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DESIGN ANALYSIS AND SIMULATION OF A RAILING SYSTEM SECURITY CAGE AT TAMAN BUAYA

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of the requirements for the award of the degree of
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Mechanical Engineering Faculty

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"I declare that this report is the result of my own research except as cited in the references"

Signature : ………………….........................

Name : ………………….........................

Date : ………………….........................

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ABSTRACT

A performing stage similar to a mini stadium consisting of a secure railing system was built at Taman Buaya, Ayer Keroh in 2009. The overall railing system consists of cage guardrail, handrail, and decorative railing are installed as safety feature and must be observed to avoid unexpected accidents. Although the maximum stress is not exceeding the yield strength of material, a safety factor below 2 is considered unsafe for most buildings. The failure is obvious whenever the maximum stress from the analysis exceeds the yield strength of material. Finite element analysis in conjunction with numerical simulation was carried out to predict the behavior of the cage rails under load and understand the bonding characteristics at the supports. The results obtained from the analysis software based on parameters provided were then compared with the structural analysis to determine the accuracy of the analytical results and the safety factor for the critical location of railings are generated to provide strength analysis for future reference. Good comparisons are obtained in these areas indicating that the finite element analysis has proven to be a successful tool to analyze the behaviour of railing connections.

ABSTRAK

Satu pentas pertunjukan menyerupai stadium mini yang merangkumi sistem pagar yang rapi telah dibina di Taman Buaya, Ayer Keroh pada tahun 2009. Keseluruhan system pagar ini terdiri daripada penahan sangkar, penahan tangan, dan juga pagar hiasan telah dipasang sebagai cirri keselamatan dan harus dipantau untuk mengelakkan kemalangan yang tidak diizinkan dari berlaku. Walaupun daya maksima kekuatan tegangan tidak melebihi kekuatan alah bahan, nilai faktor keselamatan di bawah 2 dianggap tidak selamat untuk kebanyakan binaan. Kegagalan fungsi struktur adalah nyata apabila nilai kekuatan tegangan melebihi kekeuatan alah bahan. Suatu kaedah unsur terhingga serentak dengan simulasi pengiraan telah dijalankan untuk mengkaji ciri-ciri penahan sangkar yang dikenakan daya dan juga untuk memahami ciri-ciri penyambungan pada tiang sokongan. Berdasarkan data yang tersedia, keputusan yang diperolehi daripada perisian analisis tidak sejajar telah dibandingkan dengan hasil keputusan analisis struktur untuk menentukan ketepatan hasil perisian dan juga faktor keselamatan untuk bahagian yang kritikal pada penahan sangkar dihisab bagi menyediakan maklumat analisis kekuatan untuk rujukan masa hadapan. Dari keputusan tersebut,didapati kaedah unsur terhingga mampu memberi keputusan yang jitu untuk menganalisa sifat sistem pagar.

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g	-	Gravitational acceleration
σ_y	-	Yield strength
σ_v	-	Von Mises stress
σ^{dev}	-	Stress deviator tensor
M	-	Moment
$\emptyset$	-	Rotation
R	-	Restraint
L	-	Length
2D	-	Two dimensional
3D	-	Three dimensional
u_i	-	Vector quantity in the direction of i
f_j	-	Vector quantity in the direction of j
A	-	Cross-sectional area
E	-	Young's modulus
V	-	Poisson's ratio
FS	-	Factor of safety
A-A	-	Side view from the right hand of the performing stage
B-B	-	Centre of the performing stage
C-C	-	Side view from the left hand side of the performing stage
ASTM	-	American Society for Testing and Materials
ASCE	-	American Society of Civil Engineers

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CHAPTER 1

INTRODUCTION

1.1 General

A structure refers to a system of connected parts used to support a load. Important examples related to civil engineering include buildings, bridges and towers; and in other branches of engineering, ship and aircraft frames, tanks, pressure vessels, mechanical system, and electrical supporting structures are important. Substructure and superstructures used concrete and steel reinforcement to complete the system. It shows that these elements are very important. So, in order to make analysis and design a structure, structural steel must be considered as the main construction materials.

Design is an innovative and highly iterative process. It is also a decision-making process. Decisions sometimes have to be made with too little information, or with an excess of partially contradictory information. Decisions are sometimes made tentatively, with the right reserved to adjust as more becomes known. The point is that the engineering designer has to be personally comfortable with a decision making, problem-solving role.

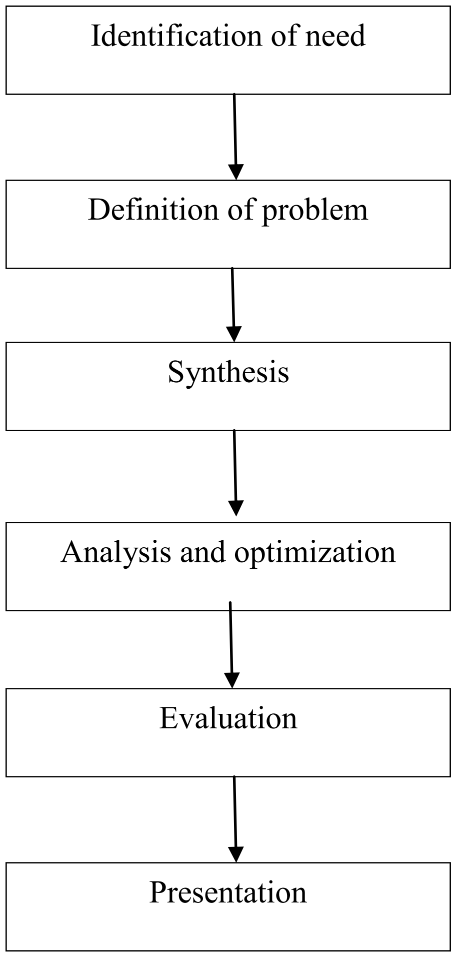

Figure 1.1 : The phases in design analysis for this project

1.2 Problem Statement

It is of interest to have durable structures with long life and low maintenance cost in consideration of safety aspects. Nowadays, in Malaysia, safety railings is the best options to safeguard people from area prone to danger. Manufacturers provide different barrier security products to the areas according to the necessity. Machines are guarded by safety machines guards, from uv light, flying debris, smoke and heat.

This safety railing system prevents people from getting easy access to hazardous areas, thus it is a work area protection.

Based on the situation at a show stage at Taman Buaya, Ayer Keroh, Melaka, the railing system cage that is being built to hold dangerous reptiles during a show, a detailed design analysis and simulation upon the existing railing system has to be done before the show stage is opened to public in order to optimize its safety and reliability. Within this research, it will help to identify the weakness of the system to prevent unexpected misfortunes in the future and thus providing data on the strength of the system.

1.3 Objectives of Study

The purpose of this study is to implement and make design analysis of the existing railing system at Taman Buaya. It is also crucial to identify various factors that can possibly influence the deflection of beams and columns. Besides, another aim is to provide strength analysis of the railing system.

1.4 Scopes of Study

The scopes of the study are:

i. Structural analysis of cage railings.
ii. Analysis and simulation of cage rails at the performing stage by using CATIA Finite Element Method software.
iii. Provide analysis of data for future reference.
iv. To provide strength analysis of the existing design of cage rail at Taman Buaya.

CHAPTER 2

LITERATURE REVIEW

2.1 Definitions

Railing system, or balustrade is a structure made of rails and upright members that is used as a guard or barrier or for support basic structure of a building. In the other word, it is the complete system of railings and pickets that prevents people from falling over the edge. Sometimes it is called banister or handrail, the angled member for handholding, as distinguished from the vertical pickets which hold it up for stairs that are open on one side. Like other mechanical parts and structures, railings are abundant in types as well as the joint parts. Some of the most well-known railings are picket, mesh, glass and cable railings.

2.1.1 Classification of Structures

All structural forms used for load transfer from one point to another are 3-dimensional (3-D) in nature. In principle one could model them as 3-D elastic structure and obtain solutions like response of structures to loads by solving the associated partial differential equations. Most commonly used structural forms for load transfer are beams, plane truss, space truss, plane frame, space frame, arches, cables, plates and shells. Each one of these structural arrangement supports load in a specific way.

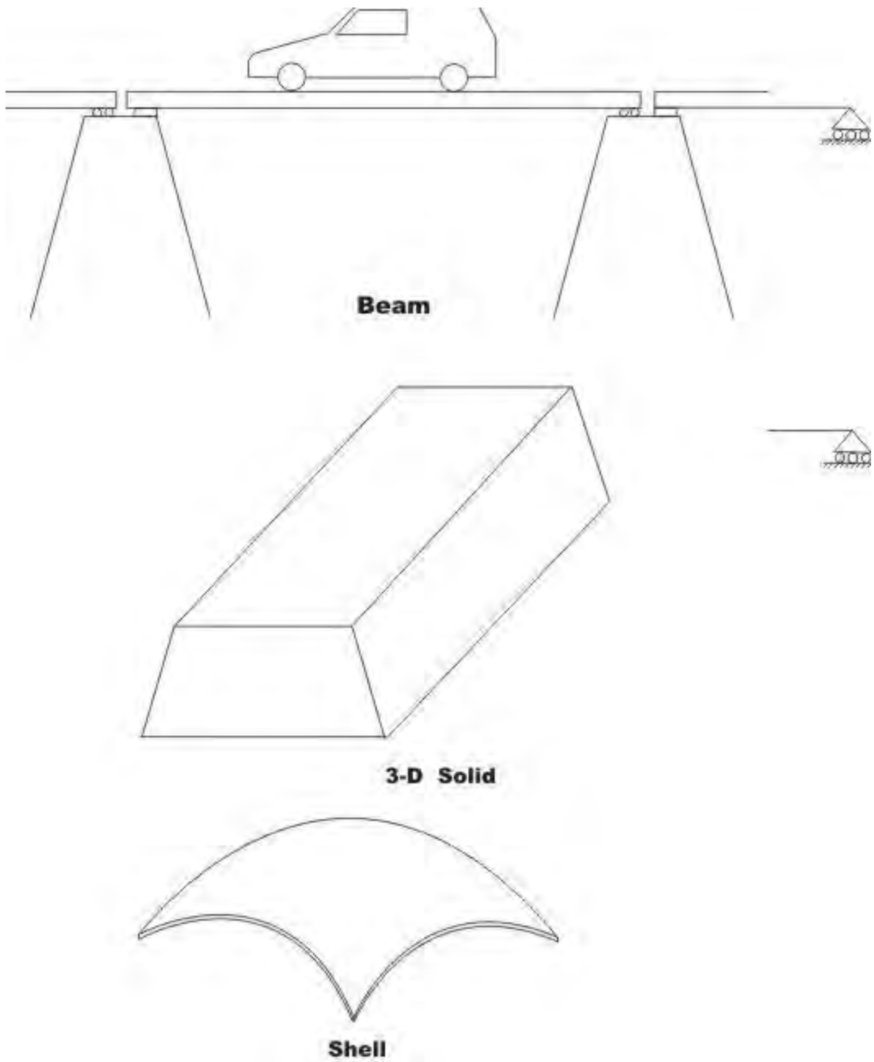

Figure 2.1: Commonly used structural forms
(Leet, K. M. and Uang, C-M., 2003, Fundamentals of Structural Analysis)

2.1.2 Beams

Beams are the simplest structural elements that are used extensively to support loads. They may be straight or curved ones. For example, the one shown in Fig. 1.2 (a) is hinged at the left support and is supported on roller at the right end. Usually, the loads are assumed to act on the beam in a plane containing the axis of symmetry of the cross section and the beam axis. The beams may be supported on two or more supports as shown in Fig. 1.2(b). The beams may be curved in plan as shown in Fig. 1.2(c). It is possible for the beam to have no axis of symmetry. In such cases, one needs to consider unsymmetrical bending of beams. In general, the internal stresses at any cross section of the beam are bending moment, shear force and axial force.

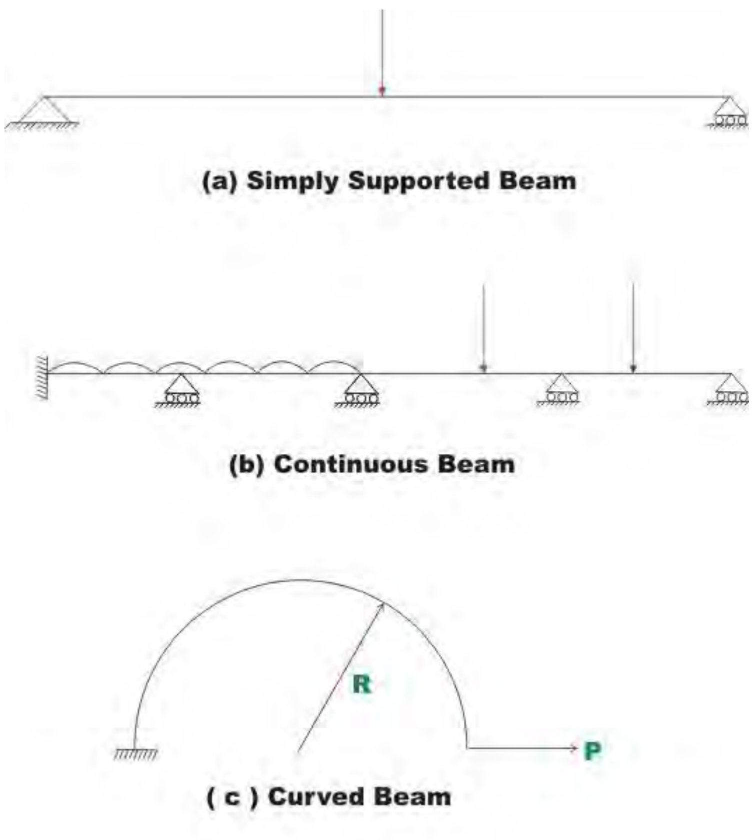

Figure 2.2: Beams

(Leet, K. M. and Uang, C-M., 2003, Fundamentals of Structural Analysis)

2.1.3 Plane Frames

Plane frames are also made up of beams and columns and the only difference is they are rigidly connected at the joints as shown in the Figure 2.3. Major portion of this course is devoted to evaluation of forces in frames for variety of loading conditions. Internal forces at any cross section of the plane frame member are bending moment, shear force and axial force. As against plane frame, space frames members also in Figure 2.3 may be oriented in any direction and there is no restriction of how loads are applied on the space frame. For this project, the cage railing being analyzed belongs to plane frame type as the joints are welded together and resist rotation. They are typically statically indeterminate.

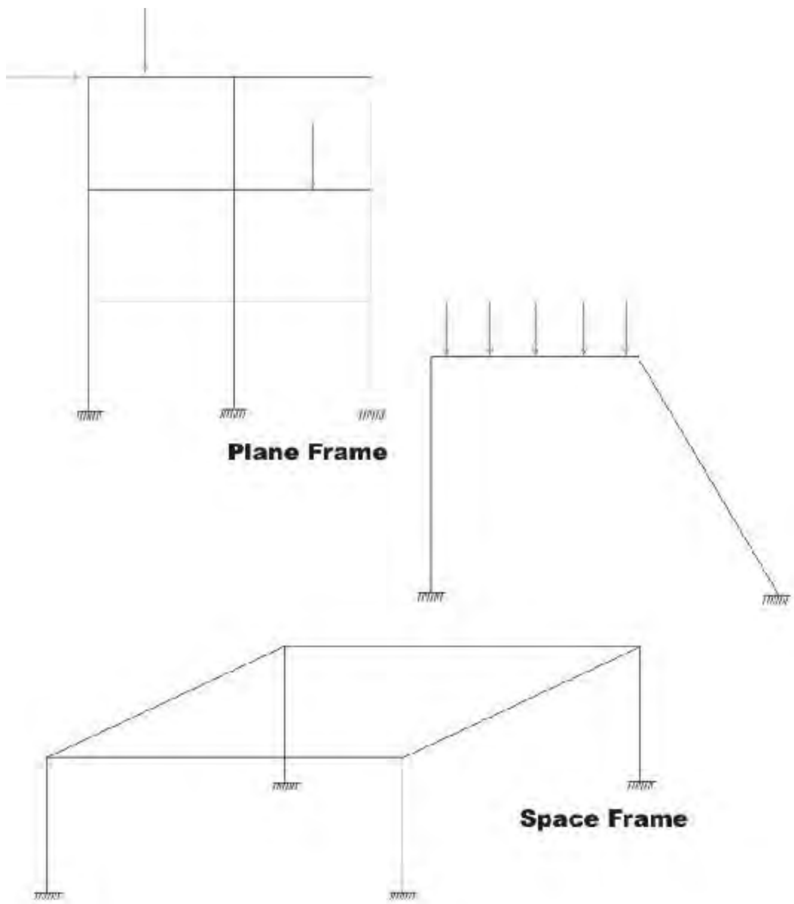

Figure 2.3: Plane frame and space frame
(Leet, K. M. and Uang, C-M., 2003, Fundamentals of Structural Analysis)

2.1.4 Static Indeterminacy

The aim of structural analysis is to evaluate the external reactions, the deformed shape and internal stresses in the structure. If this can be accomplished by equations of equilibrium, then such structures are known as determinate structures. However, in many structures it is not possible to determine either reactions or internal stresses or both using equilibrium equations alone. Such structures are known as the statically indeterminate structures. The indeterminacy in a structure may be external, internal or both. A structure is said to be externally indeterminate if the number of reactions exceeds the number of equilibrium equations.

The degree of indeterminacy may be calculated as $i = (m + r) - 2j$ where m stands for members, j for joints and r for unknown reaction components in the structure. For example, the plane frame shown in Figure 2.4 has 3 members, 4 joints and 6 reaction components. Hence, the degree of indeterminacy of the structure is

$i = (15 \text{ x } 3 + 6) - (4 \text{ x } 3) = 15$

Please note that at each joint there are 3 equations of equilibrium for plane frame.

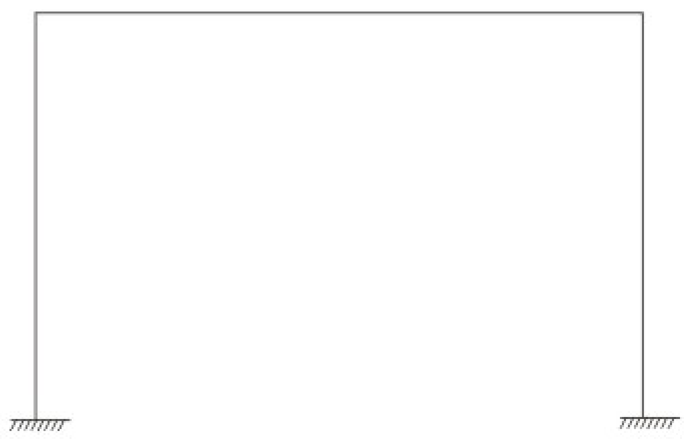

Figure 2.4: Indeterminate structure

2.2 Design Loads

A railing truss, as a structural component of a building, must be designed to support the applied loads that may occur during the life of a building. In addition to dead load, these applied loads are generally live load, snow load, wind load and seismic load. Load intensities are generally specified by a building code. In the absence of a building code, loads and load combinations shall be determined in accordance with acceptable engineering practice as stipulated by the Minimum Design Loads for Buildings and Other Structures (ASCE 7).

2.2.1 Dead Load

Dead load consists of the weight of the truss and material permanently attached to the truss. The actual dead load should be applied on a horizontal projection. Attached materials may consist of sheathing, purlins, insulation, ceiling drywall, and others.

2.2.2 Load Combinations

One or more of the above loads may occur during the life of a building. It is the responsibility of the design engineer to determine the applicable loads and combination of loads that are to be considered. Design loads are to be combined based on their probability of occurrence.