Parametric Studies on Integral Bridge: Bending Moment Analysis

by

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15101

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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Approved by,

(Professor Dr. Nasir Shafiq)

UNIVERSITI TEKNOLOGI PETRONAS
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Alex Seeni a/l Yesuvadian

ABSTRACT

For several decades, the design of bridge structures in Malaysia has been based on BS 5400. Recently there has been a surge in application of EUROCODES as the preferred code of practice in European countries. The design of structural members using Eurocodes is found to be more economical in many countries. For example, in India, researches have found that the Eurocodes provides a more economical bridge design compared to the Indian Standards. However in Malaysia, the industry tends to continue with BS 5400 as there is a lack of exposure using EUROCODES. Therefore, the main objective of this research is to compare the different parameters of Bridge Design using different codes of practice namely Eurocode and British Standard 5400 for the design of integral and composite bridge. This comparison study is done by designing two types of bridge namely composite bridge and integral bridge using excel spreadsheet and Oasys Civil Bridge Designing software. Upon completion relevant parameters will be compared to provide design samples and suggest the better code of practice.

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Alex Seeni

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Chapter 1

Introduction

Malaysian bridge designers has long adopted British Standard (BS) as the national code of practice for the design of bridge structures. However, since the instalment of Eurocodes (EC) as the mandatory code of practice in United Kingdom beginning March 2010, the British Standards Institution will cease to revise its structural codes. With this Malaysia seems to be at catch-22 situation, with the only option available other than adopting Eurocodes would be to continue using BS or to develop our own code. The latter option would be an enormous task as it requires finding the right expertise, resources and financial backing for the researches apart from being time consuming. Professor Wahid Omar in his article in *Jurutera* stated that continuing to use BS means we will not achieve best designs as BS is no longer updated. Hence it is important to adopt the recent code of practice and explore the possible savings and design methods. This research proposal is intended to compare the different parameters of Bridge Design using different codes of practice namely Eurocode and British Standard 5400 for the design of Integral Bridge. By using the findings after this paper, bridge engineers will be able to consider the best approach to design a bridge and as well decide to make transition to the design of bridges using Eurocodes. This paper provides parametric studies which will provide adequate comparison between different codes of practice, provide design samples and suggest the best code of practice to use based on the type of bridge designed

1.1 Background

The background study on this area of expertise is mainly done in comparing their respective codes of practice with the international standard. As the Eurocodes are being used internationally, the need to have a proper parametric study between different codes practice are becoming more crucial than ever before. Various researches have already explored in comparing the clauses between these two codes of practice. Sankar and Jacob from India previously in the year 2011 compared Indian Structural Codes to the European standards. Apart from that, background studies on the type of bridges was also carried out to determine the most economical type of bridge. The modern trend in designing a superstructure is to avoid having system with much maintenance works. This trend is notable with the increasing number of integral bridges being designed around the world.

1.2 Problem Statement

As the EC began replacing BS in structural design, board of engineers in Malaysia (IEM) took steps to implement EC in Malaysia. Universities and institutions that offer civil engineering course have shifted their structural courses to EC. However strategies of shifting to EC have been hampered by the industry. Majority of the engineering firms tend to continue with BS as switching to a new code of practice will require effort, time and dedication. In a recent Engineering Conference held in 2011, Ir Tu Yong Eng, from The Institution of Engineers Malaysia highlighted that our industry is not ready to adopt the EC. He also highlighted that the industry, authority and the lawmakers must work together in order to stay competitive globally. Hence a clear picture of Eurocode needs to be painted to the industry. Engineers and manufactures must start to adopt and prepare their products to satisfy the codes.

Apart from that, in a recent study found that majority of the bridges in Malaysia are deteriorating (S.Kee, 2008).The main problem in bridge structures are found in the secondary bridge members like bearings and expansion joints. This incur heavy expenditure to do maintenance to these bridges. In order to reduce maintenance cost, integral bridges have taken the centre stage in choice of new bridges being built. This is mainly due to low construction cost and maintenance cost posed by these integral bridges.

1.3 Objectives and Scope of Study

The main objective of this study is to carry out parametric studies on integral composite bridges using different codes of practice. The following will be the sub-objectives:

- ✓ Investigate the differences in the design of bridges for Eurocode and BS 5400 for the design of integral bridges
- ✓ Conduct a parametric studies on different factors affecting the design of integral bridges using Eurocode
- ✓ Compare support reactions of integral Bridges as compared to composite bridge.

Chapter 2

Literature Review

2.1 Introduction

Bridge is a structure built to span over a physical obstruction such as river, sea, valley or road. Bridges serves as a passage to reach destinations which previously not reachable trough a flat terrain. Design of bridges varies according to its purpose and function, terrain and the material available locally. Modern bridges use sophisticated tools and material to construct. Currently, the major types of bridges constructed will be the integral bridge and composite bridges. Integral bridges have recently became a favorite choice of bridge design as it is cheaper to construct and easier to maintain (NYSDOT, 2005).

Apart from having to decide on the type of bridge design, bridge designers are also burdened with the task of having to adopt to a new code of practice. The major issue in implementing Eurocodes will always be in educating designers and staff in the new code of practice. It will be difficult for an experienced bridge designer who is well versed with the BS 5400 to make an immediate shift to Eurocode. Besides that, EC does not have a specific bridge design codes as the British Standard with its BS 5400. This is seen as a major problem for many designers as they need to follow the entire Eurocode of structural design to be able to design a complete bridge.

2.2 Types of Bridges

Bridges are one of the common type of engineering superstructures that can be found easily all over the world. The key components of a bridge construction will be beams, arches, trusses and cables. Combining all these four types of key components enables us to design a combination of complex bridge variations. The main types of bridges will be the beam bridge, arch bridge, truss bridge, and the suspension bridge. These types of bridge mainly differ in the length they can cross in a single span (the distance between two bridge supports).This study will focus on Beam Bridge which will be divided into two main types, the composite bridge and an integral bridge.

A composite bridge will be a beam bridge is the simplest form of bridges. It is also known as the plate girder bridge. A rigid superstructure, being a beam is normally supported at both ends. The beam is normally connected to the support by means of an expansion joint, ball bearing or sliding bar. The height of the beam controls the length that the beam can span. A beam bridge normally exist in the form of composite bridge with lattice work of steel truss to enable it to rigid and strong.

During the early industrial revolution, beam bridges began to make way for truss bridge. A truss bridge is simply a beam bridge with braces. Two of the common types of truss bridge will be a through truss and a deck truss. Truss bridge dissipate loading trough the truss frame work. The triangular truss work makes use of the rigid structure to form a rigid structure. With the advancement in steel technology in the earlier days, truss bridges gain popularity as it is easier and faster to construct. However problems with the maintenance of the truss bridge always posed a problem as steel structures are always susceptible to rusting (How stuff work, 2005).

Integral bridges are bridges without joints. Although an integral bridge look similar to a beam bridge or a plate girder bridge, its working mechanism is totally different compared to the normal beam bridges. The New York State Department of Transportation in the year 2005 through their studies found that Integral Bridges have proven themselves to be less expensive to construct, easier to maintain, and more economical to own over their life span. Integral bridges can be classified into two types, which is the Frame Abutment Bridges (fully integral bridge) and the End Screen Abutment Bridges (Semi Integral bridges). In a Fully Integral Abutment Bridges (FIAB) the superstructure is directly connected to the substructure, in this case the bridge deck and the beams directly connected to the substructure. During the action of forces upon the bridge, the superstructure and substructure moves together. A FIAB does not consist of bearings or expansion joints. While in a Semi-Integral Abutment Bridge (SIAB) the back wall portion of the substructure is directly connected to the superstructure. A bearing is used to separate the beams from the abutment. Similar to the FIAB, the semi-integral does not use an expansion joint (NYSDOT, 2005)..

2.3 General Discussion

Codes of practice play an important role in determining a more economical structure. Engineers tend to compare and use the best code of practice with reference to the local law to achieve better safety standards. For, structures exposed to marine environment, the design of pre-stressed section of highway bridges to EN 1992-2:2005 comes out similar to BS 5400. However when not exposed to chlorides, significant savings was seen in the amount of pre-stress re required when compared to BS 5400 (Jackson and Walker, 2011).

Certain parameters tend to produce similar results despite following different codes of practice. In a study done be Indian Engineers, both Eurocode and Indian Standards for a railway of constant span and depth, the total deflection of the girder increases as the grade of steel increases but the weight reduces. Furthermore, both codes of practice suggest that the stiffeners spacing have much impact on the deflection of plate Girder Bridge. However as per design requirement, for a plate girder bridge, European code is more economical compared to Indian Standard (Sankar and Jacob, 2013)

2.4 Loadings and Bridges

Malaysia being a developing country requires a reliable transport network. Bridges form an integral part of our transport network system. Furthermore Malaysia being a tropical country and comprised of hilly land, bridges are almost impossible to avoid. Adequate load carrying capacity of these bridges are important to avoid any structural failure. Majority of bridges will be designed to withstand heavy traffic loadings. These can be either a simple loading from a motorcycle or massive 300 ton truck load. This done to ensure accessibility for road users despite their heavy loads from their vehicles. Besides that vehicles like trucks are continuously upgrading with improvements in power and weight to carry more loads. Hence it is important to ensure all bridges are designed for a specific future load bearing capacity. Realizing this, the JKR Bridge Management System initiated a load testing on all bridges and newly constructed bridges to determine the structural bearing capacity of the bridges. Two Scania Load Loader trucks was gradually loaded with concrete blocks weighing about 2 tons each. According to JKR Executive Engineer, Ir. Ku Mohd, results from these test will always show a higher stiffness compared to the assumed model. The test truck configuration and loads imposed is shown below.

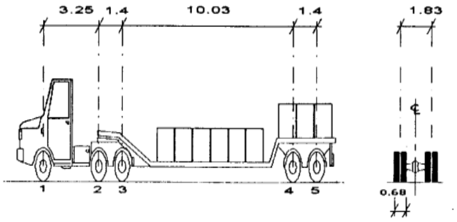
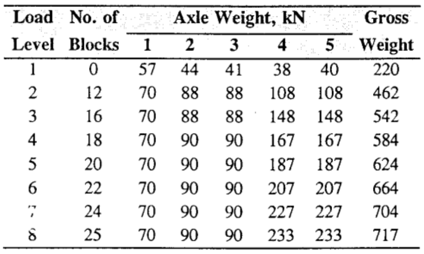


Figure 2.1 Configuration of SCANIA Truck



Load Level	No. of Blocks	Axle Weight, kN					Gross Weight
		1	2	3	4	5	
1	0	57	44	41	38	40	220
2	12	70	88	88	108	108	462
3	16	70	88	88	148	148	542
4	18	70	90	90	167	167	584
5	20	70	90	90	187	187	624
6	22	70	90	90	207	207	664
7	24	70	90	90	227	227	704
8	25	70	90	90	233	233	717

Table 2.1 Axle Load and Truck Load

Apart from the traffic loading, bridges are also prone to other types of loading. For example the wind loading and the thermal loading. Meteorological Department of Malaysian records an approximate of 2.0-3.8m/s on its daily average wind speed. Wind speed play an important factor in the design of suspension bridge and truss bridges. For example, the design of Penang Bridge requires a complete analysis of wind speed for a period of 50 years. Excessive wind can cause the bridge to sway and create unwanted rotational, vibrational and shear force to be developed along the bridge. Furthermore, as Malaysia is a tropical country, we experience wet and dry season continuously throughout the year. During the dry spells, temperature can reach up to 37◦C. This will cause massive thermal expansion on bridge substructure and superstructure. Hence all these loading factors needs to be considered in a bridge design.

2.5 Code of Pratice

This project mainly studies on code of practice for concrete structures. The main components of comparison will be the British Standard and the Eurocode. Hence the background study of the code of practice will be looked into before comparing the structural design in detail.

British Standard

British Standards are the standards produced by BSI Group (British Standards Institution) under the authority of the Charter. The objective of BS is to set up standards of quality for goods and promote the general adoption of British Standards To nations worldwide. The BSI is also responsible to revise, alter and amend such standards and schedules as experience and circumstances require. Products and services which are certified by BSI for having met the requirements of specific standards are awarded with the kitemark. This effort was first started by James Mansergh in the year 1901. While leading the Engineering Standards Committee, James standardised the number and type of steel sections in order to make British manufacturers more efficient and competitive. Over the time, standards were developed to cover many aspects of tangible engineering, quality systems, safety and security.

The production of British Standards within the BSI is decentralized. The standards Board sets up Sectors Boards according to their field of specialization such as ICT, Quality, Agricultural, Manufacturing or Fire. The respective sectors then in turn appoint technical committees. The technical committees normally approve a BS, which is then presented to the Secretary of the supervisory Sector Board for endorsement that standard. BS 5400 is the British Standard for the design and construction of concrete bridges. Using the limit state design principles, BS 5400 used to be the commonly known code of practice for the design of bridges. However following the harmonization of standards in Europe, some British Standards are superseded or replaced by European Standards.

Eurocode

Structural Eurocodes, also known as Eurocodes are a set of ten harmonized technical rules that holds the structural rules for the design of buildings and civil engineering structures. Eurocodes was developed by European Committee for Standardisation for structural design works in European Union. Eurocode is applicable to the entire structure as well as the individual elements of the structure. The set of codes is applicable to almost all construction materials such as concrete, steel, timber, masonry and aluminium. Furthermore Eurocode is expected to lead to a higher level of safety in construction in public services.
Eurocodes was developed for:

- A compliance for mechanical strength and stability
- To full fill safety requirements established by European Union Law in case of Fire
- To be the standardized set of rules for construction and contract specification.
- A framework for creating harmonized technical specification for building products.

European countries began to adopt Eurocode back in 2008 and Eurocodes became mandatory in public sectors in Europe starting March 2010. The Eurocode is slowly replacing the existing national building codes published by national standard bodies.
Each country using Eurocode will be expected to issue a National Annex . The main role of National Annex is to take into account the local differences, such as the climate, geography and seismicity between the countries that have adopted Eurocode. The ten parts of Eurocode is summarized in the figure below.

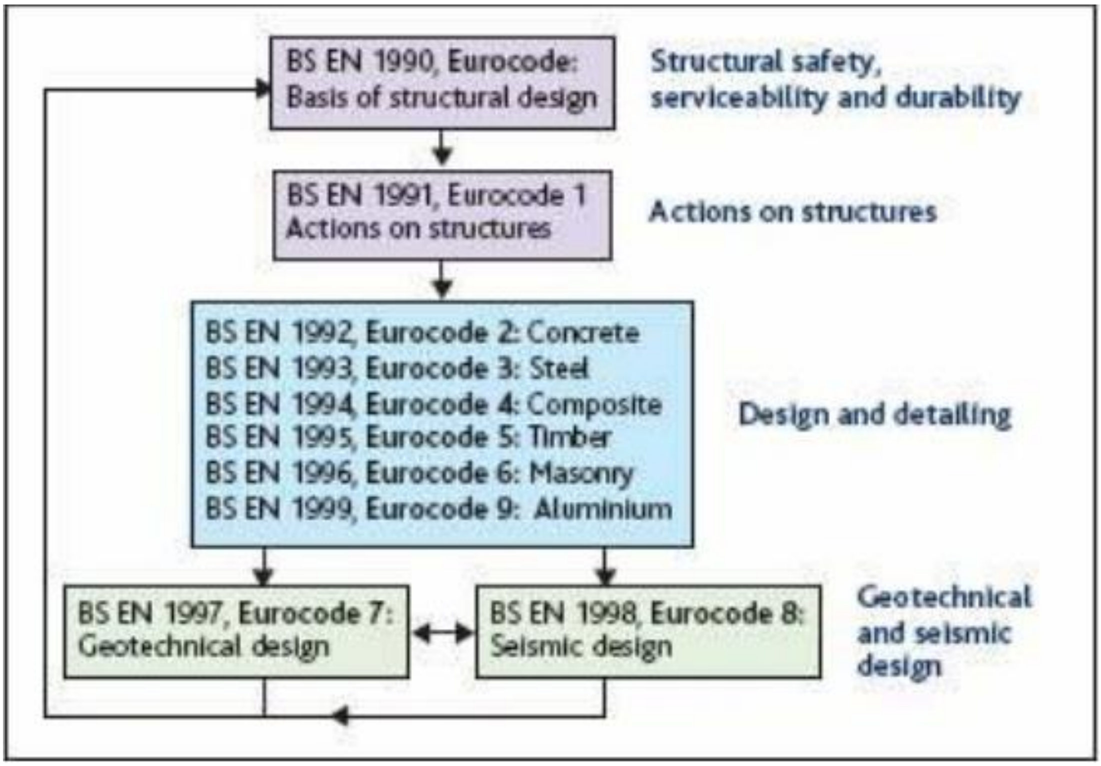


Figure 2.2- The ten parts of Eurocodes and its relationship.

Chapter 3

Methodology

3.1 Introduction

The methodology for the parametric studies on integral composite will comprise of the following steps. Firstly the conceptual design and layout of the entire bridge, taking into account the basis of structural design. Secondly, the loadings on the bridges will be tabulated. Next, the bridge design will be simulated and finally a comparison will be made between the different codes of practice.

3.2 Bridge Design Concept and Layout

The focus of this research will be on the design of bridge using Eurocode and BS 5400 code provisions for all the three types of bridge- integral and a composite bridge. A conceptual layout plan will be drafted for all three types of bridge using a common location and general environmental factors. These conceptual designs will be drafted using AutoCAD and used as a guidelines for the entire design process.

3.3 Basis of Design

Once the layout plan of the bridge is completed, the design variables will be investigated. Both Eurocode and British standard codes are based on three limit states: the ultimate limit state, the serviceability limit state and fatigue design. All bridge members will be designed according to Ultimate Limit State (ULS) and Serviceability Limit State (SLS). The next step will be to determine the loadings on the bridge. Generally bridges are designed to withstand traffic loading and its self-weight. The actions which will be acting on the bridge will be the permanent action and the variable action due to the weight of traffic. While for the permanent actions, the specific weight of steel is 77kN/m3 and concrete will be 24 kN/m3. Furthermore external factors like wind actions and thermal actions will be taken into consideration. For the design of composite bridges, fatigue assessment needs to be done in order to take into account the fatigue loadings.

3.4 Design of Bridges

The first part of this project will be to design a composite plate girder bridge and a truss deck bridge. Upon completion, an integral bridge will be designed in accordance to the respective code of practice. The choice of steel sections will be based available steel sections in the Malaysian market. Once the steel sections are identified, they will first be classified according to its section properties. Its resistance of beam cross section and buckling resistance of the beams will be taken into consideration. The similarities and difference of the main structural elements- beams, slabs and columns in the final design output will be taken into consideration. This includes the set of forces acting on the bridge and its imposed deformations. For further accuracy in the research, the effects of actions such as the internal moment, axial force, stress and strain, material properties and resistance of the structural member will determined. Apart from that, the yield strength of steel will be in accordance to BS EN 10025 to ease the designing process and the comparison part.

Throughout this project traffic load model 1 was used, in which the load model represents normal traffic. Under the load model 1, (LM1), the two components will be a uniformly distributed load over a full width of a traffic lane and a pair of axle. The influence line that leads to adverse load effects will be taken as the length of lane loaded. A pair of tandem system will be positioned centrally in the lane at the position that causes the maximum adverse effect. The arrangement for LM1 is given below:

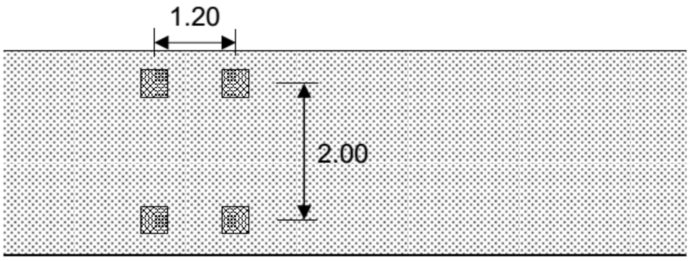


Figure 3.1 Load Model 1- arrangement of Tandem System within loaded lane.

The final part of the design will be to conduct a software modelling for all the designed bridge. Midas Civil together with excel spreadsheet will be used to design the structural elements. For uniformity of design purposes, standard precast and beam sections available in the Malaysian Market will be used. The resistance, shear force and bending moment diagrams, lateral torsional buckling will be tabulated and compared between the different codes of practice.

3.5 Comparison between codes of practice.

The final step of this research will be to do a parametric studies of the final design output between different codes of practice. The total deflection, total weight of steel and concrete used, varying parameters such as grade of steel, panel aspect ratio and web slenderness graphs between different types of bridge and codes of practice will be tabulated and compared. This final step will determine the most economical type of bridge and code of practice.

3.6 Proposed Process Flowchart

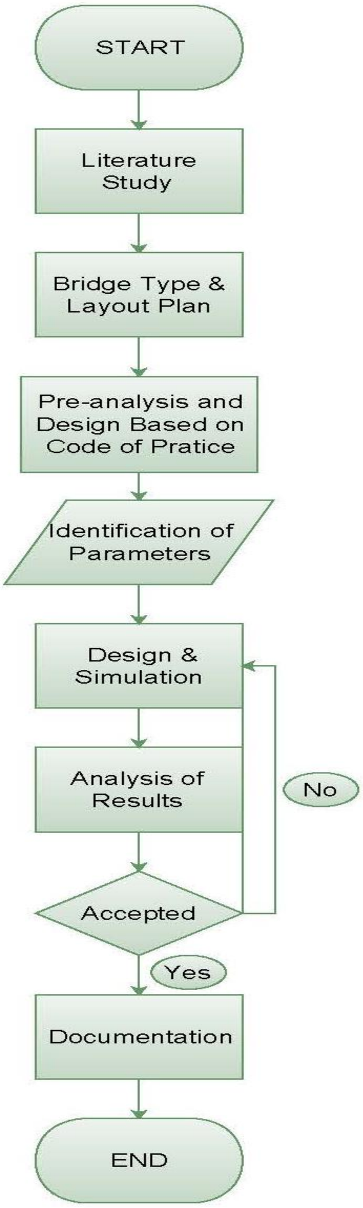


Figure 3.2 Process Flowchart on Parametric Studies of Integral Composite Bridge

3.7 Gantt Chart and Key Milestone

	Detail/Work	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Selection of Project Topic	🟪	🟪																										
2	Preliminary Research Work		🟪	🟪	🟪	🟪	🟪																						
3	Submission of Extended Proposal & Proposal Defence							🟪		🟪	🟪																		
4	Bridge Design Layout								🟥																				
4.1	Design of Truss and Girder Bridge									🟥	🟥	🟥	🟥																
4.1.1	Based on EC									🟥	🟥																		
4.1.2	Based on BS 5400											🟥	🟥																
4.2	Design of Composite Bridge													🟥	🟥	🟥	🟥												
4.2.1	Based on EC													🟥	🟥														
4.2.2	Based on BS 5400															🟥	🟥												
4.3	Design of Integral Bridge																	🟥	🟥	🟥	🟥								
4.3.1	Based on EC																	🟥	🟥										
4.3.2	Based on BS 5400																			🟥	🟥								
4.4	Design Analysis																					🟥							
4.5	Design & Cost Comparison																					🟥	🟥						
5	Interim Report														🟪														
6	Progress Report																					🟪							
7	Pre-SEDEX																								🟪				
8	Final Report																									🟪			
9	Dissertation																										🟪		
10	Submission of Technical Paper																											🟪	
11	Viva																											🟪	
12	Submission of Project Dissertation																												🟪

Table 3.1- Gantt Chart and Key Milestone

🟪 *Pink Boxes indicate key progress*

🟥 *Red Boxes indicate key milestone*

Chapter 4

Results and Discussion

4.1 Introduction

This paper focuses on parametric studies between two different codes of practice and types of bridge. A two span integral bridge each spanning 25m each carrying two-lane road was designed. The reinforced concrete deck acts integrally with abutments while a pin support is assumed at the piers

4.2 Structural Arrangement

This bridge is designed based on Eurocodes and British Standard, in accordance to the UK National Annex. This bridge carries a 2-lane single carriageway road. The carriage way has 1.0m wide marginal strips and a 1m wide footway on either side. A three girder arrangement was chosen and a deck slab thickness of 300mm has been assumed. The deck cantilevers 1.6m outside the centerlines of the outer girders.

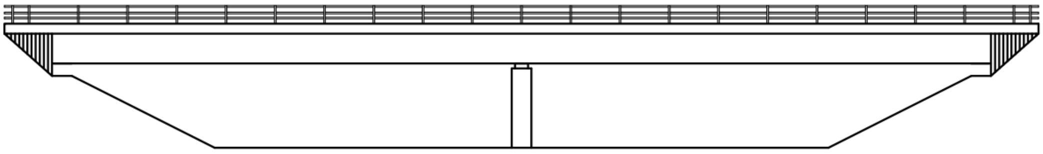


Figure 4.1 – Side View of the bridge

4.3 Structural Material Properties and Actions on the Bridge

The following material properties was used

Structural Steel :S355
Concrete :C40/50
Reinforcement : B 500

All the acting forces on the bridge was listed and tabulated as follows. However thermal and geotechnical actions was not included in this design of multi-girder bridge. The table below will highlight all the actions taken into consideration.

3	**Actions on the Bridge**	**Value**	**Unit**	**Remarks**
3.1	***Permanent Actions***			
3.1.1	Density of Concrete	24.00	kN/m^3	
3.1.2	Density of Steel	77.00	kN/m^3	
3.1.3	***Self-Weight of Surfacing***			
3.1.3.1	Thickness of Surfacing (waterproofing)	130.00	mm	
3.1.3.2	Nominal Dimension	1.55	Units	+55% nominal thickness
3.1.3.3	Density of Surfacing	23.00	kN/m^3	
3.1.3.4	Self-Weight, gk	4.63	kN/m^2	gk= 1.55 x 0.13 x 23
3.1.4	***Self-Weight of Footway***			
3.1.4.1	Thickness of Footway	200.00	mm	
3.1.4.2	Nominal Dimension	1.00	Units	
3.1.4.3	Density of Footway	24.00	kN/m^3	
3.1.4.4	Self-Weight, gk	4.80	kN/m^2	gk= 1.0 x 0.2 x 24
3.1.5	Self-weight of Parapets	2.00	kN/m	
3.1.6	Self-weight of Soil	21.00	kN/m^3	
3.2	***Construction Loads***			
3.2.1	Uniform Construction Load, Q_{ca}	0.75	kN/m^2	
3.2.2	Load of Temporary Formwork, Q_{cc}	0.50	kN/m^2	
3.2.3	Load of Wet Concrete, Q_{cf}	0.25	kN/m^2	
3.2.4	Σ Construction Load, Q	1.50	kN/m^2	
3.3	***Traffic Loads***			
3.3.1	Load Model 1 was Used			
3.3.2	Pedestrian Traffic	3.00	kN/m^2	$0.6q_{fk}$
3.3.3	Fatigue Loads - Load Model 3			

Table 4.1- Sample Excel Spreadsheet for Actions on Bridge.

4.4 Software Analysis

Oasys GSA was used to model the bridge according to the design data. The software uses the following concept in design to produce the most economic and reliable structures.

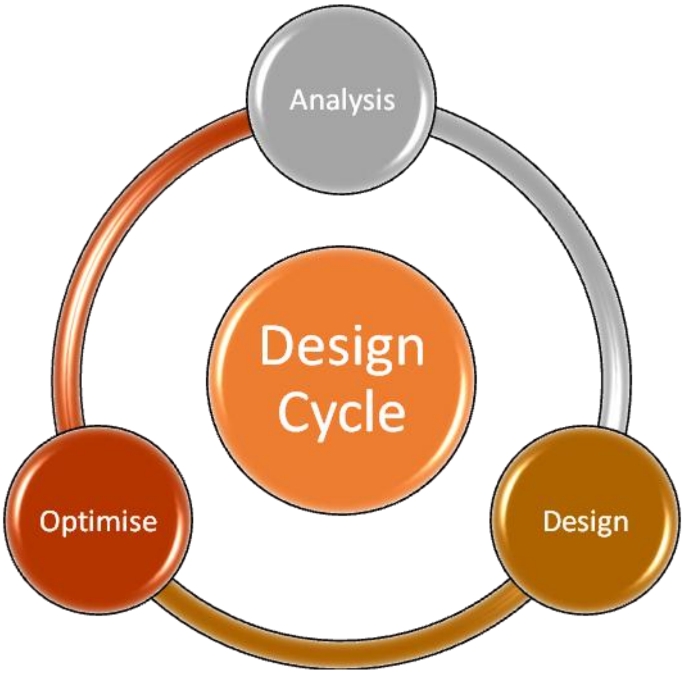


Figure 4.2 – Design Cycle of OASYS Bridge software.

A total number of 229 numbers of elements was defined from the oasys software. Fixed support as assigned at the abutments with pin support at 24m from abutment 1. A two carriageway path way was defined on the bridge

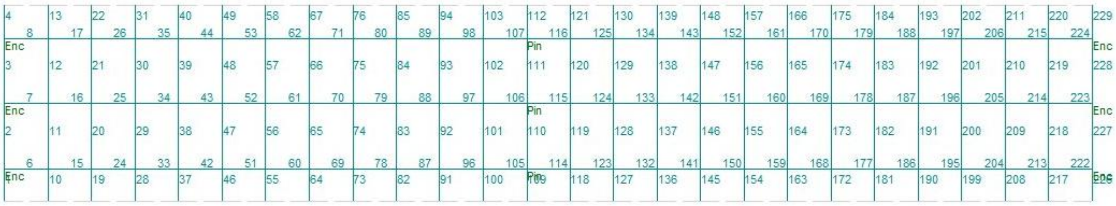


Figure 4.3 – 229 elements defined on the bridge deck.

4.5 Comparative study between Eurocode and BS 5400 results

A two span bridge was modeled using Oasys design suite. The design was then analyzed using separate analysis to obtain the forces acting on the bridge. Eurocode 1 was used as the bridge design loading code which included load combination 1 (traffic loading) and load combination 3 (leading actions). In a separate case UK BD 37 loading standard was chosen for the BS5400 analysis which included ULS combination and SLS combination.

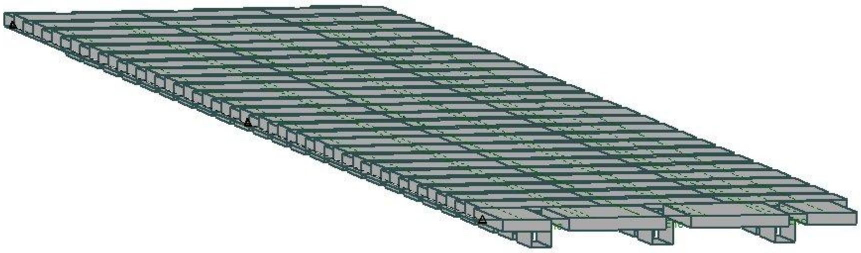
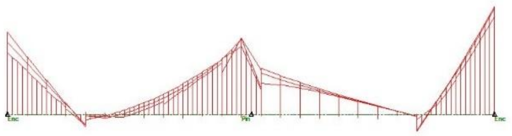


Figure 4.4 - A modeled bridge using Oasys GSA.

The table and graph below gives a comparison of shear force diagram and moment diagram along the bridge.

Moment M_{yy} diagram from Eurocode



Moment M_{yy} diagram from BS 5400

	Eurocode		*BS 5400*	
	Element	Value	Element	Value
Moment, Myy	224	1897 kNm	224	2154 kNm
	111	57.05kNm	111	132.1kNm

Table 4.2 – Maximum Moment comparison between EC and BS 54 00

Max Moment Along Bridge Deck (Right)				Max Moment Along Bridge Deck (Middle)				Max Moment Along Bridge Deck (Left)			
Distance	**Elem**	**Mxx**	**Myy**		**Elem**	**Mxx**	**Myy**		**Elem**	**Mxx**	**Myy**
		[kNm]	**[kNm]**			**[kNm]**	**[kNm]**			**[kNm]**	**[kNm]**
0	6	0.4196	1021.00		7	13.95	974.70		8	34.76	749.6
5	15	4.582	607.00		16	24.02	557.40		17	42.11	428.5
9	24	6.76	240.00		25	31.6	211.70		26	47.9	135.1
13	33	-0.8878	-19.22		34	-1.002	-18.32		35	-0.959	-17.34
17	42	-0.8594	0.38		43	-1.04	0.68		44	-1.014	1.26
21	51	-0.7091	20.02		52	-0.9987	19.57		53	-1.017	19.93
25	60	12.94	31.19		61	-0.8653	38.25		62	-0.943	38.59
29	69	5.254	9.17		70	3.334	-5.34		71	-0.2601	-3.078
33	78	6.836	168.30		79	3.589	153.80		80	-2.127	163.8
37	87	6.221	372.60		88	2.627	362.20		89	-4.131	382.2
41	96	0.5946	616.90		97	-0.3617	625.90		98	-4.583	651.3
45	105	-14.34	890.50		106	-6.374	960.40		107	-0.2239	966.4
49	114	-40.9	1173.00		115	-15.63	1398.00		116	11.69	1316
53	123	-85.31	601.70		124	-84.16	707.90		125	-69.8	765.7
57	132	-85.54	265.90		133	-86.86	295.50		134	-70.24	329
61	141	9.704	-18.39		142	13.43	-17.12		143	15.2	-4.764
65	150	4.376	-78.42		151	-0.823	-70.85		152	10.83	-47.84
69	159	2.606	-61.57		160	-1.043	-54.60		161	-3.792	-57.1
73	168	1.263	-44.63		169	-1.163	-39.65		170	-3.057	-41.92
77	177	0.3552	-27.95		178	-1.211	-24.82		179	-2.444	-26.38
81	186	-0.7562	-15.93		187	-2.063	-13.50		188	-3.008	-14.61
85	195	30.48	-210.20		196	14.88	-212.20		197	-3.021	-230.8
89	204	28.1	176.60		205	14.29	175.30		206	-1.797	176.3
93	213	25.09	604.80		214	11.64	616.80		215	63.8	529.7
97	222	21.56	1067.00		223	7.485	1120.00		224	43.95	1166

Table 4.3– Table of bridge moment along the deck

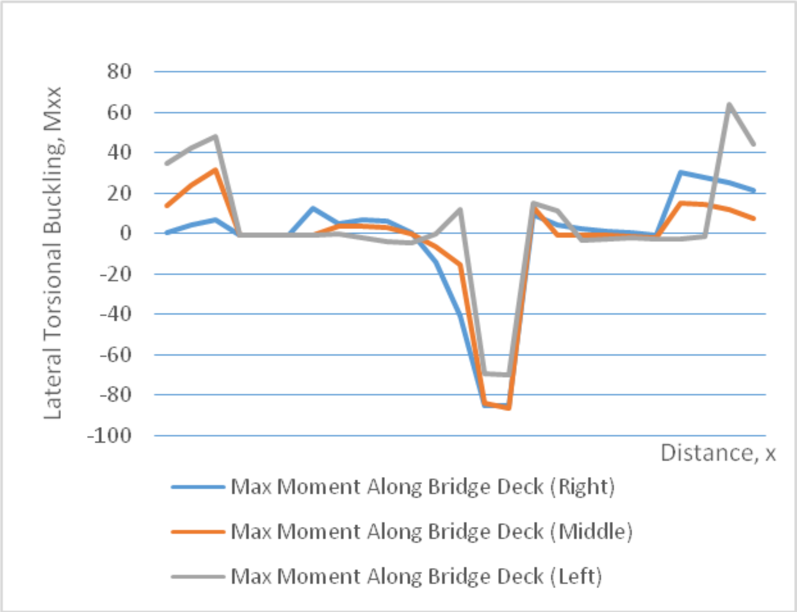


Figure 4.6 – Lateral Torsional Buckling along a bridge designed using EUROCODE.

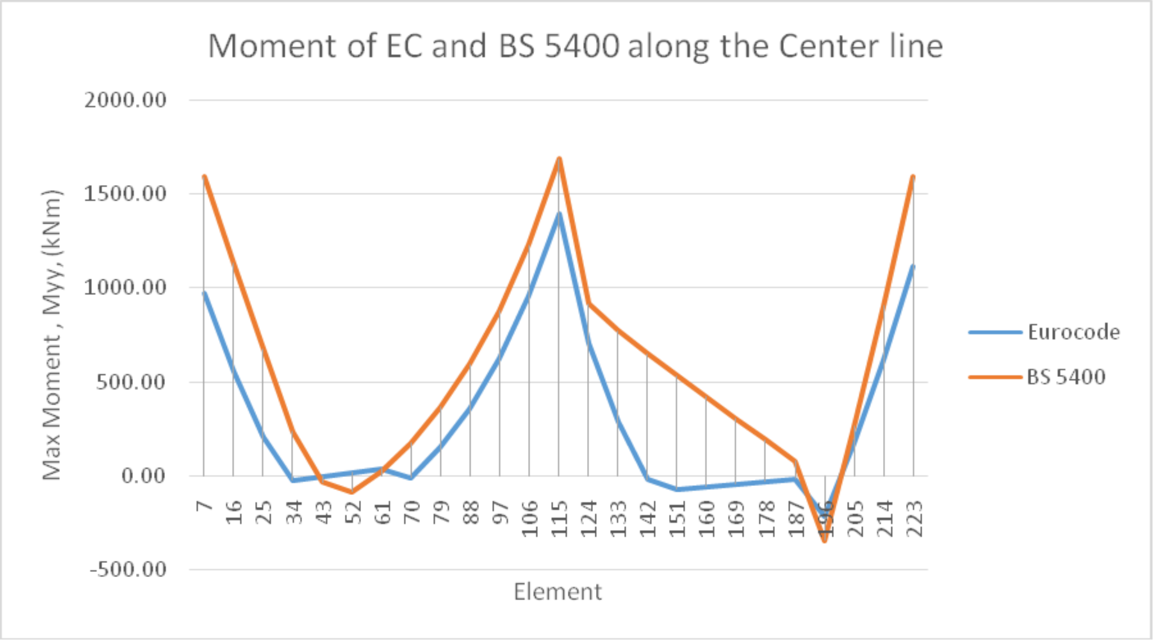


Figure4.7 – Graph of Moment of EC and BS 5400 along the center line.

4.6 Parametric Studies Of Integral Bridge

4.6.1 Light Weight concrete and Normal Concrete Design

Properties of concrete plays a crucial role in determining the outcomes of a design. In this parametric studies, the normal concrete was replaced with light weight concrete and the outcomes of the design was compared. Under light weight concrete the Elastic modules of concrete decreases to 2.2x 10^{10}. Besides that the density of concrete decreases to 1800 kg/m^3.

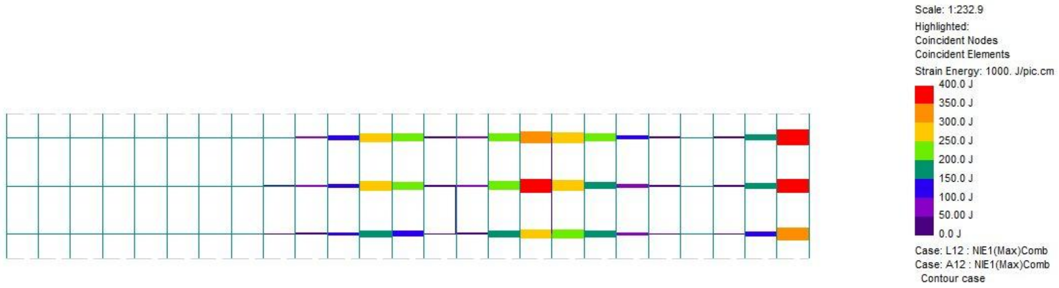


Figure 4.7 - Energy Strain in Normal concrete

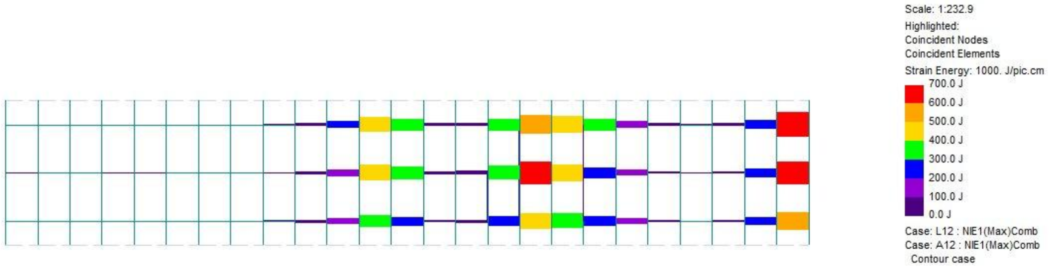


Figure 4.8 - Energy Strain in Light weight concrete

	Normal Concrete		*Lightweight*	
	Element	Value	Element	Value
Element Strain Energy Output, J	222	314.9J	222	504.1 J
	223	384.0J	223	614.8 J
	224	398.9J	224	638.6 J

Table 4.4 - Element Strain energy output for different concrete types.

Elem	Strain Energy Normal Concrete	Strain Energy Light Weight Concrete
	[J]	[J]
7	214.7	343.7
16	62.54	100.1
25	12.57	20.12
34	0.0676	0.1082
43	0.07605	0.1218
52	0.3245	0.5194
61	0.8055	1.29
70	4.694	7.515
79	27.41	43.88
88	90.52	144.9
97	224.6	359.5
106	483.5	774
115	407.1	651.7
124	112.4	180
133	29.28	46.87
142	1.404	2.248
151	1.316	2.107
160	0.7567	1.211
169	0.37	0.5923
178	0.1267	0.2028
187	0.0594	0.09509
196	17.83	28.55
205	76.08	121.8
214	284.1	454.8
223	704.6	1128

Table 4.5-

Element Strain energy output for different concrete types under maximum moment

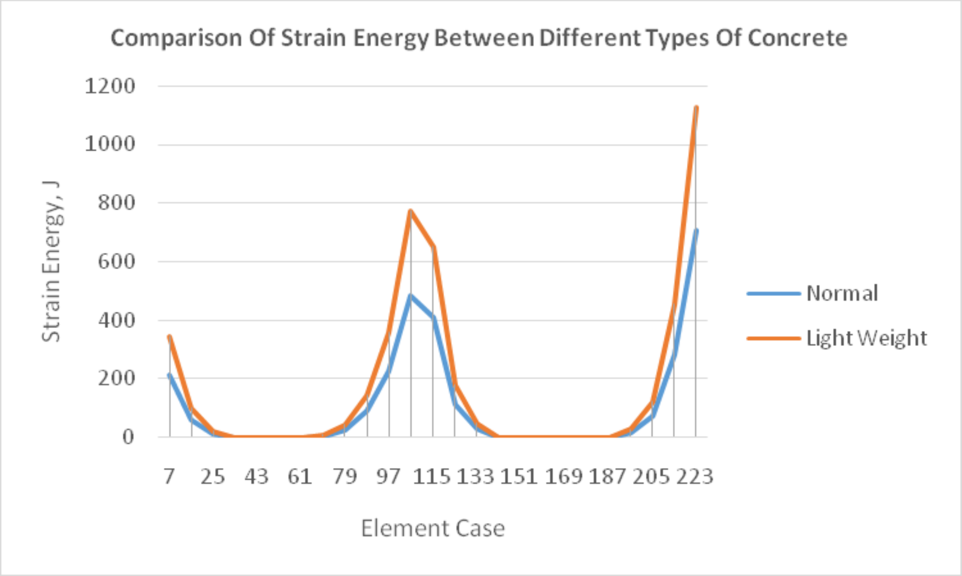


Figure 4.9 - Comparison Of Strain Energy Between Different Types Of Concrete

As the modulus of elasticity and density of the light weight concrete decreases, hence the concrete elements are subjected to higher strain energy under the exact loading. The diagram above shows the difference between strain energy. Concrete with lesser density tends to be at higher strain energy under the same loading.

4.6.2 T Beam, I Beam and Rectangle Beam

Beams are important load carrying members. A suitable beam will increase the efficiency of the superstructure and its design. Three different types of beams are used in this parametric studies to study the effects of beam on the forces on the bridge.

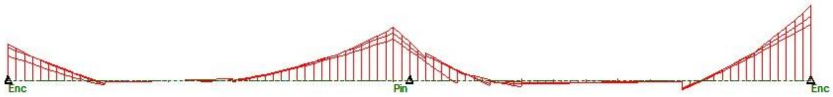


Figure 4.10 – Moment Diagram of an I-Beam

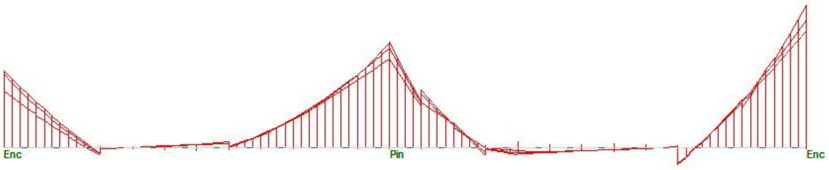


Figure 4.11 – Moment Diagram of a T-Beam

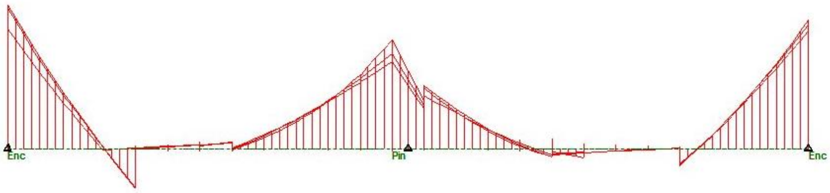


Figure 4.12 – Moment Diagram of a Rectangle Beam

	I Beam	*T Beam*	*Rectangle Beam*
	mm	mm	mm
Depth, D	1000	1000	1000
Width, W	3000	3000	3000
F. Thickness, T	300	300	-
Thickness, t	500	500	-

Table 4.6 - Comparison of beam sizing

	Length	**Mass**	**Surface Area**	**Element Cost**	**Price/m**
	m	Kg	mm^2	USD	USD/m
I- Beam	100	12490	2100	25,980	259.80
T- Beam	100	7807	1350	21,050	210.50
Rectangle	100	18740	3000	32,100	321.00

Table 4.7 - Comparison of beam properties between I-Beam, T-Beam and Rectangle.

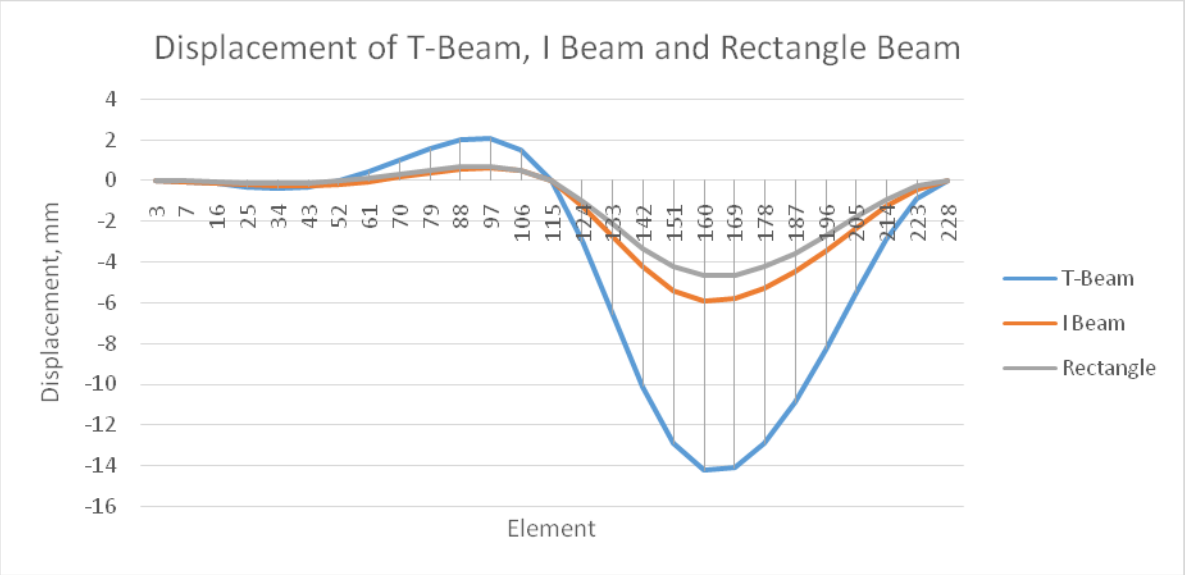


Figure 4.13 – Displacement of T-Beam, I-Beam and Rectangle Beam

The parametric studies shows the difference in the values obtained between an I-beam, T-beam and rectangle. I-Beam is found to be the most economic configuration for this step up of deck. As for the rectangle sections, different sizes needs to be tested to achieve the optimum beam sizing. Despite having smaller displacement for the maximum load combination, rectangle beams will be too costly as it uses higher material.

4.6.3 Curved Bridge and Straight Bridge

The following parametric studies will involve in the comparison between a curved bridge deck and a straight deck. The following deck design was adopted for the curved bridge.

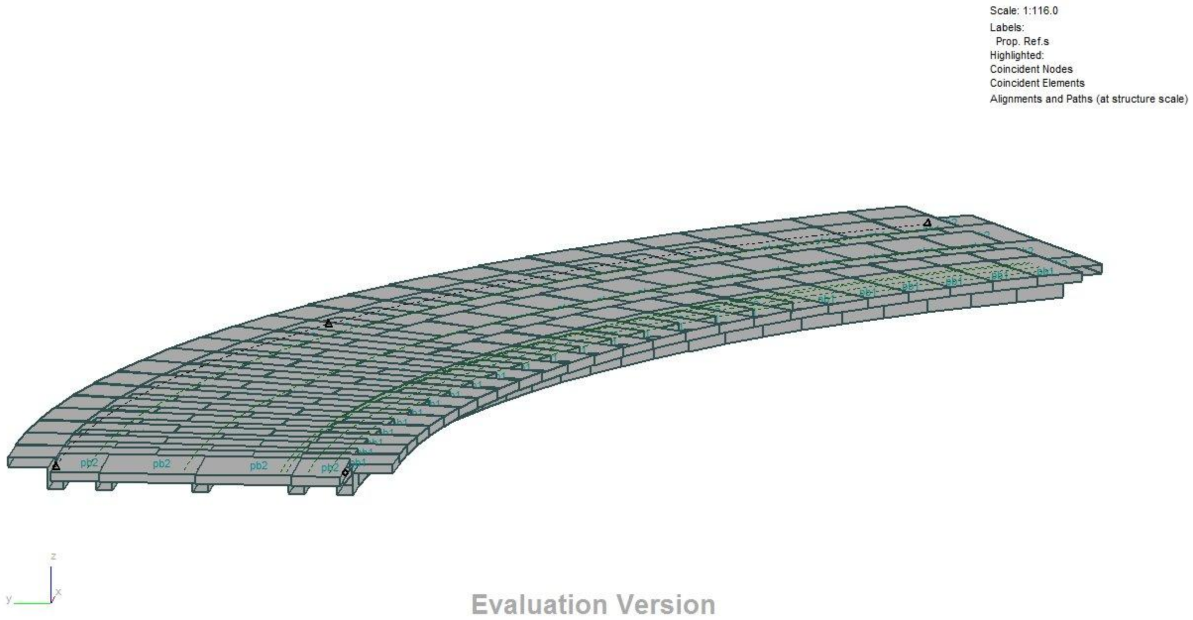


Figure 4.13 Isometric view of a curved bridge deck

The moment graphs along the bridge deck was compared to study the effects of road curvature and reactions. The moment of a curved bridge deck is distributed higher to the outer span. This is due to the path configuration opted, which included two carriageway and a footpath towards the right hand side of the bridge. Higher moments are seen on the bridge deck as a result of curvature, and to counter these effects a thicker beam and reinforcement is suggested. Higher moment is exerted towards the left side of the bridge. As the vehicles are moving tangent to the curve the force of inertia (weight) is exerted outwards

Hence the moment is higher at the outside of the curve. The graph and diagram below shows the effects of moment along the bridge.

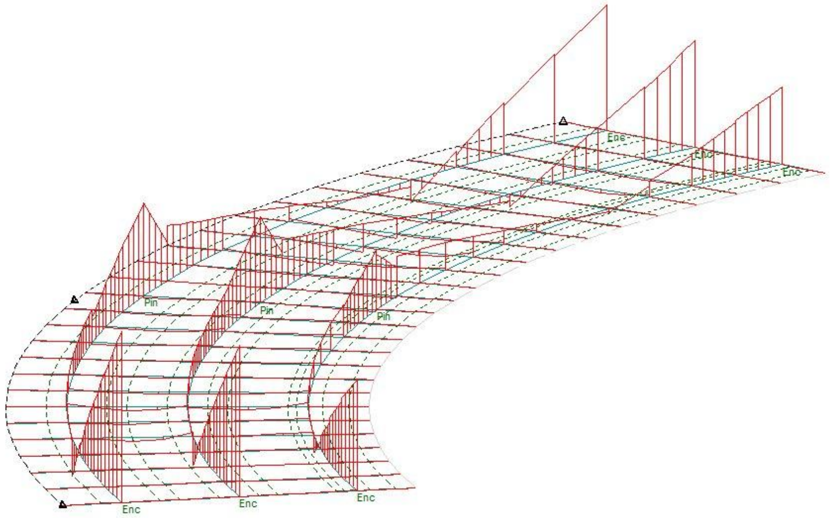


Figure 4.15 - Moment across the curved bridge along the influence lines.

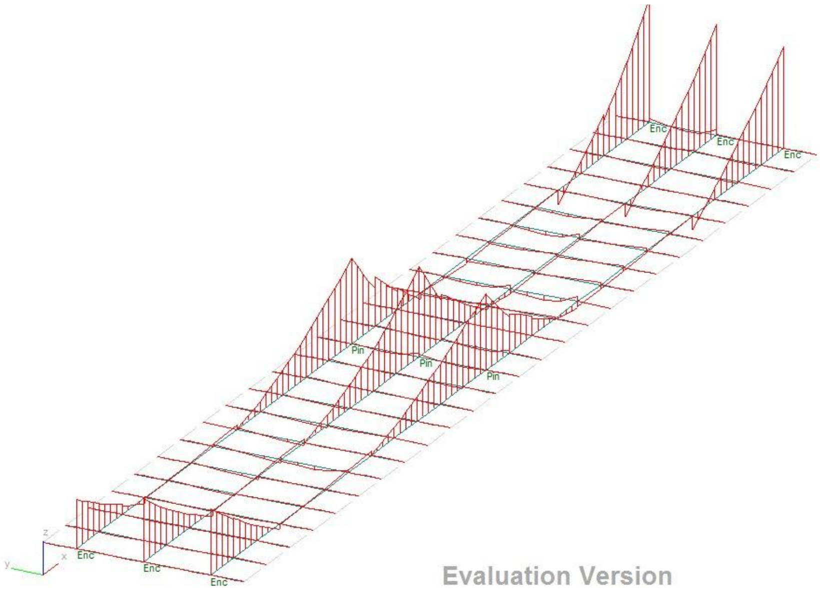


Figure 4.16 - Moments across the straight bridge deck along the influence lines

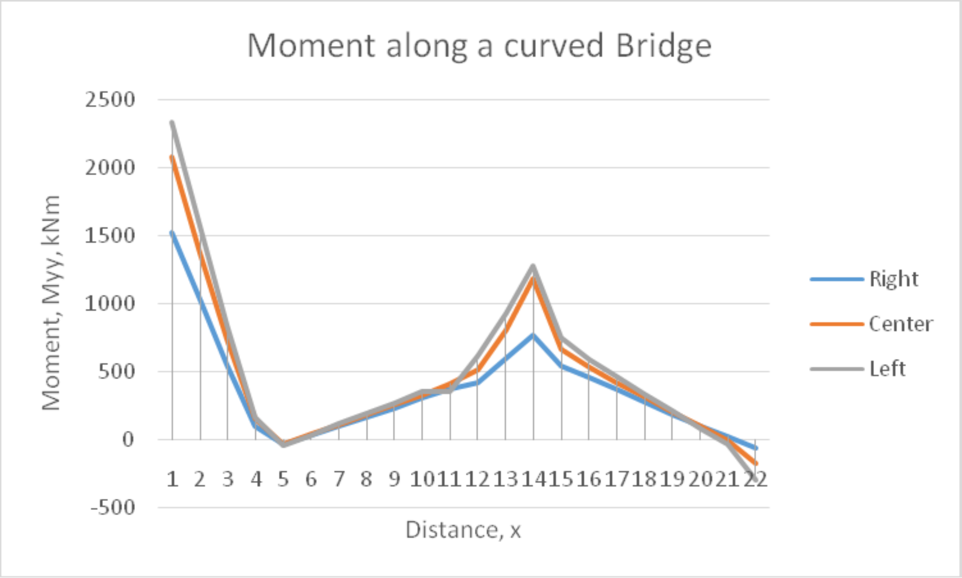


Figure 4.17 - Moment along a curved bridgealong the influence line

4.6.4 Single Pier Support and Double Pier support

The final parametric study was conducted on a single pier support and a double pier support system. A three span bridge was used while maintaining the original length. Piers was introduced at 14m from each abutments. Both piers was assumed pin support while fixed at the abutments. The following was the results of the moment graph under maximum load combination. A double pier support showed lesser moment exerted as the supports divide the loads equally. However positioning of the piers needs to be given due consideration as the depth of river or valley need to be given due consideration.

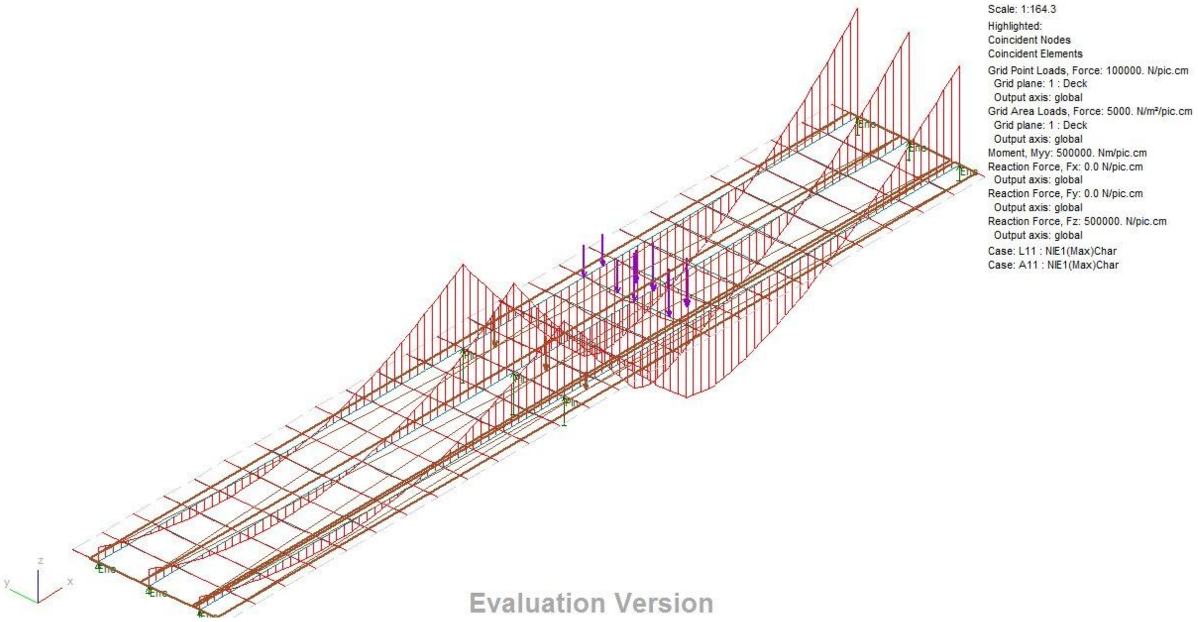


Figure 4.18 - Maximum load combination for a two span bridge

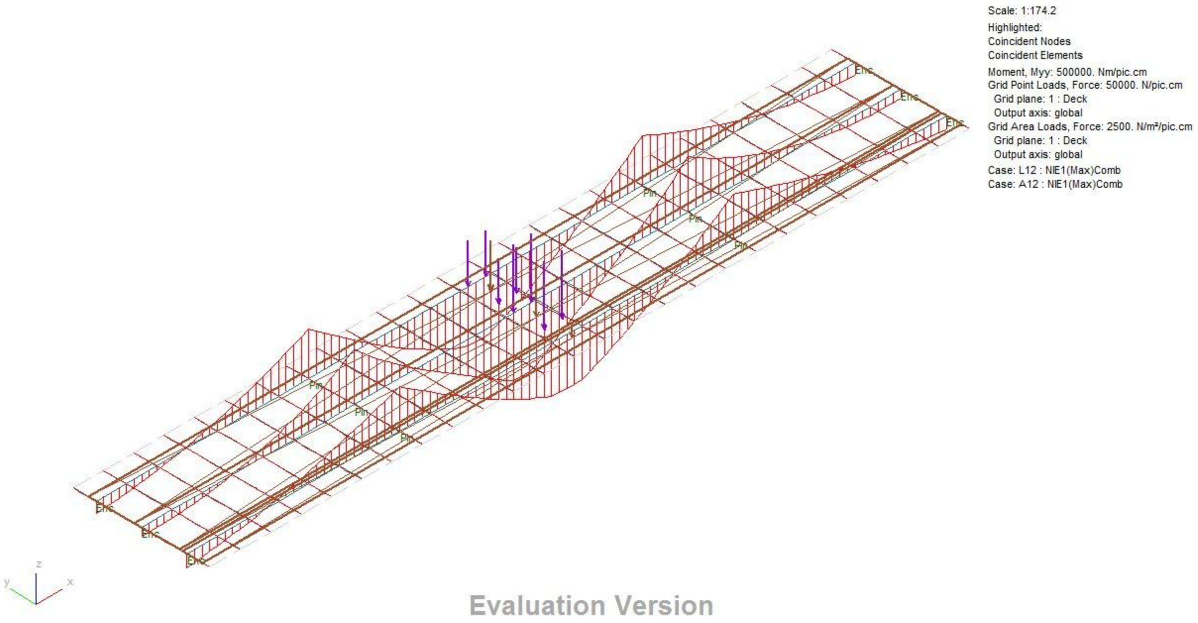


Figure 4.19 - Maximum load combination for a three span bridge

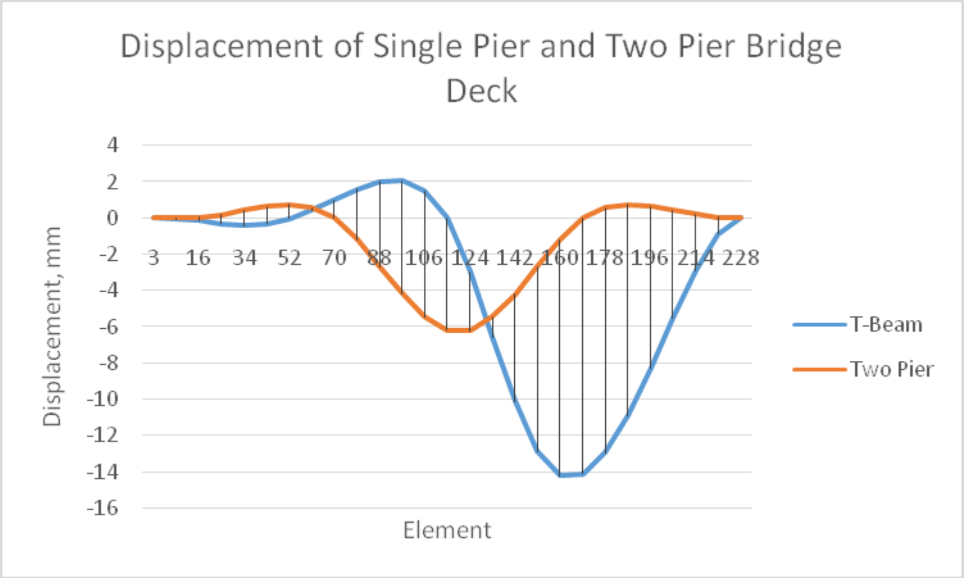


Figure 4.20 –Displacement of Single Pier and Two Pier Bridge Deck

The graph above shows displacement of elements under maximum load combination. From this the displacement of elements are reduced by 44% using a two pier configuration for the same length of bridge.

4.7 Comparison between Integral and Composite.

Under the third objective, the results of the integral bridge using Eurocode will be compared against the composite bridge. As the duration for final year project was limited, a results sharing approach was used to compare the results of both integral and composite bridge. Integral bridge gives higher moments at the abutments and this leads to higher reinforcements at the abutments. As for the composite bridge, the support system at the abutments were considered pin support and moments will be minimal at end span support system. As for the shear force diagram, similarities was seen between both types of the bridge.

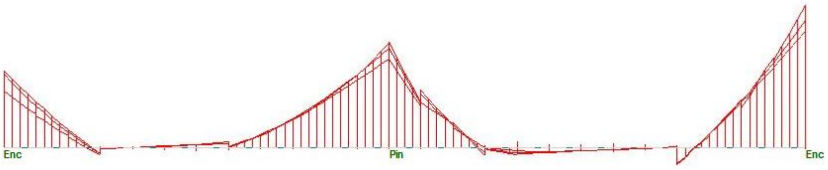


Figure 4.21 - Bending moment diagram of an integral bridge

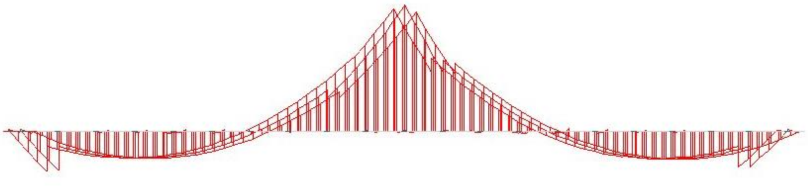


Figure 4.22 - Bending moment diagram of a composite bridge

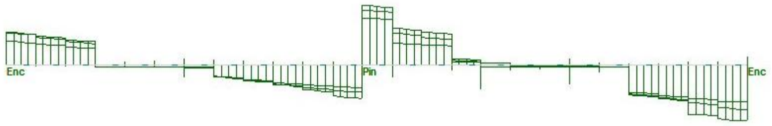


Figure 4.23 - Shear Force diagram of an integral bridge

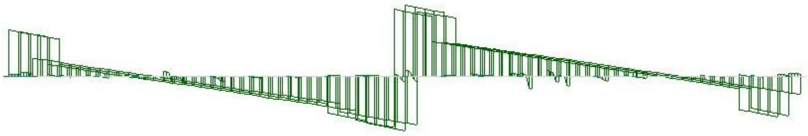


Figure 4.24 - Shear Force diagram of a composite bridge

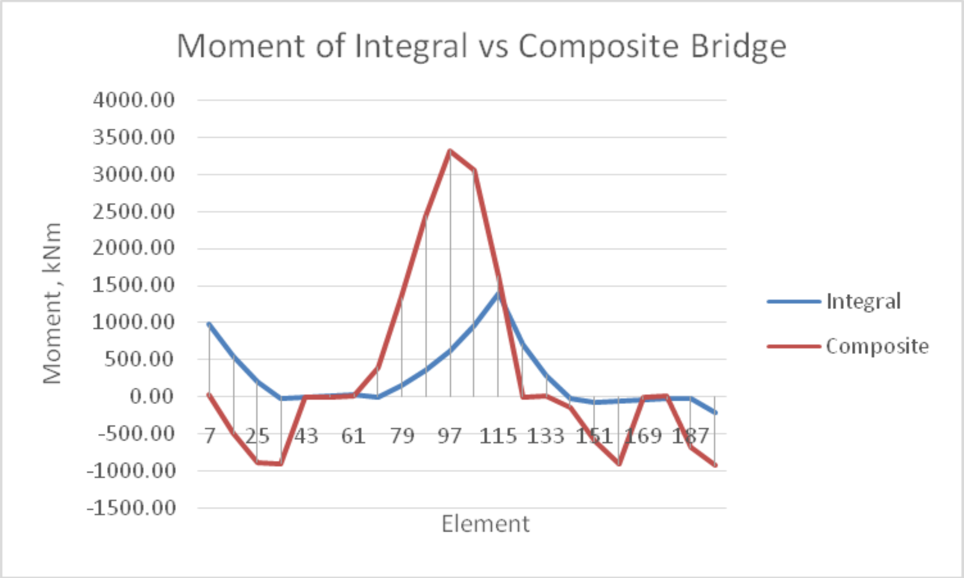


Figure 4.25 Moment comparison between Integral and Composite Bridge

From the graph above the overall moment of composite bridge is higher compared to integral bridge along the deck center. This gives effect to the design of beam sizing, reinforcement and other load support members. Hence the integral bridge will be a more economic bridge for short span bridges.

Chapter 5

Conclusion and Recommendation

This project is found to be both feasible and relevant to the needs of the current industry. As for now a complete parametric study on selected parameter have been carried out. All design process is carried out with the aid of worked examples from the steel construction institute. Mostly all calculation are based on spreadsheet and hand calculation. In order to provide a comprehensive parametric studies when comparing different codes of practice, a software analysis was used. The bridges model was analysed in Oasys Bridge designing software.

Integral bridge design using Eurocode yielded a bridge with a significantly lower moment values and shear force diagrams. This in turn will affect the overall design of the reinforced concrete. Overall reduction of 33% on the moment was observed.

Four different types of parametric studies was also carried out in this project, namely by using different types of beam, different types of concrete material, different pier configuration, and a curved bridge. From the graphical results it is evident that the moment is affected by using different beam and pier configuration. The beam configuration affects significantly as the surface area of contact between the slab and the beam is altered. As for the strain energy, a lower density of concrete gives a higher strain energy. This could lead to higher impact of the moment on the bridge defection and torsion. Hence designing for reinforcement would need to factor these changes in the concrete property.

The comparison between integral and composite bridge gave expected results. Moments of integral bridge was higher at abutment. Hence this deduces the difference in the shape of the moment graph. Moment at pier however, for composite bridge far exceeds the integral bridge. This in turn will affect the overall bridge design. However for shearing forces both bridges behaves equally.

In conclusion, this study achieved its objectives. Further study needs to be done to enhance the value of this study. A more sophisticated designs are needed to improve the outcomes of this project.

The following will be the recommendation to improve the study:

- Use different grades of steel to study the effects of weight when designed using different codes of practice
- Use different spans of bridge to investigate the most optimum bridge design
- Conduct a finite element analyses on the bridge designs modelled with Oasys Civil.
- Conduct this analysis on other types of bridges like cable and arch bridge.
- Conduct a cost analysis study to determine the effects of bridge loading and overall cost involved.

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