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JUDUL: ANALYSIS AND DESIGN OF HIGHWAY STEEL DECK TRUSS BRIDGE

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CHIEW SOON KING

SCHOOL OF ENGINEERING AND INFORMATION
TECHNOLOGY
UNIVERSITI MALAYSIA SABAH

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The materials in this thesis are original except for quotations, excerpt, summaries and references which have been fully acknowledged at the appropriate place.

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CERTIFICATION

Dr. S. Narayanan

PROJECT SUPERVISOR

Associate Professor Dr. Ideris Zakaria

PROJECT EXAMINER

Prof. Dr N.S.V. Kameswara Rao

CHAIRMAN

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ABSTRACT

ANALYSIS AND DESIGN OF SUPER STRUCTURAL WORK HIGHWAY STEEL DECK TRUSS BRIDGE

Bridges connects different places. Different types of truss steel bridges are used in practice. This thesis presents the analysis and design of highway steel truss bridge using commercial software according to BS 5400. Truss bridge is designed for Dead load, Live Loads, and Wind Loads. The geometry of a typical truss bridge of span 66m is modeled in the STAAD PRO and the member properties, loads are also applied. The analysis is carried out and the members are designed. The software used is STAAD PRO and the calculations are checked manually. Under slung or deck type bridge is analyzed and designed. The results of the study are reported. Abutment and slab design are also carried out.

ABSTRAK

Pembinaan jambatan adalah asas dan penting bagi menghubungkan dua lokasi berlainan. Terdapat banyak jenis kekuda keluli jambatan digunakan dalam tapak pembinaan. Penulisan ini bertujuan menganalisis dan mereka bentuk jenis Jalan Raya Keduda keluli Jambatan dengan menggunakan perisian STAAD PRO 2004. Semua analisis adalah berdasarkan pada British Standards - BS5400. Jenis kekuda jambatan direka bentuk adalah bergantung pada berat asal beban angin, berat bahan digunakan, berat benda yang bergerak di atas permukaan jambatan dan beban pergerakan. Panjang dalam reka bentuk keluli kekuda jambatan digunakan adalah sebanyak 66m, di mana ia akan direka bentuk dan dilukis dalam STAAD PRO. Semua bahan yang digunakan dan anggota dalam kekekuda keluli termasuk beban dalam jamabatan akan dianalisis secara automatik dalam perisian. Pengiraan secara manual diperlukan bagi membandingkan jawapan akhir dengan pengiraan daripada perisian. Analisis secara terperinci termasuk struktur sekunder seperti empangan dan konkrit reka bentuk juga termasuk dalam proses kajian.

LIST OF NOTATIONS

kN/m^3	Unit weight
kN	Kilo - Newton
$\sum$	Sum
V_b	Basic wind speed
k_1	Wind coefficient related to the return period
S_1	Funneling factor
S_2	Gust factor
Z	Zone factor
I	occupancy of importance factor
F	Shear Force
BM	Bending moment
kN/m^2	Kilo Newton per meter square
kNm	Kilo Newton Meter

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The first bridges were natural, such as the huge rock arch that spans the Ardeche in France or Natural Bridge in Virginia, United States. The first man-made bridges were tree trunks laid across streams in girder fashion, flat stones or festoons of vegetation, twisted or braided and hung in suspension. These three types of the bridges, beam, arch, and suspension have been known and built since ancient times and are the origins from which engineers and builders derived various combinations such as the truss, cantilever, cable-stayed, tied-arch, and moveable spans.

A complex form of the beam is the truss. It is a supporting system of triangles transferring both dead and live loads to the abutments or piers. Three principal types beam, arch, and suspension are combined in a variety of ways to form composite structures. The type selected depending on the nature of the crossing, the span required, the materials at hand, and the type of load anticipated which is pedestrian, vehicular, railroad or a channel of water as in aqueducts.

The traditional building materials for bridges are stone, timber and steel, and more recently reinforced and prestressed concrete. For special elements aluminum and its alloys and some types of plastics are used. These materials have different qualities of strength, workability, durability and resistance against corrosion. They differ also in their structure, texture and color or in the possibilities of surface treatment with differing texture and color. For bridges one should use that material which results in the best bridge regarding shape, technical quality, economics and compatibility with the environment.

Structural steel is stronger and suppler than cast or wrought iron. It is allowed greater design flexibility. The last thirty years of the 19th century witnessed the phasing in of steel plates and rolled shapes, leading to the enormous production of steel trusses and plate-girder spans of ever-increasing lengths throughout the world. Steel arches and cantilevers were favored for long spans because they better withstood the impact, vibration, and concentrated loads of heavy rail traffic.

Steel and aluminum is the among bridge materials steel has the highest and most favorable strength qualities and it is therefore suitable for the most daring bridges with the longest spans. Normal building steel has compressive and tensile strengths of 370 N/mm^2, about ten times the compressive strength of a medium concrete and a hundred times its tensile strength. A special merit of steel is its ductility due to which it deforms considerably before it breaks, because it begins to yield above a certain stress level. This yield strength is used as the first term in standard quality terms.

Bridges with high strength steel is often preferred. The higher strength required, the smaller is the proportional difference between the yield strength and the tensile strength. This means that high strength steels are not as ductile as those with normal strength. It fatigues strength rise in proportion to the tensile strength. It is necessary to have a profound knowledge of the behavior of these special steels before using them. For bearings and some other items, cast steel is used.

The high strengths of steel allow small cross-sections of beams or girders and therefore a low dead load of the structure. It was thus possible to develop the light-weight 'orthotropic plate' steel decks for roadways, which have now become common with an asphalt wearing course, 60 to 80 mm thick.

The pioneers of this orthotropic plate construction called it by the less mysterious and less scientific name 'stiffened steel slabs'. Plain steel plate, stiffened by cells or ribs, forms the chord of both the transverse cross girders and the longitudinal main-girders. Simultaneously it acts as a wind girder. This bridge deck owes its successful application mainly to mechanized welding which is now in general use and which has greatly influenced the design of steel bridges.

Today all stiffeners are placed on the inside so as to achieve a smooth outer surface allowing no accumulation of dust or dirt deposits that retain humidity and promote corrosion - the 'Achilles heel' of steel structures. Modern steel girder bridges now hardly differ from prestressed concrete bridges in their external appearance. This is perhaps regrettable, because stiffeners on the outside enliven the plate-faces, give scale and make the girder look less heavy. In addition to plate girders, trusses also take full advantage of the material properties of steel. Very delicate looking bridges can be built by joining slender steel sections together to form a truss.

Welding has improved the potential for good form. Hollow sections can be fabricated and joined without the use of big gusset plates. In this way smooth looking trusses arise without the 'unrest' which occurs by joining two or four profiles of rolled section with lattice or plates. Steel must be protected against corrosion and this is usually done by applying a protective paint to the bare steel surface. Painting of normal steels is technically necessary and can be used for color design of the bridge.

The choice of colors is an important feature for achieving good appearance. There are steels which do not corrode in a normal environment but are so expensive that they are used only for components that are either particularly susceptible to the attacks of corrosion or that are very inaccessible.

1.2 Scope of Study

This project is to get use the basic knowledge of mechanics to design a truss bridge which are referring to British Standards (BS 5400). This work is to differentiate and determine the different kinds of the bridges built. Loads play the most important part in deciding the materials using and also design the super structural work. Different kinds of loads are acting on the bridge are determined. Highway bridge truss bridge is being determined in the design.

1.3 Objective of the Study

The main aim of this thesis is to design steel truss bridge. Different types of bridges will perform different loads on it. Therefore, it is need a specialist to analyzed loads onto it. STAAD PRO 2004 is being used as to calculate and design for the steel truss bridge. Highway steel truss deck bridge is determined. The length of span, 66m is being determined for analysis. It is also beneficial for the real field to get use these kinds of knowledge apply on it. Hand calculation is also being used as to compare the differential loading values and material use that is done by STAAD PRO 2004. Several manual calculations will perform. Besides, several works are covered in this project:

1. Examine the provision of British Standards (BS 5400) for design steel bridge.
2. Model, analysis and design of steel highway bridge for 66m span.
3. To highlight methods of checking the analysis and design work provisions to BS 5400 and also manual calculation.
4. Check on limit state of ultimate limit state (UDL) and serviceability limit state (SLS).
5. Recommendations based on the study regarding:
   - (i) weight and span relationship
   - (ii) Sizes of top chord, bottom chord, bracing members
   - (iii) Highlight need for built up sections, if rolled section are not sufficient.
   - (iv) Comparison of different structural analysis for truss, bracing etc.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Truss bridge can be divided into several types. The most common we know are concrete bridge, timber truss bridge and steel type bridge. Bridge designs differ in the way they support loads. These loads include the weight of the bridges themselves, the weight of the material used to build the bridges, and the weight and stresses of the vehicles crossing them. Each design differs in appearance, construction methods and materials used, and overall expenses in the construction.

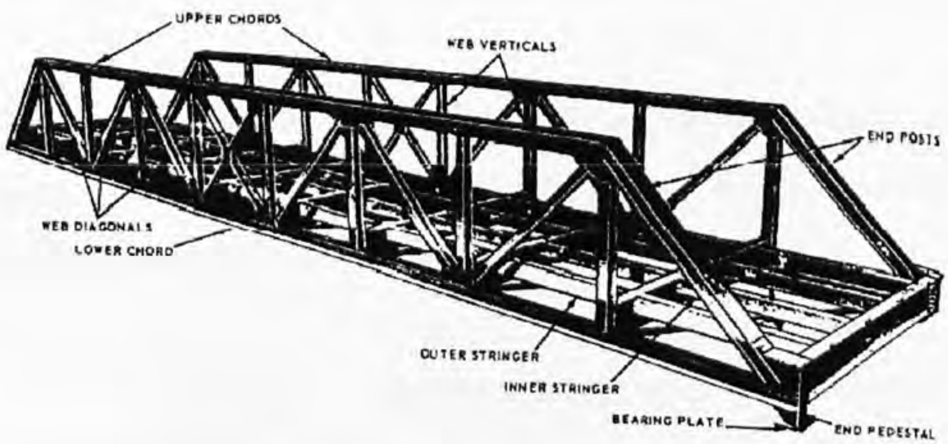

Figure 2.1: Example of structural element of steel truss bridge - Through type steel truss bridge

Truss is a common method of efficiently to support weight. It is designed to maximize the loading per unit of material It has the obvious advantages in theatrical situations. In reality, the analysis of both is based on the rules of static equilibrium and basic trigonometry.

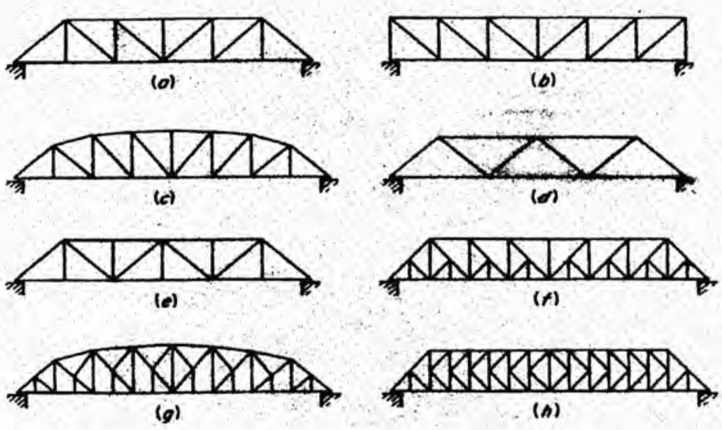

Figure 2.2: Types of the trusses bridges

Common types of bridge truss: (a) Pratt truss through bridge; (b) Pratt truss deck bridge; (c) curved - chord Pratt truss; (d) Warren truss; (e) Warren truss with verticals; (f) subdivided Pratt truss (Baltimore truss); (g) Petit or Pennsylvania truss; (h) K truss.

Figure 2.2 shows the common types of the simple span bridge trusses. By varying the depth of a truss throughout its length, forces in the chord members can be nearly equalized and the forces in the web reduced.

Trusses of economical proportions usually result if the angle between diagonals and verticals ranges from 45° to 60°. However, if long span trusses are made deep enough for adequate rigidity as well as for economy, a suitable slope of the diagonals may produce panels too long for an economical floor system. The subdivided panels of the Baltimore and Petit trusses solve this problem. Certain objections to subdivided panels were overcome with the invention of the truss.

Cantilever bridges, continuous bridges, arch bridges and suspension bridges are common suitable for long span. A cantilever bridge consists of two shore, or anchor, spans flanked by cantilever arms supporting a suspended simple span, while the cantilever and anchor arms supporting a suspended simple span.

2.1.1 Traditional truss

Trusses like beams, are a means of supporting transverse loads which span between two points. Solid beams are unlike with the individual members of a truss are assumed to undergo only axial stress which there is no flexural stresses are present. Efficient beams, such as I beam, concentrate material at the extreme edges of the shape and make the center as light as possible. Trusses are the same pattern. Like flexural members over a simple span, the top edge is subject to compression and the bottom edge is subject to tension. Unlike flexural members, the middle truss members are in tension or compression caused by the differences in elongation between the top and bottom chords. The general direction of the diagonals, i.e., whether the bottom ends point toward or away from the center of the truss, determines whether they are in tension or compression. In general, two-dimensional trusses can be categorized as tension, compression, or combined tension or compression trusses.

As a rule, tension trusses are lighter and more efficient than compression trusses because the allowable tensile stress of most members is higher than their allowable compressive stress. This is especially true for trusses which have long diagonals with high slenderness ratios. However, a tension truss is not always the best choice for a given application. Convenience of construction may require a compression truss because the reaction points need to be along the bottom chord. Homemade compression and combined tension or compression trusses are often seen in theatrical applications because of the lengths of the diagonals are so short that there is no significant gain top be had by designing a purely tension truss. In other words, theatrical trusses tend to be short and shallow in comparison to construction to construction industry trusses.

2.1.2 Highway Truss Bridge

The Warren configuration which is always been chosen in truss bridges. When the length of the gap to be crossed makes a multiple span bridge unavoidable, it is cheaper and usually possible to raise the road line and build another type of bridge requiring a greater depth under deck. The spans are usually between 60m and 120m which is the normal economic range.

Structures for bridges are subjected directly to loads from various sources. These loads are referred to as direct actions and include gravity and environmental effects such as wind load. In applying any quantitative approach to structural analysis, the magnitude of the actions needs to be identified.

The magnitude of loads cannot be determined precisely. In some cases, for instance in considering loads due to the self-weight of the structure, it might be thought that values can be calculated fairly accurately. In other cases, such as wind loads, it is possible to estimate likely levels of the load. The estimate can be based on observation of previous conditions and apply on it. Loads associated with the use of the structure can only be estimated based on the nature of usage. Insufficient data is available in most cases for a fully statistical approach and nominal values are therefore assigned. In addition, problems of change of use and fashion can occur.

2.2 Properties of materials (BS 5400 Part 3: Clauses 6)

The mechanical properties of materials required by the engineer should be specified in accordance with BS 5400 Part 3: Clauses 6. All steels should refer to the BS 5400: Part 6 - 6.3 and 6.4. For steel grades, unless specified otherwise, steels and steel grades should be in 'S' grades, no higher than S460. It is usually refer to the BS 7668, BS EN 10025, BS EN 10013, BS EN 10137, BS EN 10155 or BS EN 10210.

The following properties of steel should be assumed in the design:

(i) Modulus of elasticity, E = 205000 N/mm^2

(ii) Shear modulus, G = 80000 N/mm^2

(iii) Poisson's ratio, υ = 0.3

(iv) Coefficient of thermal expansion = $12 \times 10^{-6} / {}^\circ c$

2.2.1 Design minimum temperature (BS 5400 Part 3: Clauses 6.5.2)

The design minimum temperature U (in ${}^\circ c$) to be used when applying in code BS 5400 part 2: Clauses 6.5.4 should be as follows:

(a) in a part the primary function of which is to resist thermal movement,

$U = U_e - 5$

(b) in all other parts, $U = U_e$

where U_e is the minimum effective bridge temperature given in BS 5400 in degree Celsius ($°c$)

2.2.2 Modular ratio (BS 5400 Part 3: Clauses 6.7)

For global analysis of bridges of composite construction the modular ratio may be based in the long term value of the elastic modulus for concrete unless stated otherwise in this part of BS 5400. For stress analysis the modular ratio appropriate to the stage of construction and the type of loading should be adopted.

2.2.3 Maximum permitted (BS 5400 part 3: Clauses 6.5.4)

The thickness t of a steel part should be limited as follows:

where $U \le T_{27J} - 20$

$$t \le 50k\left(\frac{355}{\sigma_y}\right)^{1.4} 1.2^{\left(\frac{U-T_{27J}}{10}\right)}$$

$U < T_{27J} - 20$, not permitted.

where,

t is maximum permitted thickness of the part under stress in millimeters; k is the factor from BS 5400 part 3: Clauses 6.5.3.1; σ_y is nominal yield stress of the part as defined in BS 5400 part 3: Clauses 6.2; U is the design minimum temperature of the part in degree Celsius ($°c$). T_{27J} is the test temperature in degree Celsius for which a minimum Charpy energy of 27J is specified by the product standard for impact tests in longitudinal V - notch test pieces.

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