Tunisian Republic

Ministry of Higher Education
and Scientific Research

University of Tunis El Manar

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Civil Engineering Department

REPORT OF THE SYNTHESIS PROJECT

Development and study of a complete interchange

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Appreciation

It is with great pleasure that we reserve this page, as a sign of gratitude and deep appreciation, in order to express our sincere thanks to all those who contributed to the smooth running of this project and its completion in the best conditions.

First of all, we would like to thank Mrs "Saloua EL EUCH" for having given us the honour of directing our synthesis project, for all the attention she has given us, for her permanent assistance and for having spared no effort to put us on the right track.

Our thanks also go to the managers of the Civil Engineering Department of ENIT, who enabled us to carry out this end-of-year project to consolidate our theoretical knowledge.

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General introduction

The road network plays an essential role in the development of a country because it represents a base on which is based several sectors such as the transport of goods and people; therefore it is the vital means of the economy and social development of a country. This socio-economic growth requires the public works sector to expand the road network.

A motorway interchange is a system of road ramps allowing to switch, either from one type of road network to another (from an ordinary road or a fast lane to a motorway), or from one motorway to another. Interchanges are therefore located at intersections between road networks of different types and thus make it possible to avoid any level crossing to limit the slowing down of the lanes concerned.

A motorway interchange has at least one bridge allowing one road network to span the other. In the most complex cases, the carriageways can be spread over four different levels (so-called "four-stack" interchange).

In this context, our project is split into 4 chapters. Starting with the first chapter in which we will give you a bibliographic search about interchanges. Then, the second chapter is devoted to the study of traffic and the proposal of the interchange variant. The next chapter consists of dimensioning the pavement structure using "ALIZE". Finally, we end with modeling of a slab bridge by finite element method using "SAP2000".

Chapter 1

Bibliographic study

Plan

1.1 Introduction

In this chapter, we are going to define the concept of an interchange and define some of its components. Then we are going to talk about the different types of interchanges.

1.2 Definitions

In the field of road transport, an interchange is a road junction that uses grade separation, and typically one or more ramps, to permit traffic on at least one highway to pass through the junction without interruption from other crossing traffic streams.[1]

The definitions of the components of an interchange are as follows:

- **Exit Ramp :** This is a ramp to leave the freeway for another road.[1]
- **Entrance Ramp :** This ramp is for entrance of traffic from other roads to the freeway.[1]
- **Complete Interchange :** This is an interchange providing ramps to all directions traffic. A complete interchange between two freeways generally has at least eight ramps.[1]
- **Incomplete Interchange :** This intersection has at least one or more missing ramps as compared to complete interchanges. Hence, this interchange does not provide movement of traffic in all directions based on demand and capacity. [1]
- **Freeway :** This type of road has full access control. Access is only provided by ramps.[1]
- **Surface street :** In comparison to freeway provide access to traffic by traffic sign or signal and also allows turning.[1]

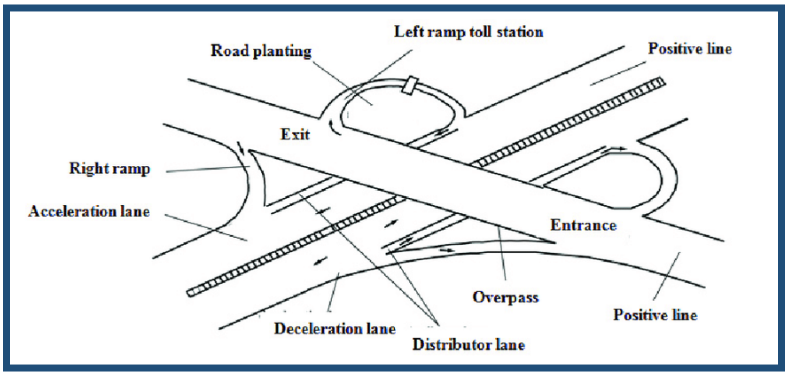

Figure 1.1: Schematic Diagram of Interchange[2]

1.3 Types of interchange

There are several interchange configurations to accommodate turning movements at a grade separation. Factors such as, safety, cost, environment, development and politics can vary at each site, thus there are hundreds if not thousands of unique, one-of-a-kind interchanges worldwide.

Interchanges can be classified into various categories, depending upon the different functions and purposes they serve. They can be categorized on the basis of their flow characteristics, shape, lane configuration and access etc...[1]

Interchanges can be broadly classified as:

1.3.1 Service Interchanges

Service interchanges are those forms which are utilized where the freeway interchanges with a rural road or highway or suburban/urban streets. Generally, the appropriate forms are diamonds, cloverleaf, partial cloverleaf and roundabouts.[1]

The types in Service Interchange are:

- **Diamond Interchange :** A diamond interchange is an interchange involving four ramps where they enter and leave the freeway at a small angle and meet the non-freeway at almost right angles in the following. These ramps at the non-freeway can be controlled through stop signs, traffic signals, or turn ramps.

  Diamond interchanges are inexpensive to build and require little land but are prone to congestion and accidents if there is high traffic.[1]

Figure 1.2: Schematic of Diamond Interchange[1]

- **Cloverleaf Interchange :** A cloverleaf interchange is typically a two-level, four-way interchange whereby all left turns are handled by loop ramps (right turns if traveling on the left). To go left, vehicles first cross over or under the targeted route, then bear right onto a sharply curved ramp that loops roughly 270 degrees, merging onto the interchanging road from the right, and crossing the route just departed, as shown in the following figure.

  The major advantage of Cloverleafs is that they require only one bridge.[1]

Figure 1.3: Schematic of a Cloverleaf Interchange[1]

- **Partial Cloverleaf (Parclos) :** A partial cloverleaf, also known as a Parclo interchange, is an interchange usually involving four to six ramps, two of which are loop ramps, which connect to the non-highway. The Parclo is a safer modification of the cloverleaf design.

  Although the interchange's capacity is reduced, it increases the safety and efficiency of the interchange. The next figure shows an example of a Parclo interchange.[1]

Figure 1.4: A Parclo interchange on the Highway 407 Route in Ontario[1]

- **Roundabout Interchange :** A further alternative found often in Europe is the three-level roundabout interchange. The ramps of the interchanging highways meet at a roundabout or rotary on a separated level above, below, or in the middle of two highways. Roundabout interchanges are much more economical in use of materials and land than other interchange designs. The next figure shows an example of a Roundabout interchange.[1]

Figure 1.5: Schematic of a Roundabout Interchange[3]

1.3.2 System Interchanges

System interchanges are those between two freeways. Typically, these are all directional interchanges, directional with one, two or three loops or cloverleaf. [1]

- **Directional or Stack Interchanges :** A directional or stack interchange is a four-way interchange whereby left turns are handled by semi-directional flyover/under ramps.

  A standard stack interchange includes roads on four levels. This is not only expensive, but also creates an eyesore among local residents, leading to considerable opposition. The next figure shows an example of a Directional interchange.[1]

Figure 1.6: Schematic of a Directional Interchange[4]

- **Cloverstack Interchanges :** Partial cloverleaf interchange (Parclos) designs modified for freeway traffic emerged, eventually leading to the cloverstack interchange.

  Cloverstacks are cheaper to build than stack interchanges and are less of an eyesore for local residents. The following figure shows that its ramps are longer to allow for higher ramp speeds, and loop ramp radii are made larger as well. [1]

Figure 1.7: Schematic of Two Levels Cloverstack[1]

- **Turbine Interchanges :** Another alternative to the four-level stack interchange is the turbine interchange. The turbine interchange requires fewer levels while retaining semi-directional ramps throughout. Schematic of two level turbine interchange is shown in the following figure.

  Turbine interchanges offer slightly less vehicle capacity because the ramps typically turn more often and change height quicker. They also require more land to construct than the typical four level stack interchange. [1]

Figure 1.8: Schematic of Two Levels Turbine[1]

1.4 Conclusion

In this chapter, we have briefly focused on the components of the interchanges as well as on a few of its types.

Chapter 2

TRAFFIC STUDY AND LAYOUT PROPOSITIONS

Plan

2.1 Introduction

Road infrastructures are essential elements to guarantee the movement of vehicles. Their creation requires preliminary studies, that's why it is very important to study the traffic. This step represents an essential stage in the design of a road project.

2.2 Traffic data

2.2.1 Lifetime

Knowing the lifespan of a pavement is an important element in defining the economic stake necessary for the maintenance or upkeep of road infrastructure. In Tunisia, the lifespan of a pavement is generally 15.years.

In this project, we have a bridge. The lifespan of a bridge is generally years so the lifespan of our project is 20 years.

2.2.2 Annual growth rate

It represents the annual evolution of heavy goods vehicles (HGV) traffic. The growth rate generally varies between 3% and 10%.

The traffic growth rate makes it possible to take into account the increase in volume vehicles on the section studied. It follows from the economic and social considerations of the area influence of the road and the role that will be allocated to the section.

In our project, the average annual growth rate is $i=3\%$.

2.2.3 Project's commissioning year

Our project's commissioning year is 2022.

The following diagram represents the traffic of our interchange in particular vehicle units during peak hours in 2017 .

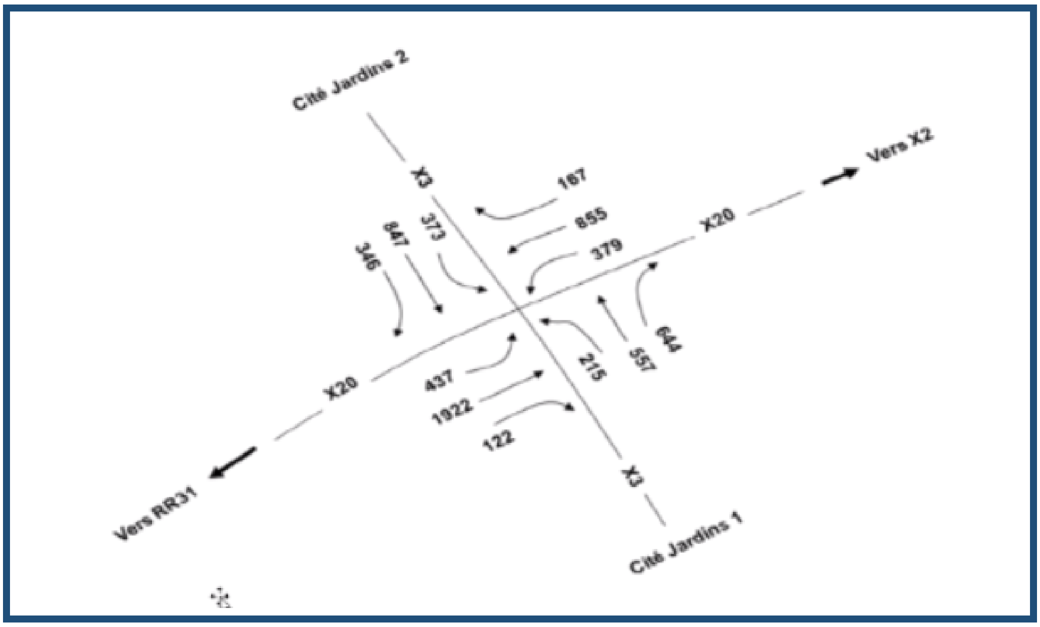

Figure 2.1: Peak hours traffic in x20-x3

The following table represents the origin-destination matrix of the interchange during the 2017 counting year.

Table 2.1: Origin-Destination matrix of x20-x3 in 2017

O/D	Jardin Manzah 1	Jardin Manzah 2	X2	RR31
Jardin Manzah 1	-	557	644	215
Jardin Manzah 2	847	-	373	346
X2	379	167	-	855
RR31	122	437	1922	-

Then, we projected the traffic after 25 years to get this matrix; 5 years of execution plus 20 years of utilisation; to have the origin-destination matrix of the interchange during the year 2042.

Table 2.2: Origin-Destination matrix of x20-x3 in 2042

O/D	Jardin Manzah 1	Jardin Manzah 2	X2	RR31
Jardin Manzah 1	-	1166,234	1348,393	450,162
Jardin Manzah 2	1773,430	-	780,979	724,447
X2	793,541	349,661	-	1790,180
RR31	255,441	914,980	4024,241	-

2.3 Justification of the layout

2.3.1 Calculation of the number of lanes

The hourly capacity of the road, expressed in particular vehicle units (p.v.u), makes it possible to determine the number of road lanes studied.

2.3.1.1 Daily u.v.p traffic in commissioning year 2022

The maximum average daily traffic in terms of heavy goods vehicles is :

$$T_{2017} = 1922 \text{ pvu/peak hour}$$

. Or,

$$T_m = T_n \times (1 + \mathrm{i})^{m-n}$$

So,

$$T_{2022} = T_{2017} \times (1 + \mathrm{i})^5 = 1922 * (1 + 0.03)^5 = 2229 \text{ pvu/peak hour}$$

2.3.1.2 Daily p.v.u traffic at end of service year 2042

$$T_{2042} = T_{2022} \times (1 + \mathrm{i})^{2042-2022} = 2229 * (1 + 0.03)^{20} = 4024 \text{ pvu/peak hour}$$

2.3.1.3 Justification of the layout

In order to determine the number of lanes of the road studied, the table below gives us the values of the different thresholds according to the type of lane.

Table 2.3: Service level: bidirectional ways

Service level	**pvu/ph/way**
Gene threshold	750
Heavy traffic threshold	1200
Congestion risk threshold	2000

We have deposited the only gene which is equal to 1200 and we have not reached saturation.

Yet, X3 and X20 are initially laid out as 2x2 lanes so there is no need to reduce the level of layout, so we keep the same existing layout.

Whereas suspenders and curls will be laid out in a single lane.

2.4 Design stages

2.4.1 Importing crossroads from google earth

We imported the photo from google earth and we scaled it in "AutoCAD".

Figure 2.2: The X20-X3 crossroads from "Google Earth"

2.4.2 Draw the bridges

We have designed two identical bridges of dimension 12 meters and 72 meters for each.

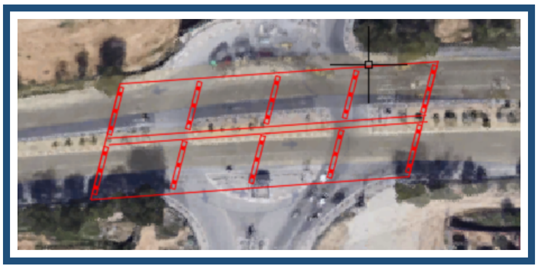

Figure 2.3: Drawing bridges in "AutoCAD"

2.4.3 Draw the roads X20 and X3

We trace roads X20 and X3 with two lanes for each direction. We leave 2 meters between the two directions,each lane is 3.5 meters wide.

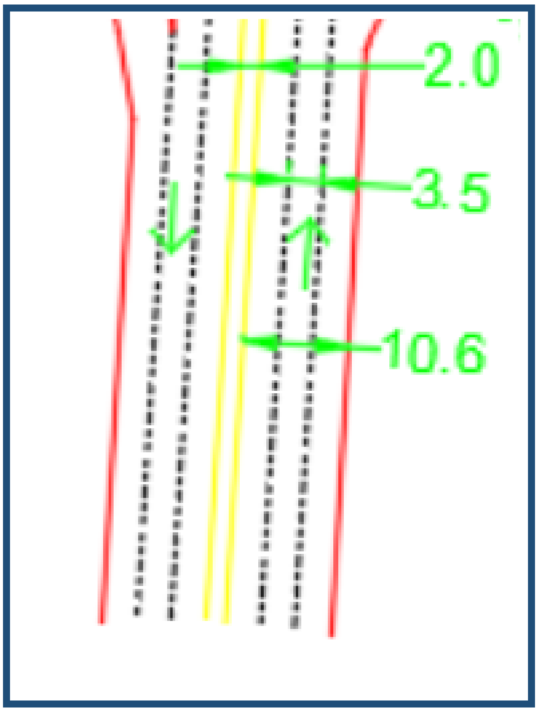

Figure 2.4: Dimensions of road lanes in "AutoCAD"

2.4.4 Draw the piers, abutments and bearings

Piers and abutments must be parallel to the direction of road X3, we start to trace the middle pier between the two directions of road X3 and we trace the other piers and the abutments and finally the bearings.

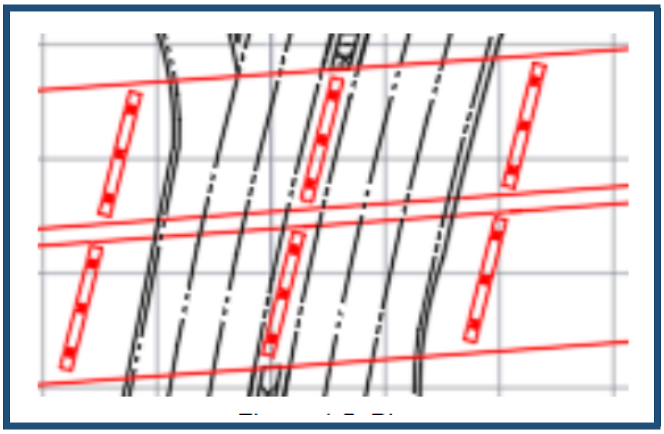

Figure 2.5: Drawing piers in "AutoCAD"

2.4.5 Draw curls

A restrictive loop-shaped configuration, requiring vehicles passing through it to change direction of approximately 270°.

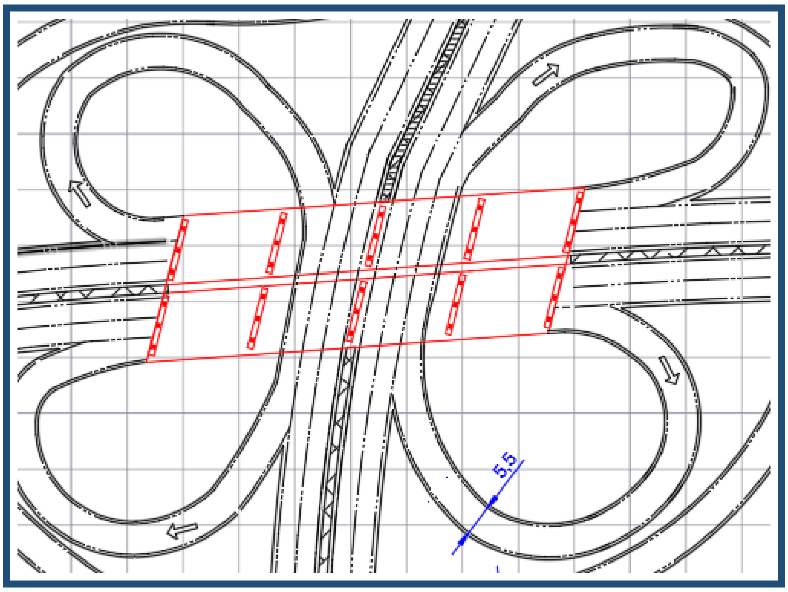

Figure 2.6: Drawing curls in "AutoCAD"

2.4.6 Draw the suspenders

Lane ensuring the transition between a highway and another lane. The suspender requires vehicles using it to change direction of approximately 270°.

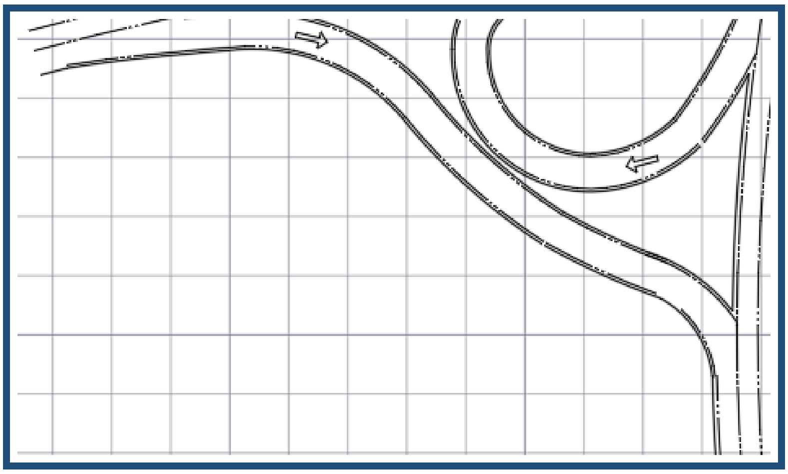

Figure 2.7: Drawing suspenders in "AutoCAD"

2.5 Layout propositions

A cloverleaf interchange is typically a two-level, four-way interchange whereby all left turns are handled by loop ramps (right turns if traveling on the left). To go left, vehicles first cross over or under the targeted route, then bear right onto a sharply curved ramp that loops roughly 270 degrees, merging onto the interchanging road from the right, and crossing the route just departed. The major advantage of Cloverleafs is that they require only one bridge, which makes such junctions inexpensive as long as land is plentiful. A major shortcoming of Cloverleafs, however, is weaving.

We have proposed 3 designs of our cloverleaf interchange:

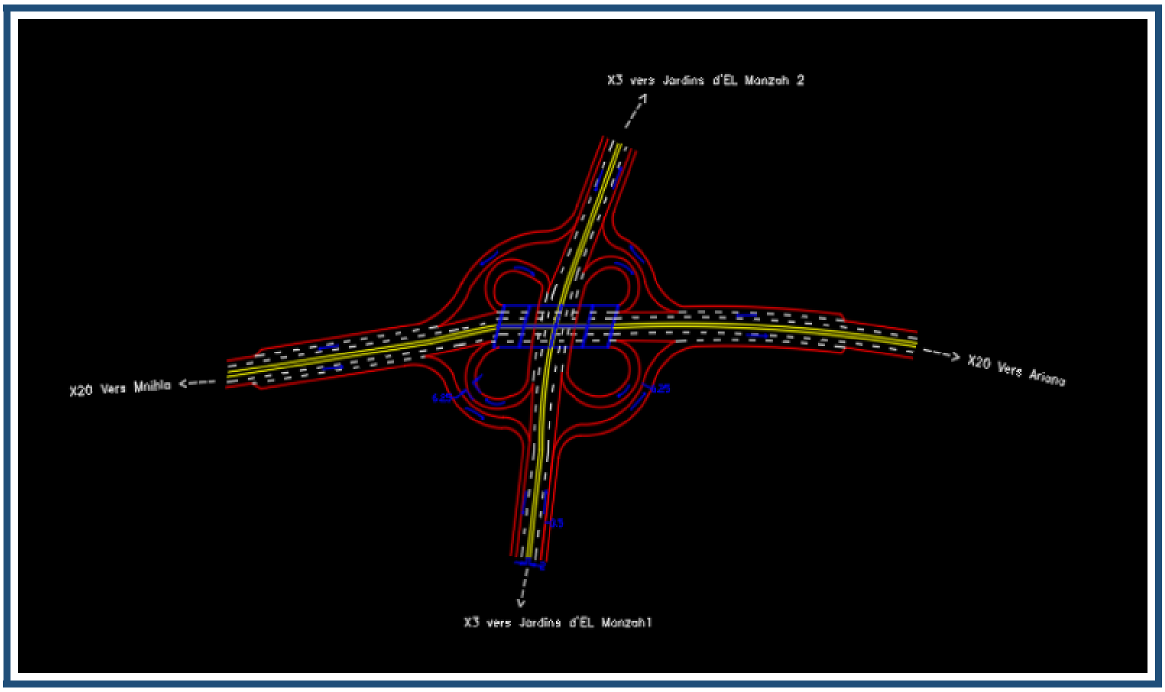

Figure 2.8: Design proposed by Mariem HAJJI

Figure 2.9: Design proposed by Mariem HAJJI with Google Earth background

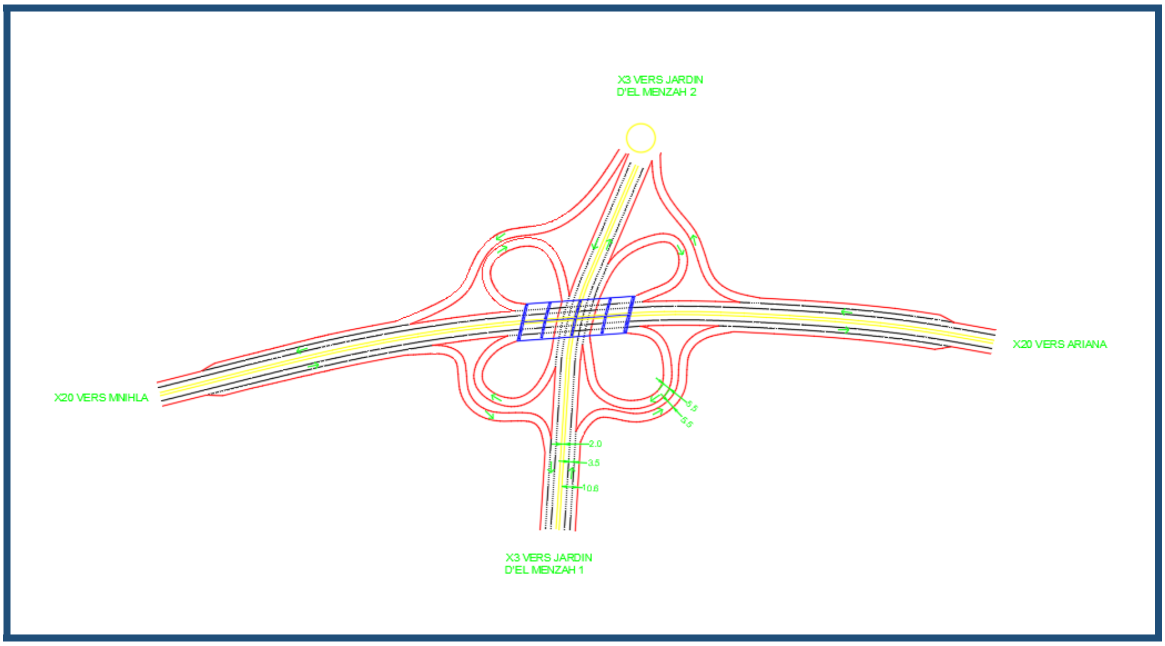

Figure 2.10: Design proposed by Fares FRIKHA

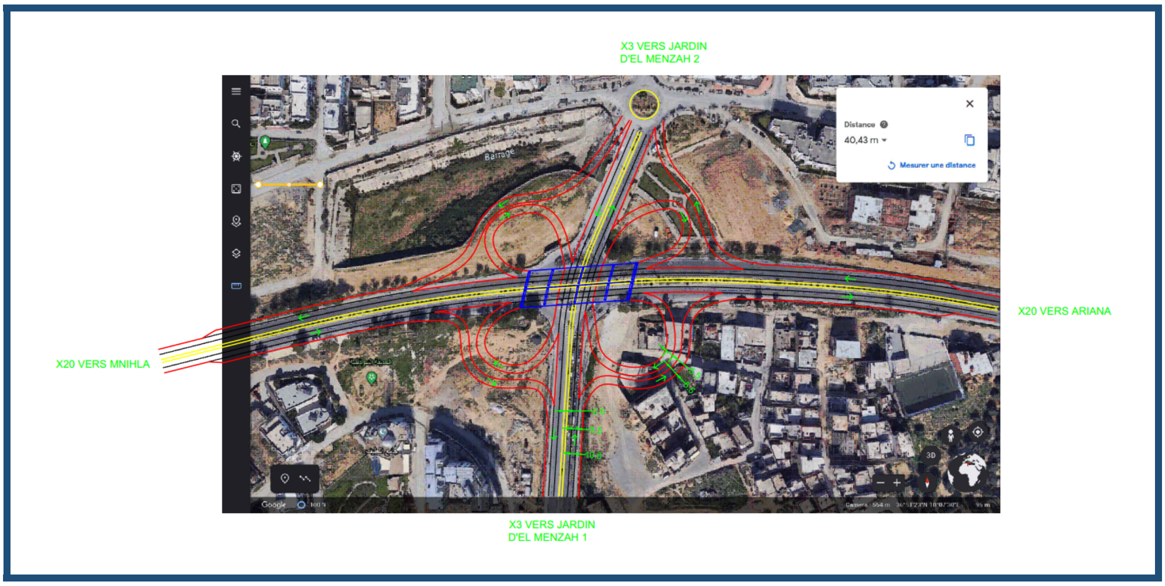

Figure 2.11: Design proposed by Fares FRIKHA with Google Earth background

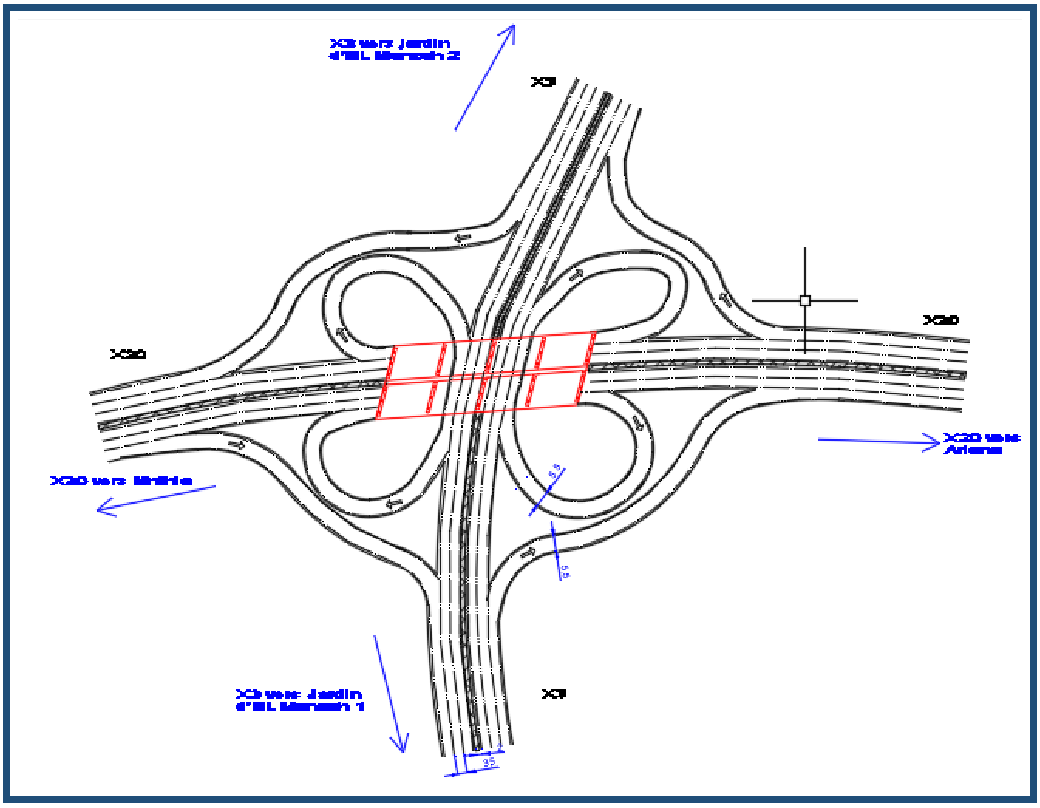

Figure 2.12: Design proposed by Chiheb BEN DAHSEN

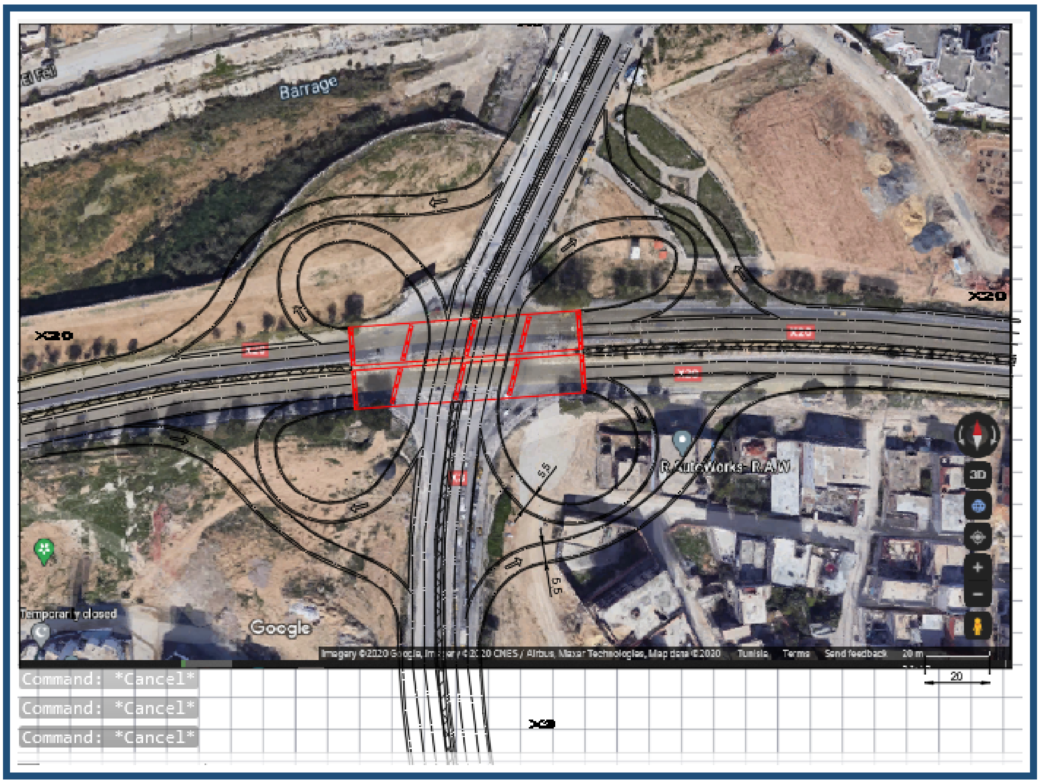

Figure 2.13: Design proposed by Chiheb BEN DAHSEN with Google Earth background

There are several designs of an interchange for each designer but the main thing is that the interchange works properly:

- The curls must be comfortable for the driver of the vehicle : radius must be less than 60m.
- The suspenders are also comfortable : radius must be more than 54m, without forgetting to surround the ground.
- It is necessary to add an insertion lane along 100 meters after the suspenders.

2.6 Conclusion

In this chapter, we calculated the Origin-Destination matrix for the year 2042 and we have deducted the number of ways for each road. We also proposed three layouts to our project and its steps.

Chapter 3

Pavement dimensioning

Plan

3.1 Introduction

The pavement of a road represents a support made up of different layers of materials to withstand the various attacks due to the different types of vehicles and to transmit it on the supporting ground while taking into account not to have deformations at the supporting ground level nor of the pavement itself throughout its life.

After determining the soil class, we will use the "ALIZE LCPC" program to check and determine the size of the roadway.

3.2 Dimensioning in heavy goods vehicles

For our project, we must refer to the total traffic per peak hour (T_{ph}), supported by the roadway, which considers heavy goods vehicles (HGV) and light vehicles (LV), and which is generally given by the following formula:

$$T_{ph}(pvu) = 2 * HGV + LV$$

3.2.1 Daily heavy traffic calculation

The maximum average daily traffic in terms of heavy goods vehicles is :

$$T_{2017} = 1922 \text{ pvu/peak hour}$$

.

- <u>Hypotheses :</u>
  - Percentage of heavy goods vehicles : 15%
  - The average daily traffic = 8 x Traffic in peak hour

$$T_{HGV} = 8 * T_{2017} \times \left(\frac{0.15}{1+0.15}\right) = 2005 \text{ PL}$$

$$=> T_{2022} = T_{HGV} \times (1+i)^5 = 2005 * (1+0.03)^5 = 2324 \text{ HGV}$$

3.2.2 Cumulative traffic

$$T_c = 365 * T_m * A_{eq} * \beta$$

$$T_c = 365 * T_{2022} * 0.5 * 0.9 = 7,1.10^6 \text{ axle of 13 T}$$

We have : $T_c > 4$ millions , so we will determine the traffic class by "ALIZE".

3.3 Geotechnical studies

3.3.1 Classification of the substrate according to the Tunisian Catalog

The characteristic lift, which will be used for the determination of the soil class, is obtained by the geometric weighting of the values of the lift at 95% before imbibition (immediate CBR) and after immersion for 4 days (soaked CBR) as shown in the following expression:

$$CBR = CBR_i^{\alpha} * CBR_s^{\beta}$$

The weighting coefficients α and β are regional coefficients depending on the climatic region considered as shown in the following table.

Table 3.1: Regional weighting factors

Region	Number of months		Weighting factors	
	Humid	Dry	α	β
A	6	6	0.5	0.5
B	4	8	0.33	0.67
C	2	10	0.17	0.83

Or , our project is located in climatic region B; according to figure 3.1; so $\alpha = 0.67$ and $\beta = 0.33$.

We also have : $CBR_i = 10$ and $CBR_s = 6$.

So,

$$CBR = CBR_i^{\alpha} * CBR_s^{\beta} = 10^{0.67} * 6^{0.33} = 8.45$$

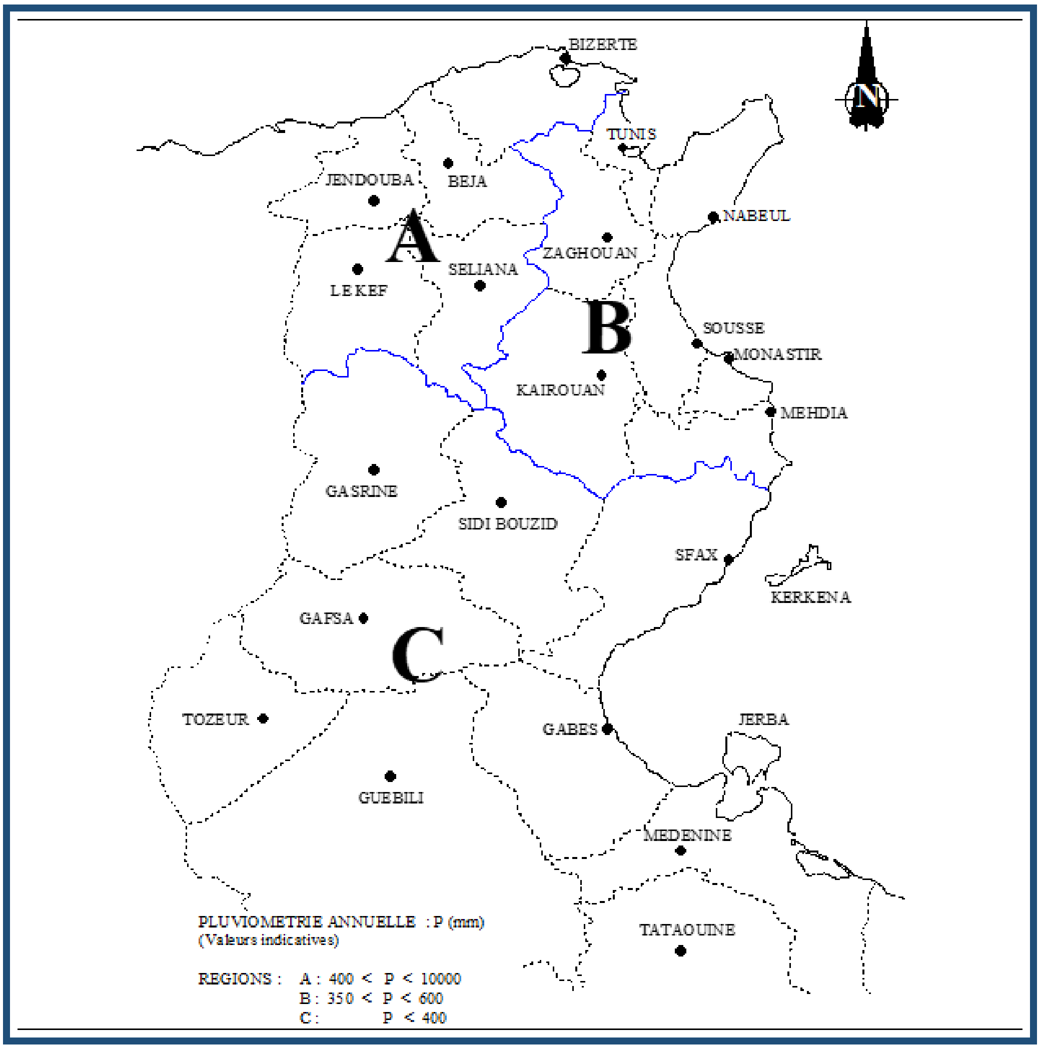

Figure 3.1: Climatic regions of Tunisia

According to the Tunisian catalog, the soil lift class is determined by the value of the weighted lift as presented in the table below.

Table 3.2: Soil classes

CBR	0 to 5	5 to 8	8 to 12	12 to 20	> 20
Class	S0	S1	S2	S3	S4

According to the table, our soil is classified as S2.

3.3.2 Determination of permissible limits of materials

Calculating the allowable soil deformation helps us determine an adequate thickness and effective pavement for the supported traffic expressed in number of axles of 13 tonnes which is equal in our case to $T_c = 7.1 * 10^6$.

3.3.3 The admissible vertical deformation of the soil

The admissible vertical deformation of the soil is calculated in two different ways as following:

- If the traffic is heavy (T>T3):

$$\epsilon_{z,adm} = 12000 * (NE)^{-0.222}$$

- If the traffic is low (T<T3):

$$\epsilon_{z,adm} = 16000 * (NE)^{-0.222}$$

Yet, our traffic is too heavy (T0) so :

$$\epsilon_{z,adm} = 12000 * (NE)^{-0.222} = 12000 * (7.1)^{-0.222} = 361.5\mu def$$

3.3.4 The admissible horizontal deformation of the soil

The admissible horizontal deformation of the soil is calculated by "ALIZE":

$$\epsilon_{t,adm} = 69.2\mu def$$

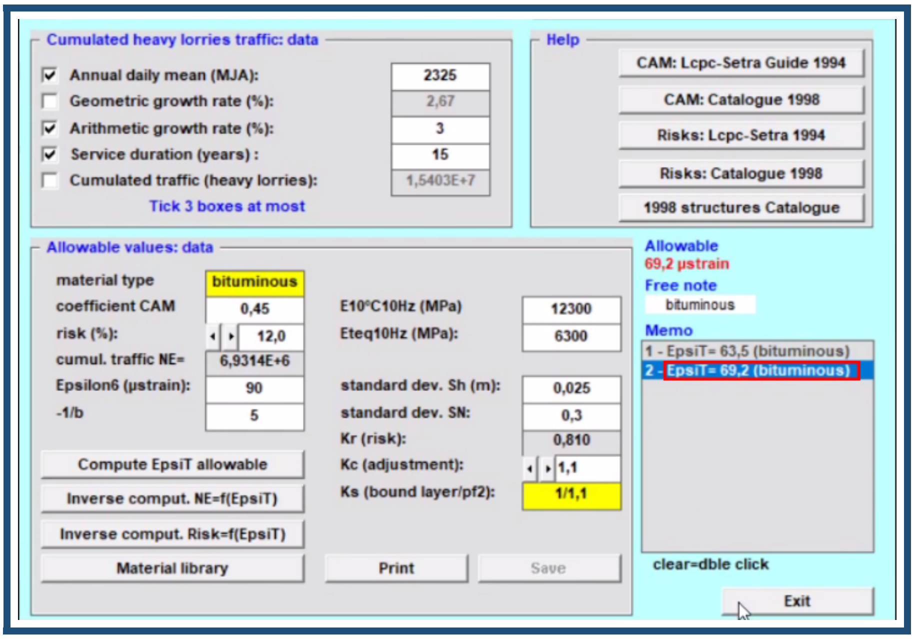

Figure 3.2: Calculation of $\epsilon_{t,adm}$ with "ALIZE"

3.4 Dimensioning with ALIZE

The goal of this modeling is to optimize the thickness of the pavement as much as possible while respecting the admissible deformations of the materials. The variant selected is :

- Wearing course of asphalt concrete AC : 0.06m.
- Base layer in gravel bitumen : 0.22m.
- Fondation layer en GRH 0.30m.
- An underlay of GC between the soil and GRH : 0.20m

After adding these layers, we have to enter the modulus to each variant :

- Wearing course of asphalt concrete AC : 3600MPa.
- Base layer in gravel bitumen : 6300MPa.
- Fondation layer en GRH 500MPa.
- An underlay of GC between the soil and GRH : 300m
- the infinite layer of soil : = 5 * CBR = 5 * 8.45 = 42MPa.

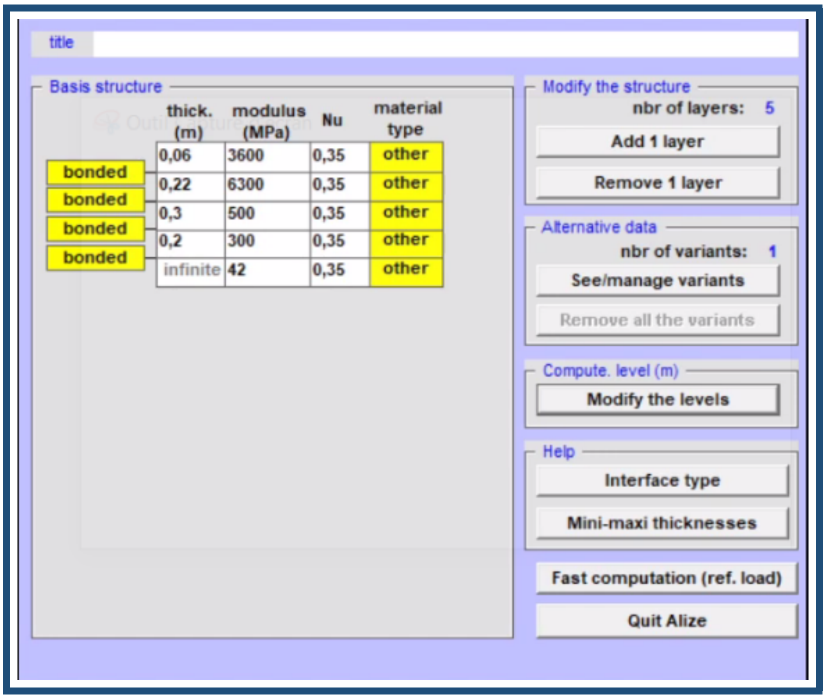

Figure 3.3: Adding layers in ALIZE

The results of the simulation on the trade wind software are presented in the figure below :

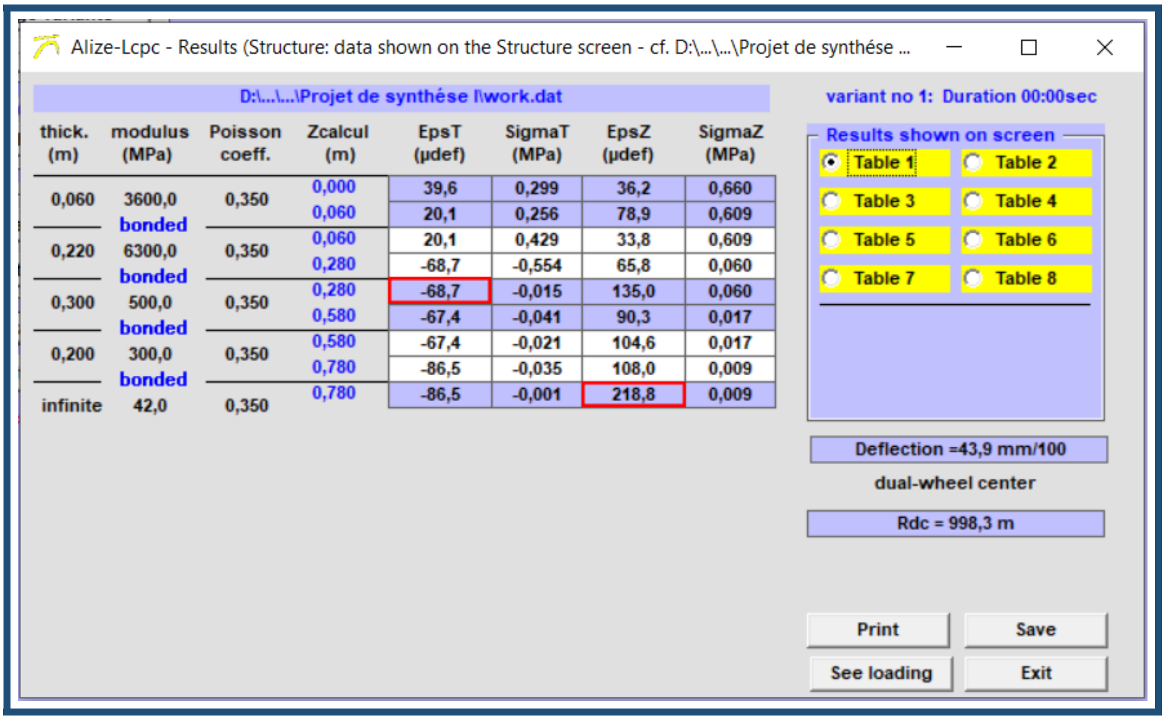

Figure 3.4: Simulation with ALIZE

The simulation with ALIZE interprets us :

- The allowable vertical soil deformation is greater than the vertical deformation maximum obtained by the simulation :

$$\epsilon_{z,adm} = 361.5\mu def > 135\mu def = \epsilon_{z,sol}$$

$$=> \text{Verified}$$

- The allowable horizontal soil deformation is greater than the horizontal deformation maximum obtained by the simulation :

$$\epsilon_{t,adm} = 69.2\mu def > 68.7\mu def = \epsilon_{t,sol}$$

$$\text{Verified}$$

The following is two tables of the values of horizontal and vertical deformations and the values of permissible horizontal and vertical deformations as a function of the thicknesses of the base layer in gravel bitumen with two summary charters.

Table 3.3: The horizontal deformation and the permissible horizontal deformation values

Layer thickness(cm)	**12**	**14**	**16**	**18**	**20**	**22**	**24**
$\epsilon_t(\mu def)$	105.1	95.9	88.2	81.1	74.6	68.7	63.4
$\epsilon_{t,adm}(\mu def)$	69.2	69.2	69.2	69.2	69.2	69.2	69.2

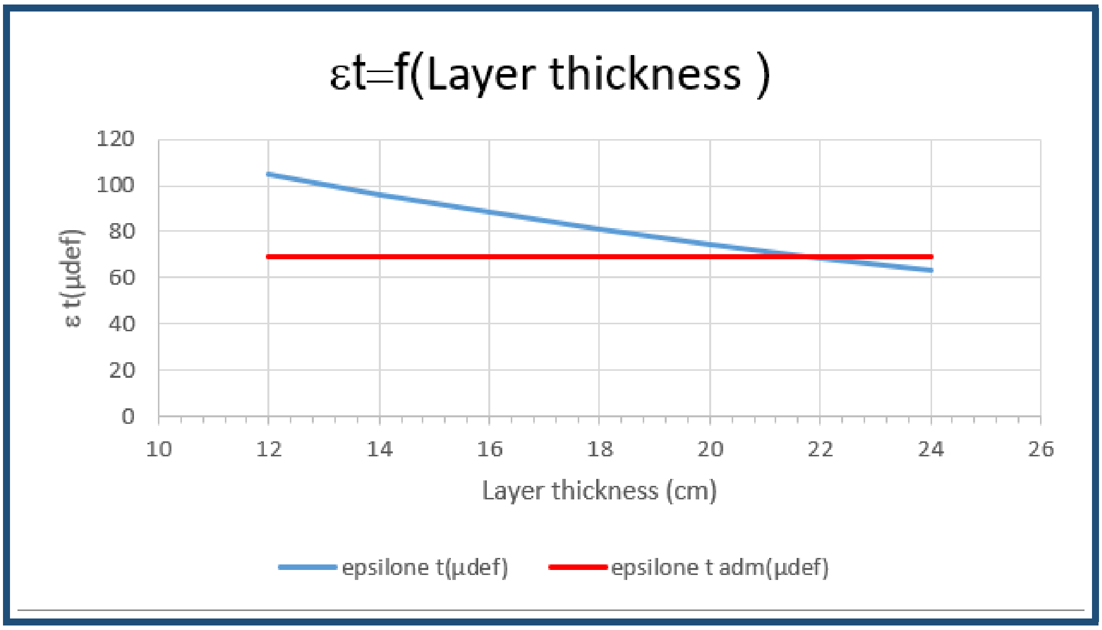

Figure 3.5: Comparison between the horizontal deformation and the permissible horizontal deformation values

Table 3.4: The vertical deformation and the permissible vertical deformation values

Layer thickness(cm)	**12**	**14**	**16**	**18**	**20**	**22**	**24**
$\epsilon_z(\mu def)$	336.8	307.7	286.1	258.3	237.4	218.8	202
$\epsilon_{z,adm}(\mu def)$	361.5	361.5	361.5	361.5	361.5	361.5	361.5

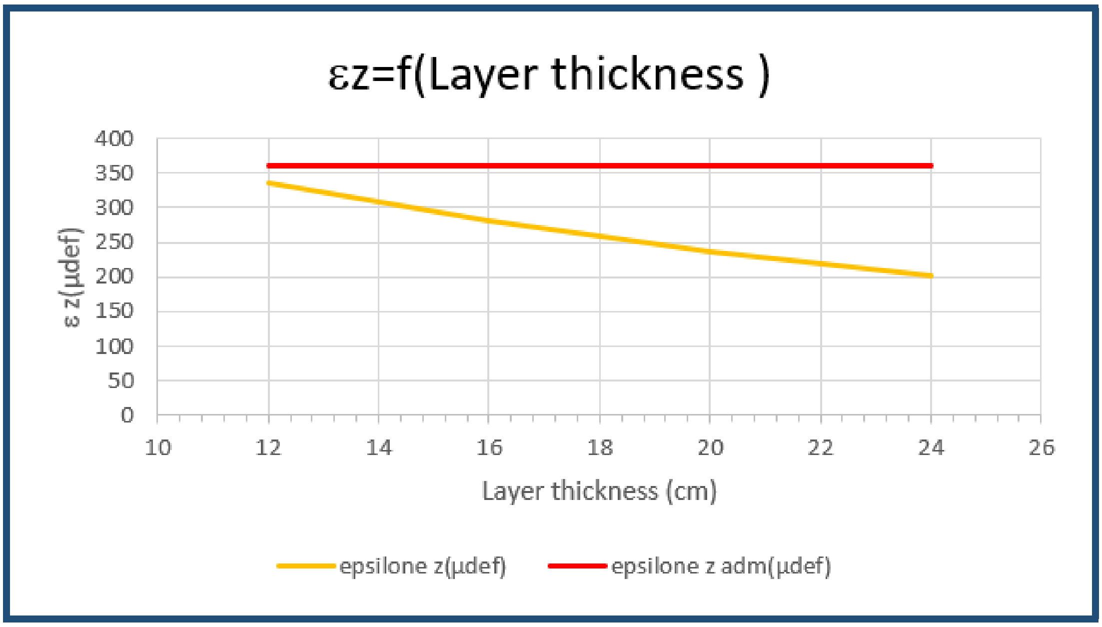

Figure 3.6: Comparison between the vertical deformation and the permissible vertical deformation values

3.5 Conclusion

The dimensioning study thus enabled us to determine the structure of our project, the nature of each layer and the thicknesses of the different layers using the "ALIZE-LCPC" software.

Chapter 4

Modeling the bridge using "SAP2000"

Plan

4.1 Introduction

Modeling makes it possible to understand the variables that influence a structure designed to optimize technically and conduct audits of stability, stiffness and strength.

In this project, we will focus on the numerical modeling by finite element method using a structural software for analysis and design "SAP2000".

In fact, The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. "SAP2000" follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

4.2 Data entry

In order to enter the data, we have followed these steps :

4.2.1 Defining the work space

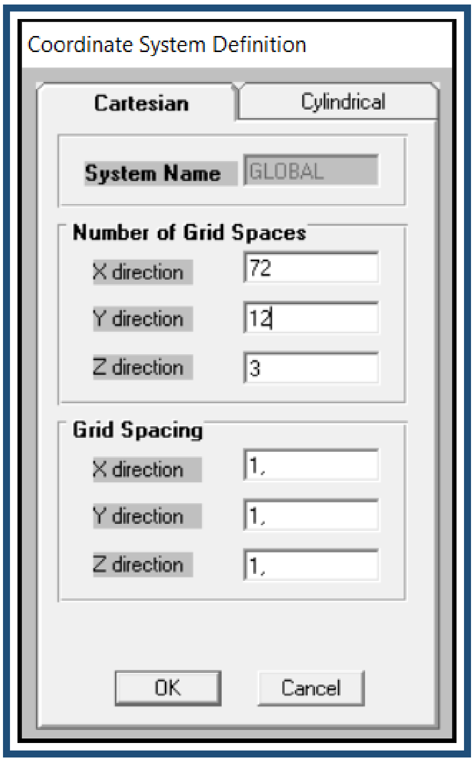

Figure 4.1: Defining Coordinate system in "SAP2000"

4.2.2 Drawing the shell

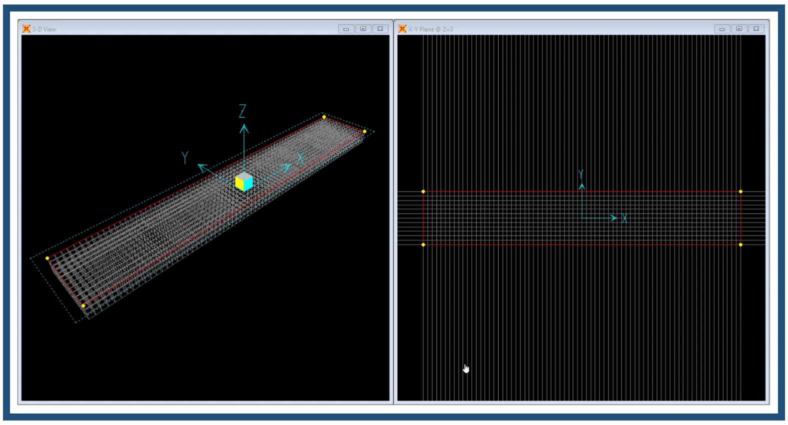

Figure 4.2: Drawing the shell in "SAP2000"

4.2.3 Defining the materials

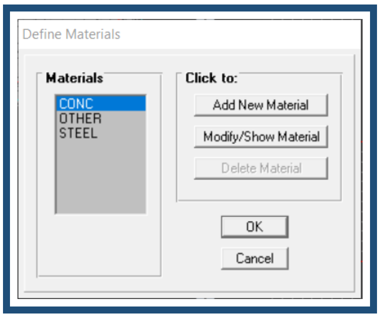

Figure 4.3: Defining the materials in "SAP2000"

4.2.4 Assigning the section to the shell

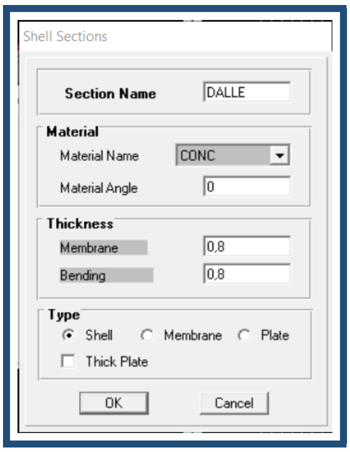

Figure 4.4: Assigning the section in "SAP2000"

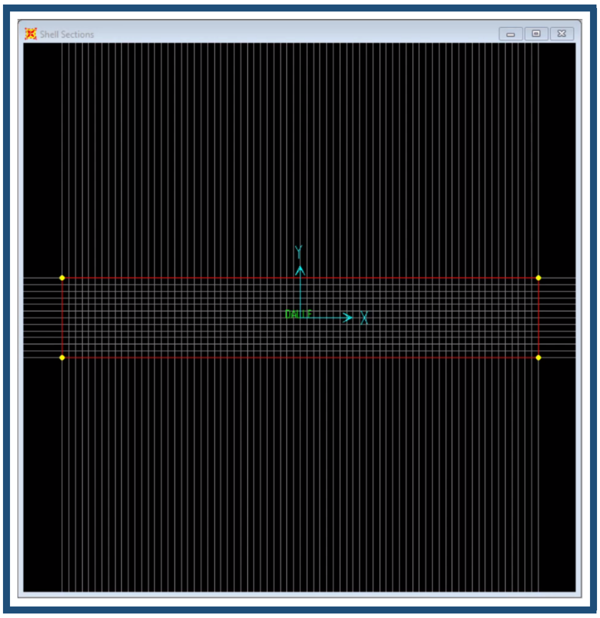

Figure 4.5: The shell after assigning the section in "SAP2000"

4.2.5 Calculating by finite element method

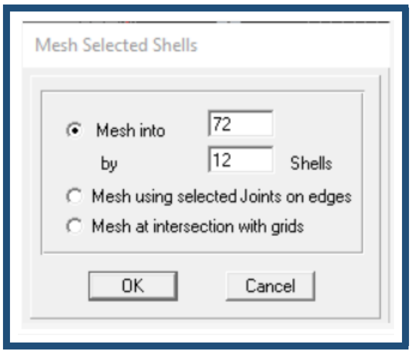

Figure 4.6: Calculationg in "SAP2000"

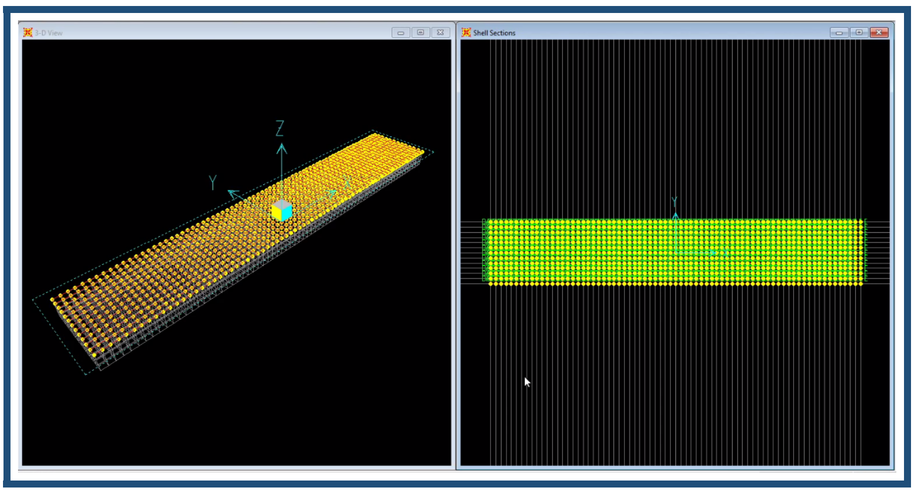

Figure 4.7: The shell after calculating in "SAP2000"

4.2.6 Locating the bearings

We have put 3 bearings in each fold, in total 3 * 5 = 15.

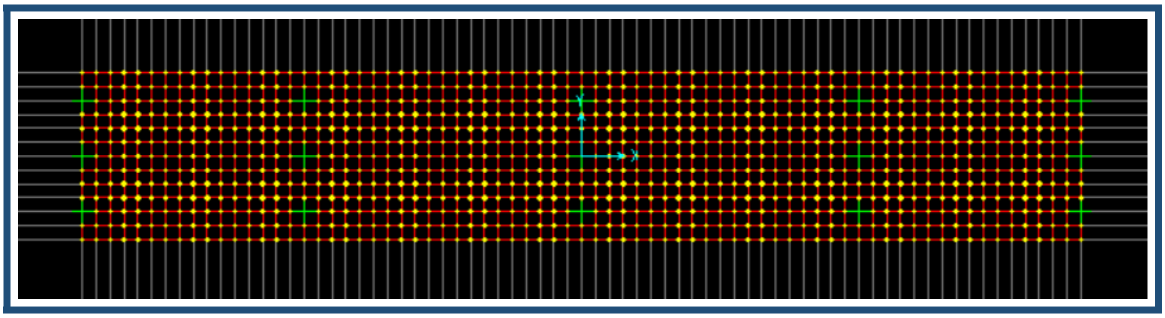

Figure 4.8: The shell after locating the bearings in "SAP2000"

4.3 Dynamic study

The purpose of dynamic structure analysis is to know its vibratory behavior in response to dynamic excitation forces.

Modeling and computation by finite elements make it possible to determine the eigen modes (modal analysis) as well as the vibratory response to a dynamic force (response computation).

4.3.1 Dynamic study of the structure up to the 6th clean modes

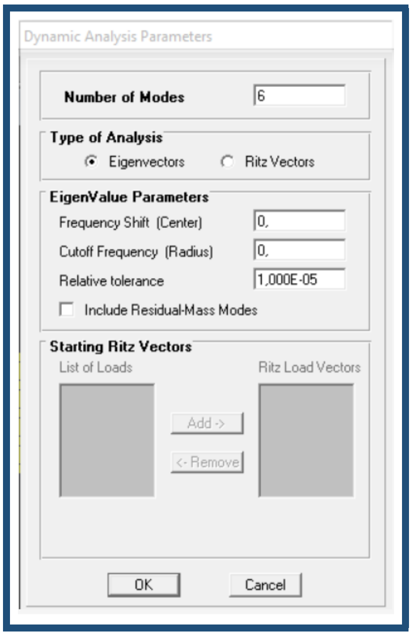

Figure 4.9: Configuring number of modes at 6 in "SAP2000"

4.3.2 Run the system

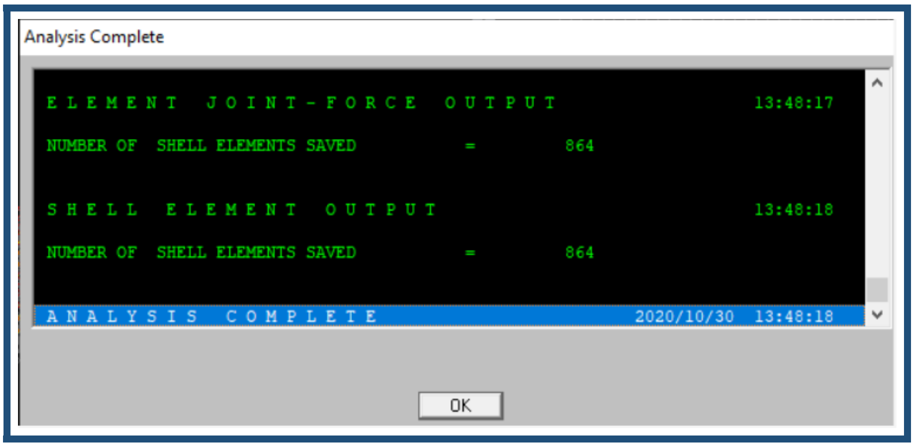

Figure 4.10: Analysing completed successfully in "SAP2000"

4.3.3 Results

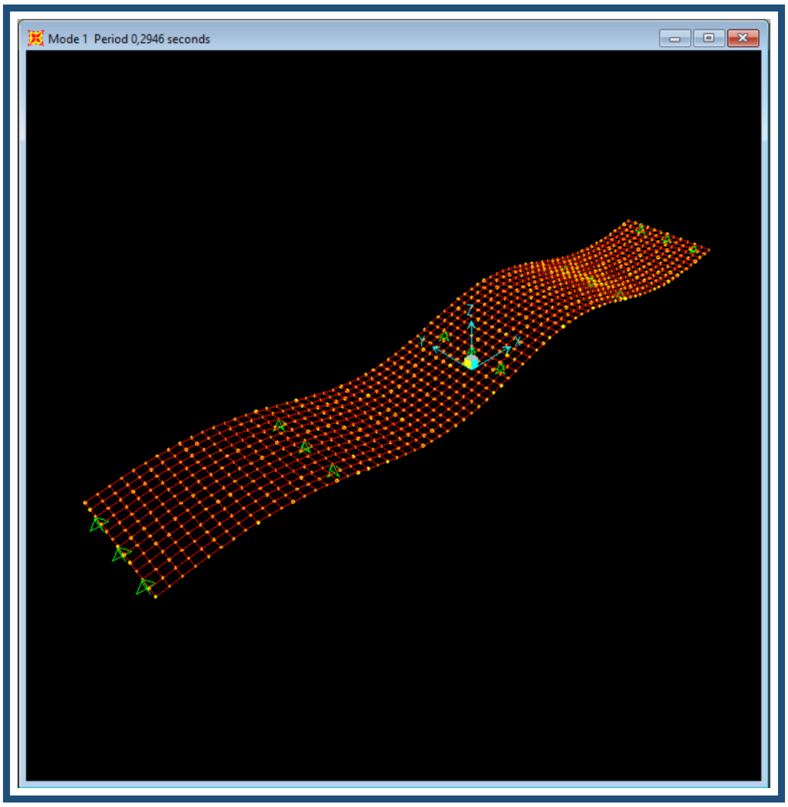

Figure 4.11: Mode 1 in "SAP2000"

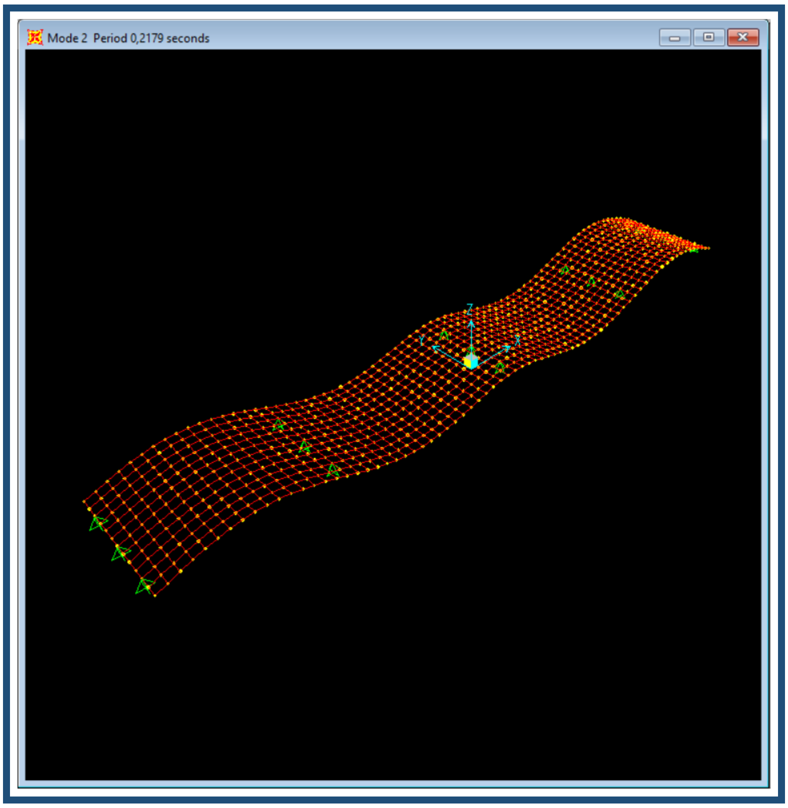

Figure 4.12: Mode 2 in "SAP2000"

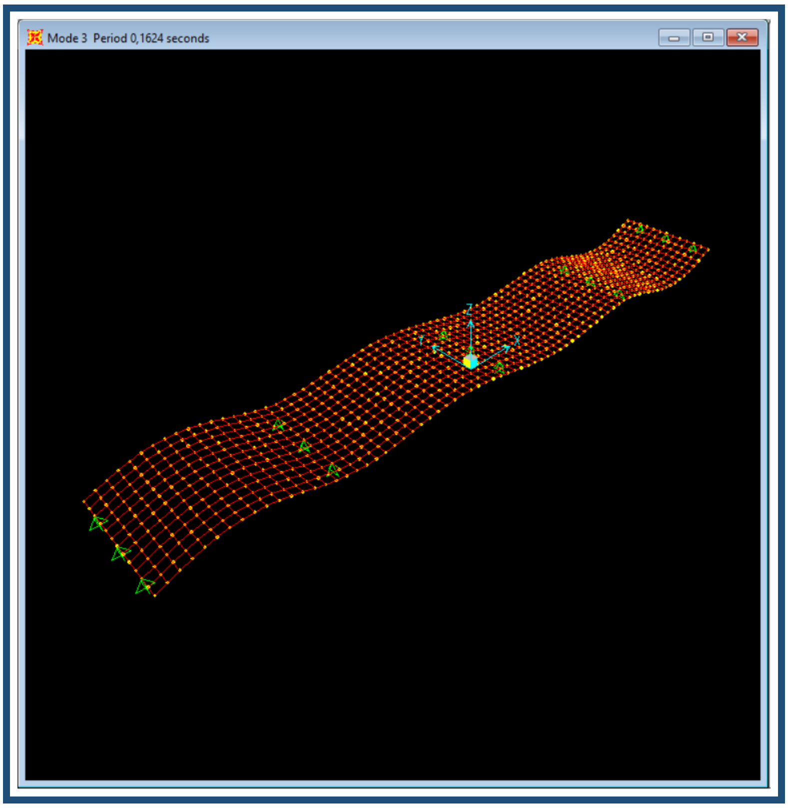

Figure 4.13: Mode 3 in "SAP2000"

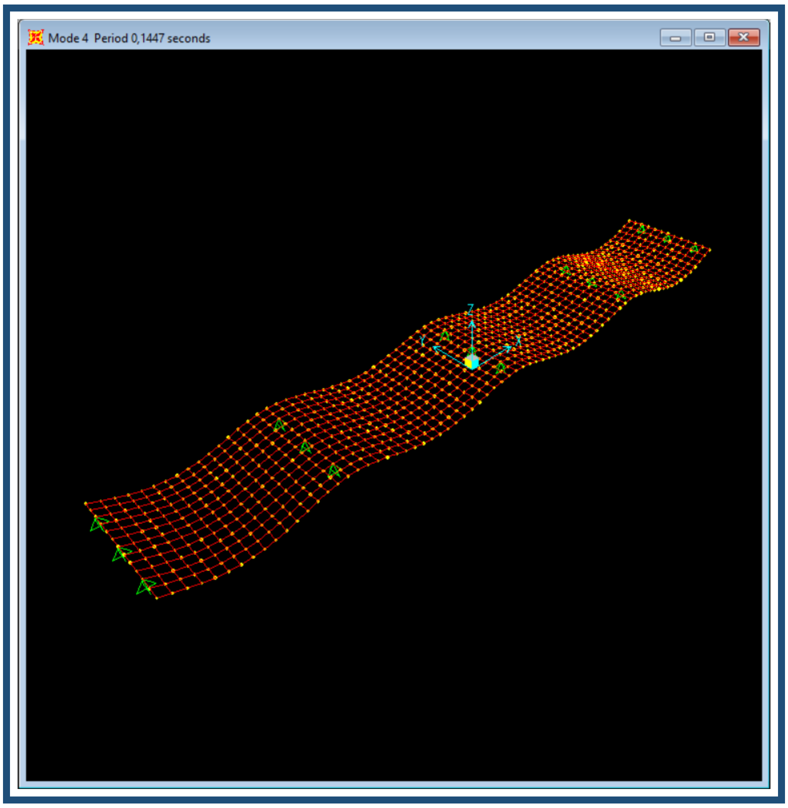

Figure 4.14: Mode 4 in "SAP2000"

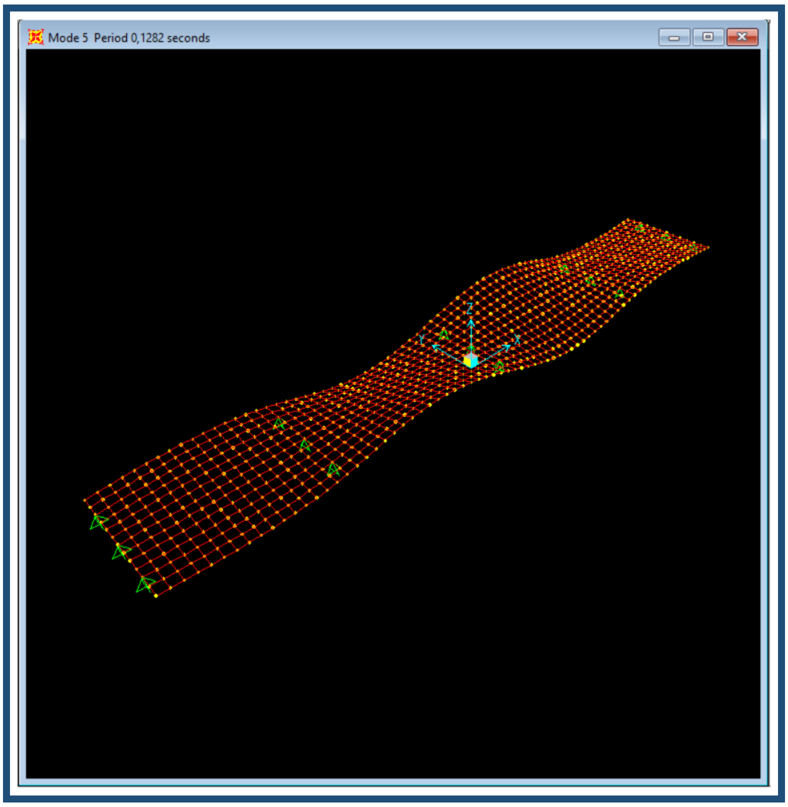

Figure 4.15: Mode 5 in "SAP2000"

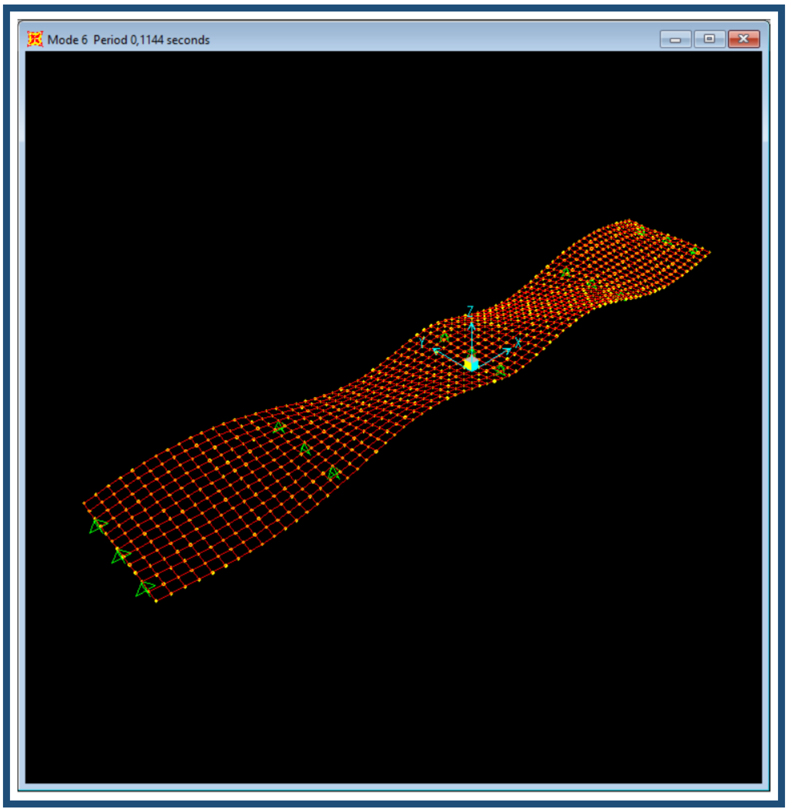

Figure 4.16: Mode 6 in "SAP2000"

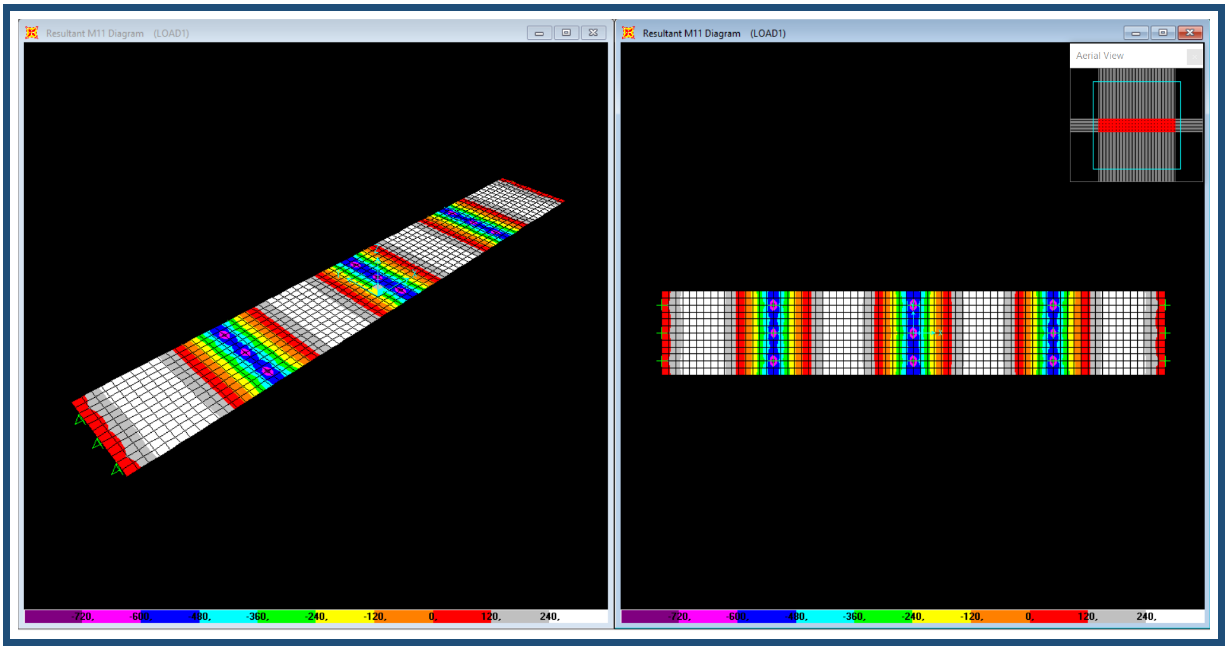

Figure 4.17: Displaying loads under the self-weight in "SAP2000"

The obtained frequencies are presented in the following table :

Table 4.1: Frequencies of each mode

Mode	Period(s)	Frequency(Hz)
1	0.2946	3.39
2	0.2179	4.589
3	0.1624	6.157
4	0.1447	6.91
5	0.1282	7.8
6	0.1144	8.74

The frequency of the seismic excitation is between the interval [2Hz ; 4Hz], or , we have F1=3.39 Hz so the structure is not safe to the from a resonance point of view.
And the structure is safe to the seismic excitation for the rest of the modes because all their frequencies do not belong to the interval [2Hz ; 4Hz].

4.3.4 Parameters that influence the natural frequency of the structure

4.3.4.1 Constant load

- Weight of the bridge construction
- The effect of before estimated tension
- The effect of solid pressure
- Hydrostatic pressure
- The effects of the concrete swell or setting down [6]

4.3.4.2 Temporary dynamic load and its effects

- Vertical load (transport vehicles and pedestrians)
- Soil pressure effect influenced by the temporary dynamic load (prism of crashes)
- Horizontal load of centrifugal power
- Horizontal impact of dynamic load
- Horizontal power of braking or load pulling[6]

4.3.4.3 Other temporary loads and their effects

- Wind effect
- Ice effect
- Wave impact
- The effects of ambient temperature change
- The effects of land bulging
- Structural weight
- Earthquake effect [6]

4.3.5 Solutions

As mentioned before, our structure is not safe to the seismic excitation from a resonance point of view in mode 1. That's why it is necessary before the construction of a bridge to know the seismic risks of the region.

Several solutions have been implemented to prevent the harmful effects of seismic excitation:

- A solution is to give the deck an inverted airplane wing profile so that, in windy conditions, it exerts a downward force instead of lifting and falling (which deteriorates the shrouds and the strength of the the structure.)[5]
- Another solution is to surround the cables with a profiled sheath in order to limit their drag.[5]
- The most effective solution is still the use of shock absorbers which absorb the energy caused by the earthquake. There are three types:
  - **Elastoplastic shock absorbers :** their role is to absorb horizontal seismic forces and to dissipate energy by alternating plasticization.[5]
  - **Friction dampers :** they decrease the amplitude linearly and completely stop the system by friction.[5]
  - **Viscous dampers :** devices comparable to a double-acting hydraulic cylinder with a high energy dissipation capacity.[5]

4.4 Studying the bridge under load "Al"

4.4.1 Moment on central support

The following figure presents the line of influence of the bending moment when we apply the load in the central support.

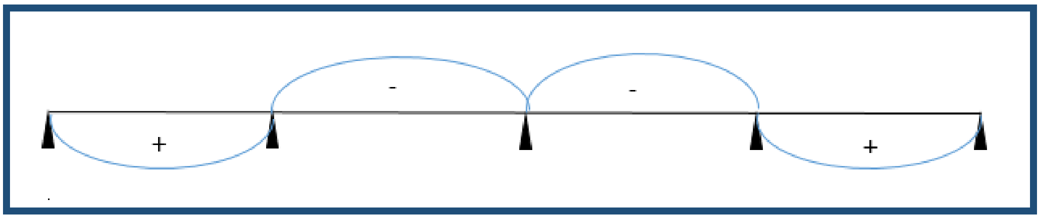

Figure 4.18: Line of influence of the bending moment

In order to find maximum negative moments, we will apply the load "A_l" as following according to 3 load cases :

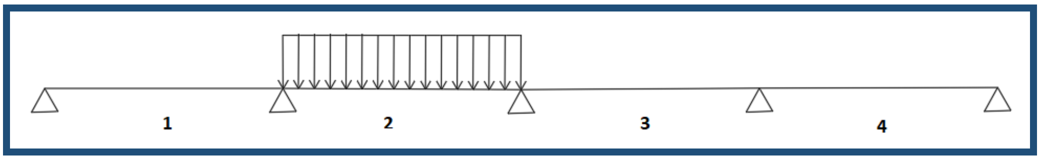

Figure 4.19: Load case 1

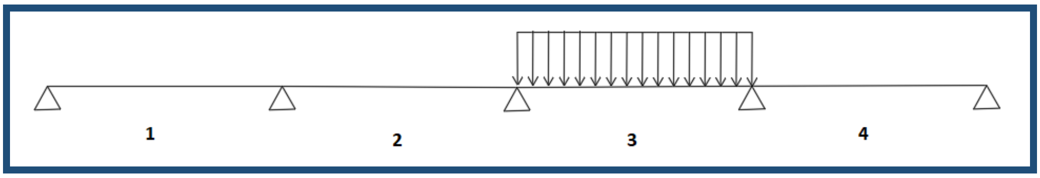

Figure 4.20: Load case 2

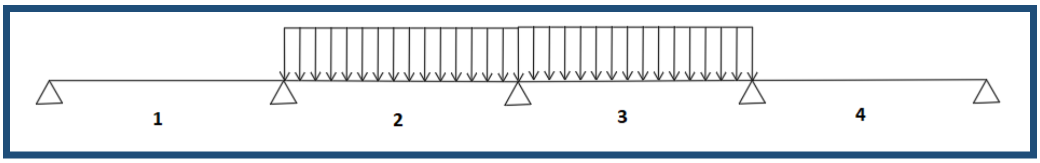

Figure 4.21: Load case 3

For the calculation of the load "Al" in each load case, the following formula is used :

$$\mathrm{A_l} = a_2(sup(a_1(2,3 + \frac{360}{\mathrm{L}+12})); 4 - 0.002 * L)\ \left(\mathrm{kN/m^2}\right)$$

with :

- "L": span length
- a_1=f(class of the bridge,number of loaded ways) $= 0.9$
- $a_2 = \frac{V_0}{V} = \frac{3.5}{3.5} = 1$

4.4.1.1 Case 1 : bay 2 loaded alone

$$\mathrm{L} = 20\mathrm{m} \quad => A_{l1} = 12.19\left(\mathrm{kN/m^2}\right)$$

- Define load

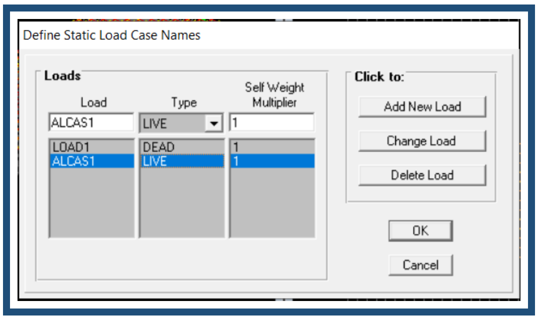

Figure 4.22: Defining A_{l1} in "SAP2000"

- Select the second bay

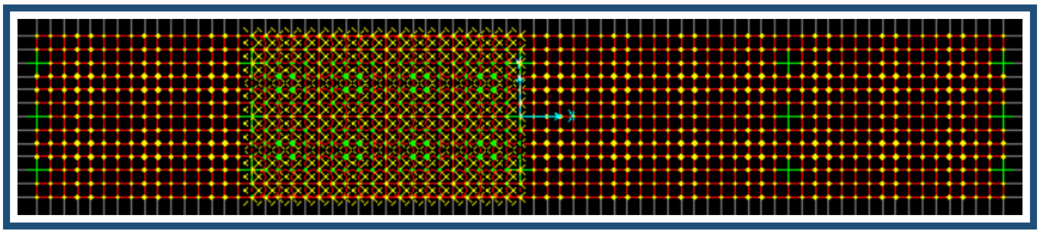

Figure 4.23: Selecting the second bay in "SAP2000"

- Apply load

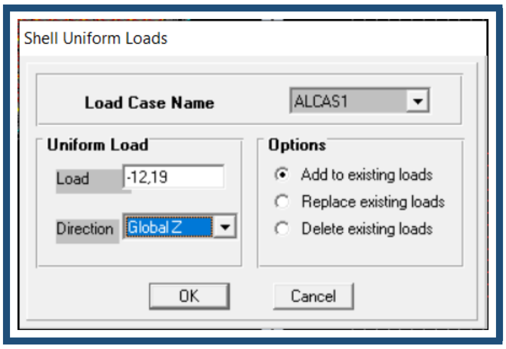

Figure 4.24: Applying A_{l1} in "SAP2000"

- Display the loads under the load A_{l1}

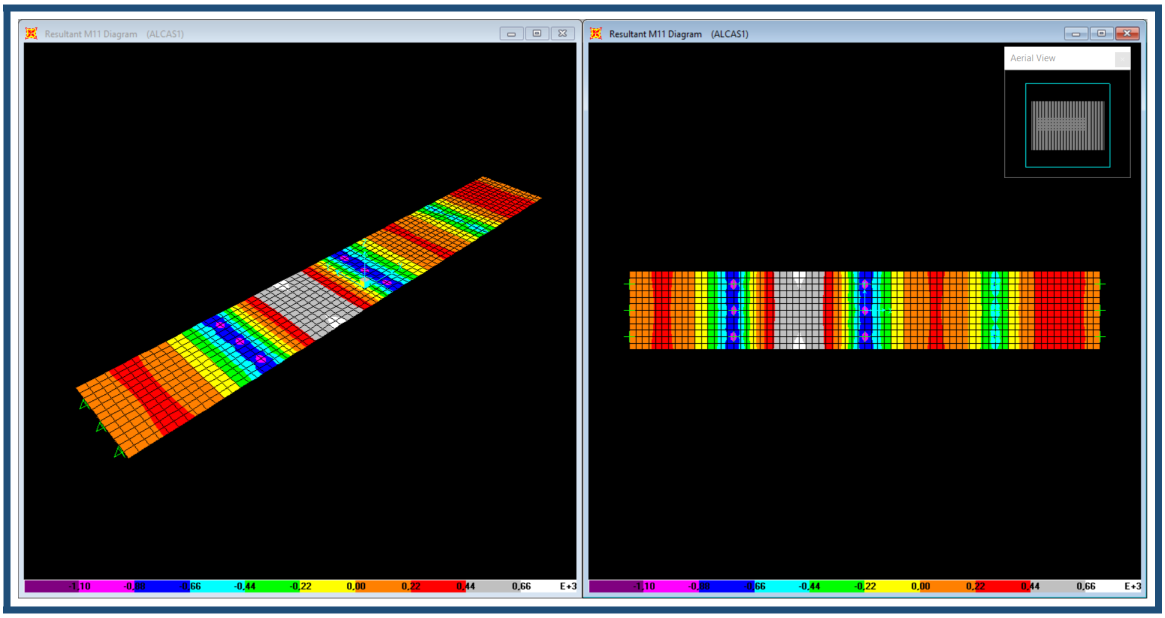

Figure 4.25: Displaying loads under the load A_{l1} in "SAP2000"

- Define load combination: COMB1ELU

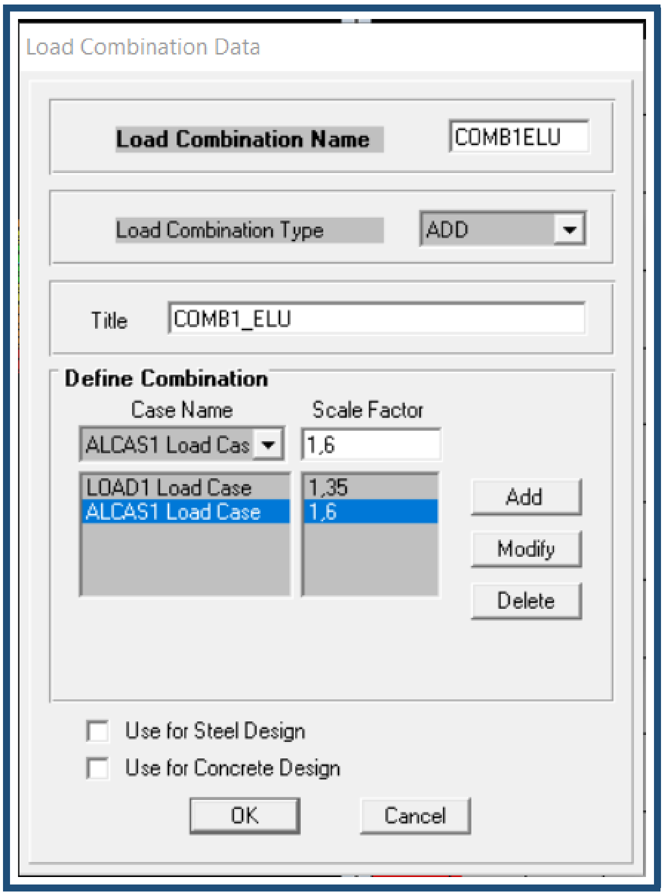

Figure 4.26: Defining load combination COMB1ELU in "SAP2000"

- Display the loads under the combination COMB1ELU

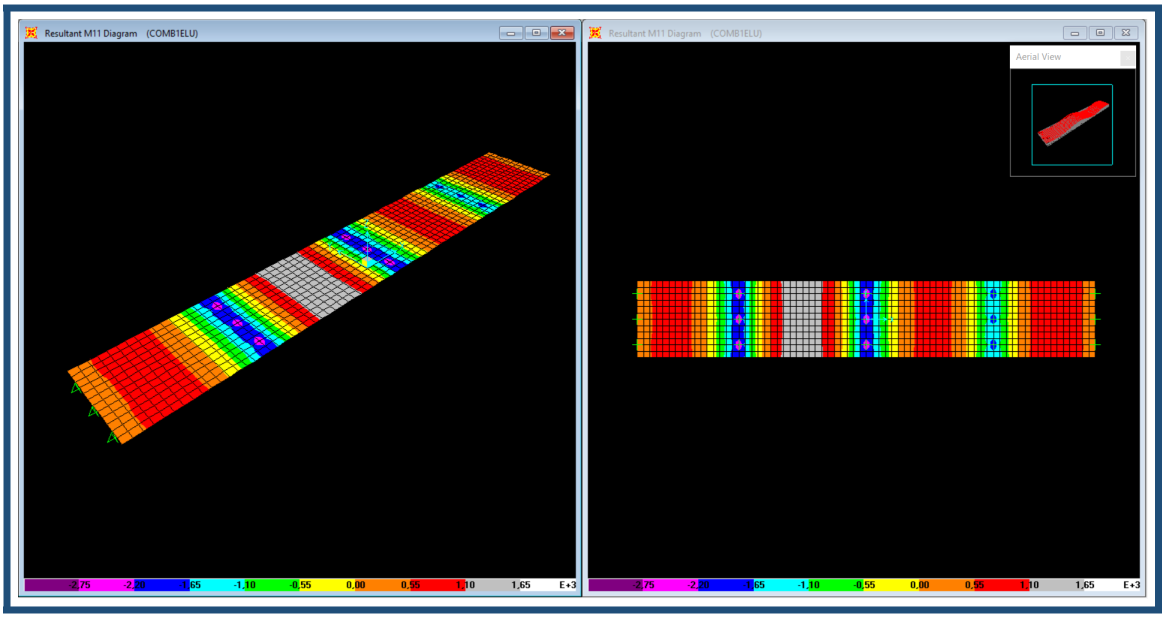

Figure 4.27: Displaying loads under the combination COMB1ELU in "SAP2000"

The maximum moment value obtained in central support from COMB1ELU is 2977.73 kN/m.

4.4.1.2 Case 2 : bay 3 loaded alone

Case 2 is identical to Case 1 as the second and the third bays are symmetric.

The maximum moment value obtained in central support from COMB2ELU is 2977.73 kN/m.

4.4.1.3 Case 3 : bay 2 and 3 loaded together

$$\mathrm{L} = 40\mathrm{m} \;\; => A_{l3} = 8.3\left(\mathrm{kN/m^2}\right)$$

- Define load

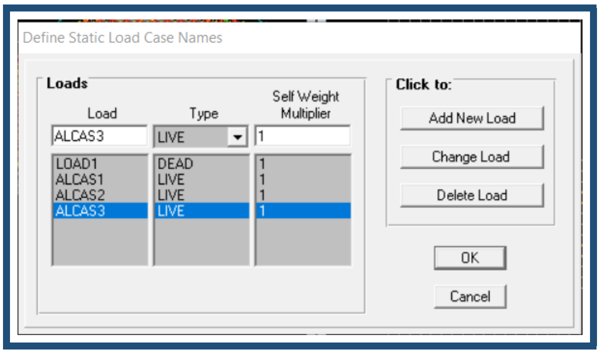

Figure 4.28: Defining A_{l3} in "SAP2000"

- Select the second and third bays

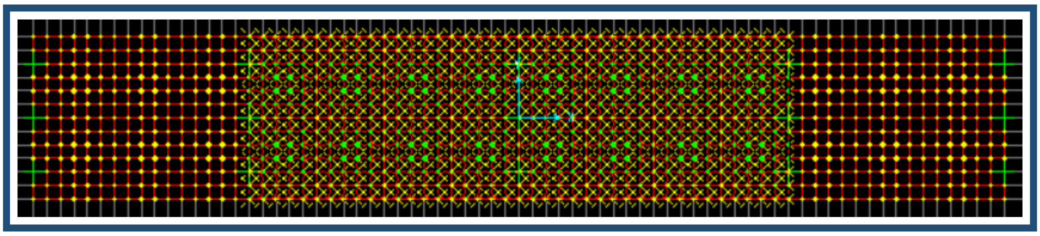

Figure 4.29: Selecting the second and third bays in "SAP2000"

- Apply load

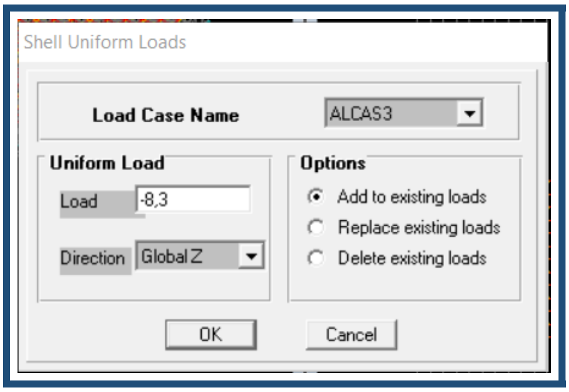

Figure 4.30: Applying A_{l3} in "SAP2000"

- Display the loads under the load A_{l3}

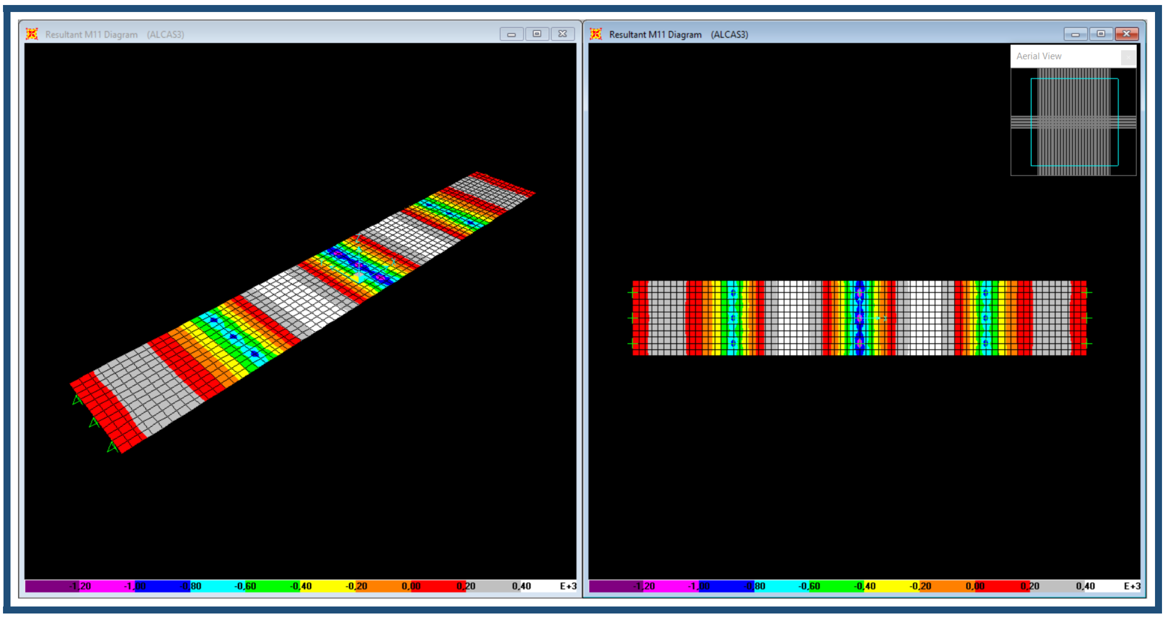

Figure 4.31: Displaying loads under the load A_{l3} in "SAP2000"

- Define load combination: COMB3ELU

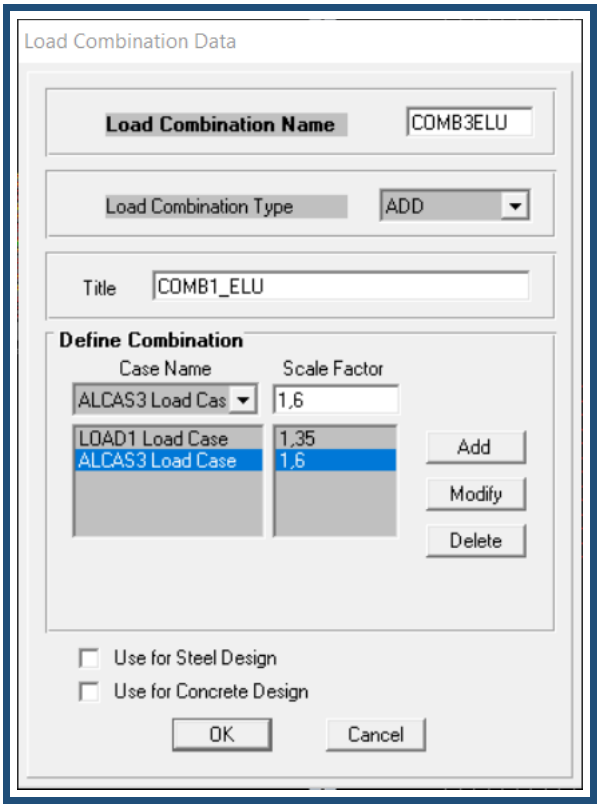

Figure 4.32: Defining load combination COMB3ELU in "SAP2000"

- Display the loads under the combination COMB3ELU

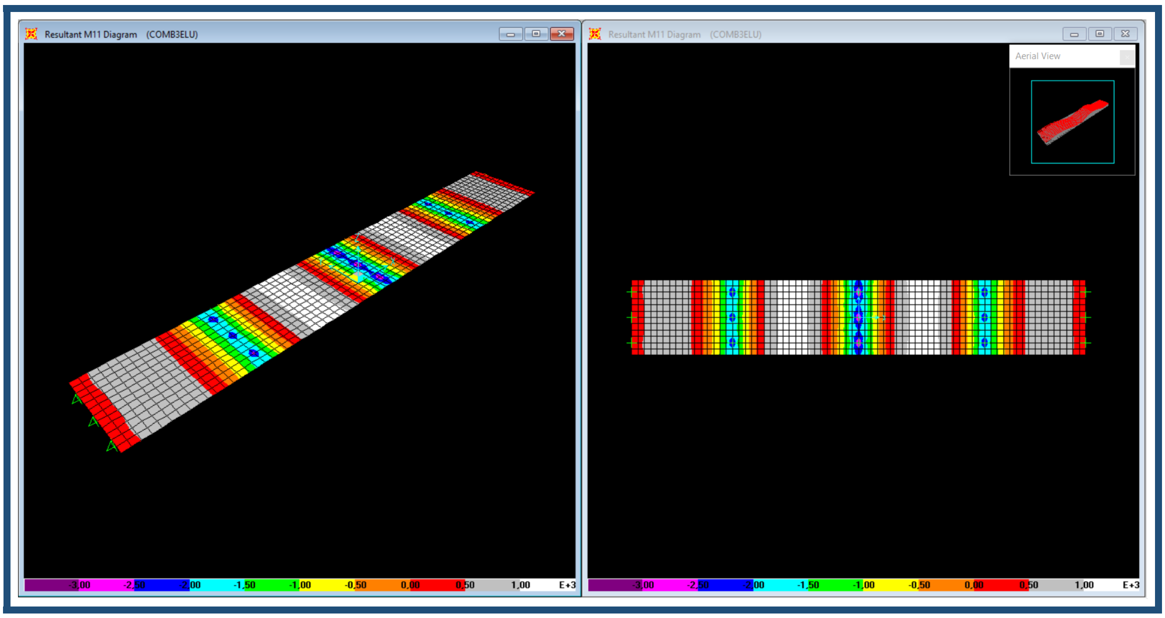

Figure 4.33: Displaying loads under the combination COMB3ELU in "SAP2000"

The maximum moment value obtained in central support from COMB3ELU is 3182.9 kN/m.

This is a summary table of the maximum moment values obtained in the central support :

Table 4.3: Maximum negative moments on central support

Combination	**Maximum negative moments on support** (kN/m^2)
COMB1ELU	2977.73
COMB2ELU	2977.73
COMB3ELU	3183

We notice that the combination COMB3ELU is more soliciting than COMB1ELU and COMB2ELU. So, we are going to dimension the moment on central support from COMB3ELU.

4.4.2 Positive moment at mid-central span

The following figure presents the line of influence of the bending moment when we apply the load at mid-central span.

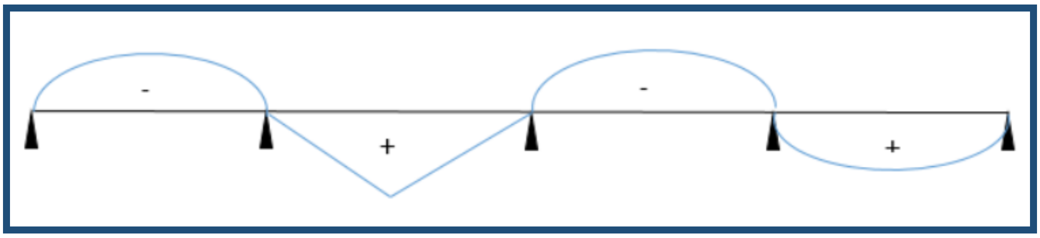

Figure 4.34: Line of influence of the bending moment

In order to look for the maximum positive moments, we will the apply the load "A_l" as following according 3 load cases :

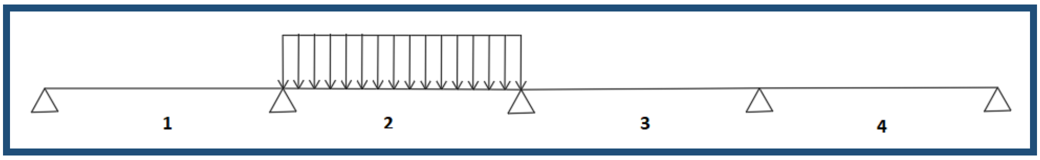

Figure 4.35: Load case 4

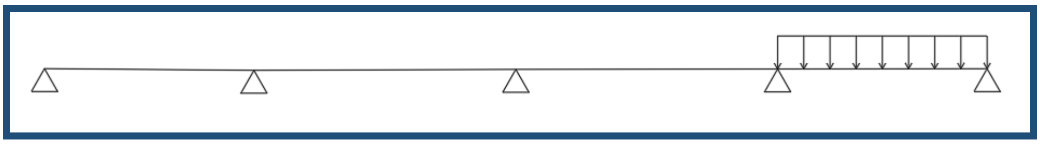

Figure 4.36: Load case 5

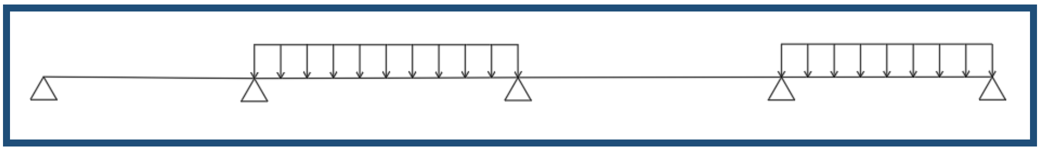

Figure 4.37: Load case 6

For the calculation of the load "Al" in each load case, the following formula is used :

$$\mathrm{A_l} = a_2(sup(a_1(2,3 + \frac{360}{\mathrm{L}+12})); 4 - 0.002 * L)\ (\mathrm{kN/m^2})$$

with :

- "L": span length
- a_1=f(class of the bridge,number of loaded ways) = 0.9
- $a_2 = \frac{V_0}{V} = \frac{3.5}{3.5} = 1$

4.4.2.1 Case 4 : bay 2 loaded alone

Case 4 is identical to Case 1.

The maximum positive moment obtained in mid-central span from COMB4ELU is 1535kN/m.

4.4.2.2 Case 5 : bay 4 loaded alone

$$\mathrm{L} = 16\mathrm{m} \;=> A_{l3} = 13.64\ (\mathrm{kN/m^2})$$

- Define load

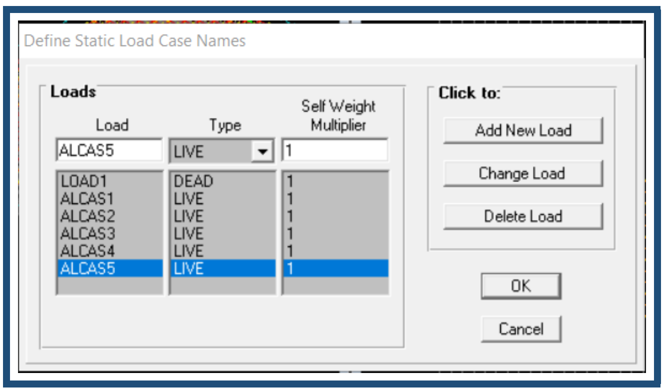

Figure 4.38: Defining A_{l5} in "SAP2000"

- Select the forth bay

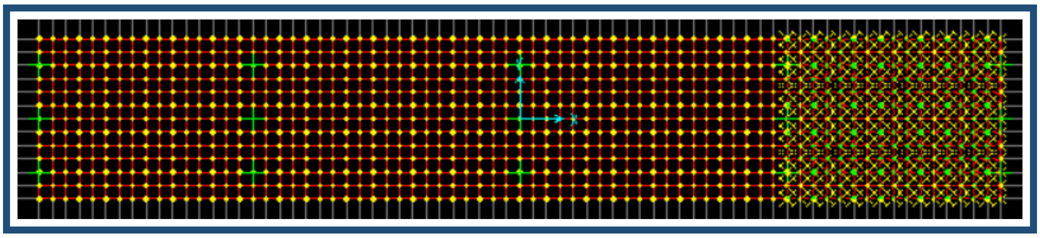

Figure 4.39: Selecting the second and forth bays in "SAP2000"

- Apply load

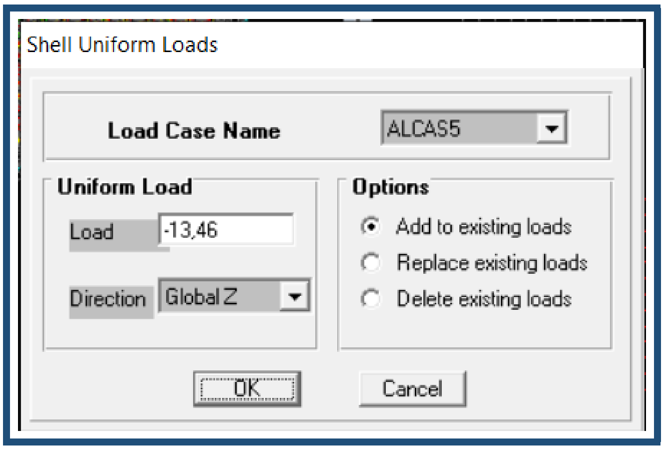

Figure 4.40: Applying A_{l5} in "SAP2000"

- Display the loads under the load A_{l5}

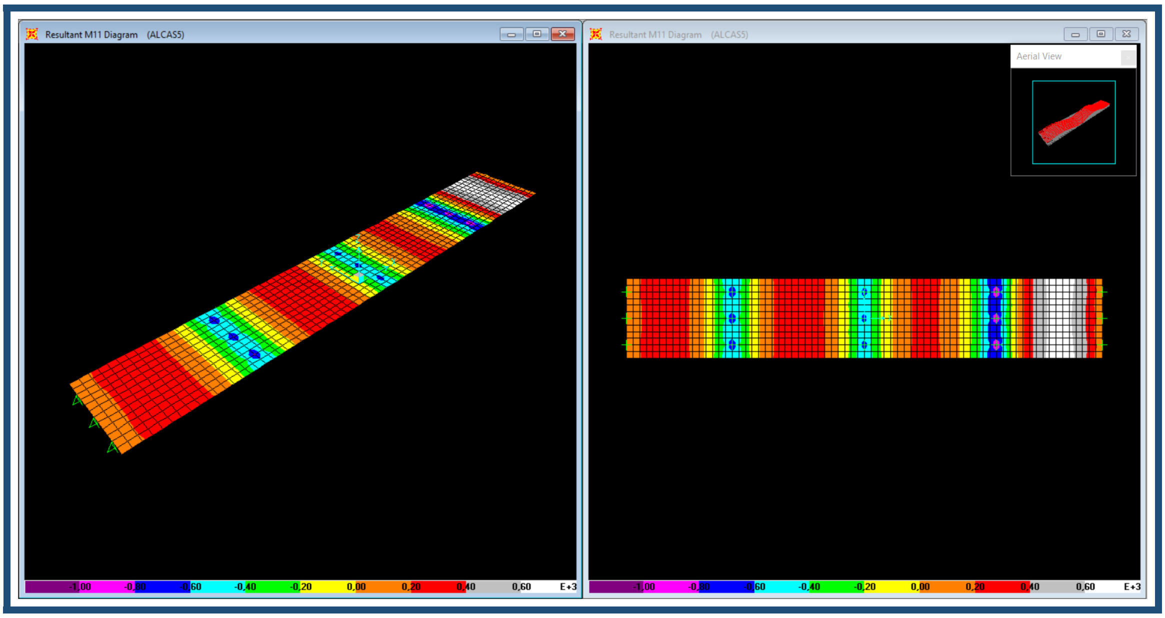

Figure 4.41: Displaying loads under the load A_{l5} in "SAP2000"

- Define load combination: COMB5ELU

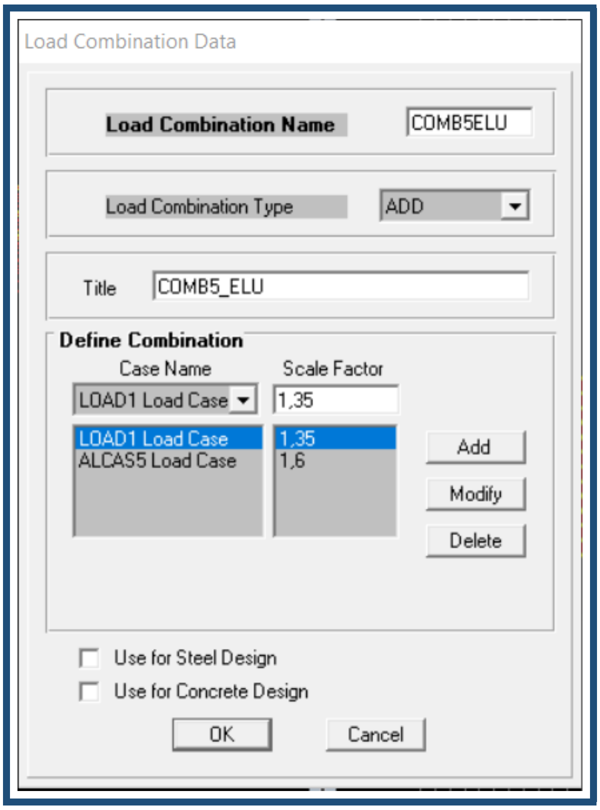

Figure 4.42: Defining load combination COMB5ELU in "SAP2000"

- Display the loads under the combination COMB5ELU

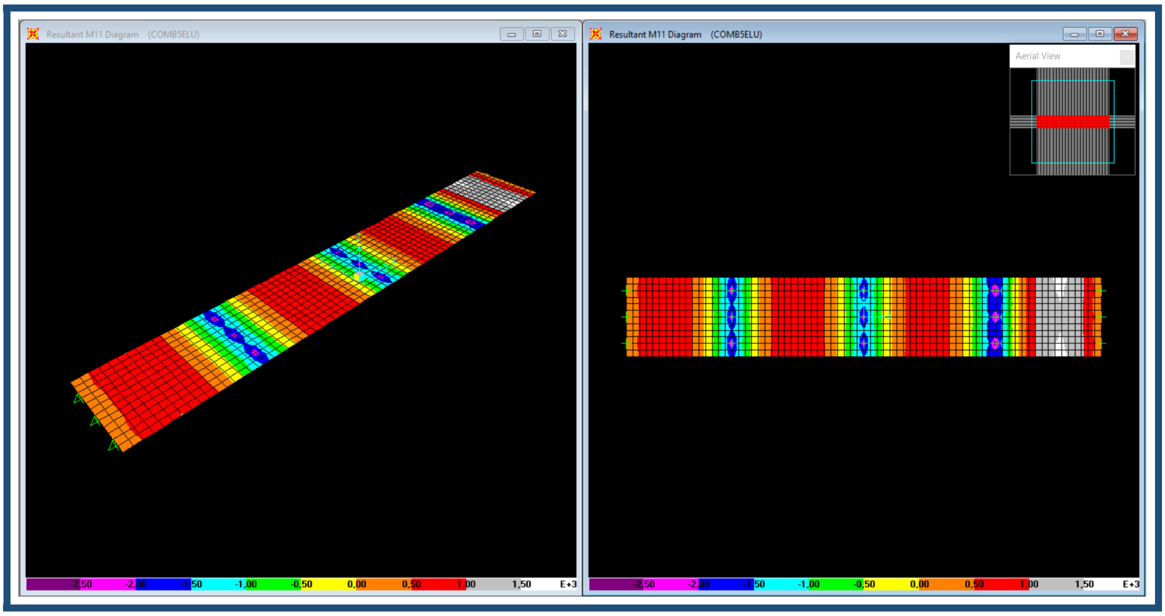

Figure 4.43: Displaying loads under the combination COMB5ELU in "SAP2000"

The maximum positive moment obtained in mid-central span from COMB5ELU is 997.4kN/m.

4.4.2.3 Case 6 : bay 2 and 4 loaded together

$$L = 40\text{m} \implies A_{l6} = 8.82\,(\text{kN/m}^2)$$

- Define load

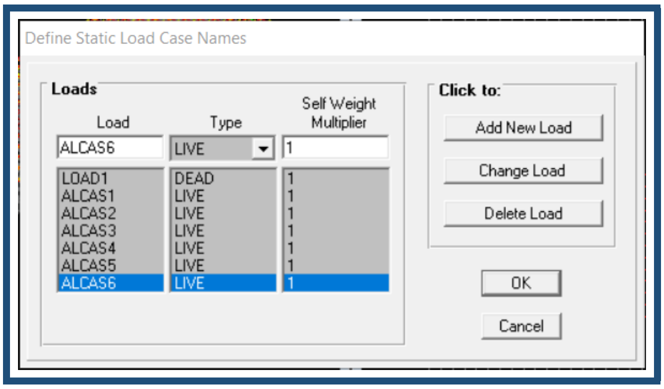

Figure 4.44: Defining A_{l6} in "SAP2000"

- Select the second and forth bays

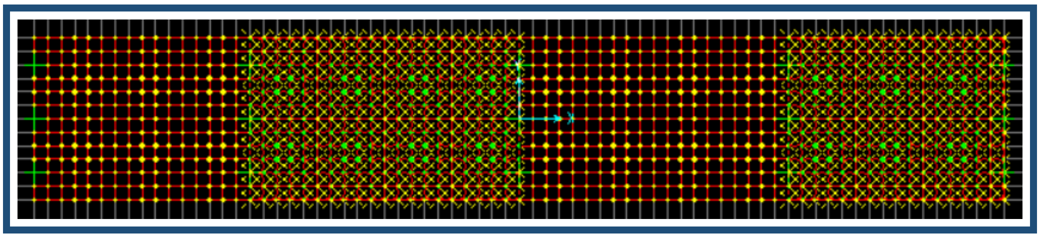

Figure 4.45: Selecting the second and forth bays in "SAP2000"

- Apply load

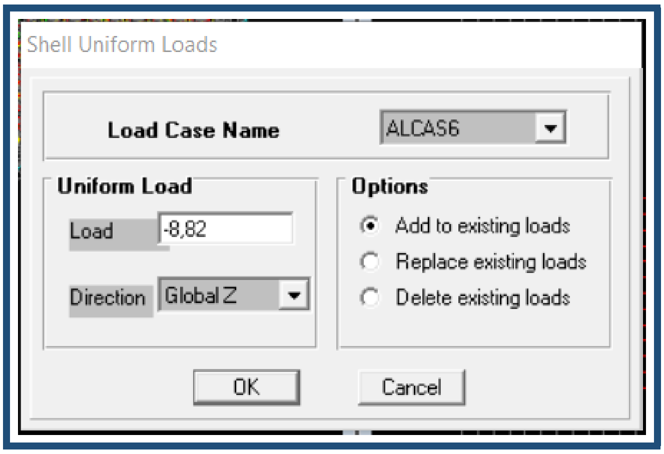

Figure 4.46: Applying A_{l6} in "SAP2000"

- Display the loads under the load A_{l6}

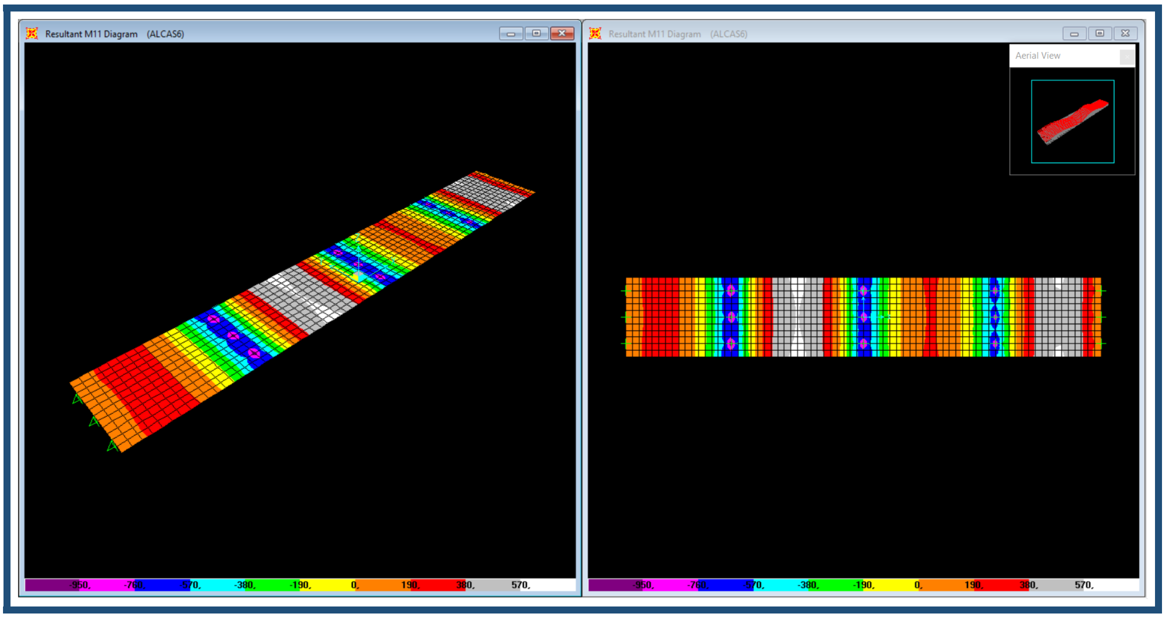

Figure 4.47: Displaying loads under the load A_{l6} in "SAP2000"

- Define load combination: COMB6ELU

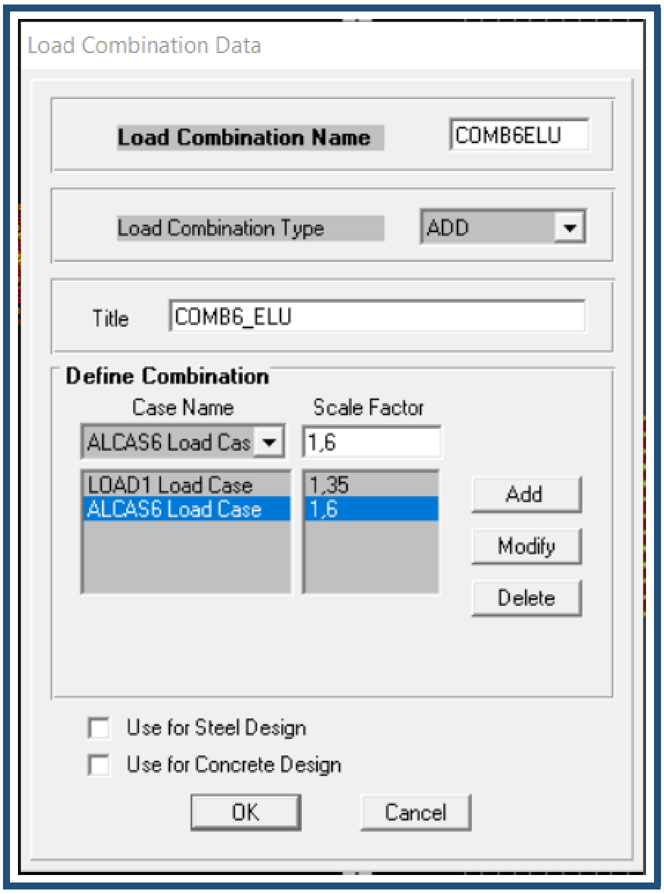

Figure 4.48: Defining load combination COMB6ELU in "SAP2000"

- Display the loads under the combination COMB6ELU

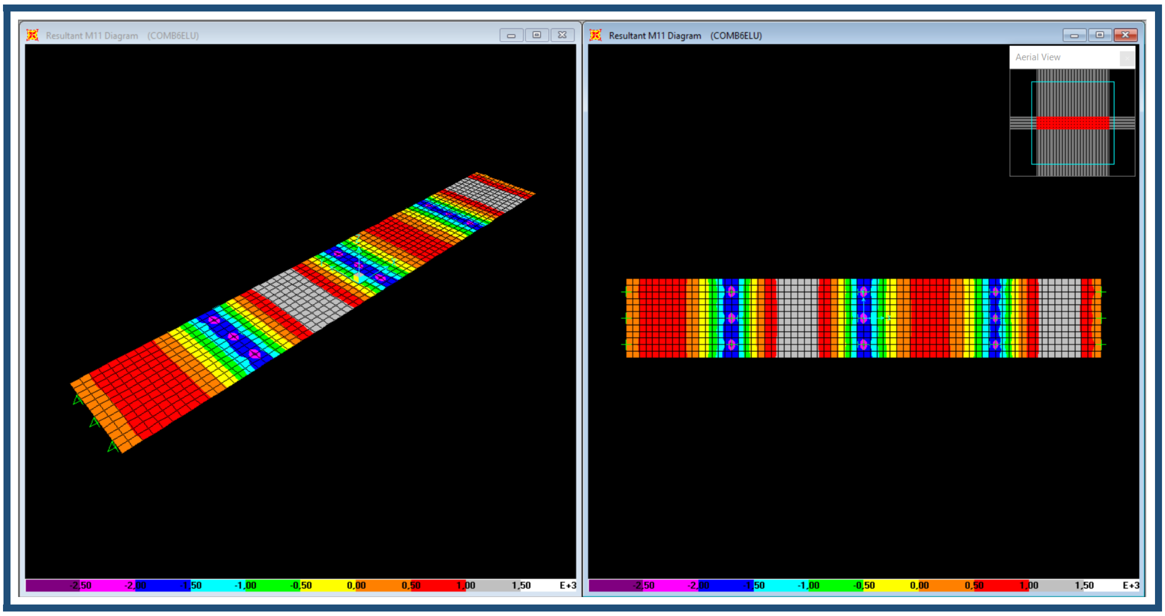

Figure 4.49: Displaying loads under the combination COMB6ELU in "SAP2000"

The maximum positive moment obtained in mid-central span from COMB6ELU is 1398.7 kN/m.

This is a summary table of the maximum positive moment values obtained at mid-central span :

Table 4.2: Maximum positive moments at mid-central span

Combination	**Maximum positive moments at mid-central span** (kN/m^2)
COMB4ELU	1534.95
COMB5ELU	997.4
COMB6ELU	1398.7

We notice that the combination COMB4ELU is more soliciting than COMB5ELU and COMB6ELU. So, we are going to dimension the moment on central support from COMB4ELU.

This is a summary table of the maximum moment values obtained in the central support and at mid-central span:

Table 4.4: Maximum moments obtained

Place	**Combinaison**	**Maximum moment value**
Central support	COMB3ELU	-3183 kN/m^2
Mid-central span	COMB4ELU	1534.95 kN/m^2

We note that:

- The most unfavorable case for the central support is to load two spans.
- The most unfavorable case for the mid-central span is to load the longest span.

4.5 Conclusion

In this chapter, we have modeled our bridge using the element finite software "SAP2000" and we have found out the most soliciting combinations on central support and at mid-central span.

General Conclusion

This synthesis project consists of studying the interchange of the Garden of El Manzah connecting X20 and X3 : Crossing of Regional Route 25 (X20) and Local Route 452 (X3), Ariana, Tunisia.

First, we make a bibliographic research related to our project. Then, a traffic study allows us to determine the number of lanes of the roadway and thus to propose a design of the interchange using “AutoCAD”.

After that, a geotechnical study showed the soil support is class S2. These two studies enabled us to size the roadway with "ALIZE".

The study of our project is not limited to this stage? but is followed by modeling the slab bridge by finite element method using "SAP2000". And in this part, we entered the data , then we made the dynamic structural analysis in order to know its vibratory behavior in response to dynamic excitation forces, and finally we studied the slab bridge under the load “Al”.

In conclusion, this project is an opportunity to familiarize with the study of engineering structures such as bridges and interchanges.

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