | 19-Dec-23 | 19-Dec-23 | 0 | 0 |
| A144 | Road fill & compact | 1 | 19-Dec-23 | 20-Dec-23 | 0 | 0 |
| A145 | Construction of Sub base layer | 1 | 20-Dec-23 | 21-Dec-23 | 0 | 73 |
| A146 | Construction of Base course layer | 1 | 21-Dec-23 | 23-Dec-23 | 0 | 73 |
| A147 | MC Binder Concrete | 1 | 23-Dec-23 | 24-Dec-23 | 0 | 73 |
| A148 | RC & Wearing course | 1 | 24-Dec-23 | 24-Dec-23 | 0 | 73 |
| A149 | Street Lighting & traffic signs | 1 | 26-Dec-23 | 26-Dec-23 | 0 | 73 |
| A150 | Road marking & moving barriers in 0+000 | 1 | 26-Dec-23 | 27-Dec-23 | 73 | 73 |
| UGP c.2.4 3+000 to 7+000 | | 79 | 20-Dec-23 | 10-Mar-24 | 0 | 0 |
| UGP c.2.4.1 Main Road | | 79 | 20-Dec-23 | 10-Mar-24 | 0 | 0 |
| A151 | Surveying works | 4 | 20-Dec-23 | 24-Dec-23 | 0 | 0 |
| A152 | Road excavation | 8 | 26-Dec-23 | 03-Jan-24 | 0 | 0 |
| A153 | Road fill & compact | 10 | 03-Jan-24 | 13-Jan-24 | 0 | 0 |
| A154 | Construction of Sub base layer | 10 | 14-Jan-24 | 23-Jan-24 | 0 | 0 |
| A155 | Construction of Base course layer | 10 | 23-Jan-24 | 01-Feb-24 | 0 | 0 |
| A156 | Construction of Median | 5 | 01-Feb-24 | 06-Feb-24 | 0 | 0 |
| A157 | MC Binder Concrete | 9 | 06-Feb-24 | 17-Feb-24 | 0 | 0 |
| A158 | RC & Wearing course | 9 | 17-Feb-24 | 25-Feb-24 | 0 | 0 |
| A159 | Street Lighting | 3 | 25-Feb-24 | 28-Feb-24 | 0 | 0 |
| A160 | Road marking | 2 | 28-Feb-24 | 29-Feb-24 | 0 | 0 |
| A161 | Traffic signs | 1 | 02-Mar-24 | 02-Mar-24 | 0 | 0 |
| A162 | Flooring | 8 | 02-Mar-24 | 10-Mar-24 | 0 | 0 |
| UGP c.2.4.2 T-Section | | 11 | 14-Jan-24 | 24-Jan-24 | 0 | 46 |
| A163 | Surveying works | 1 | 14-Jan-24 | 14-Jan-24 | 0 | 46 |
| A164 | Close existing road , transfer traffic & add barriers | 1 | 14-Jan-24 | 15-Jan-24 | 0 | 46 |
| A165 | Road excavation | 1 | 14-Jan-24 | 15-Jan-24 | 0 | 46 |
| A166 | Road fill & compact | 1 | 15-Jan-24 | 16-Jan-24 | 0 | 46 |
| A167 | Construction of Sub base layer | 1 | 16-Jan-24 | 17-Jan-24 | 0 | 46 |
| A168 | Construction of Base course layer | 1 | 17-Jan-24 | 18-Jan-24 | 0 | 46 |
| A169 | MC Binder Concrete | 2 | 18-Jan-24 | 20-Jan-24 | 0 | 46 |
| A170 | RC & Wearing course | 2 | 20-Jan-24 | 22-Jan-24 | 0 | 46 |

Remaining Level of Effort · Remaining Work · Actual Level of Effort · Critical Remaining Work · Actual Work · ◆ Milestone | Page 3 of 6 | TASK filter: All Activities | © Oracle Corporation

UGP compressed | Classic WBS Layout | 23-Dec-23 16:03

| Activity ID | Activity Name | Planned Duration | Start | Finish | Free Float | Total Float |
|---|---|---|---|---|---|---|
| A171 | Street Lighting | 1 | 22-Jan-24 | 23-Jan-24 | 0 | 46 |
| A172 | Road marking | 1 | 23-Jan-24 | 24-Jan-24 | 0 | 46 |
| A173 | Traffic signs | 1 | 23-Jan-24 | 24-Jan-24 | 0 | 46 |
| A174 | Flooring & removing all barriers | 1 | 23-Jan-24 | 24-Jan-24 | 46 | 46 |
| UGP c.5 Hand Over | | 8 | 10-Mar-24 | 18-Mar-24 | 0 | 0 |
| A175 | Site cleaning | 6 | 10-Mar-24 | 16-Mar-24 | 0 | 0 |
| A176 | Hand over | 2 | 16-Mar-24 | 18-Mar-24 | 0 | 0 |

- Volume of fill

It was calculated using the trapezoidal method using Civil 3D

- Construction of sub base layer

Area = Length of street x 23

Activity A132 →

| Resource ID | Resource Name | Unit of Measure | Planned Units |
|---|---|---|---|
| 008 | grader | | 9 |
| 005 | roller | | 9 |
| 001 | skilled labor | | 9 |
| 011 | Sub Base Layer | Sqaure Meter | 2300 |
| 003 | truck | | 9 |
| 002 | unskilled labor | | 27 |

Area = 100m x 23m

Area = 2300 m²

- Construction of Base course layer

Area = length of street x 23

Activity A133 →

| Resource ID | Resource Name | Unit of Measure | Planned Units |
|---|---|---|---|
| 013 | Base Course Layer | Sqaure Meter | 2300 |
| 008 | grader | | 9 |
| 005 | roller | | 9 |
| 001 | skilled labor | | 9 |
| 003 | truck | | 9 |
| 002 | unskilled labor | | 27 |

Area = 100m x 23m

Area = 2300 m²

- Construction of median

| Resource ID | Resource Name | Unit of Measure | Budgeted Units | Price / Unit | Budgeted Cost |
|---|---|---|---|---|---|
| 010 | Fill | meter cubic | 51 | jd110.00/m3 | jd43.45 |
| 021 | Median Block | meter | 200 | jd2.20/m | jd440.00 |
| 001 | skilled labor | | 18 | jd4,000.00/h | jd57.60 |
| 002 | unskilled labor | | 72 | jd5.50/h | jd194.40 |

- Fill Volume = 3.6 x 0.14 x L

  Activity A134 →

  Fill volume = 3.6 x 0.14 x 100

  Fill volume = 51 $m^3$

- Median Block = 2 x L

  Activity A134 →

  Length = 2 x 100

  Length of median block = 200 m

- Construction of MC binder course

Area = Length x 23

Activity A135 →

| Resource ID | Resource Name | Unit of Measure | Planned Units |
|---|---|---|---|
| 006 | finisher | | 18 |
| 014 | MC Binder Course | Sqaure Meter | 2300 |
| 001 | skilled labor | | 9 |
| 002 | unskilled labor | | 18 |

Area = 100 m x 23 m

Area = 2300 $m^2$

- Construction of RC & Wearing course

Area = Length x 23

Activity A136 →

| Resource ID | Resource Name | Unit of Measure | Planned Units |
|---|---|---|---|
| 006 | finisher | | 18 |
| 015 | RC & Wearing Cours | Sqaure Meter | 2300 |
| 005 | roller | | 36 |
| 001 | skilled labor | | 18 |
| 003 | truck | | 18 |
| 002 | unskilled labor | | 63 |

Area = 100m x 23m

Area = 2300 m²

- Street lighting

Hight of lighting pole 12 m
D between two poles : 36 m

100m / 36 = 2.78

We use 3 poles

- Road marking

Painting = L x 4 + L x (2/3)

Activity A126 →

General | Status | Resources | Predecessors | Successors | Codes | Notebook | Steps | Feedback | WPs & Docs | Expenses | Summary

Activity A138 Road marking

| Resource ID | Resource Name | Unit of Measure | Budgeted Units | Price / Unit | Budgeted Cost |
|---|---|---|---|---|---|
| 019 | Painting | meter | 467 | jd0.03/m | jd14.01 |
| 024 | Painting MAchine | | 18 | jd2.00/h | jd36.00 |
| 002 | unskilled labor | | 18 | jd5.50/h | jd48.60 |

Painting = l00 x 4 + 100 x (2/3)

Painting = 467 m