Study on Telescopic Walkway Design of Jetty Gangway

by

P Dhinesh Kumar A/L Panneerchelvam

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

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(Ir. Idris Ibrahim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2009

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.

P DHINESH KUMAR A/L PANNEERCHELVAM

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P Dhinesh Kumar Panneerchlvam

ABSTRACT

This project studies on the telescopic walkway design of the jetty gangway used in the oil and gas industry jetties. The objective of the project is to conduct study on the optimal design parameters for the telescopic walkway of gangway which suits the operational conditions at various jetties of the oil and gas companies in the South East Asia region. The limitations with respect to various marine terminal aspects are studied and the drawbacks are analyzed. Besides, the tidal conditions in the South East Asia region are surveyed to obtain the range of tidal conditions that the design must comply with. Upon gathering data regarding the standard structural beams which are appropriate for the design, static load analysis is done and the data is incorporated into a Microsoft Excel worksheet. This worksheet is a primary tool to analyze different parameters of the beams and its stress distributions. The study managed to produce results on the shear force, bending moments, shear stress and bending stress which would be essential to understand how telescopic beams are subjected to stress distributions. The study on the tidal conditions on the other hand has revealed the range of beam length that can be standardized for the South East Asia region.

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INTRODUCTION

1.1 BACKGROUND STUDY

Marine terminal operations require that shore personnel periodically board vessels at their terminal. For example, after the vessel first moors, the berth operator or another appropriate shore representative boards the vessel to complete a ship/shore safety checklist and to conduct a pre-cargo transfer conference. While the vessel is at the berth, shore personnel will periodically board the vessel to recheck certain items on the ship/shore safety checklist. Shore personnel also are typically involved in measuring and sampling the vessel's cargo tanks at certain times in the cargo transfer procedure. Either a ship mounted or shore based gangway can be used to provide a means for personnel to pass between a moored ship and the deck of a conventional pier or sea island. Every ship will have some form of gangway. Larger vessels, normally those above 10,000 dwt, will have a permanently mounted, power operated gangway. Smaller vessels and barges may only carry a manual gangway.

However, ship gangway systems can be operationally limited due to design, damage, equipment malfunction, or space limitations on the berth deck to land the gangway. In addition, local tidal conditions or the overall pier layout may restrict the use of the ship's gangway.

1.2 PROBLEM STATEMENT

Many jetties of the oil and gas (O&G) industries are facing challenges in operating the gangways which are used by berth personnel, ship crews and technicians to get on board and off board of the anchoring tankers. The existing gangway designs have limited ability to fulfill the operational requirements of the jetties. These designs are only functional for a narrow size range of ships at berth. In addition, the existing gangway designs also pose hazard for the berth personnel when the gangway is in use.

1.3 OBJECTIVES

The objective of this project is to conduct a study on the design of the telescopic walkway of a gangway that suits most of the operational conditions of the jetties and applicable to a wide range of jetty parameters as well as tidal conditions. This project therefore, aims to conduct study on the static load analysis which provides insightful design parameters for the development of detailed design of a jetty gangway. This study also aims to provide sufficient information to configure ultimate solution to the shortcomings faced by the O & G companies, berth personnel and ship crews. Furthermore, the study is aimed to be beneficial for the future studies and development of telescopic walkway designs.

1.4 SCOPE OF STUDY

The study on gangways may vary from one region to another. This is because, different parts of the world has different sea conditions, wind speed, tidal condition and operating envelope. Therefore, in this project, the scope of study of the jetty gangway design has been narrowed down to the South East Asian region. This means that the study on the telescopic walkway of this project will account for the operating conditions of oil and gas industry jetties around the South East Asia region. Thus, tidal conditions and wind speed in this region will be studied to aid the designing process. Engineering analysis is done for the static loading conditions to study the shear force, bending moments, shear stress and bending stress distribution. The ANSYS software is used to conduct stress analysis apart from the conventional stress calculation method.

CHAPTER 2

LITERATURE REVIEW

The gangway is a bridge-like structure used at berth to access the ship's deck from the jetty and vice versa. The present invention relates to a so-called gangway that is particularly suited for embarking on ships that have to dock on a floating pontoon such as used, for example in seaports, where the tidal currents cause noticeable differences in the level of the pontoon in relation to the wall of the jetty.

The gangway is comprised of two parallel sides, on which steps are arranged with a defined spacing from each other, and on which handrails are movably hinged on both sides on a railing. The handrails and the sides form a parallelogram with each inclination and the sides each are supported at the lower end on a roller and rotatable base secured at the upper ends. The trapezoidal steps are flexibly suspended with spacing from the sites in which the sides are secured. It was found that said known gangway is afflicted with the drawback that the runners, which are secured on the undersides of the sides, have the same track width as the sides over the full length. This may cause damage to the stairway, which, under normal operating conditions, compensates listings of the pontoon of up to 12° when listings of the pontoon in excess of 6° occur at high tide.

Many small jetties in the Asia pacific region are facing obstacles in operating their shore based (stationary) gangways due to certain limitations. The limitations vary from one jetty to another and are illustrated in the following diagrams:

Figure 2.1: Gangway used in ExxonMobil Refinery Jetty in Wakayama, Japan

[Courtesy of Esso Port Dickson Refinery]

Figure 2.2: Gangway used in ExxonMobil Refinery Jetty in Sriracha, Thailand

[Courtesy of Esso Port Dickson Refinery]


2005 10 25

Figure 2.3: Unsafe action taken by a jetty crew to board onto ship's deck

[Courtesy of Esso Port Dickson Refinery]

2.1 TYPES OF SHORE BASED GANGWAYS

Shore gangway systems can generally fall into one of two categories depending on how the onshore end of the gangway is fixed to the berth: "mobile systems" and "stationary gangway systems". Brief descriptions of each type of system are given below.

2.2 MOBILE GANGWAY SYSTEMS

2.2.1 Conventional

The simplest type of gangway system, consisting of a fixed length walkway with handrails and wheels or a roller on the shore end with wheels or gunwale clips at the ship end. This gangway moved about manually or with the assistance of a shore crane.

2.2.2 Platform Mounted

A gangway attached to a tower that is mounted on a platform supported by wheels. The wheels of the platform may be powered, or the structure may be pulled about the pier deck by a small, motorized vehicle. The gangway is normally controlled by a hydraulic piston between the tower and the underside of the gangway [ASCE 7-24].

2.2.3 Carriage Mounted

This type of gangway consists of a conventional type gangway with the shore end attached to a carriage, which moves on tracks either parallel or perpendicular to the pier face. Normally it is positioned with the assistance of a shore crane [ASCE 7-24].

2.3 STATIONARY GANGWAY SYSTEMS

2.3.1 Column Mounted

The most versatile type of gangway system, consisting of a telescopic gangway with it onshore end connected to the top of a column fixed to the pier deck. Column mounted gangways are usually provided with self-leveling steps which allow safe access for gangway inclinations up to 50 - 55 degrees [ASCE 7-25].

2.3.2 Tower Mounted

The most sophisticated and expensive type of gangway system, consisting of a fixed length or telescopic gangway connected to a carriage mounted on vertical tracks secured to the face of a tower. The gangway can be raised or lowered to any stage (floor) of the tower to minimize the gangway angle with the vessel deck [ASCE 7-25].

2.3.3 Shore Accommodation Ladder

Basically a ship's accommodation ladder permanently mounted on the pier deck. This type of gangway provides a good solution for providing access to small vessel decks that are always below the pier deck elevation. The gangway is raised and lowered by its own motorized derrick. This system is unique in that the ship end does not actually sit on the vessel deck. Rather it is held alongside the vessel at the proper elevation by the gangway derrick. The operator must be periodically reposition the gangway as the vessel changes draft or the tide changes the vessel deck elevation relative to the pier deck [ASCE 7-25].

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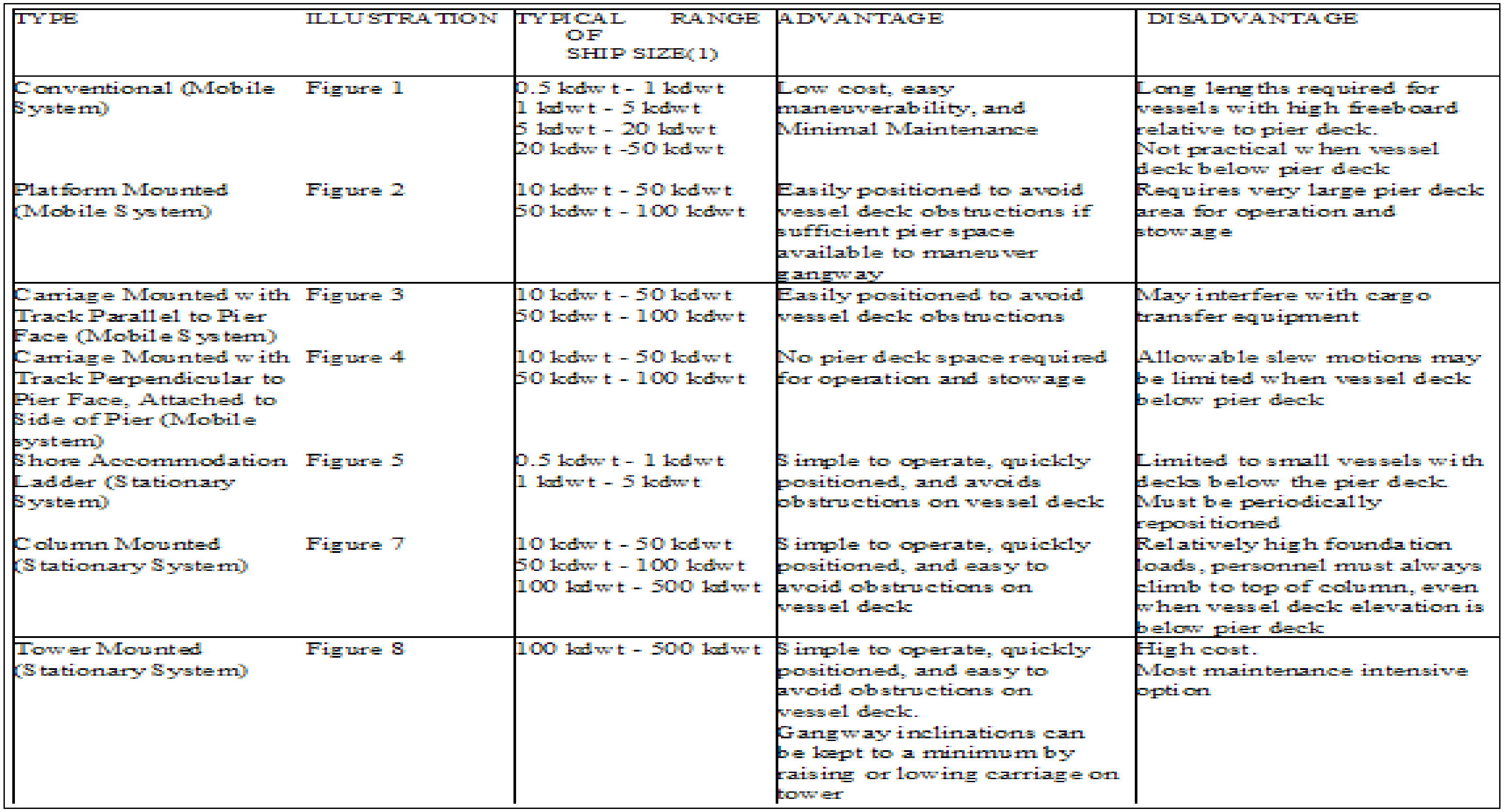
Ship/shore access for smaller vessels can be more complex, sometimes requiring that two separate gangways be provided, one for use when the vessel deck is below the pier deck, and one for use when the vessel deck is above the pier deck. In this case, a conventional gangway may be specified for use when the vessel deck is at or above the pier deck, and a shore accommodation type gangway installed for use when the vessel deck is below the pier deck. For locations where there is negligible tidal range (an infrequent occurrence), a small column mounted gangway can be used for vessels less than 10 kdwt [ASCE 7-27].

When selecting a gangway for existing facilities, the space available and the load carrying capacity of the pier deck are the most significant factors affecting the choice of gangway. Detailed drawings of the pier should be provided to the vendor illustrating the open areas on the pier for locating a shore-based gangway. A vendor may be able to use existing structures and equipment on the pier deck, such as a hose tower or shore crane, in the gangway design. The dimensions, locations on the pier, and design load capacities of such structures and equipment should be given to the vendor. The use of existing structures or equipment may lower the total investment cost for a gangway. However, checks must be made to insure that the existing structures or equipment have adequate capacity for the additional loads imposed by the gangway [ASCE 7-27

Table 2.1: Lists of the various types of gangway systems, the range of vessel sizes they can typical accommodate, and their advantages and disadvantages. [Based on American Society of Civil Engineers Code 7-30]



TYPE	ILLUSTRATION	TYPICAL RANGE OF SHIP SIZE(1)	ADVANTAGE	DISADVANTAGE
Conventional (Mobile System)	Figure 1	0.5 kdwt - 1 kdwt 1 kdwt - 5 kdwt 5 kdwt - 20 kdwt 20 kdwt -50 kdwt	Low cost, easy maneuverability, and Minimal Maintenance	Long lengths required for vessels with high freeboard relative to pier deck. Not practical when vessel deck below pier deck
Platform Mounted (Mobile System)	Figure 2	10 kdwt - 50 kdwt 50 kdwt - 100 kdwt	Easily positioned to avoid vessel deck obstructions if sufficient pier space available to maneuver gangway	Requires very large pier deck area for operation and stowage
Carriage Mounted with Track Parallel to Pier Face (Mobile System)	Figure 3	10 kdwt - 50 kdwt 50 kdwt - 100 kdwt	Easily positioned to avoid vessel deck obstructions	May interfere with cargo transfer equipment
Carriage Mounted with Track Perpendicular to Pier Face, Attached to Side of Pier (Mobile system)	Figure 4	10 kdwt - 50 kdwt 50 kdwt - 100 kdwt	No pier deck space required for operation and stowage	Allowable slew motions may be limited when vessel deck below pier deck
Shore Accommodation Ladder (Stationary System)	Figure 5	0.5 kdwt - 1 kdwt 1 kdwt - 5 kdwt	Simple to operate, quickly positioned, and avoids obstructions on vessel deck	Limited to small vessels with decks below the pier deck. Must be periodically repositioned
Column Mounted (Stationary System)	Figure 7	10 kdwt - 50 kdwt 50 kdwt - 100 kdwt 100 kdwt - 500 kdwt	Simple to operate, quickly positioned, and easy to avoid obstructions on vessel deck	Relatively high foundation loads, personnel must always climb to top of column, even when vessel deck elevation is below pier deck
Tower Mounted (Stationary System)	Figure 8	100 kdwt - 500 kdwt	Simple to operate, quickly positioned, and easy to avoid obstructions on vessel deck. Gangway inclinations can be kept to a minimum by raising or lowing carriage on tower	High cost. Most maintenance intensive option

2.4 DESIGN OF OPERATING ENVELOPE

The operating envelope of a gangway significantly influences the type and design of gangway that might be proposed by a vendor. A shore-based gangway operating envelope is defined as that volume in space within which the ship's end of the gangway must be able to operate. At all positions within the envelope, the gangway must clear the ship's rail. The operating envelope takes into consideration the maximum and minimum freeboard of the maximum and minimum sized ship (based on tidal variations and changes in ship draft), as well as a safety allowance for ship surge along the pier face and drift away from the pier.

A basic gangway operating envelope is shown in APPENDIX A. The specific information that defines the operating envelope is shown in APPENDIX A. If a shore accommodation ladder is used, only the upper and lower bounds of the envelope need be considered, as this type of gangway does not actually cross over the ship's rail. Refer to APPENDIX A for the types of gangway.

The height of the berth platform deck above low, low water, fender depth, and water level elevations should be readily available from the berth elevation drawings or can be requested directly from the operating affiliate. The height of the ship's rail is normally taken as 1.2 meters and is not normally a function of ship size. Gangway drift allowance is normally taken as 3 m (10 ft) in all directions (off the berth and both forward and aft surge along the berth).The gangway operating allowance is dependent on the size of the vessel and can vary significantly from one vessel size to another. It is important to discuss this variable with the operating affiliate and the operating affiliate's marine depart [BS BSI MA 78 – 15].

2.5 DESIGN CRITERIA

2.5.1 General Design Requirements

Gangways must provide safe footing at all operating inclinations. Generally, gangways should not be used at angles of inclination greater than 35 degrees. At sites that require a greater angle of inclination than 35 degrees, a powered gangway with "self-leveling steps" should be provided [ASCE 7-28].

All gangways should meet the following general design criteria:

a. Minimum walkway width of 2 ft (0.6 m) for gangways less than 13 ft (4 m) in length and 3.2 ft (1 m) width for longer gangways.
b. Continuous handrail height of 3.9 ft (1.2 m), including the "step-down" from the gangway walkway to the vessel deck (if provided).
c. Store behind deflected fender face.
d. Designed for a specified operating envelope.

2.5.2 Load Conditions

There are four load sources that must be considered in the design of a marine gangway. The basis for the selection of these loads must be developed during the design basis memorandum or design specification preparation phase of a project [ASCE 7-34].

Table 2.2: Types of gangway loads

Type of load	**Abbreviation**
Self-weight-load	DL
Life load	LL
Wind load	WL
Earthquake load	EL

2.5.3 Self-Weight Load

Self-Weight Load is the gravity loading acting on the mass of the individual components and members that make up the complete gangway. For gangways to be installed in locations that experience ambient temperatures below freezing, the self weight load should include a specified ice build up (ice specific gravity = 0.80) of at least 1 inch (2.5 mm). For arms to be installed in areas of especially severe cold weather conditions, additional ice build up may be specified after consultation with the operating affiliate or local project team [ASCE 7-34].

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2.5.4 Live Load

Live loading (personnel using the gangway) only applies to the operating load condition. All gangway walkways should be designed for a minimum operating load of 2.4 kN/m. Handrails should be designed for a load of 1.2 kN/m [ASCE 7-34].

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2.5.5 Wind Load

Wind load is the air pressure due to wind acting on the surface of the gangway (including any ice build-up). The wind pressures should be based on the calculation procedures in and ASCE 7, *Minimum Design Loads for Buildings and Other Structures*.

Wind loading is based on the design wind (fastest mile wind speed) which has been established for the site. The magnitude of the wind pressure also depends on the surface roughness and topography of the site, and the geometric shape and height of the gangway. These design wind speeds are applicable only when the gangway is in the stored position.

The maximum wind speed for the gangway in the operating condition (maneuvering or resting on the ship's deck) is 56 mph (25 m/sec). However, in all cases the operating wind speed should be higher than the mooring system wind limit to ensure the safety of shore personnel who may need to board the vessel to disconnect loading arms or hoses in high wind conditions.

2.5.6 Earthquake Load

Earthquake Load is the load generated due to rapid horizontal motions of the gangway structure base due to ground movement in an earthquake. The magnitude of earthquake for which the gangway must be designed is described in terms of a *Seismic Coefficient*. **Offsite Design Practice,** *Seismic Design* should be consulted to determine the appropriate Seismic Coefficient to specify in the marine loading arm design specification

2.6 MATERIALS

Gangways may be constructed in steel, aluminum, or a combination of steel and aluminum. Usual practice is to construct manual gangways entirely from aluminum. Aluminum manual gangways designed for small vessels are often light enough to be handled by one or two men. Aluminum extrusions for gangway structures shall be aluminum alloy 6061-T6, 6063-T5 and 6063-T6 and the stainless steel fasteners shall be grade 304 [Federal Specification QQ-A-200].

Rollers used at the end of the gangway shall be ultra high molecular weight polyethylene (UHMW) with black ultra violet light inhibitor added. Manual gangways constructed in steel are acceptable, but are usually too heavy to be moved by hand, and therefore often require a crane to maneuver them onto or off of a vessel.

Powered gangway support structures are usually constructed in steel, with the walkway from the support structure to the ship constructed in aluminum to minimize the gravity loading applied to the support structure and the size of the hydraulic control system required to maneuver the walkway to and from the vessel. Where steel and aluminum is used in combination, special care must be taken at the interface of the two materials to avoid the potential for "galvanic" corrosion.

2.7 MANEUVERING AND CONTROL SYSTEMS

Powered gangways may be maneuvered by a variety of means. Both column mounted gangways and tower mounted gangways are classified as stationary systems. Only the actual walkway to the ship is maneuvered. The walkway of a column mounted gangway is normally maneuvered with large diameter hydraulic pistons. The walkway of a tower mounted gangway uses a system of winches and lifting cables. The winches are often electrically driven, but may be hydraulic or air driven. Mobile gangway systems, such as a platform mounted gangway, normally have less sophisticated maneuvering and control systems. A typical platform mounted gangway is moved about the berth deck by a small, motorized vehicle such as a "fort lift" truck. Alternatively, platform mounted gangways have been provided with electrically driven wheels.

Control systems for powered gangways may be either electro-hydraulic or totally hydraulic. Electro-hydraulic systems are more expensive but provide more reliability and less maintenance. Powered gangways should provide for control of all motions of the gangway (luffing, slewing, telescoping, and transversing). To provide an adequate factor of safety, the hydraulic components of the gangway maneuvering and control system should be sized taking into account accelerative loads and 110% of the operating design wind load [ASCE 7 – 44].

The hydraulic cylinders shall be fed by several hydraulic pumps to guarantee 100% operation Hydraulic lift cylinders shall be designed in compliance with Det Norske Veritas (DNV) standards. Limit switches can be attached to the PLC, warning light or traffic gate. This simple yet effective device warns operators that the gangway is out of the stored locked position, preventing drive-offs with the equipment down on vehicles and damage during rail switches.

2.8 ELECTRICAL ISOLATION

The underside of aluminum gangways should be protected with a hard plastic or wooden strip to prevent the gangway from becoming an electrical path between the ship and shore. If wheels are fitted at one end of the gangway, they should be made of a non-conductive material such as hard rubber.

Aluminum is an excellent conductor of electricity. It is important to prevent an electrical path through the gangway to avoid potential sparking when setting or removing the gangway from the ship. An electrical connection between the ship and the shore can also cause a large drain on the terminal's cathodic protection system. In addition to the above, aluminum equipment dragged or rubbed across rusty steel may leave a smear. If a dropped steel object, such as a tool for example, strikes this smear, an incendive spark can be generated.

2.9 WELDING

All connections to be welded shall be of new material, clean and free of any contaminants. All joints shall fit properly and be prepared for the appropriate weld as described in the shop drawings. All welding shall be performed by currently certified welders, per AWS D1.2- 97' for structural aluminum and per AWS D1.1-2000 for structural Steel. Welder’s proof of certification shall be provided upon request. Weld procedure qualifications shall be kept on file.

2.10 INSTALLATION

The gangway shall be installed on the floating dock and the toe end adjusted as to allow the dock system free movement to travel the full range of water levels without binding or stressing the gangway or dock system. The gangway roller guide tracks shall be adjusted to suit the full range of lateral movement of the rollers and shall be adequately secured to the dock surface. The gangway shore mount shall be installed as per the project specifications.

2.11 MAINTENANCE

All machinery requires periodic maintenance to ensure safe operation. By using only the best materials and components, together with intelligent design and maintenance training, the level of maintenance is reduced

CHAPTER 3
THEORY

3.1 BENDING CAPACITY OF STEEL BEAMS

Beams in bending develop tension and compression in their flanges. The bending capacity of the beam is limited by how much force can be carried by each flange.

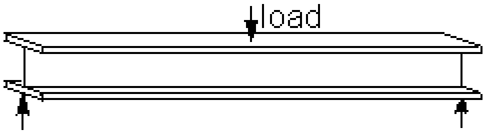


Figure 3.1: Load orientation on an I-beam

The tension flange acts like the string in an archer's bow and the maximum force that can be developed is limited only by the yield stress of the flange material. The compression flange acts like a strut and is susceptible to buckling before yield stress can be developed. Unless the compression flange is fully restrained then the beam may fail by lateral torsional buckling.

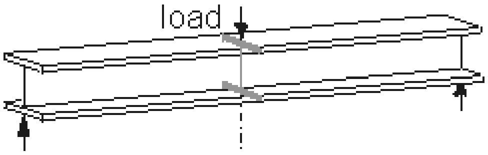


Figure 3.2: Lateral torsional buckling.

All beams to be restrained at their supports [BSI 78 - Clause 9.6.1]. The restraint is required to hold the compression flange in place and is usually provided at the support by use of the bearing stiffeners and a suitable bearing [BSI 78 - Clause 9.12.5].

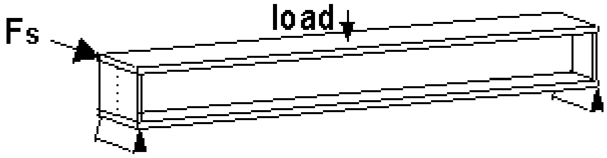


Figure 3.3: Restraint at support

The design procedure for checking a beam section is:

Determine the effective length (l_e) based on the support condition of the compression flange. The compression flange must be supported laterally at the beams' supports. This ensures that the compression flange can be assumed to have at least a pinned end support so the maximum stiffness, k_1 that may be assumed is 1.0 for non-cantilever beams. If end diaphragms are provided to prevent the compression flange from rotating in plan then a smaller value of k_1 can be used. [BSI 78 - Clause 9.6.2].

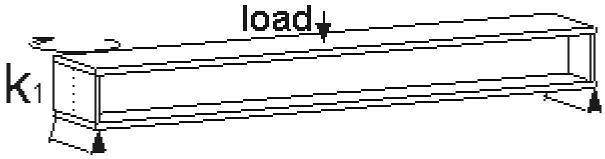


Figure 3.4: Rotational end restraint

3.2 SHEAR CAPACITY OF STEEL BEAMS

The beams must be designed to fail at Ultimate Limit State. Shear failure of a beam, with transverse web stiffeners, develops in three stages:

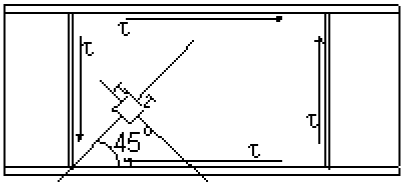


Figure 3.5: Stage1- Initially pure shear is developed within the unbuckled web.

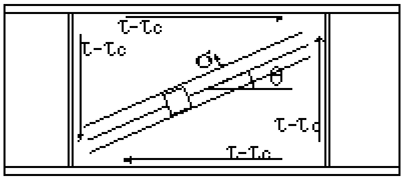


Figure 3.6: Stage2 - A diagonal tension field is developed when the web has buckled.

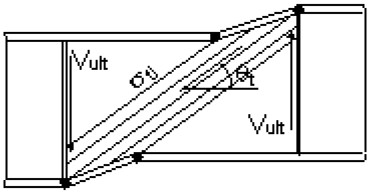


Figure 3.7: Stage3 - Plastic hinges develop in the flanges which produce a mechanism for collapse to occur.

When the web buckles, at the limit of stage 1, the diagonal compressive stress in the web is assumed to be at its maximum. The diagonal tensile stress is usually far from its maximum at this stage. If transverse web stiffeners are provided, then the beam can carry additional load by truss action. The web forms the tie members of the truss (with its spare tensile capacity), whilst the transverse stiffeners form the strut members.

The top and bottom flanges act as the top and bottom chords of the truss. Bending of these members is increased as the tension in the web increases. Failure occurs when plastic hinges form in the flanges to produce a mechanism (stage 3). The term m_{fw} in the graphs represents the plastic moment of resistance of the flanges.

Shear and bending moment diagrams are analytical tools used in conjunction with structural analysis to help perform structural design by determining the value of shear force and bending moment at a given point of an element. Using these diagrams the type and size of a member of a given material can be easily determined. Another application of shear and moment diagrams is that the deflection can be easily determined using either the moment area method or the conjugate beam method.

3.2.1 Normal Convention

The normal convention used in most engineering applications is to label a positive shear force one that spins an element clockwise (up on the left, and down on the right). Likewise the normal convention for a positive bending moment is to warp the element in a "u" shape manner (Clockwise on the left and counterclockwise on the right).

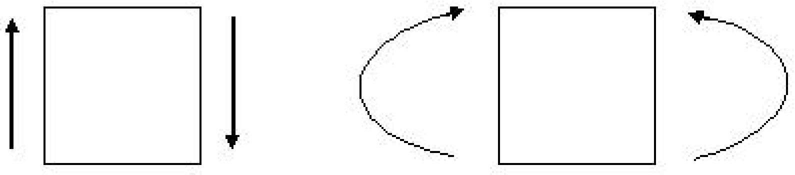


Figure 3.8: Normal positive shear force convention (left) and normal bending moment convention (right).

This convention was selected to simplify the analysis of beams. Since a horizontal member is usually analyzed from left to right and positive in the vertical direction is normally taken to be up, the positive shear convention was chosen to be up from the left, and to make all drawings consistent down from the right. The positive bending convention was chosen such that a positive shear force would tend to create a positive moment.

3.2.2 Concrete Design Convention

An exception to using the normal convention is used when designing concrete structures. Since concrete is weak in tension the most important part of designing a member with a high bending moment is to show whether the top or bottom of the concrete member is in tension. Because of this the positive moment diagram is always drawn such that the tension on top is defined to be positive. This is opposite of the normal convention. The shear convention for reinforced concrete remains the same as the normal convention.

3.2.3 Vertical and Angled Members

For vertical members deciding the convention is to start from the bottom and move up in the same way that horizontal members start from the left and move to the right. In this way a force pushing to the left from the bottom will inspire a positive shear moment which will also be drawn to the left. For angled members if there is a conflict of interest between the normal convention and the vertical convention most often an engineer will follow the normal or horizontal reaction but either can be followed and the engineer should make note of which convention they are following. For concrete in either vertical or angled members the shear diagrams are drawn as stated above but the moment diagram should be drawn to show which side the tension of the member will be on.

3.2.4 Procedure

There are three major steps to constructing the shear and moment diagrams. The first is to construct a loading diagram, the second is to calculate the shear force and the bending moment as a function of the position of the beam, and the third is to draw the shear and moment diagrams.

3.2.5 Loading Diagram

A loading diagram shows all loads applied to the beam which includes the service loads as well as the reaction loads. The service loads are loads put on the building during its use these include dead, live, roof live, snow, wind, earthquake, and other types of load. In practice these loads are factored in a way such that they place the maximum reasonable stresses on a structure. From the service loads and the structural configuration the reaction loads can be determined using one several structural analysis methods including finite element method and static analysis. Once the reaction loads have been determined the loading diagram can be drawn.

3.2.6 Calculating the Shear and Moment

With the loading diagram drawn the next step is to find the value of the shear force and moment at any given point along the element. For a horizontal beam one way to perform this is at any point to "chop off" the right end of the beam and calculate the internal shear force needed to keep the left portion of the beam in static equilibrium. That internal shear force is the value of the shear force needed to plot on the shear diagram. The moment is done in similar method by "chopping off" one end and calculating the bending moment at that point but will generally be more complicated.

Both the shear and moment functions should be written as stepwise functions with respect to position on the beam.

3.2.7 Drawing the Shear and Moment Diagrams

After the value of the shear force and bending moment diagram are defined for all regions of the member the diagrams can finally be drawn. Important positions where maximum or minimum values of shear force or bending moment occur should be dimensioned from one end of the member noted with a dimension. Normally the shear diagram is drawn directly below the loading diagram with the moment diagram drawn directly beneath the shear diagram to show which points on the shear and moment diagrams line up with the different loadings that the member is subjected to. The step functions and any calculations are usually written out below the shear and moment diagrams.

3.2.8 Relationships between Load, Shear, and Moment Diagrams

Since this method can easily become unnecessarily complicated with relatively simple problems, it can be quite helpful to understand different relations between the loading, shear, and moment diagram. The first of these is the relationship between a distributed load on the loading diagram and the shear diagram. Since a distributed load varies the shear load according to its magnitude it can be derived that the slope of the shear diagram is equal to the magnitude of the distributed load.

$$\frac{dV}{dx} = w \qquad \text{...(3.2.8.1)}$$

Some direct results of this is that a shear diagram will have a point change in magnitude if a point load is applied to a member, and a linearly varying shear magnitude as a result of a constant distributed load. Similarly it can be shown that the slope of the moment diagram at a given point is equal to the magnitude of the shear diagram at that distance.

$$\frac{dM}{dx} = V \qquad \text{...(3.2.8.2)}$$

Note: Relationship between distributed shear force and bending moment

A direct result of this is that at every point the shear diagram crosses zero the moment diagram will have a local maximum or minimum. Also if the shear diagram is zero over a length of the member, the moment diagram will have a constant value over that length. By calculus it can be shown that a point load will lead to a linearly varying moment diagram, and a constant distributed load will lead to a quadratic moment diagram.

3.2.9 Practical Considerations

In practical applications the entire stepwise function is rarely written out. The only parts of the stepwise function that would be written out are the moment equations in a nonlinear portion of the moment diagram; this occurs whenever a distributed load is applied to the member. For constant portions the value of the shear and/or moment diagram is written right on the diagram, and for linearly varying portions of a member the beginning value, end value, and slope or the portion of the member are all that are required

CHAPTER 4
METHODOLOGY

The flowchart in Figure 4.1 shows the methodology of the project. The project is initiated with a literature review of the types of gangways that are being used in the South East Asia region. Then, standard structural beams that can be used to build the telescopic walkways for the design are studied.

On the other hand, the tidal conditions in South East Asia region are studied in order to configure the operating envelope of the gangway. The study on the tidal conditions will assist in the determination of the types of vessels that anchor at jetties in this region and would enable to outline the range of required length of the beams for the telescopic walkway construction.

Once the types of standard beams have been studied, the beams are then paired into different combinations to analyze the bending and shear stresses. This would be essential to determine the best combination of beam designs for the telescopic walkway. Then, load analysis is assimilated into a Microsoft Excel worksheet and the variation of the stresses along the length of the beams is analyzed.

To check for the accountability of the worksheet, the beams are analyzed using the ANSYS software for the stress variation. The values obtained form the Excel worksheet and the ANSYS software is compared. The validity of the Excel worksheet is approved if the values match. However, if the values do not match, the calculations used for the worksheet will be amended accordingly and re-analyzed using the ANSYS software.

Once the worksheet is validated, the standard beams parameters are inserted into the worksheet for different combinations of the beams and the stresses are analyzed. Based on the results obtained, the most appropriate dimensions of the beams for the South East Asia region are recommended.

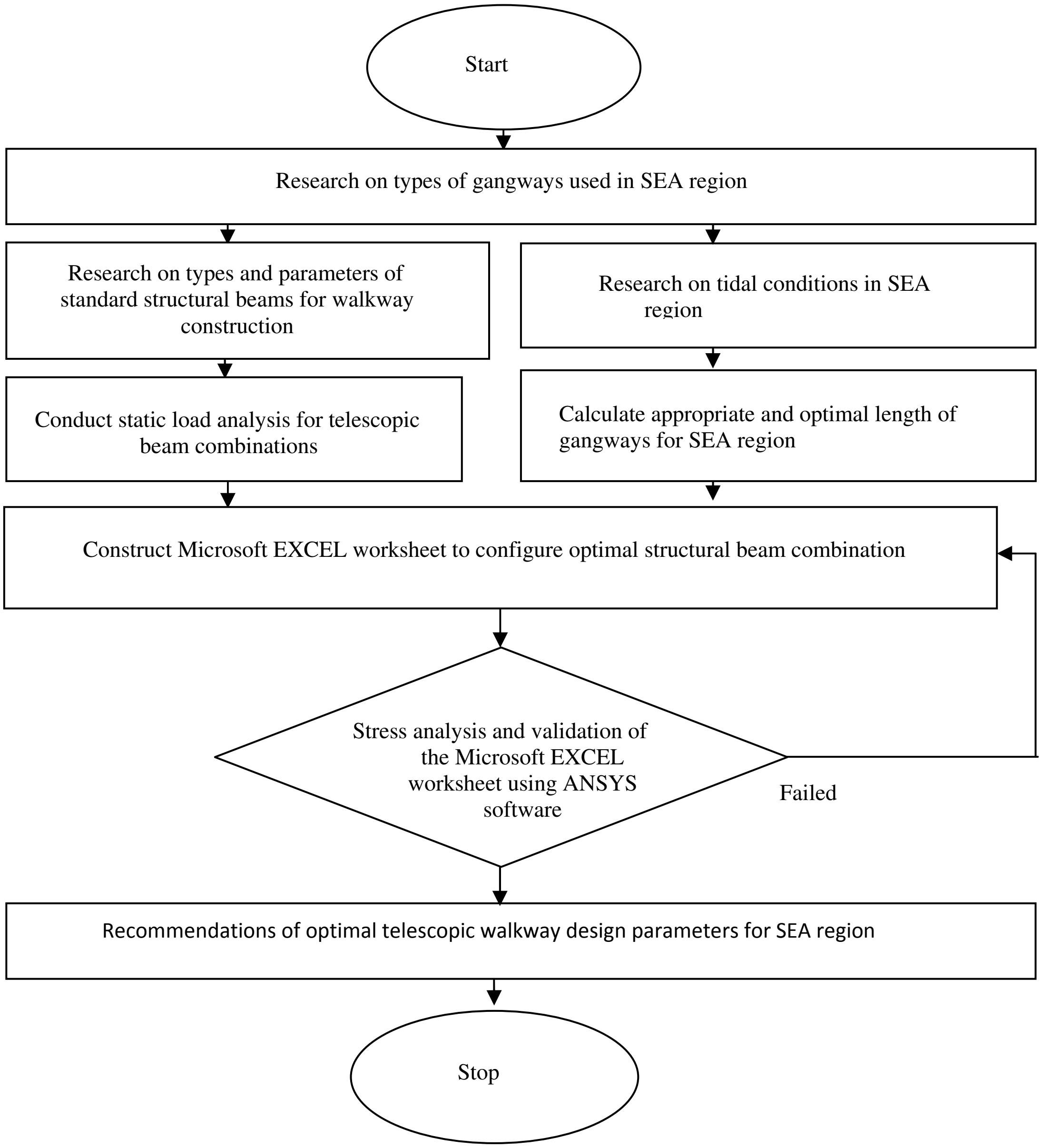


Figure 4.1: Methodology flowchart of the project

CHAPTER 5
RESULTS AND DISCUSSION

5.1 STATIC LOADING ANALYSIS

The static loads are the forces that act on the gangway system when the gangway is not operating or not moving. The static load may be due to the weight of the gangway itself, the life load due to the weight of the personnel using the gangway or the reaction forces that is exerted on the gangway by the components of the gangway like the hydraulic piston arm and even the reactions by the telescopic section of the walkway on the main walkway. In this section, the effects of the static loads on the stress and the bending moments of the gangway are analyzed.

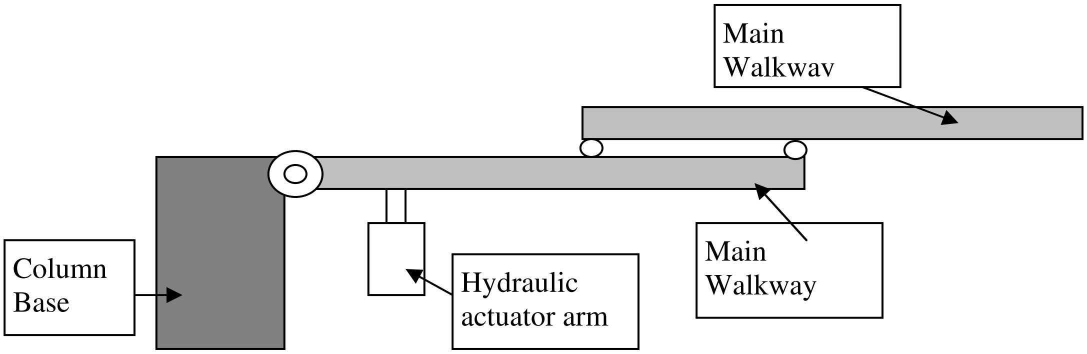


Figure 5.1: Components of walkway included in static load analysis

Figure 5.1 shows the gangway components that are subjected to the static loads during its operation. Main walkway is the component which attached to the column base on the jetty while telescopic walkway is the component of the gangway which is attached to main walkway.

W_A is the weight of mainwalkway and the telescopic walkway respectively. A distributed load of 2400 N/m is exerted on the whole length of the walkway due to the live load of the walkway which is the load caused by the personel using the walkway. This is also in accordance with the requirements in
ASCE 7.

The following terms are used to represent the loads that act on the walkway:

N_{y1} - Normal reaction at the hinge in the Y direction
N_{y2} - Normal reaction exerted by the weight of the telescopic walkway in Y direction
N_{y3} - Normal reaction exerted by the weight of the telescopic walkway in Y direction
W_d - Distributed load that acts on the walkway as required by ASCE 7
$N_{support}$ - Reaction force exerted by the support arm to counter the weight and moments.
NOTE: The support could be a hydraulic actuator arm or metallic cable hooked up to pulleys.

The expressions of reaction forces that have been obtained are applied in the analysis of stress and bending moments of these segments of the walkway. The shear force and bending moment analysis of the beams require the application of sectional weights of the beams because every inch of the beam will be subjected to weight. The sectional loads that are applied on the beams are shown below:

For the main beam, let the length of the beam as L . The weight of the beam is equals to the product of density (ρ), cross sectional area (A), length L and the gravitational acceleration, g of 9.81 ms^{-2}. Therefore, the sectional weight of the beam is

$W_A = \rho gAL$……………………………………………………………………..(5.1.1)

The weight of the beam is distributed along the beam's length and acts together with the standard required distributed load of 2400 N/m as W_A/L. Similarly, the distributed load will be as below:

$W_d = 2400L$……………………………………………………………………...(5.1.2)

Therefore, the combination of the weight and the distributed load contributes to the following load:

Total distributed load = $(W_A/L + W_d)(L)$………………………………………(5.1.3)

The analysis of the shear force, bending moment, shear stress and the bending stress are done by considering three cases of the walkway extension length. The first case discusses the analysis for fully retracted walkway; the second case discusses analysis of the half-extended walkway and the third case discusses analysis of three-quarter extended walkway.

The three cases of analysis mentioned are discussed in the following analyses:

5.2 CASE 1 - THE WALKWAYS FULLY RETRACTED

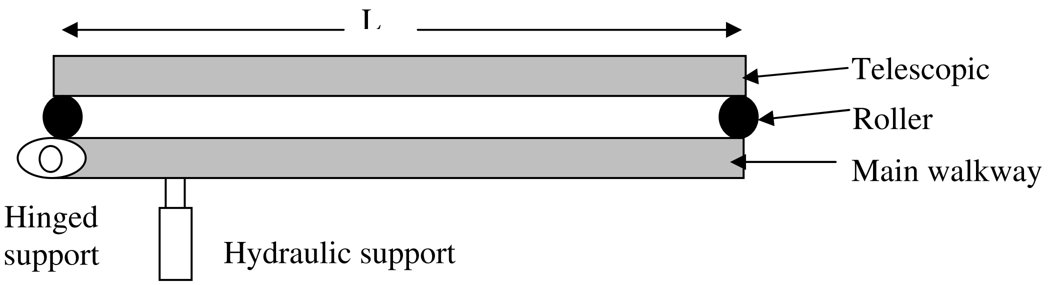


Figure 5.2: Orientation of the walkway when fully retracted

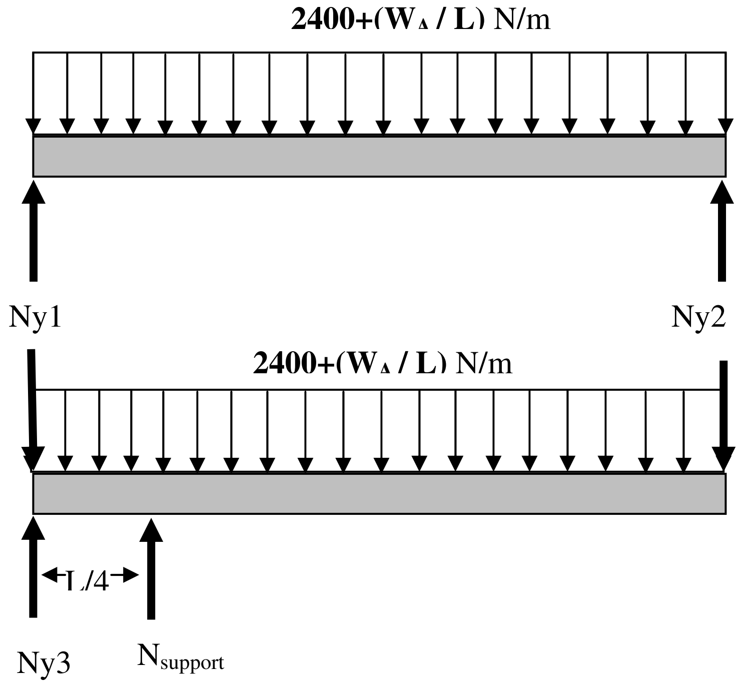


Figure 5.3: Loads acting on individual walkways of retracted walkway

Calculation for reaction forces:

a) For telescopic walkway:

$+\uparrow\sum F_y = 0;$

$Ny1 + Ny2 = [2400 + (W_A / L)](L)$

$Ny1 = [2400 + (W_A / L)]\,(L) - Ny2$……………………………………………….(5.2.1)

$+\circlearrowright M = 0;$

$Ny2\,(L) = [2400 + (W_A / L)](L/2)$

$Ny2 = 2(L)\,[2400 + (W_A / L)]$……………………………..…….…………..(5.2.2)

b) For Main walkway:

$+\uparrow\sum F_y = 0;$

$Ny3 + N_{support} = [2400 + (W_A / L)](L) + Ny1 + Ny2$

$Ny3 = [2400 + (W_A / L)]\,(L) + Ny1 + Ny2 - N_{support}$ …………………………………………....(5.2.3)

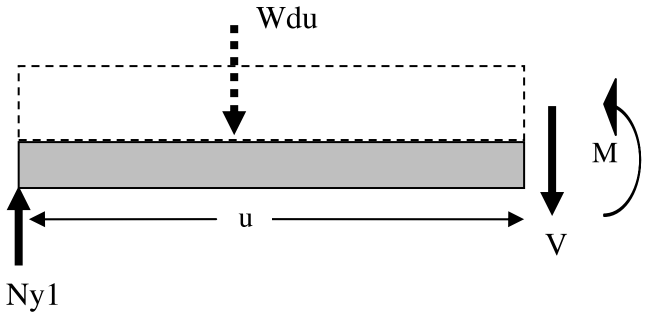
$+\circlearrowright M = 0;$

$N_{support}(L/4) = [2400 + (W_A / L)](L)\,(L/2) + Ny2(L)$

$N_{support} = 2(L)\,[2400 + (W_A / L)] + 4Ny2$………………..…………………………(5.2.1)

5.2.1 Calculation for shear force and bending moment

a) Telescopic Walkway



Shear force and bending moment:

$+\uparrow\sum F_y = 0;$

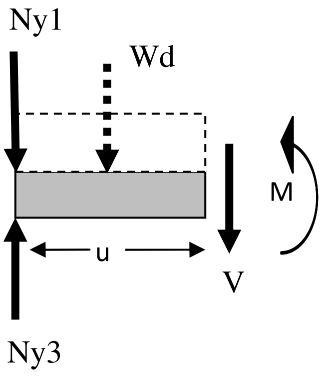
$V = Ny1 - [2400 + (W_A / L)]\, u$ ……………………………………..…………..(5.2.1.1)

$+\circlearrowright M = 0;$

$M = Vu + [2400 + (W_A / L)]\, (u/2)$……………………………………..………..(5.2.1.2)

b) Main walkway

For $0 \leq u < L/4$



Shear force and bending moment:

$+\uparrow\sum F_y = 0;$

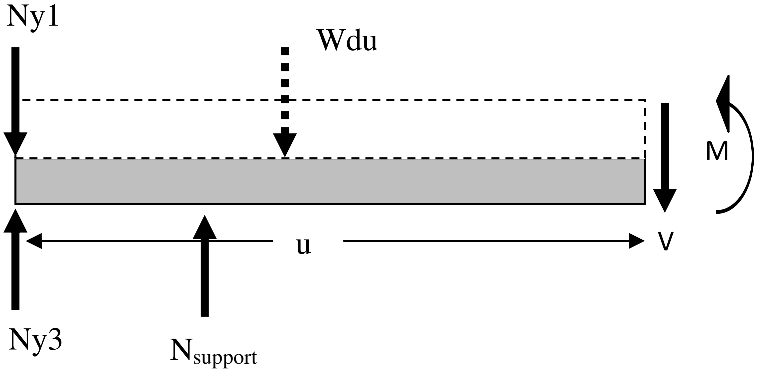
$V = Ny3 - [2400 + (W_A / L)]\, u - Ny1$…………..…..(5.2.1.3)

$+\circlearrowright M = 0;$

$M = Vu + [2400 + (W_A / L)]\, u\, (u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2$…………………..(5.2.1.4)

For $L/4 \leq u < L$



Shear force and bending moment:

$+\uparrow\sum F_y = 0$;

$V = Ny3 + N_{support} - [2400 + (W_A / L)]\, u - Ny1$……………………………………..(5.2.1.5)

$+ \circlearrowright M = 0$;

$M + N_{support}(L/4) = Vu + [2400 + (W_A / L)]u(u/2)$

$M = Vu + [2400 + (W_A / L)]\, u2/2 - N_{support}(L/4)$ ……………….………………..(5.2.1.6)

5.2.2 Results of analysis on Case 1

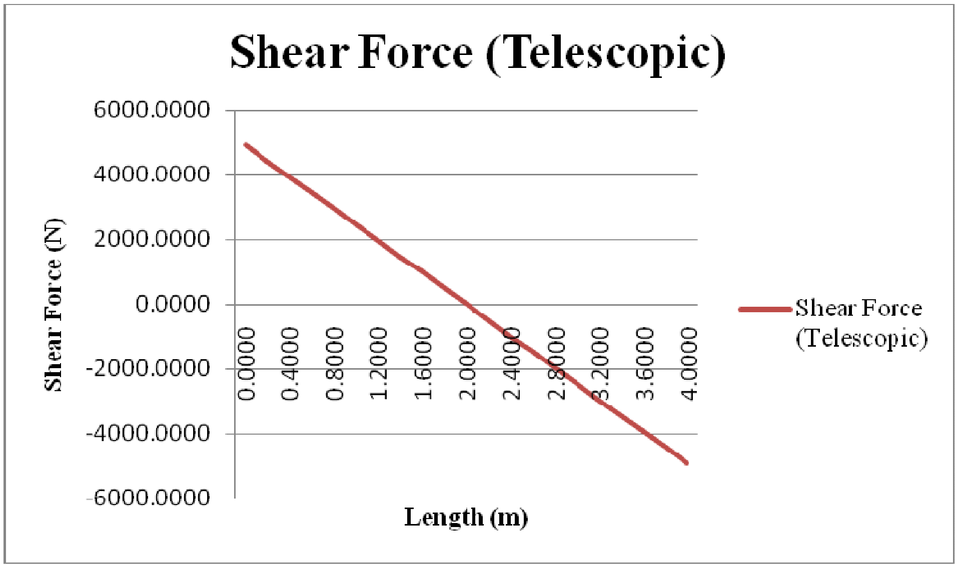


Figure 5.4: Shear force variation of the telescopic walkway when the walkway is fully retracted

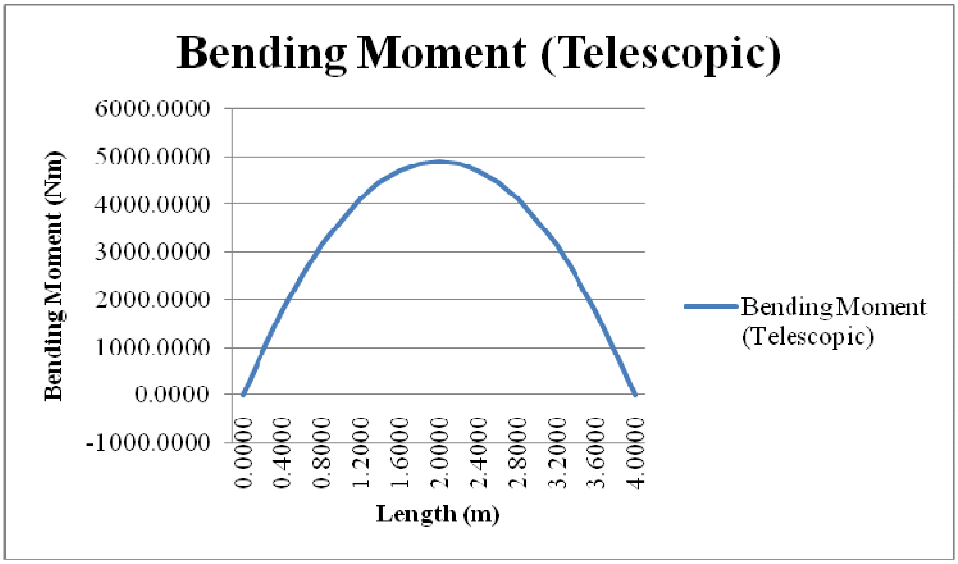


Figure 5.5: Bending moment variation of the telescopic walkway when the walkway is fully retracted

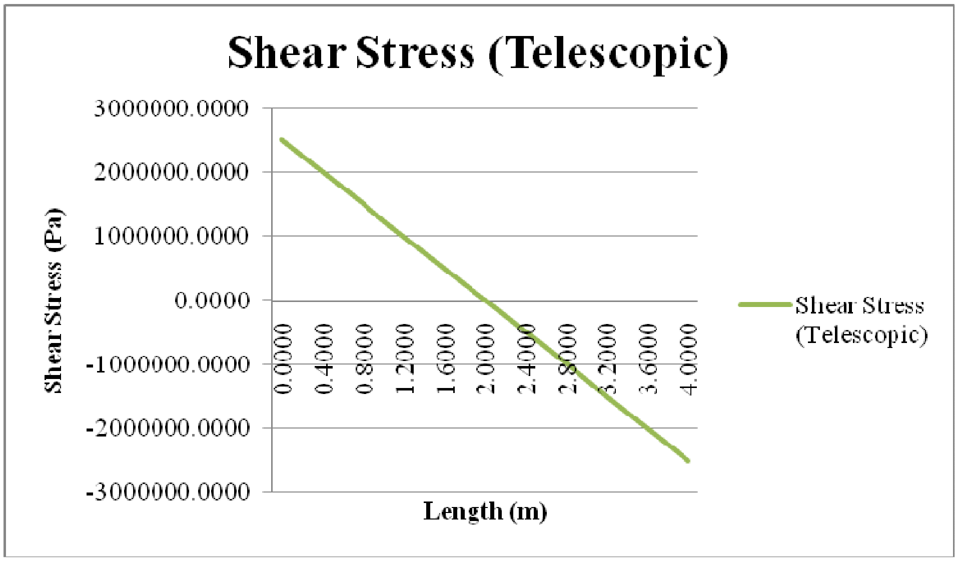


Figure 5.6: Shear Stress variation of the telescopic walkway when the walkway is fully retracted

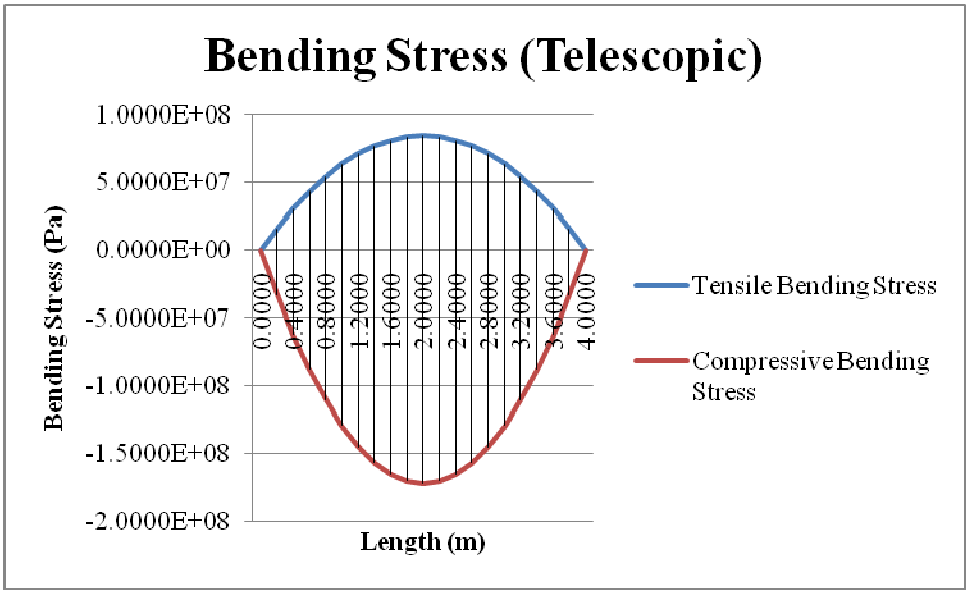


Figure 5.7: Bending Stress variation of the telescopic walkway when the walkway is fully retracted

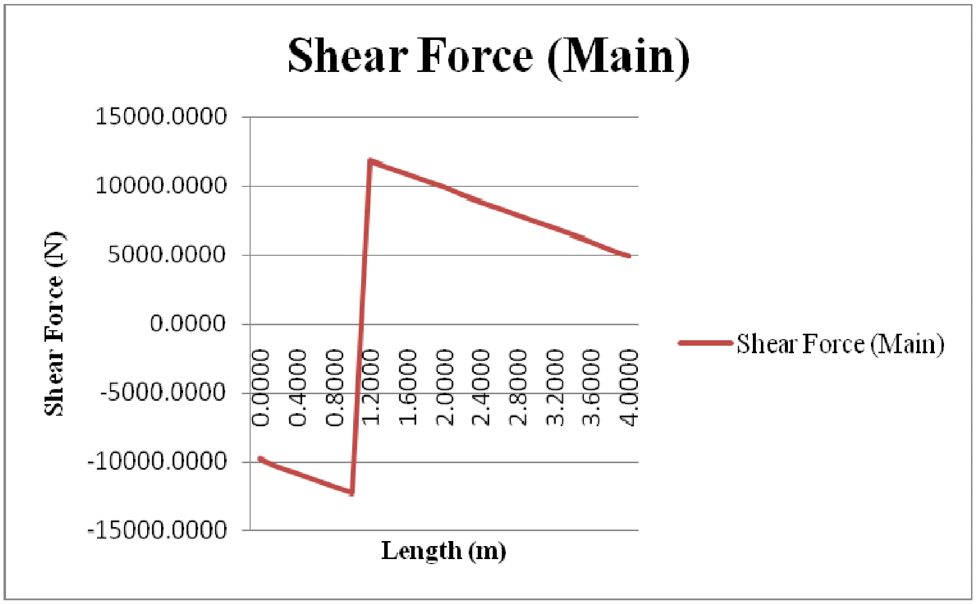


Figure 5.8: Shear force variation of the main walkway when the walkway is fully retracted

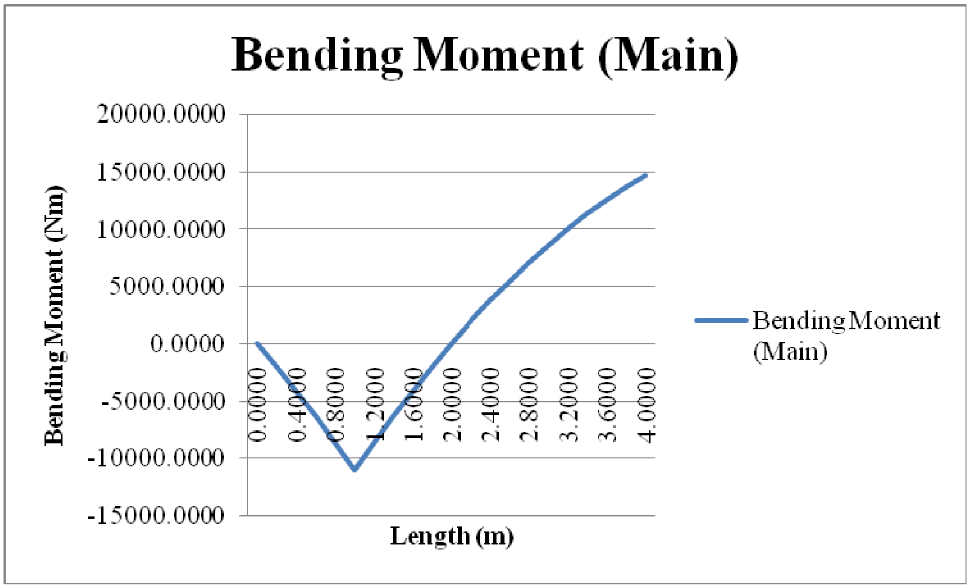


Figure 5.9: Bending moment variation of the main walkway when the walkway is fully retracted

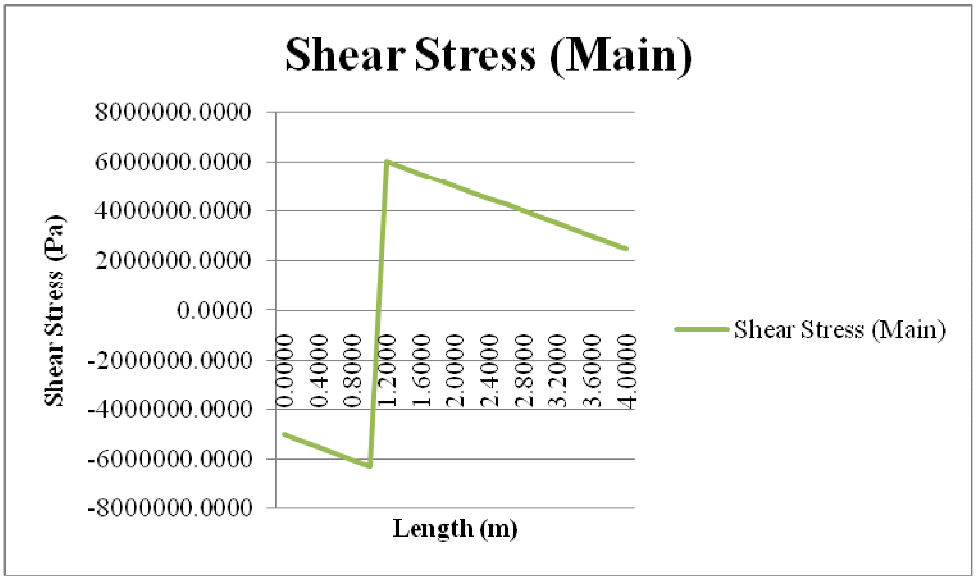


Figure 5.10: Shear stress variation of the main walkway when the walkway is fully retracted

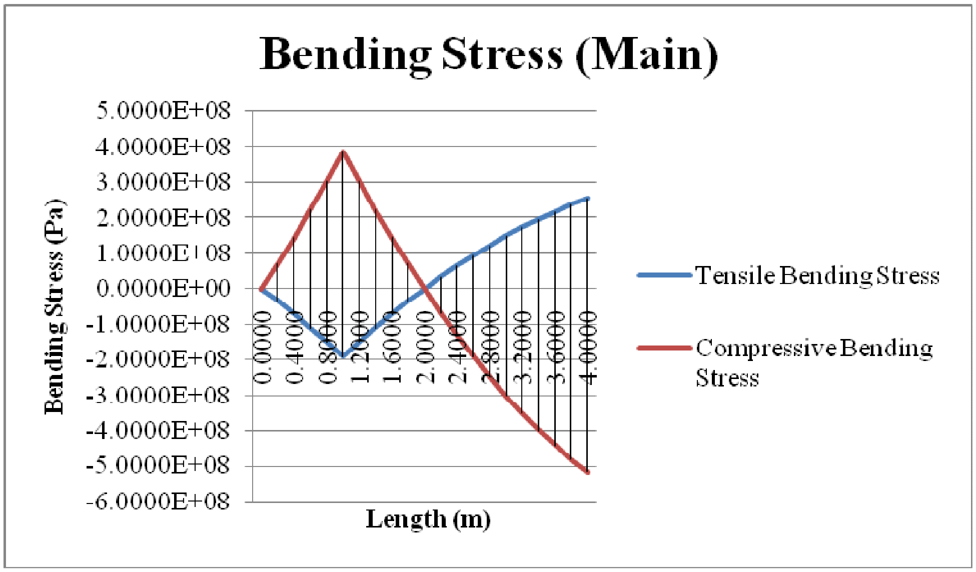


Figure 5.11: Bending Stress variation of the main walkway when the walkway is fully retracted

5.3 CASE 2 - WALKWAY IS HALF-EXTENDED

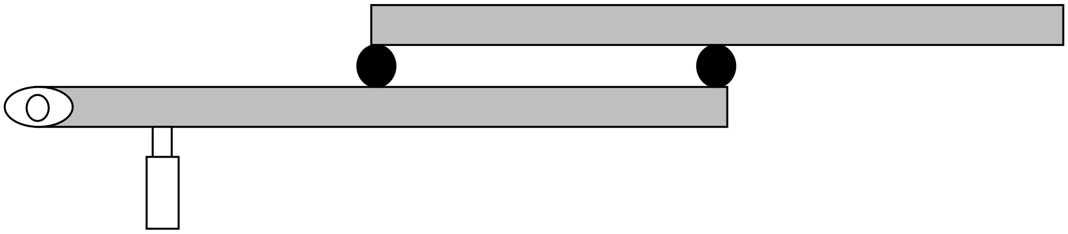


Figure 5.12: Orientation of the walkway when the walkway is half extended

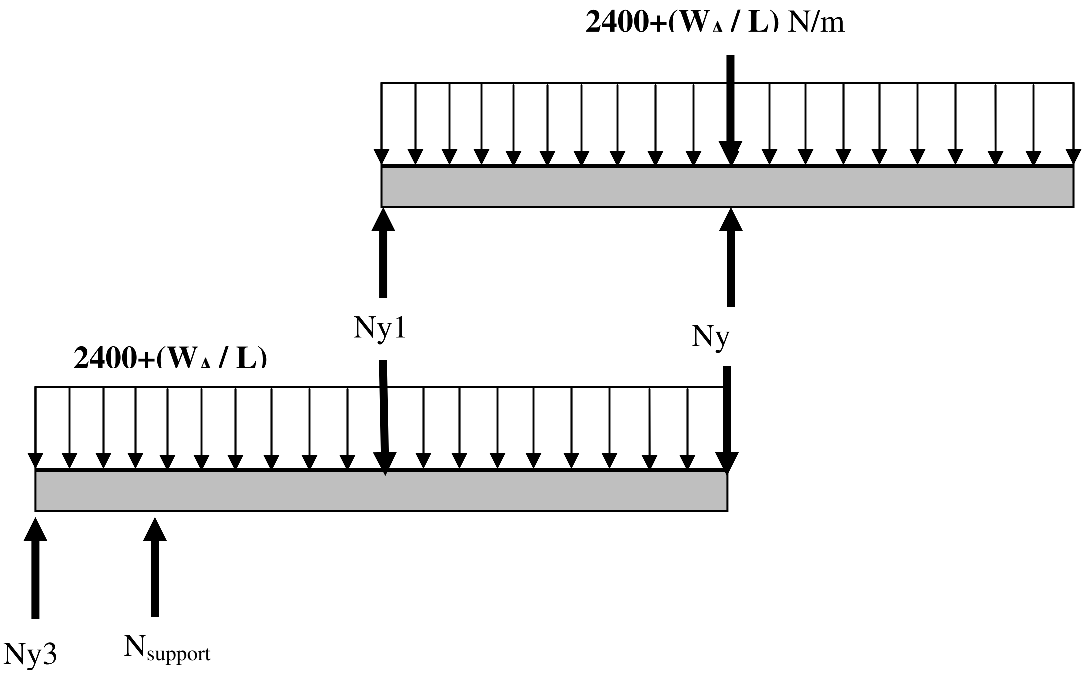


Figure 5.13: Loads acting on individual walkway when the walkway is half-extended

Calculation for reaction forces:

a) For telescopic walkway:

$+\uparrow\sum F_y = 0;$

$Ny1 + Ny2 = [2400 + (W_A / L)]\,(L)$

$Ny1 = [2400 + (W_A / L)]\,(L) - Ny2$……………………………………………..(5.3.1)

$+\circlearrowright M = 0;$

$Ny2\,(L) = [2400 + (W_A / L)]\,(L)\,(L/2)$

$Ny2 = [2400 + (W_A / L)]\,(L)/2$…………….………………………………...…..(5.3.2)

b) For Main walkway:

$+\uparrow\sum F_y = 0;$

$Ny3 + N_{support} = [2400 + (W_A / L)]\,(L) + Ny1 + Ny2$

$Ny3 = [2400 + (W_A / L)]\,(L) + Ny1 + Ny2 - N_{support}$……………………………..(5.3.3)

$+\circlearrowright M = 0;$

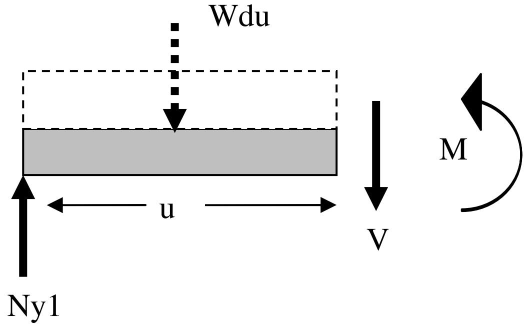
$N_{support}(L/4) = [2400 + (W_A / L)]\,(L)\,(L/2) + Ny2(L) + Ny1\,(L/2)$

$N_{support} = 2(L)\,[2400 + (W_A / L)] + 4(Ny2) + 2(Ny1)$ ……………………………..(5.3.4)

5.3.1 Calculation for shear force and bending moment

a) Telescopic walkway

For $0 \leq u < L/2$



Shear force and bending moment calculation:

$+\uparrow\sum F_y = 0$;

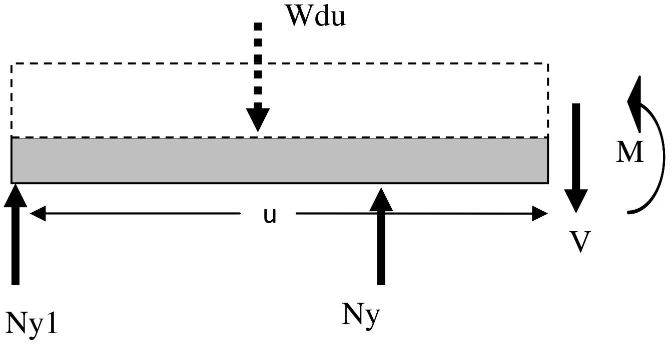
$V = N_{y1} - [2400 + (W_A / L)]\, u$.......(5.3.1.1)

$+\circlearrowleft M = 0$;

$M = Vu + [2400 + (W_A / L)]\, (u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2$…(5.3.1.2)

For $L/2 \leq u < L$



Shear force and bending moment calculation:

$+\uparrow\sum F_y = 0$;

$V = N_{y1} + N_{y2} - [2400 + (W_A / L)]\, u$…………………………………….............(5.3.1.3)

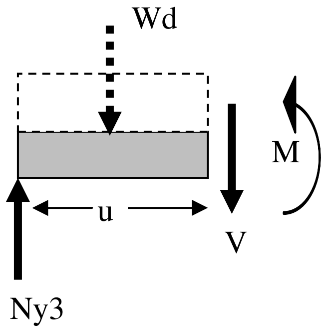
$+\circlearrowleft M = 0$;

$M + N_{y2}\,(L/2) = Vu + [2400 + (W_A / L)]\, u(u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2 - N_{y2}\,(L/2)$ ....(5.3.1.4)

b) Main walkway

For $0 \le u < L/4$



Shear force and bending moment calculation:

$+\uparrow \sum Fy = 0;$

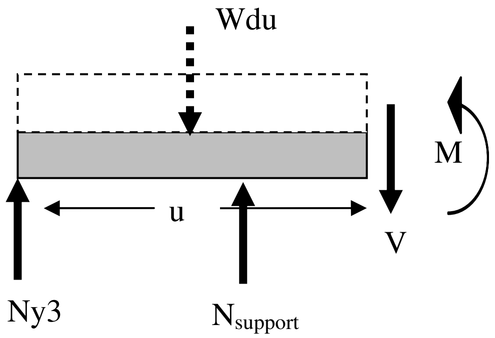
$V = Ny3 - [2400 + (W_A / L)]\ u$…………………...(5.3.1.5)

$+ \circlearrowleft M = 0;$

$M = Vu + [2400 + (W_A / L)]\ u(u/2)$

$M = Vu + [2400 + (W_A / L)]\ u^2/2$………….……...(5.3.1.6)

For $L/4 \le u < L/2$



Shear force and bending moment calculation:

$+\uparrow \sum Fy = 0;$

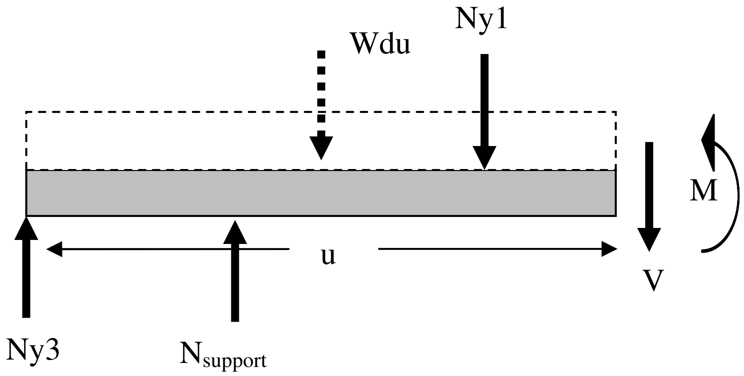
$V = Ny3 + N_{support} - [2400 + (W_A / L)]\ u$…………………….…..……...………..(5.3.1.7)

$+ \circlearrowleft M = 0;$

$M + N_{support}(L/4) = Vu + [2400 + (W_A / L)]\ u(u/2)$

$M = Vu + [2400 + (W_A / L)]\ u^2/2 - N_{support}(L/4)$ ……………………......…......(5.3.1.8)

For L/2 ≤ u < L



Shear force and bending moment calculation:

$+\uparrow\sum Fy = 0;$

$V = Ny3 + N_{support} - [2400 + (W_A / L)]\, u - Ny1$ ……………………..……………...(5.3.1.9)

$+\circlearrowright M = 0;$

$M + N_{support}(L/4) = Vu + [2400 + (W_A / L)]\, u(u/2) + Ny1(L/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2 - N_{support}(L/4) - Ny1(L/2)$ ……………..…......(5.3.1.10)

5.3.1 Results of analysis on Case 2

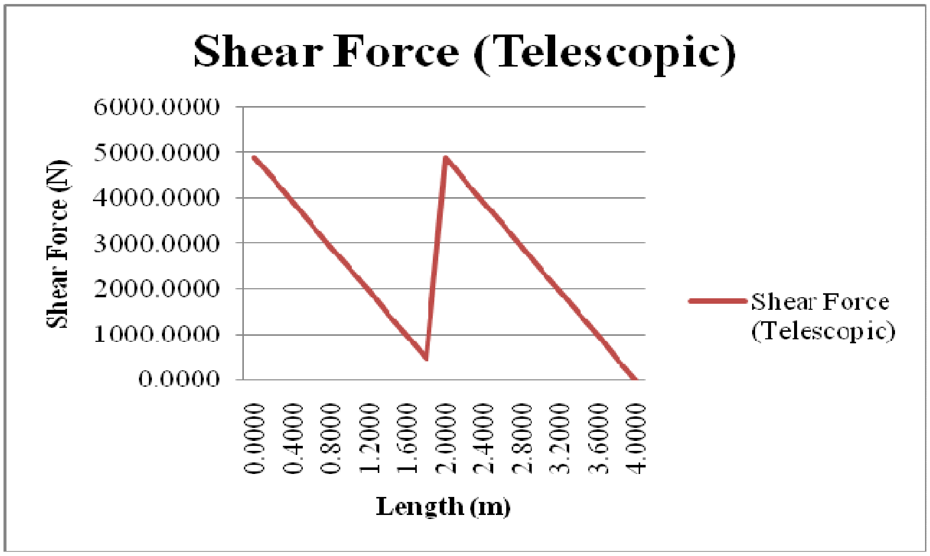


Figure 5.14: Shear force variation of the telescopic walkway when the walkway is half extended

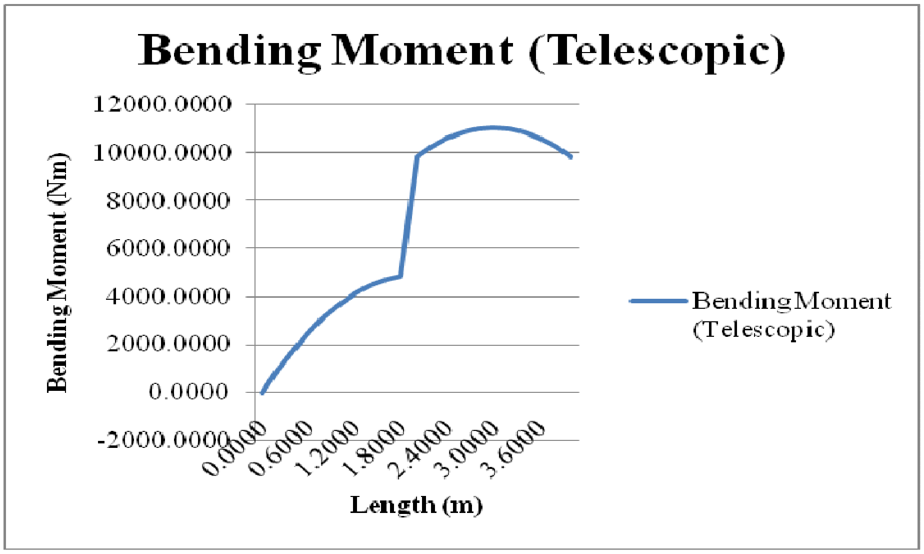


Figure 5.15: Bending moment variation of the telescopic walkway when the walkway is half extended

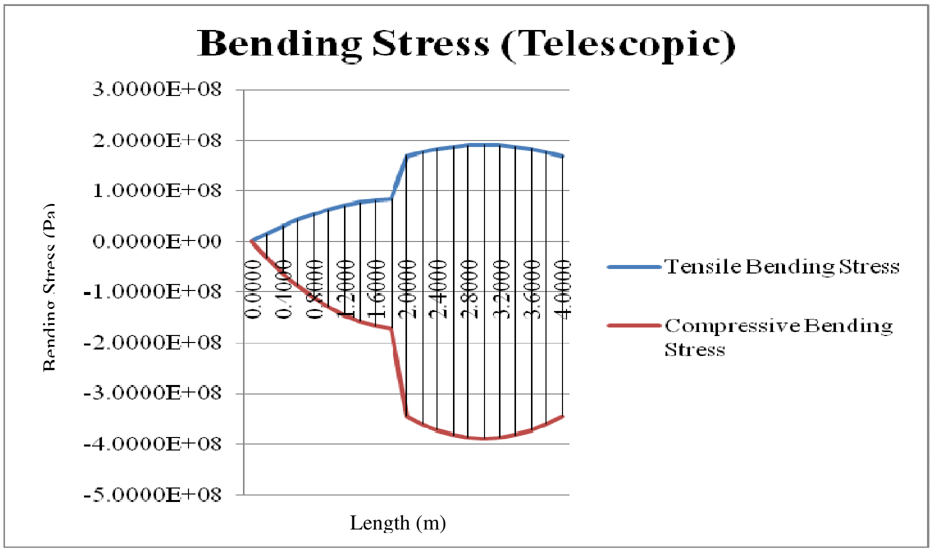


Figure 5.16: Bending stress variation of the telescopic walkway when the walkway is half extended

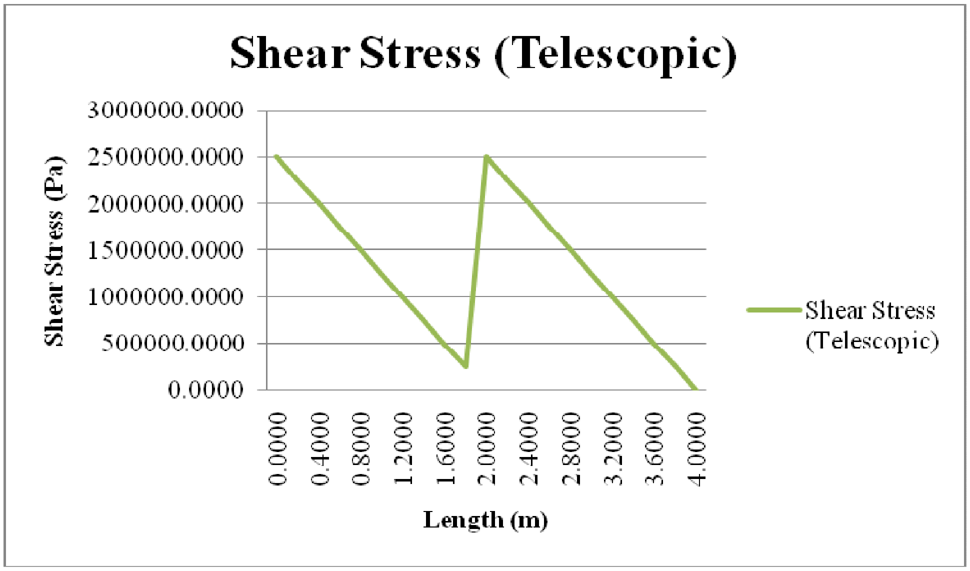


Figure 5.17: Shear stress variation of the telescopic walkway when the walkway is half extended

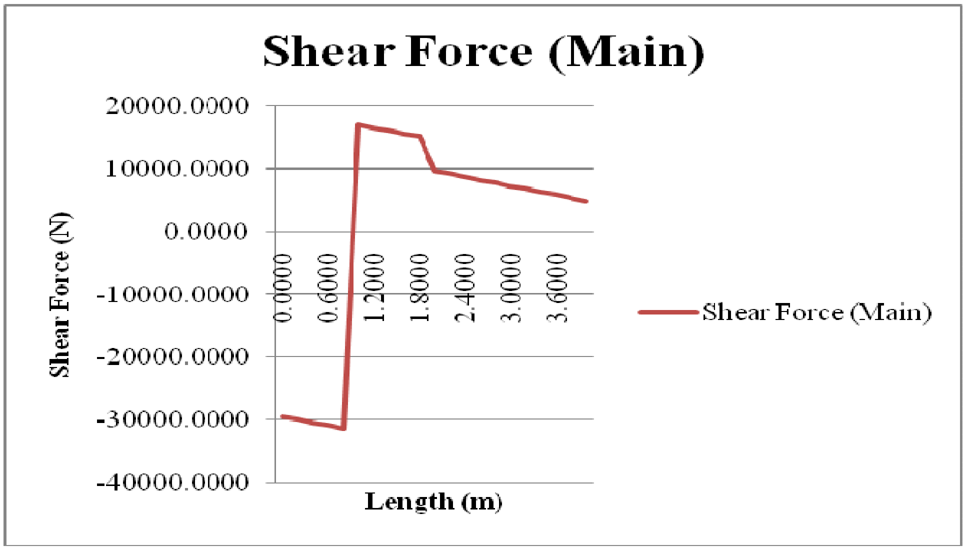


Figure 5.18: Shear force variation of the main walkway when the walkway is half extended

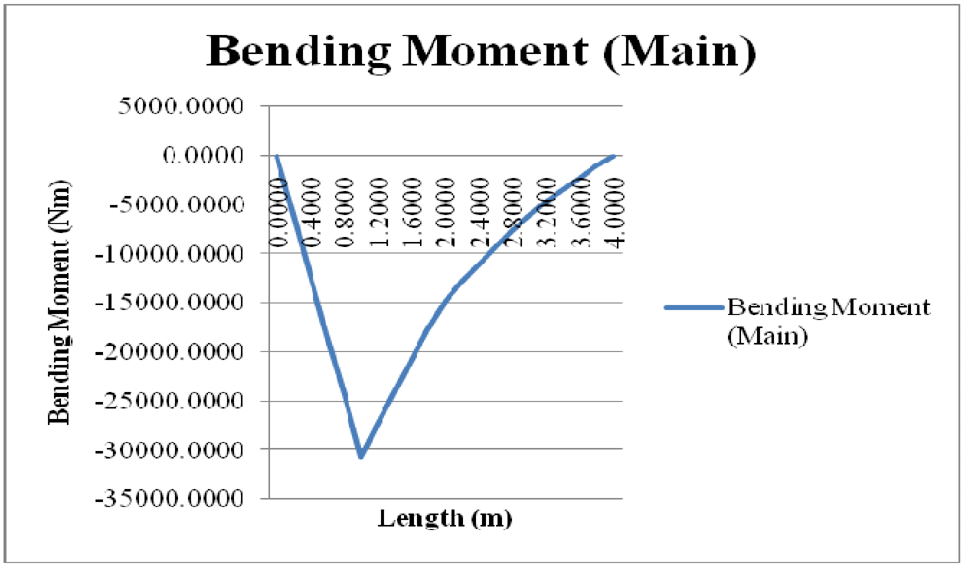


Figure 5.19: Bending moment variation of the main walkway when the walkway is half extended

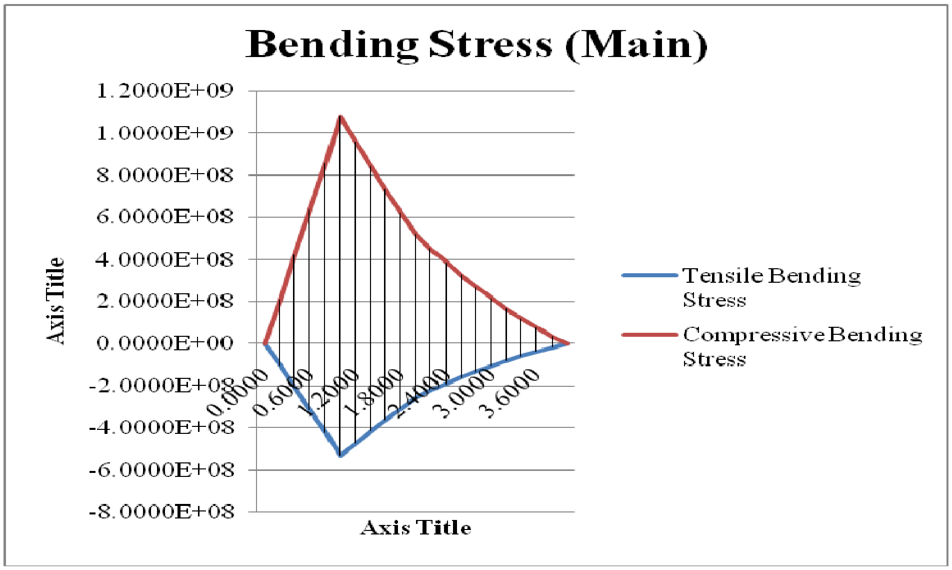


Figure 5.20: Bending stress variation of the main walkway when the walkway is half extended

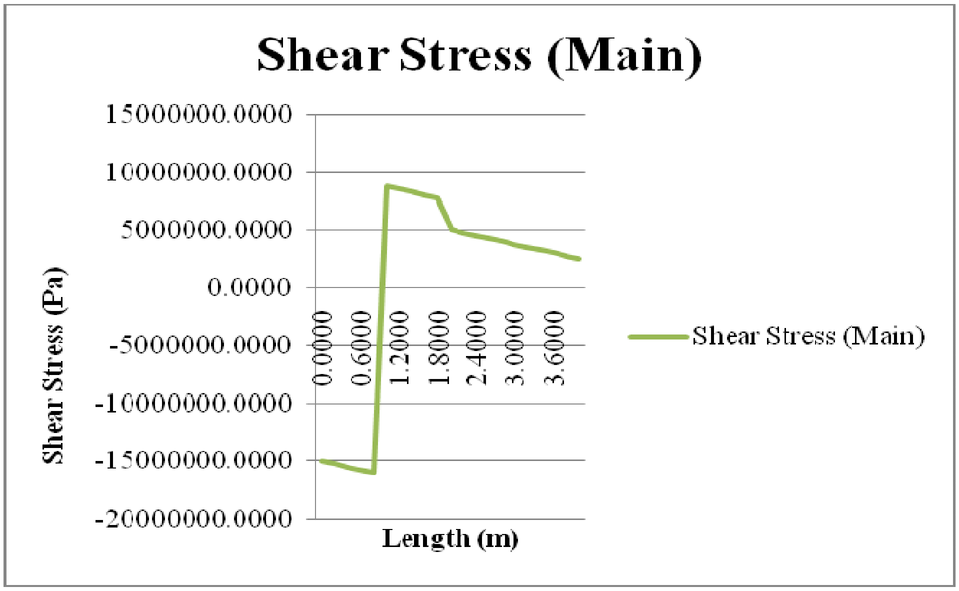


Figure 5.21: Shear stress variation of the main walkway when the walkway is half extended

5.4 CASE 3 - WALKWAY IS THREE QUARTER – EXTENDED

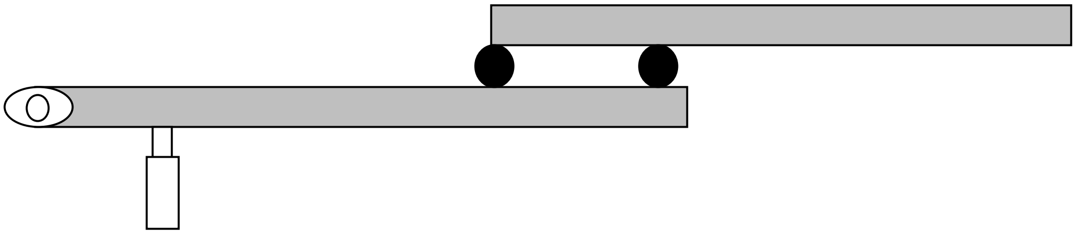


Figure 5.22: Orientation of the walkway when the walkway is three-quarter extended

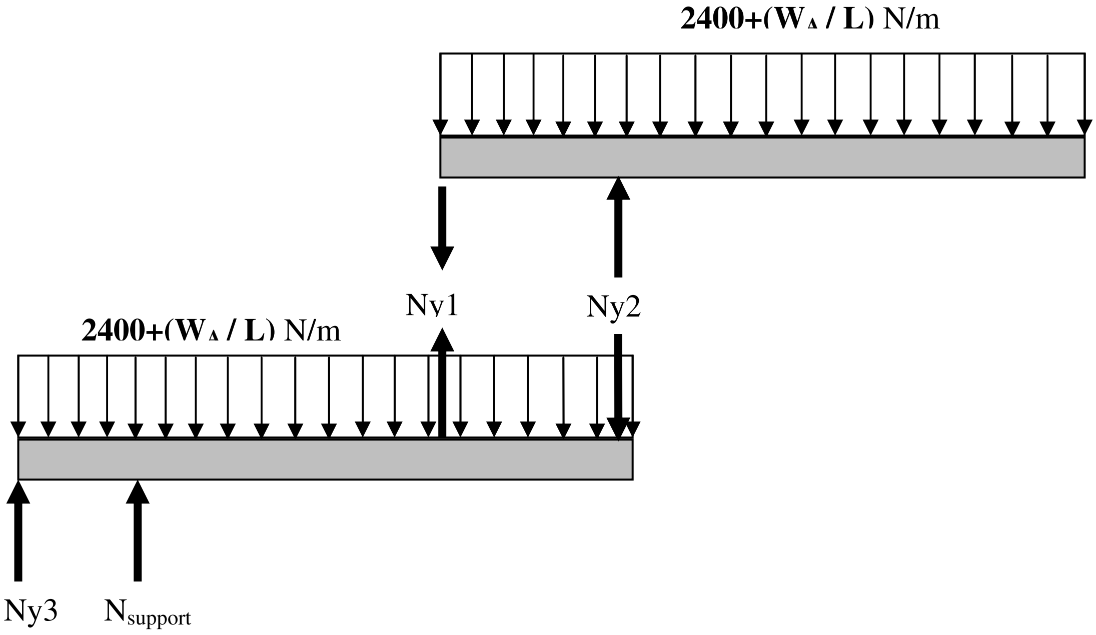


Figure 5.23: Loads acting on the walkway when the walkway is three-quarter extended

Calculation for reaction forces:

For telescopic walkway:

$+\uparrow\sum Fy = 0;$

$Ny2 - Ny1 = [2400 + (W_A / L)] (L)$

$Ny2 = [2400 + (W_A / L)] (L) + Ny1$……………………..……………..………...(5.4.1)

$+\circlearrowleft M = 0;$

$Ny2 (L/4) = [2400 + (W_A / L)] (L) (L/2)$

$Ny2 = 2(L) [2400 + (W_A / L)]$ ……………….…………..……..………..………...(5.4.2)

For Main walkway:

$+\uparrow\sum Fy = 0;$

$N_{support} + Ny1 = [2400 + (W_A / L)] (L) + Ny3 + Ny2$

$Ny3 = N_{support} + Ny1 - [2400 + (W_A / L)] (L) - Ny2$ ………………..……..…….(5.4.3)

$+\circlearrowleft M = 0;$

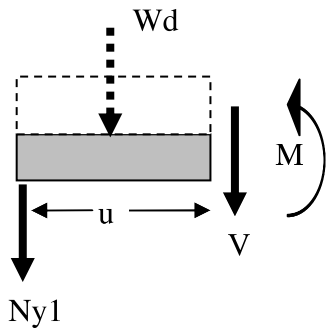
$N_{support}(L/4) + Ny1 (3L/4) = [2400 + (W_A / L)] (L/2) + Ny2(L)$

$N_{support} = 4Ny2 + 2(L) [2400 + (W_A / L)] - 3Ny1$...……..…………………………...(5.4.4)

5.4.1 Calculation for shear force and bending moment

a) Telescopic walkway:

For $0 \leq u < L/4$



Shear force and bending moment calculation:

$+\uparrow\sum Fy = 0;$

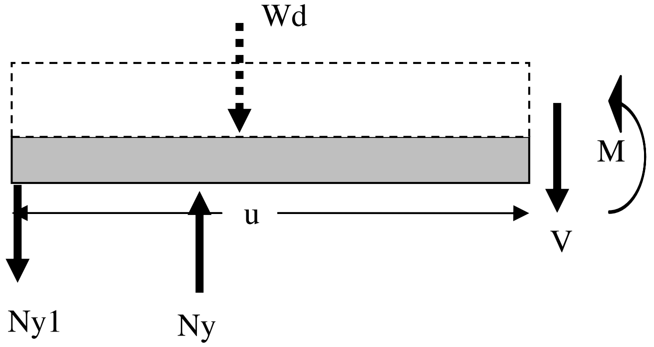
$V = - Ny1 - [2400 + (W_A / L)] u$…………….………...(5.4.1.1)

$+\circlearrowleft M = 0;$

$M = Vu + [2400 + (W_A / L)] u(u/2)$

$M = Vu + [2400 + (W_A / L)] u^2/2$...……..…...……...(5.4.1.2)

For $L/4 \leq u < L$



Shear force and bending moment calculation:

$+\uparrow\sum Fy = 0;$

$V = Ny2 - Ny1 - [2400 + (W_A / L)]\, u$……………………..…………………..…...(5.4.1.3)

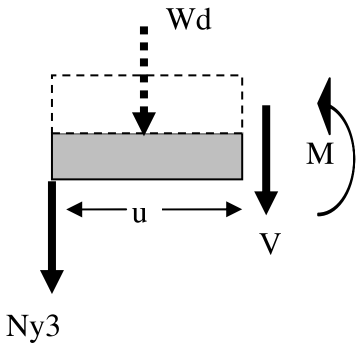
$+\circlearrowright M = 0;$

$M + Ny2\,(L/4) = Vu + [2400 + (W_A / L)]\, u(u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2 - Ny2\,(L/4)$ …………………....……....…...(5.4.1.4)

b) Main walkway

For $0 \leq u < L/4$



Shear force & bending moment calculation:

$+\uparrow\sum Fy = 0;$

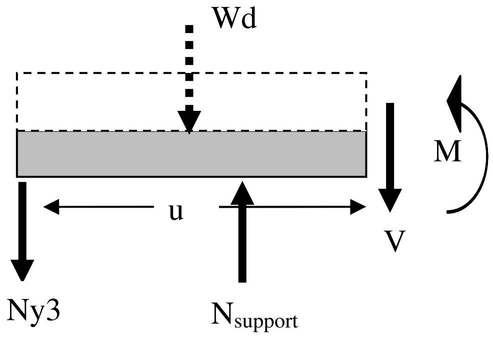
$V = - Ny3 - [2400 + (W_A / L)]\, u$………..…..…...(5.4.1.5)

$+\circlearrowright M = 0;$

$M = Vu + [2400 + (W_A / L)]\, u(u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2$………...…...(5.4.1.6)

For $L/4 \leq u < 3L/4$



Shear force:

$+\uparrow \sum Fy = 0;$

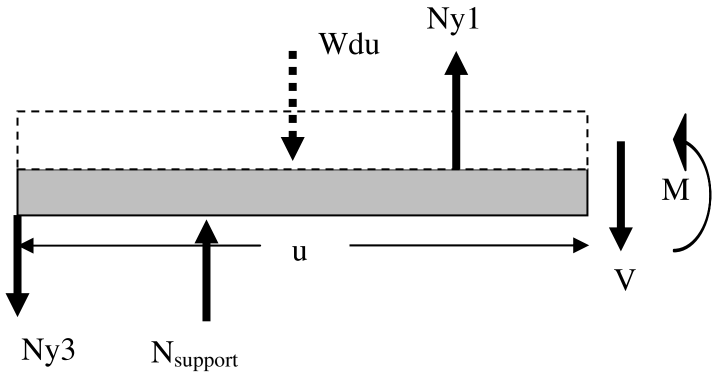
$V = N_{support} - Ny3 - [2400 + (W_A / L)]\, u$……………………...……….................…...(5.4.1.7)

$+ \circlearrowright M = 0;$

$M + N_{support}(L/4) = Vu + [2400 + (W_A / L)]\, u(u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2 - N_{support}(L/4)$ ……………………...……..…....(5.4.1.8)

For $3L/4 \leq u < L$



Shear force & Bending moment:

$+\uparrow \sum Fy = 0;$

$V = N_{support} + Ny1 - Ny3 - [2400 + (W_A / L)]\, u$ …………………….……….…......(5.4.1.9)

$+ \circlearrowright M = 0;$

$M + N_{support}(L/4) + Ny1(3L/4) = Vu + [2400 + (W_A / L)]\, u(u/2)$

$M = Vu + [2400 + (W_A / L)]\, u^2/2 - N_{support}(L/4) - Ny1(3L/4)$ ………………….…...(5.4.1.10)

5.4.2 Results of analysis on Case 3

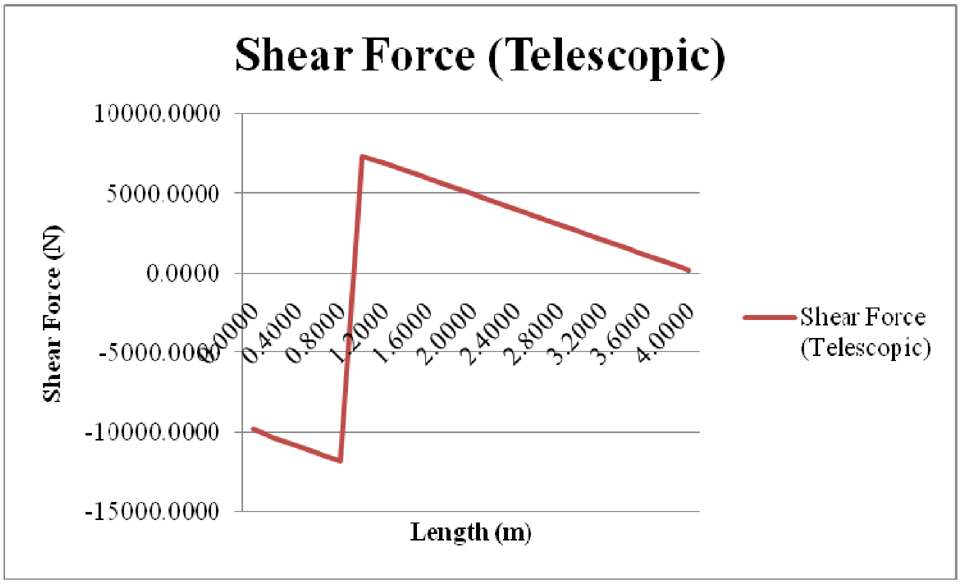


Figure 5.24: Shear force variation of the telescopic walkway when the walkway is three quarter extended

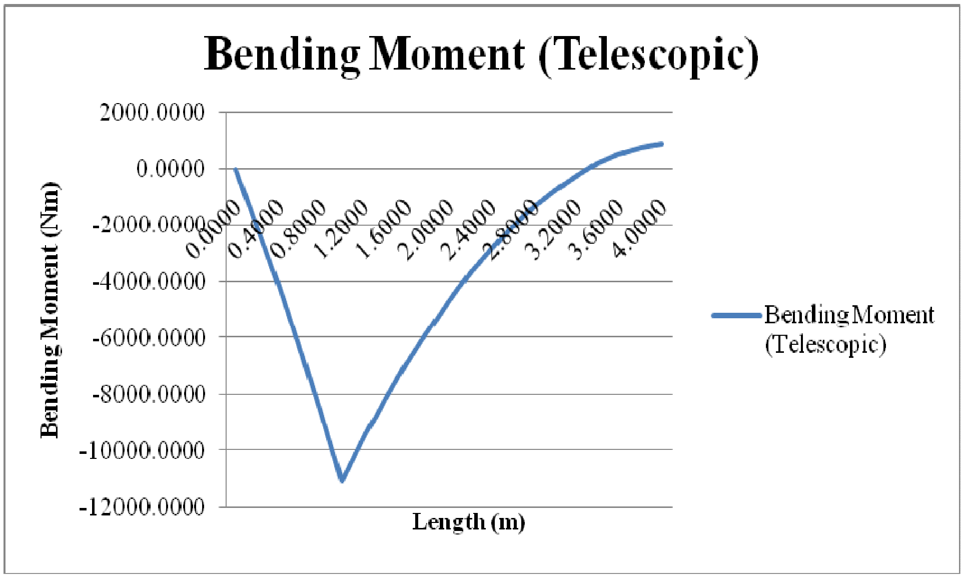


Figure 5.25: Shear force variation of the telescopic walkway when the walkway is three quarter extended

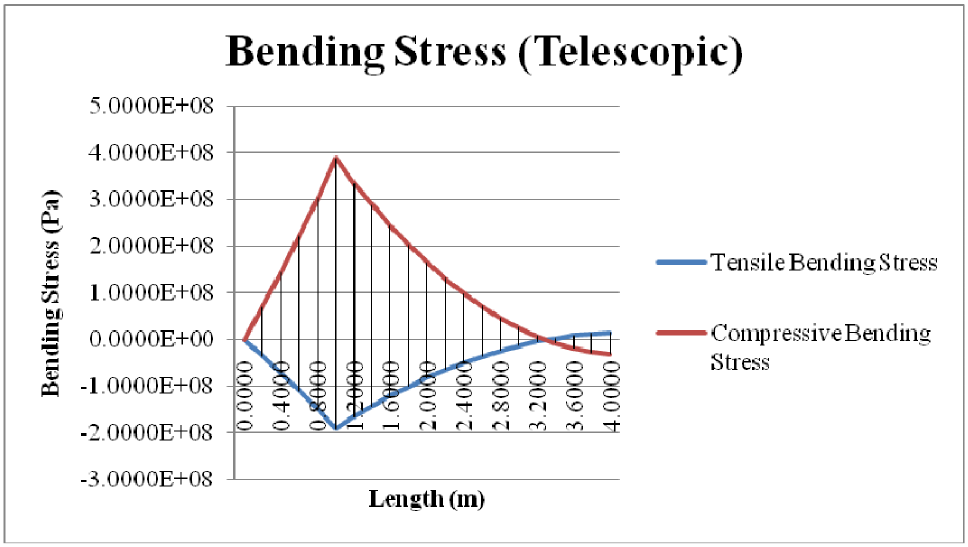


Figure 5.26: Shear force variation of the telescopic walkway when the walkway is three quarter extended

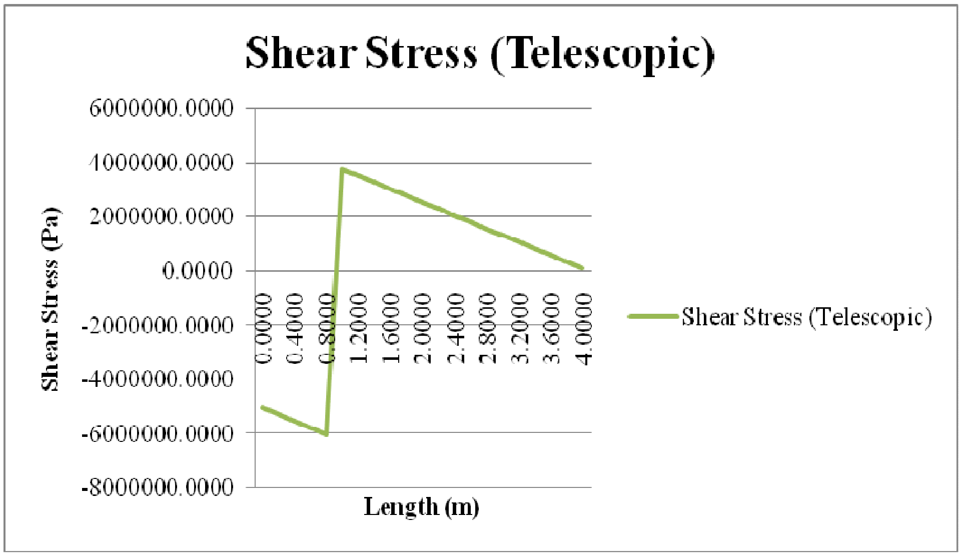


Figure 5.27: Shear force variation of the telescopic walkway when the walkway is three quarter extended

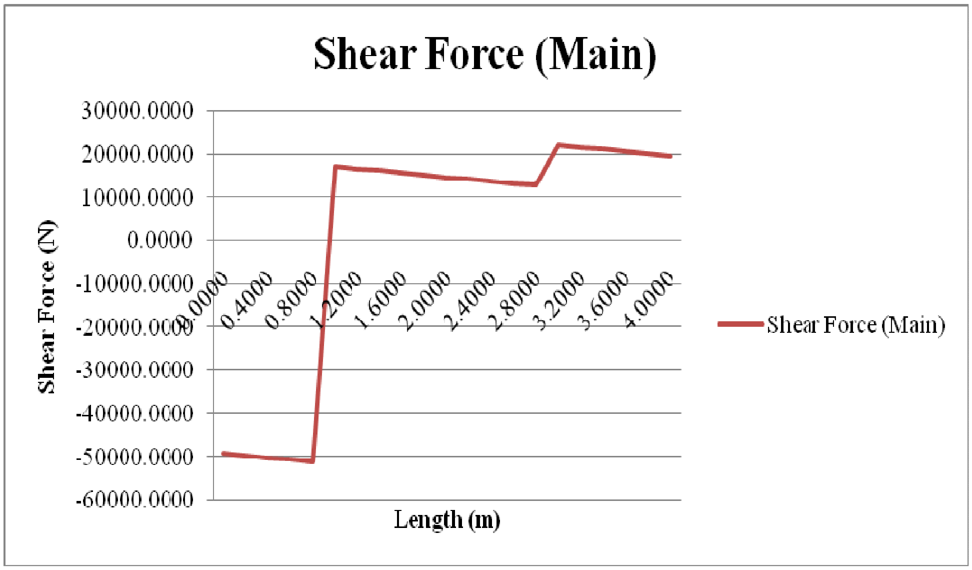


Figure 5.28: Shear force variation of the telescopic walkway when the walkway is three quarter extended

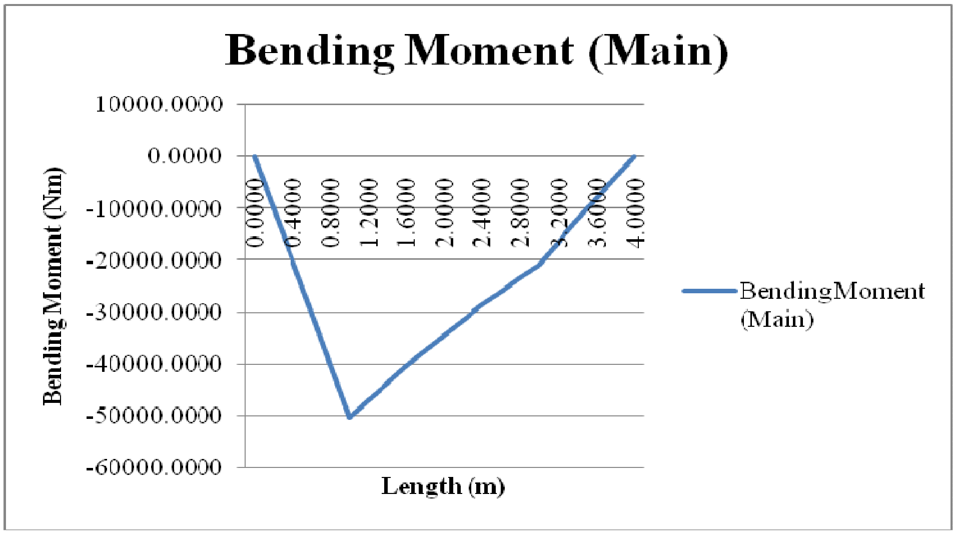


Figure 5.29: Shear force variation of the telescopic walkway when the walkway is three quarter extended

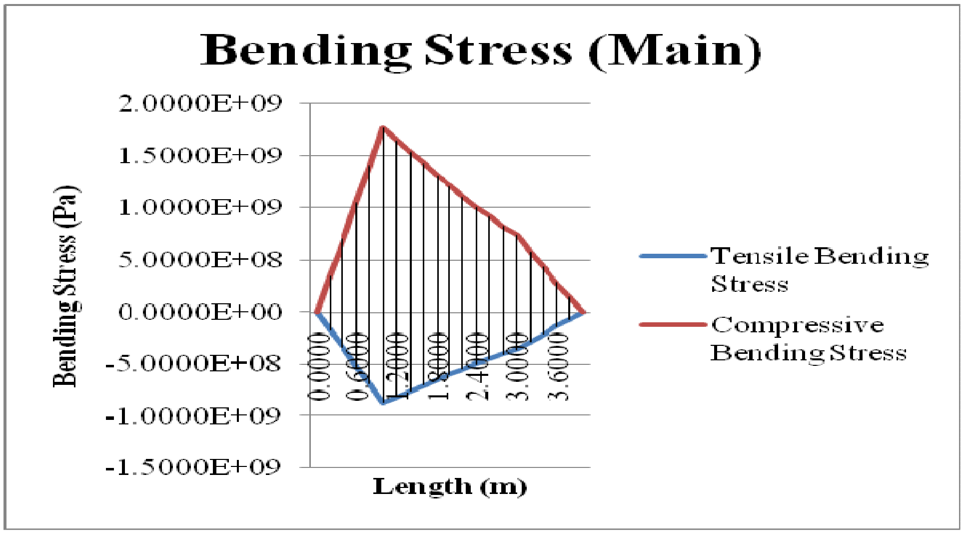


Figure 5.30: Shear force variation of the telescopic walkway when the walkway is three quarter extended

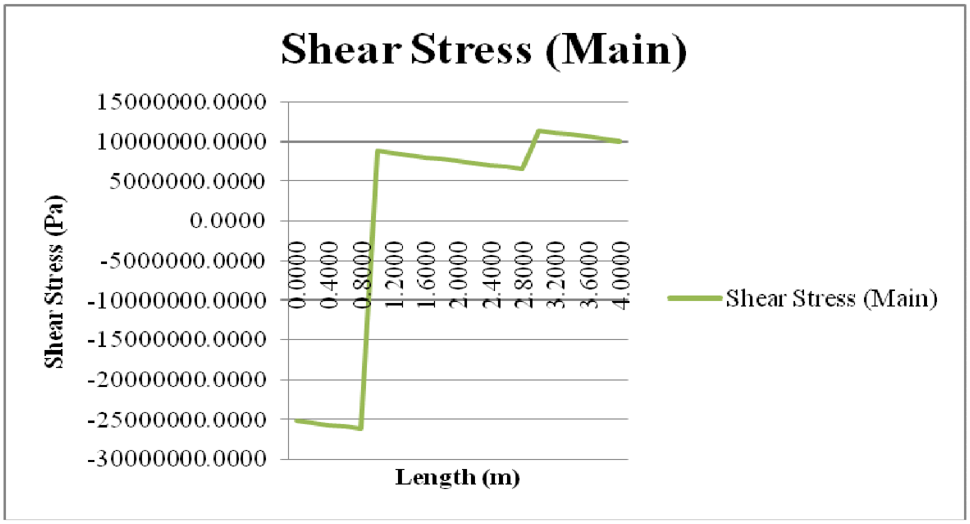


Figure 5.31: Shear force variation of the telescopic walkway when the walkway is three quarter extended

Upon obtaining the expressions for the shear force and bending moments, the shear stress and bending stresses are calculated using the following equations.

Shear stress (τ) = Shear force / cross sectional area of the beam

= V / A……………………...…………………………...…....…...(5.4.2.1)

The standard structural beams recommended for the construction of gangway's walkway are the T-beam and the I-beam. Typical rectangular beams are also applicable.

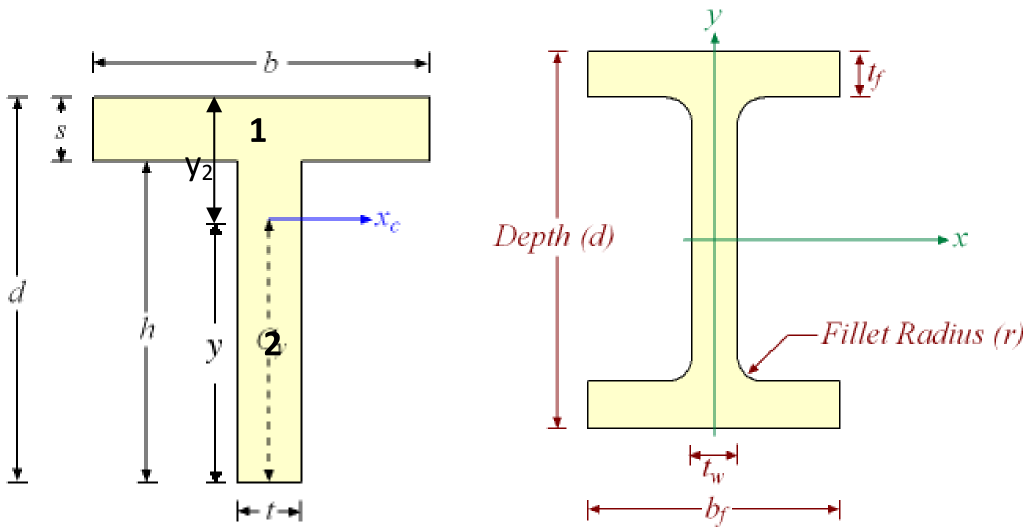


Figure 5.32: Standard structural beams used for gangway construction

The parameters of the beams that are considered in the design of the gangway are shown in the Figure 5.32 above i.e. breadth (b) or (b_f), depth (d), height (h), center of gravity (y) and (y_2), thickness (t) or (t_w), peripheral thickness (s) or (t_f).

Considering the T-beam as an example, divide the beam into two sections, 1 and 2, and sum the moments of these areas about the top edge. We then have

$Ay_2 = sb(s/2) + t(d-s)((d-s)/2 + s)$ ……………...……………………...…...…...(5.4.2.2)

From this equation, y_2 can be obtained. Then

$y = d - y_2$…………………....…………………………...…...………………….(5.4.2.3)

Now, we can calculate the second moment of area of each rectangular area about its own centroidal axis. For the top rectangle

$I_1 = sb^3/12$……………………....…………………………..................…......…...(5.4.2.4)

$I_2 = th^3/12$……………………………....…………………………...…...…...(5.4.2.5)

We now employ the parallel-axis theorem to obtain the second moment of area of the composite figure about its own centroidal axis.

$I_x = I_{cg} + Ad^2$……………………...………………………………………...…....…...(5.4.2.6)

where I_{cg} is the second moment of area about its own centroidal axis and I_x is the second moment o area about any parallel axis and a distance d removed. For the top rectangle, the distance is

$d_1 = y_2 - s/2$………………………..…....…………………………...…....…...(5.4.2.7)

and for the bottom rectangle,

$d_2 = y - h/2$……………………………………....…………………………......(5.4.2.8)

Using the parallel axis theorem twice, we now find that

$I = [(I_1 + A_1d_1^2) + (I_2 + A_2d_2^2)$ …………………....…………………………........(5.4.2.9)

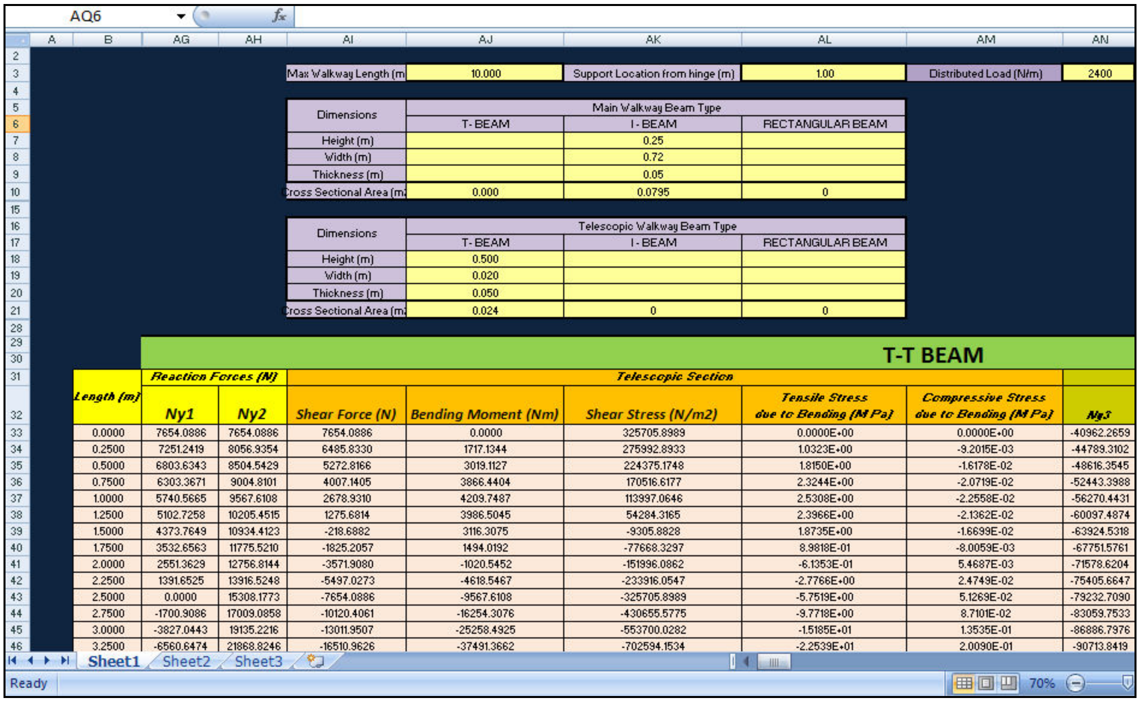
Therefore, the maximum tensile stress due to bending is found to be

$\sigma = My_2 / I$……………………………....…………………………...…..…...(5.4.2.10)

Maximum compressive stress due to bending is found to be

$\sigma = - My / I$…………………....……………………………………....…....…...(5.4.2.11)

Using the derived equations, a Microsoft Excel worksheet is developed to study the shear and bending stresses acting on combination of standard structural beams which make up the telescopic walkway. Figure 5.33 below shows the worksheet mentioned above. Refer to the APPENDIX C for the full version of the worksheet.



Max Walkway Length (m	10.000	Support Location from hinge (m)	1.00	Distributed Load (N/m)	2400

Dimensions	Main Walkway Beam Type		
	T- BEAM	I - BEAM	RECTANGULAR BEAM
Height (m)		0.25	
Width (m)		0.72	
Thickness (m)		0.05	
Cross Sectional Area (m	0.000	0.0795	0

Dimensions	Telescopic Walkway Beam Type		
	T- BEAM	I - BEAM	RECTANGULAR BEAM
Height (m)	0.500		
Width (m)	0.020		
Thickness (m)	0.050		
Cross Sectional Area (m	0.024	0	0

T-T BEAM

Length (m)	Reaction Forces (N)		Telescopic Section					
	Ny1	Ny2	Shear Force (N)	Bending Moment (Nm)	Shear Stress (N/m2)	Tensile Stress due to Bending (M Pa)	Compressive Stress due to Bending (M Pa)	Ny3
0.0000	7654.0886	7654.0886	7654.0886	0.0000	325705.8989	0.0000E+00	0.0000E+00	-40962.2659
0.2500	7251.2419	8056.9354	6485.8330	1717.1344	275992.8933	1.0323E+00	-9.2015E-03	-44789.3102
0.5000	6803.6343	8504.5429	5272.8166	3019.1127	224375.1748	1.8150E+00	-1.6178E-02	-48616.3545
0.7500	6303.3671	9004.8101	4007.1405	3866.4404	170516.6177	2.3244E+00	-2.0719E-02	-52443.3988
1.0000	5740.5665	9567.6108	2678.9310	4209.7487	113997.0646	2.5308E+00	-2.2558E-02	-56270.4431
1.2500	5102.7258	10205.4515	1275.6814	3986.5045	54284.3165	2.3966E+00	-2.1362E-02	-60097.4874
1.5000	4373.7649	10934.4123	-218.6882	3116.3075	-9305.8828	1.8735E+00	-1.6699E-02	-63924.5318
1.7500	3532.6563	11775.5210	-1825.2057	1494.0192	-77668.3297	8.9818E-01	-8.0059E-03	-67751.5761
2.0000	2551.3629	12756.8144	-3571.9080	-1020.5452	-151996.0862	-6.1353E-01	5.4687E-03	-71578.6204
2.2500	1391.6525	13916.5248	-5497.0273	-4618.5467	-233916.0547	-2.7766E+00	2.4749E-02	-75405.6647
2.5000	0.0000	15308.1773	-7654.0886	-9567.6108	-325705.8989	-5.7519E+00	5.1269E-02	-79232.7090
2.7500	-1700.9086	17009.0858	-10120.4061	-16254.3076	-430655.5775	-9.7718E+00	8.7101E-02	-83059.7533
3.0000	-3827.0443	19135.2216	-13011.9507	-25258.4925	-553700.0282	-1.5185E+01	1.3535E-01	-86886.7976
3.2500	-6560.6474	21868.8246	-16510.9626	-37491.3662	-702594.1534	-2.2539E+01	2.0090E-01	-90713.8419

Figure 5.33: Microsoft Excel worksheet for studying the standard structural beams combination

The parameters of the standard beams are inserted into the appropriate tabs of the worksheet. The worksheet then calculates the shear and bending stress of the beams. Various combinations of the beams can be analyzed using the worksheet to obtain an optimal beam combination depending on the stakeholders' requirements.

In order to validate the worksheet, the parameters of a T-beam are inserted into the worksheet and the same parameters are analyzed using the ANSYS software. The result of the stress analysis using ANSYS is shown in the figures below:

The beam parameters that are used for the Excel worksheet validation is based on the T-beam and with assumption that both beams used for the telescopic walkway construction to be square T-beams.

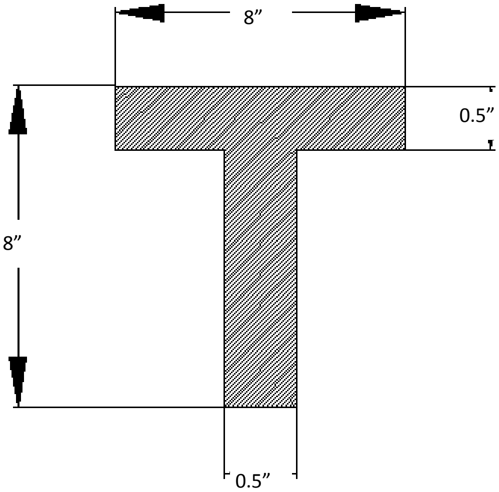
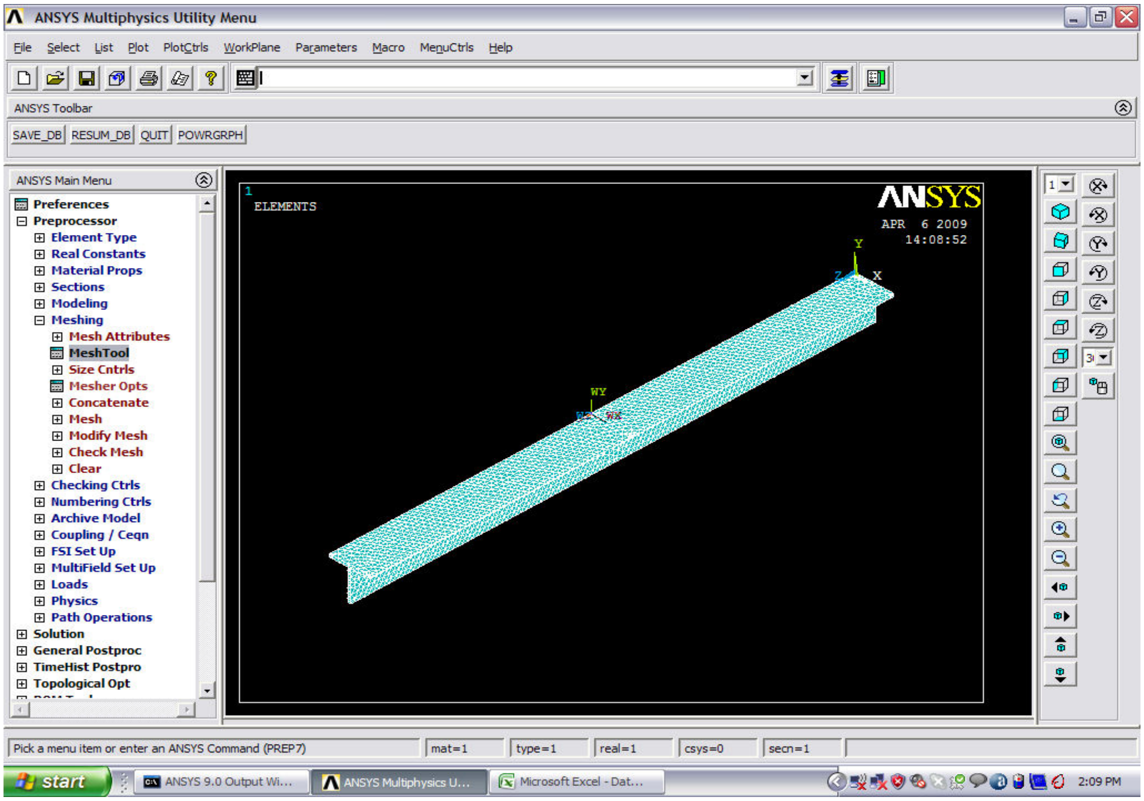


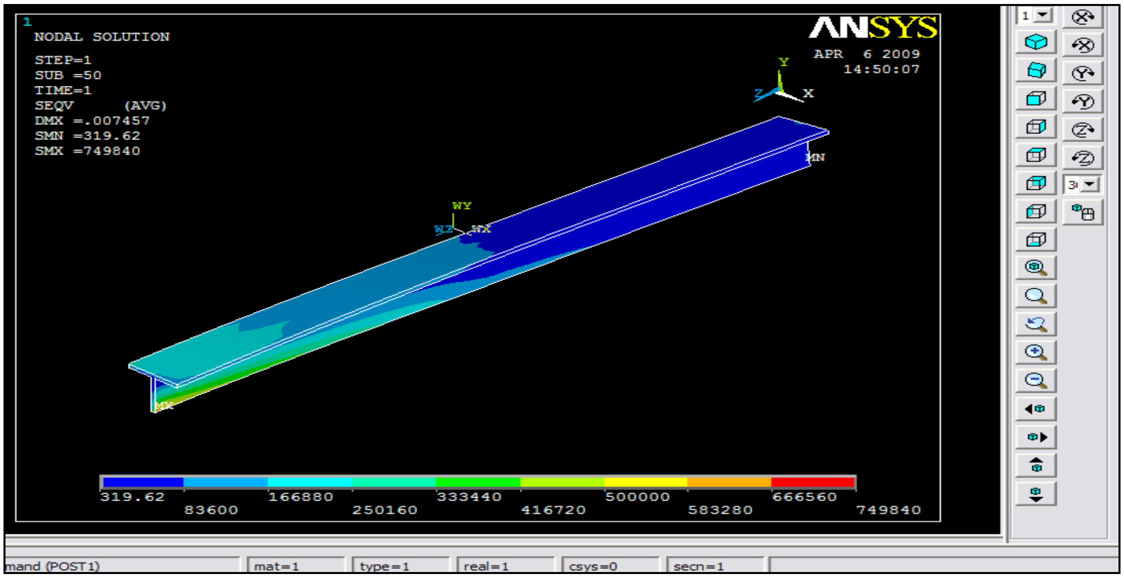
Figure 5.34: Parameters used for the validation of the Excel worksheet



Pick a menu item or enter an ANSYS Command (PREP7)

mat=1 type=1 real=1 csys=0 secn=1

Figure 5.35: Meshing diagram of the T-beam



```
1
NODAL SOLUTION
STEP=1
SUB =50
TIME=1
SEQV      (AVG)
DMX =.007457
SMN =319.62
SMX =749840
```

Figure 5.36: Stress variation on the T-beam

The maximum stress acting on the beam obtained from the Excel worksheet matches with the stress value obtained from the analysis using ANSYS which is 50 GPa. Therefore, the Excel worksheet is validated and can be applied to analyze the beam combinations.

The length of the beams that is used to be inserted in the stress analysis is obtained from the study of the operating envelop of the gangways in the South East Asian tidal conditions. Refer to APPENDIX B for the report on the tidal conditions of the seas in South East Asia. The tidal conditions in South East Asia with respect to the design of vessel size are summarized in the following table and illustrated in Figure 37.

Table 5.1: Vessel depth, draft and deck elevation in South East Asia seas

Design vessel size (DWT)	Vessel Depth (m)	Vessel Draft (m)		Deck Elevation (m)	
		Light Draft	Loaded draft	Ballast condition at HWL	Full Load at HWL
32 000	18.00	6.50	11.50	13.50	6.50
21 000	13.00	5.50	9.50	9.50	3.50
13 000	10.00	5.00	8.00	7.00	2.00
3 000	6.50	3.50	5.00	5.00	1.50

The highest deck elevation is 14.5 m from the datum point whereas the lowest deck elevation is 0.7 m from the datum. An allowance of 3.0 meters must be included in the drift, draft and sway of the ship in accordance with ASCE 7. This is to account for the variance is tidal conditions of the sea.

Using the Pythagoras theorem for different deck elevations, the required length of the walkway is obtained. The standard range of length of the walkway for South East Asian region is 8.50 m to 9.0 m. These values can be used in the Excel worksheet for the stress analysis of the structural beam combinations and design for the gangway construction. Refer to the Excel worksheet for the details of application of the length obtained here.

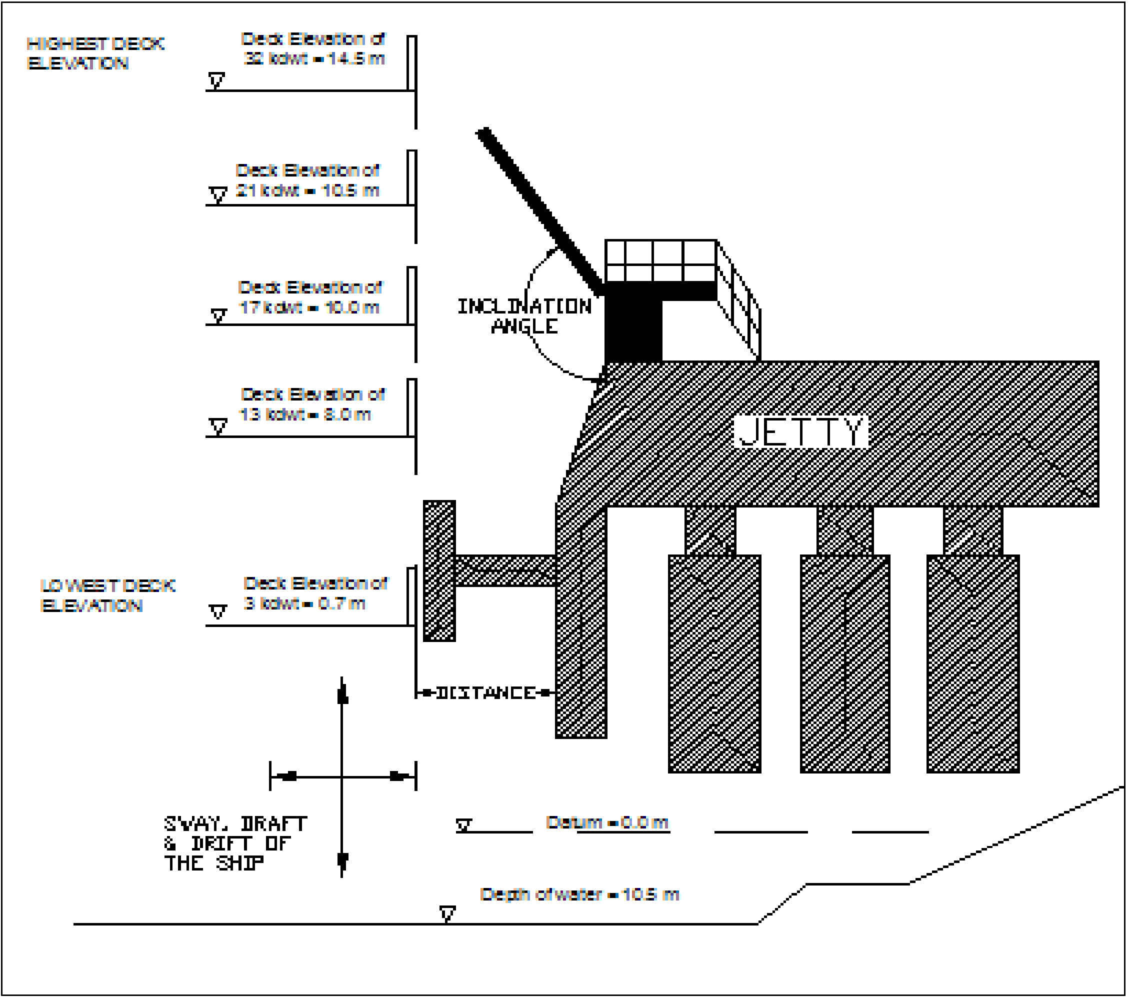


Figure 5.37: Illustration of deck elevations with respect to design vessel sizes

CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The study has revealed that the construction of the walkway beams of a jetty gangway is constantly subjected to varying stresses while walkway is under operation. Based on the study of the static loading analysis, it can be concluded that maximum stress occurs due to the bending of the walkways upon subjected to the operational loads discussed. The stress data obtained using the conventional Microsoft Excel agrees positively with stress analysis using the ANSYS software that the beam is under highest stress condition when the walkway extension reaches its maximum. Therefore, the Microsoft Excel worksheet that has been developed in this study will be essential in determining the design parameters of the beams that are to be used in the walkway designing. Besides that, the study also has found that a standardized range of length of beams can be used for the South East Asian region based on the study that has been done on the tidal and wind conditions. The data, thus, concludes that a length range of 8.5 to 9.0 meters is most suitable for this region. In conclusion, these parameters and the Microsoft Excel worksheet have achieved the objective of this study which is to obtain insightful design parameters for the walkway designing and to be an essential study for future design development efforts in this field.

6.2 RECOMMENDATION

6.2.1 Dynamic Loading Analysis

In order to further improve the project outcome, dynamic loading analysis must be studied. The dynamic load analysis may include the vibrational forces acting on the beams due to the life loads applied. The analysis may be explained using mode shapes of the vibration of the beams and also simulation of the dynamics.

6.2.2 More standard structural beams combination analysis

The analysis of the walkway designing in this project covers only the T-beams for both the main walkway and the telescopic walkway. Study on the combinations of T-beams, I-beams, etc. would enhance the details of design parameters.

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[6] http://www.sciencedirect.com/gangway

[7] http://www.patentstorm.us/patents/611769.html

[8] http://www.mantleramp.com/technical.html

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[10] http://www.australasianjettys.com.au/boatlifts.html

[11] http://www.scopus.com/gangway

APPENDIX A

TYPES OF GANGWAYS

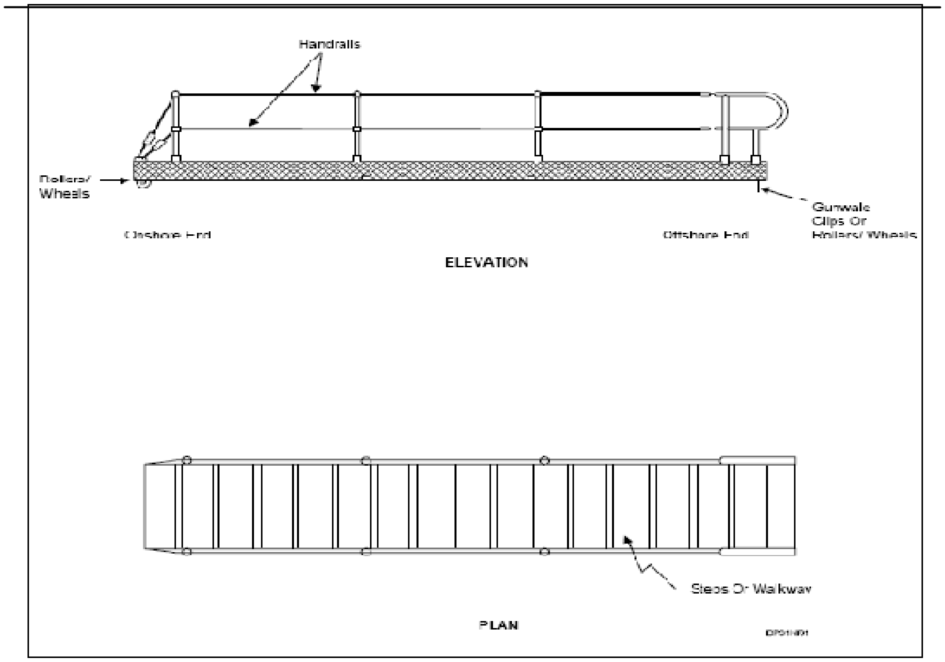


Figure A-1: Conventional gangway (mobile system)

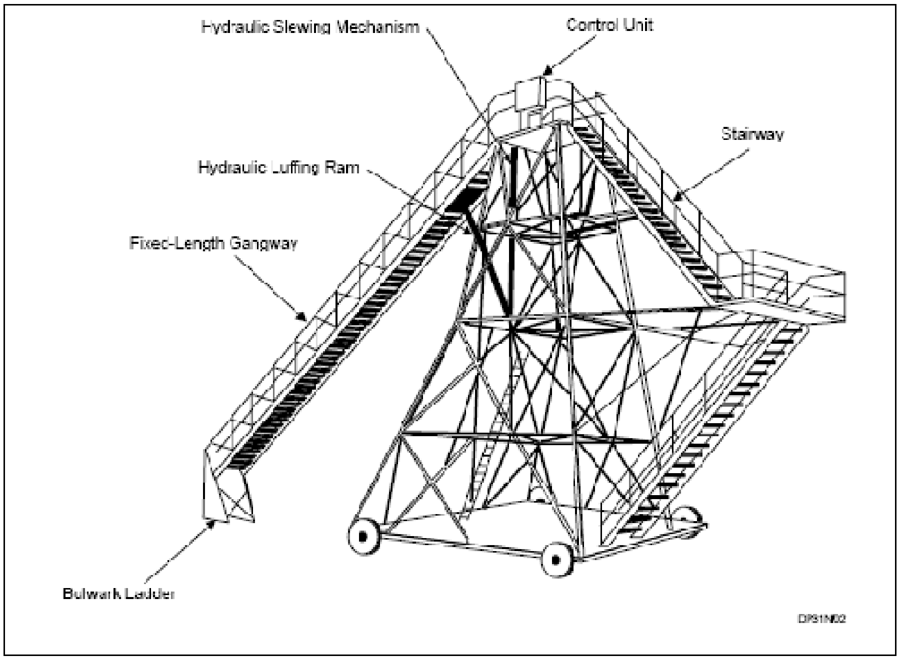


Figure A-2: Platform mounted (mobile system)

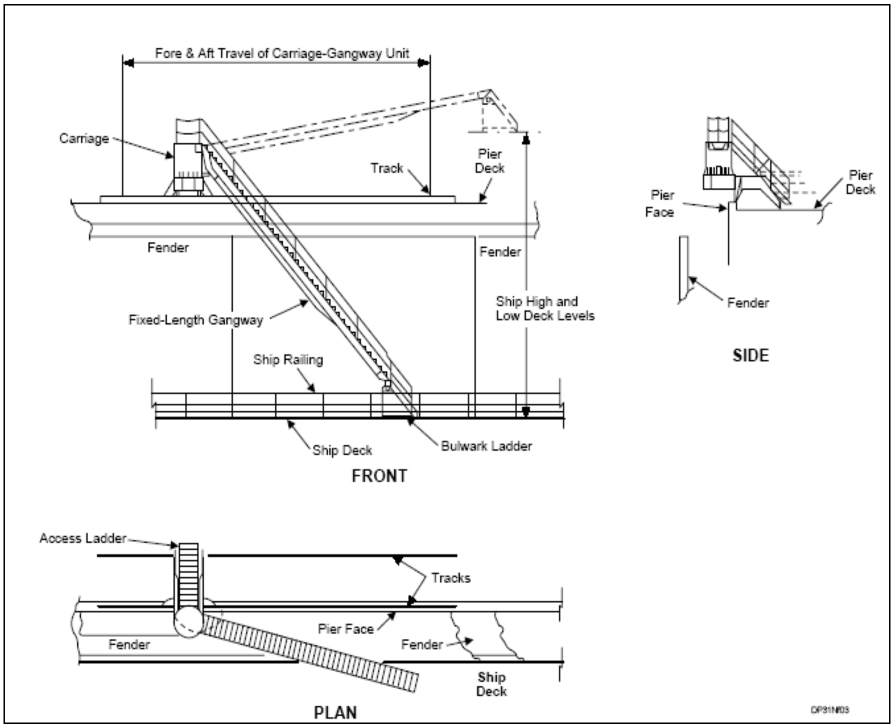


Figure A-3: Carriage mounted with track parallel to pier face (mobile system)

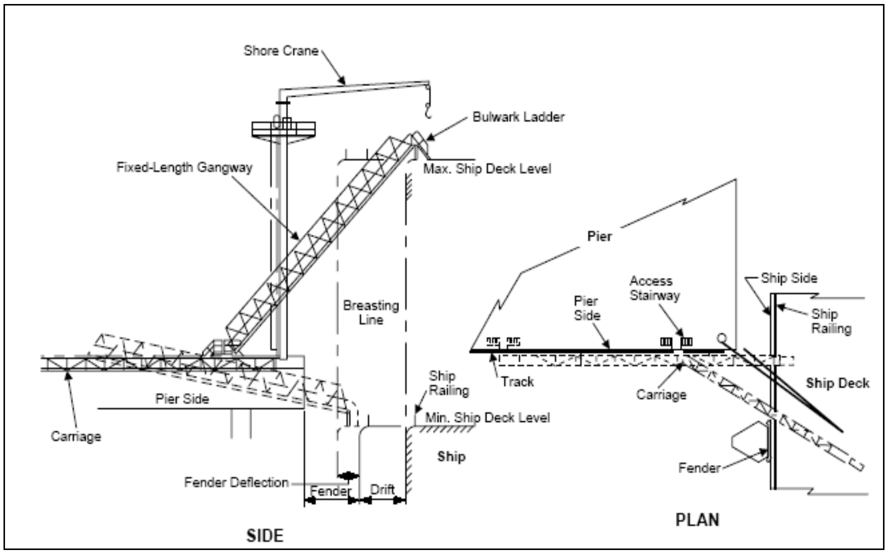


Figure A-4: Carriage mounted with track parallel to pier face, attached to side of pier (mobile system)

Figure A-5: Shore accommodation ladder (stationary system)

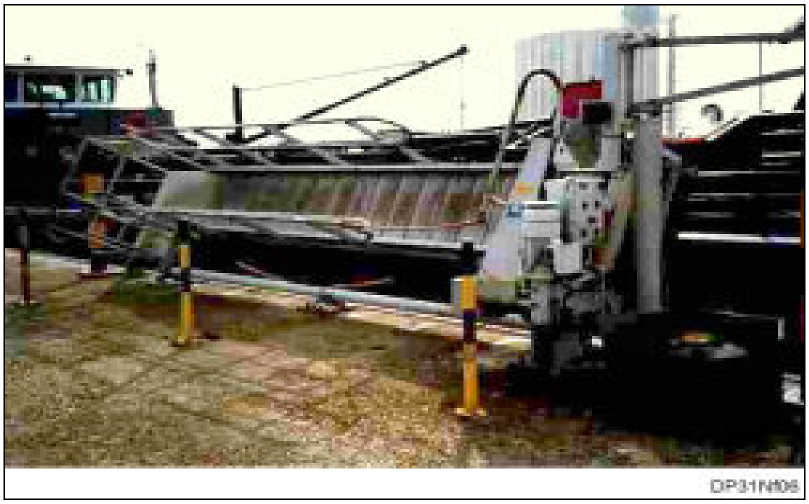


Figure A-6: Front mounted shore access ladder (stationary system)

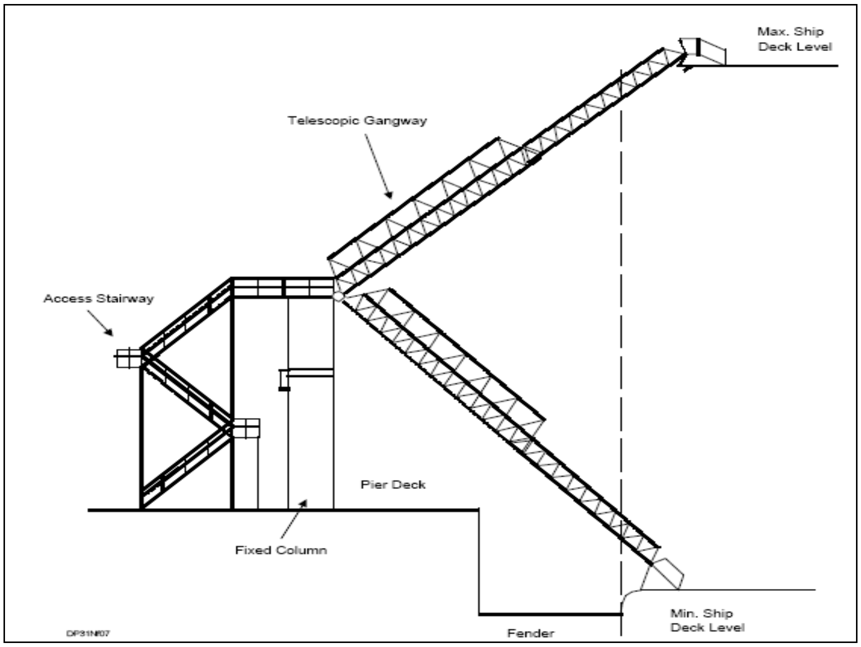


Figure A-7: Column mounted (stationary system)

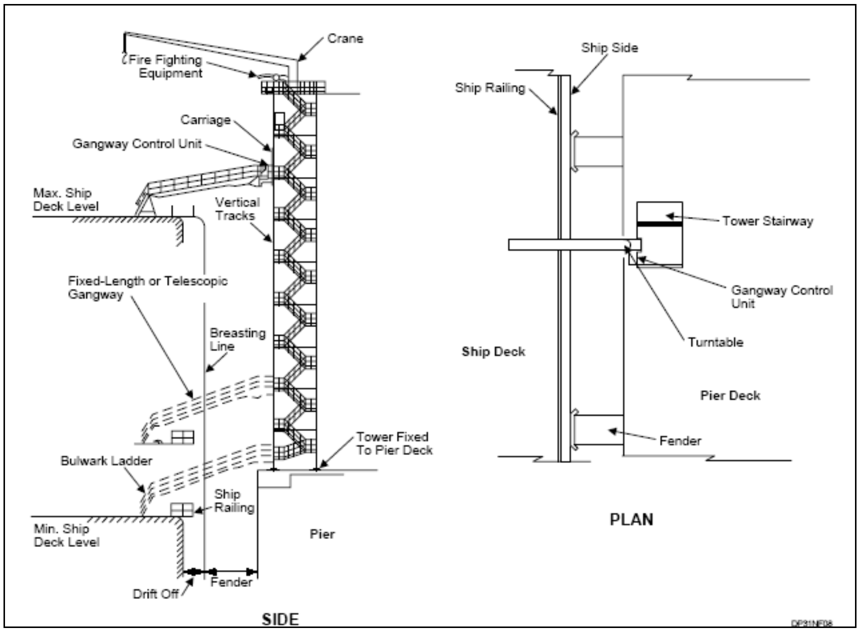


Figure A-8: Tower mounted (stationary system)

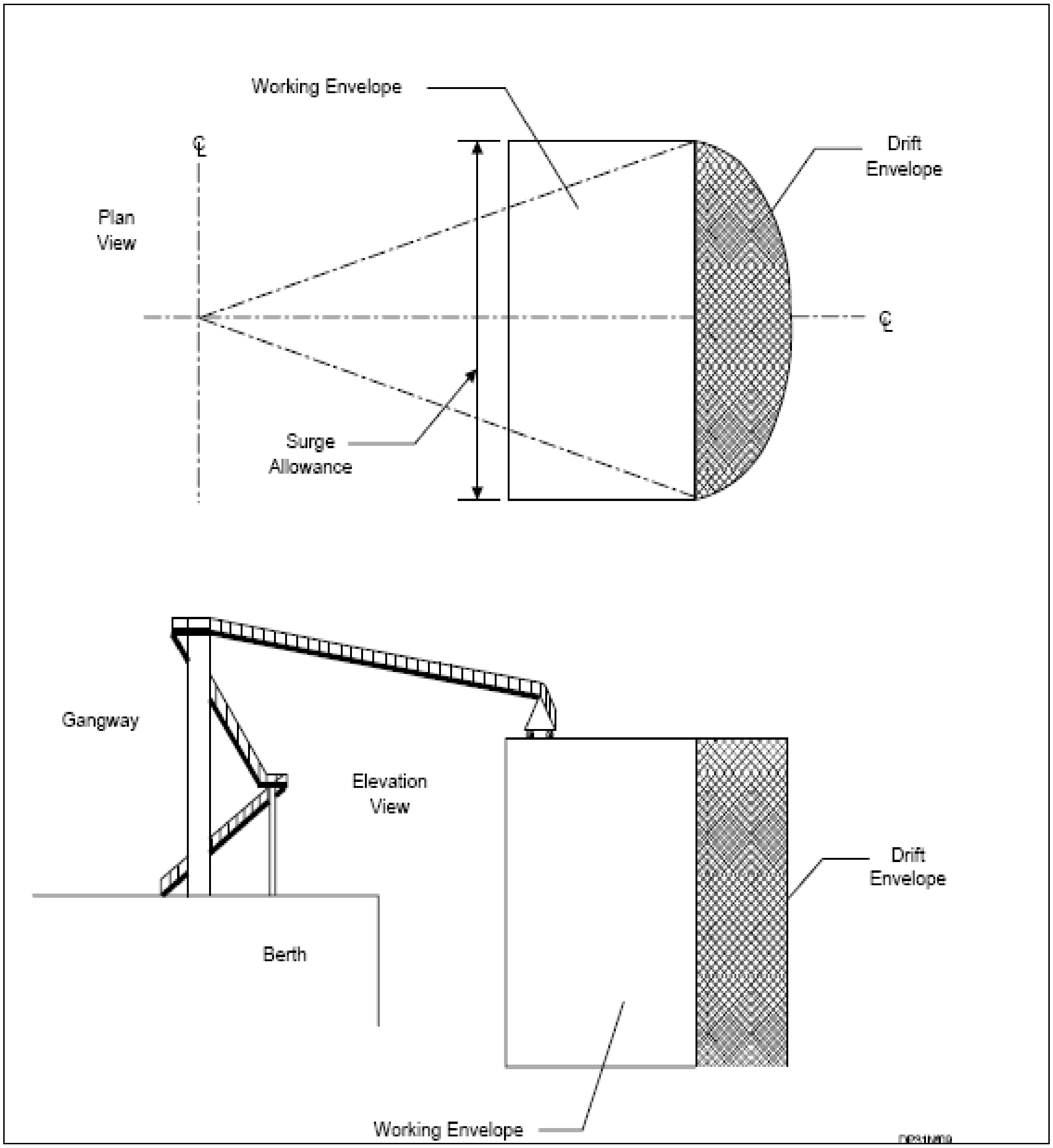


Figure A-9: Basic gangway operating envelope

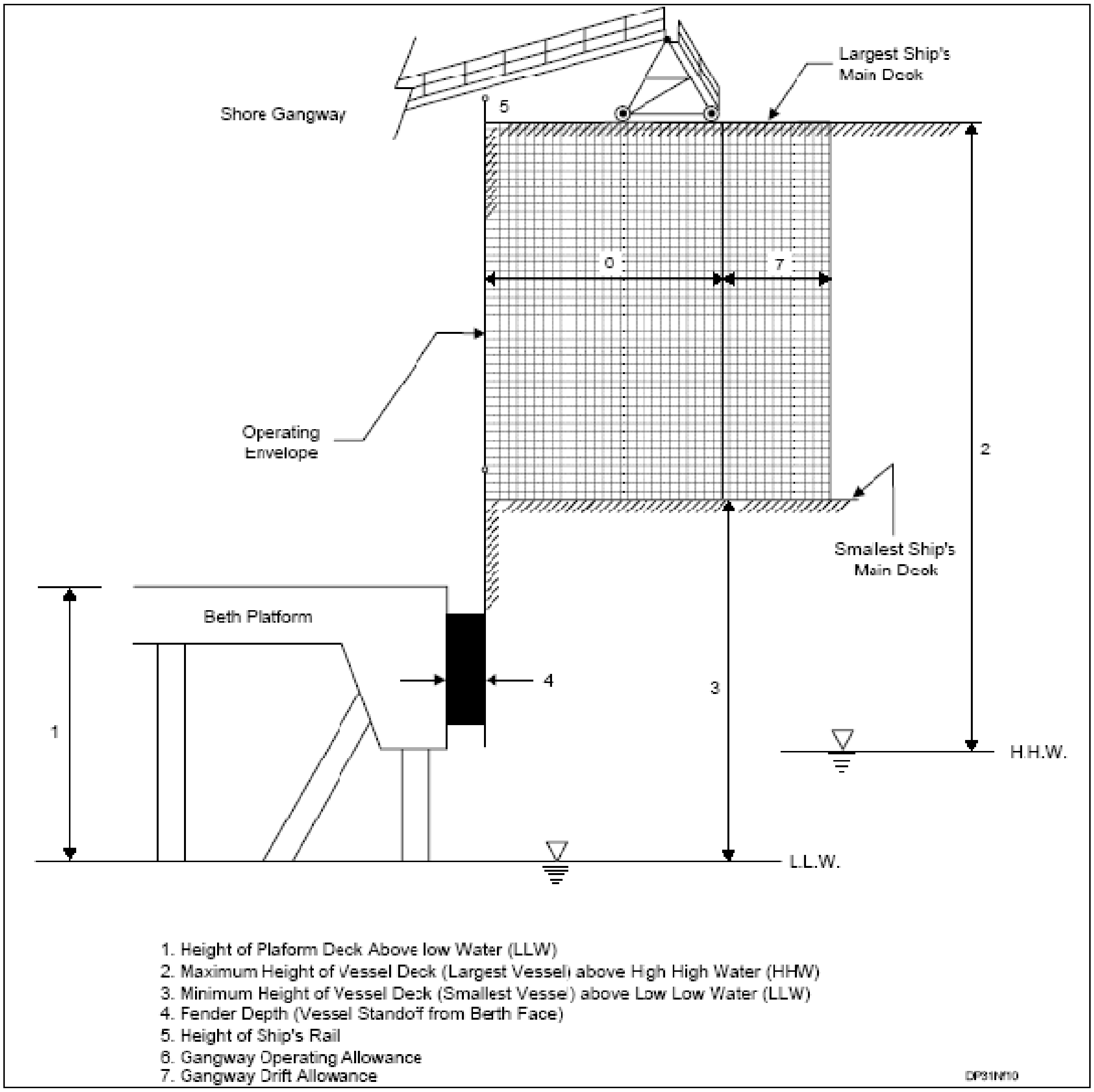


Figure A-10: Design operating envelope data

APPENDIX B

DATA OF TIDAL CONDITIONS IN SOUTH EAST ASIA

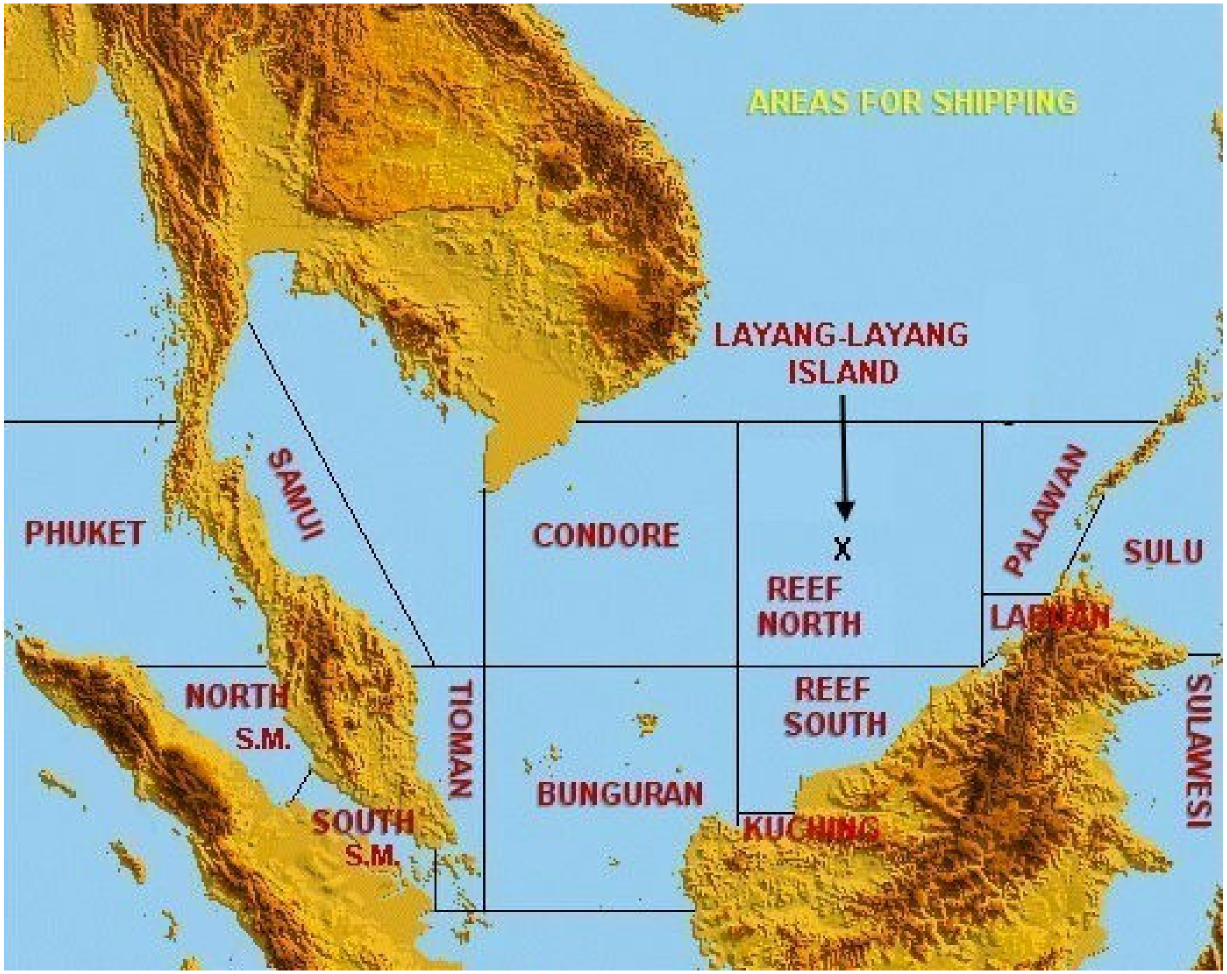


Figure B-1: Seas considered for the tidal condition analysis

Table B-1: High and low tide levels for Cendering

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW	0430	0.37	0456	0.42	0515	0.50	0530	0.60	0530	0.73	0142	0.74	0122	0.68
HIGH	1348	1.94	1445	1.89	1547	1.85	1645	1.81	1730	1.76	0650	0.91	0718	1.11
LOW											0950	0.86	1142	0.91
HIGH											1810	1.69	1837	1.60

Table B-2: High and low tide levels for Geting

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW	0410	0.18	0400	0.20	0350	0.22	0300	0.25	0150	0.24	0142	0.22	0130	0.19
HIGH	1330	0.96	1430	0.93	1530	0.90	1645	0.88	1740	0.86	1818	0.83	0800	0.57
LOW													1230	0.47
HIGH													1856	0.80

Table B-3: High and low tide levels for Johor Bahru

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0232	2.81	0303	2.66	0341	2.48								
LOW	0903	0.46	0951	0.67	1108	0.84	0006	1.80	0135	1.68	0239	1.44	0322	1.14
HIGH	1619	2.49	1719	2.32	1847	2.22	0440	2.29	0618	2.16	0839	2.26	0942	2.49
LOW	2126	1.62	2230	1.77			1239	0.90	1352	0.86	1452	0.76	1537	0.66
HIGH							2030	2.28	2118	2.42	2152	2.55	2221	2.68

Table B-4: High and low tide levels for Kota Kinabalu

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW					0006	0.30	0106	0.33	0200	0.36	0230	0.40	0313	0.46
HIGH	1339	1.40	1418	1.34	1506	1.28	1630	1.20	1100	1.02	1000	1.04	0950	1.10
LOW	2254	0.26							1300	1.01	1440	0.88	1530	0.72
HIGH									1830	1.15	1954	1.14	2108	1.15

Table B-5: High and low tide levels for Kudat

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW							0106	0.42	0200	0.43	0239	0.46	0310	0.50
HIGH	1336	1.71	1406	1.62	1500	1.53	1630	1.43	1830	1.40	1000	1.21	0947	1.28
LOW	2230	0.36	2354	0.40							1418	1.04	1513	0.86
HIGH											1950	1.39	2100	1.40

Table B-6: High and low tide levels for Kukup

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0221	3.22	0300	3.02	0354	2.77	0530	2.57						
LOW	0927	0.87	1011	1.08	1130	1.24	1324	1.21	0030	1.52	0218	1.33	0327	1.07
HIGH	1507	2.08	1552	1.84	1754	1.70	1954	1.85	0719	2.61	0823	2.76	0911	2.90
LOW	2046	0.98	2117	1.19	2213	1.42			1435	1.07	1519	0.92	1555	0.80
HIGH									2044	2.13	2116	2.46	2144	2.77

Table B-7: High and low tide levels for Labuan

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW					0000	0.38	0106	0.41	0210	0.43	0250	0.46	0330	0.50
HIGH	1356	1.61	1439	1.54	1530	1.45	1650	1.37	1050	1.19	1018	1.21	1015	1.27
LOW	2250	0.33							1350	1.15	1500	0.99	1545	0.80
HIGH									1830	1.32	2010	1.30	2122	1.31

Table B-8: High and low tide levels for Lahad Datu

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH									0300	1.21	0347	1.42	0424	1.65
LOW	0230	0.50	0254	0.64	0330	0.80	0500	0.98	0821	0.93	0937	0.78	1025	0.62
HIGH	0914	1.82	1000	1.66	1118	1.51	1342	1.50	1503	1.61	1557	1.73	1638	1.83
LOW	1530	0.86	1621	1.01	1900	1.09	2110	0.99	2142	0.87	2214	0.73	2239	0.60
HIGH	2043	1.36	2110	1.25	2150	1.13								

Table B-9: High and low tide levels for Langkawi

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0315	1.94	0354	1.73	0515	1.55								
LOW	0856	0.86	0924	1.08	1030	1.32	0130	1.14	0303	0.96	0347	0.76	0421	0.56
HIGH	1530	2.22	1605	2.01	1720	1.82	0845	1.61	0946	1.86	1015	2.12	1046	2.39
LOW	2145	0.90	2252	1.08			1345	1.38	1518	1.20	1605	0.97	1646	0.74
HIGH							1956	1.82	2120	2.02	2204	2.24	2244	2.44

Table B-10: High and low tide levels for Lumut

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH									0008	1.56	0120	1.72	0210	1.89
LOW	0143	0.52	0221	0.68	0318	0.83	0457	0.89	0630	0.82	0730	0.66	0819	0.50
HIGH	0804	1.83	0857	1.73	1022	1.68	1213	1.75	1320	1.93	1408	2.12	1445	2.31
LOW	1356	0.90	1452	1.06	1640	1.15	1839	1.08	1945	0.92	2030	0.75	2105	0.57
HIGH	1948	1.86	2042	1.66	2213	1.53								

Table B-11: High and low tide levels for Miri

	Thursday 16 Apr		**Friday 17 Apr**		**Saturday 18 Apr**		**Sunday 19 Apr**		**Monday 20 Apr**		**Tuesday 21 Apr**		**Wednesday 22 Apr**	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW			0000	0.31	0110	0.34	0200	0.37	0230	0.41	0306	0.48	0330	0.57
HIGH	1330	1.54	1415	1.47	1500	1.39	1600	1.30	1200	1.15	1115	1.11	1042	1.11
LOW									1330	1.14	1500	1.00	1554	0.82
HIGH									1800	1.22	2000	1.17	2140	1.14

Table B-12: High and low tide levels for Pelabuhan Kelang

	Thursday 16 Apr		**Friday 17 Apr**		**Saturday 18 Apr**		**Sunday 19 Apr**		**Monday 20 Apr**		**Tuesday 21 Apr**		**Wednesday 22 Apr**	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH							0000	2.68	0150	2.79	0252	3.06	0340	3.38
LOW	0309	0.91	0339	1.25	0423	1.60	0622	1.80	0807	1.62	0914	1.29	1004	0.93
HIGH	0913	3.43	0952	3.16	1100	2.92	1302	2.91	1422	3.18	1520	3.53	1606	3.87
LOW	1515	1.21	1559	1.53	1730	1.81	1947	1.74	2103	1.46	2159	1.14	2245	0.80
HIGH	2125	3.27	2215	2.92										

Table B-13: High and low tide levels for Pulau Lakei

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH											0057	3.00	0200	3.30
LOW	0154	0.68	0238	0.89	0336	1.10	0446	1.26	0602	1.33	0709	1.30	0805	1.22
HIGH	0903	3.76	1001	3.64	1109	3.59	1216	3.64	1314	3.74	1357	3.86	1432	3.97
LOW	1444	2.13	1552	2.27	1721	2.26	1839	2.09	1939	1.81	2019	1.48	2052	1.12
HIGH	1944	3.16	2038	2.95	2156	2.80	2337	2.81						

Table B-14: High and low tide levels for Pulau Pinang

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0423	1.50	0518	1.35										
LOW	1000	0.80	1020	1.00	0010	0.87	0250	0.90	0421	0.76	0500	0.59	0534	0.43
HIGH	1617	1.75	1654	1.58	0730	1.26	1030	1.39	1100	1.58	1121	1.77	1147	1.94
LOW	2308	0.73			1130	1.19	1600	1.20	1657	1.03	1734	0.85	1809	0.66
HIGH					1830	1.43	2100	1.45	2212	1.59	2258	1.76	2334	1.91

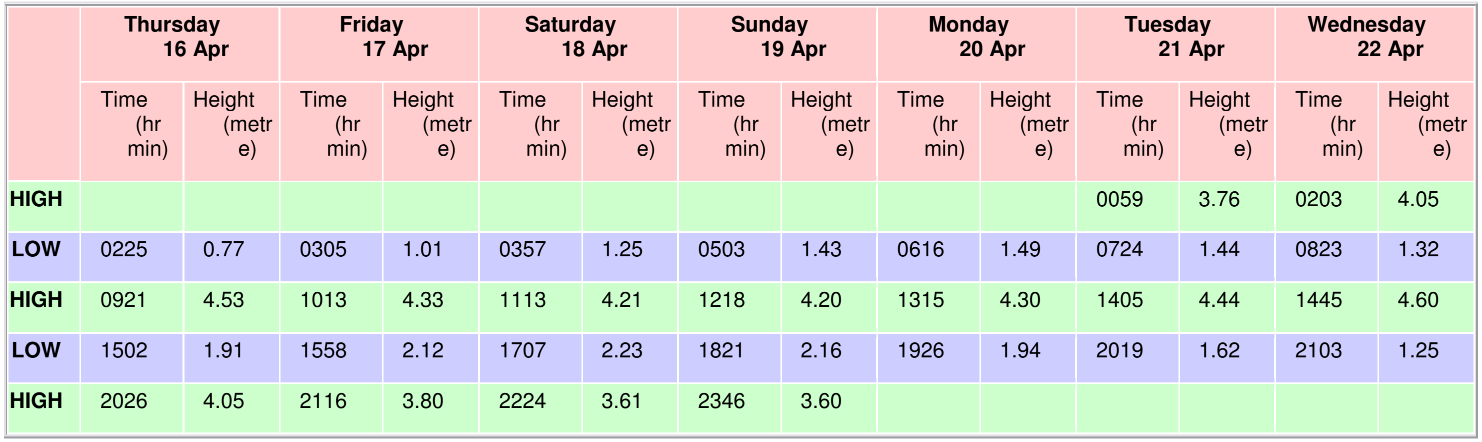
Table B-15: High and low tide levels for Pulau Tioman

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0023	1.64	0056	1.54	0150	1.45								
LOW	0656	0.47	0735	0.59	0830	0.72	0020	1.29	0108	1.17	0130	1.04	0158	0.91
HIGH	1450	2.42	1541	2.34	1642	2.27	0330	1.37	0530	1.42	0654	1.60	0751	1.83
LOW	2130	1.39	2300	1.37			0942	0.85	1103	0.93	1230	0.95	1330	0.91
HIGH							1742	2.23	1835	2.20	1917	2.18	1954	2.13

Table B-16: High and low tide levels for Sandakan

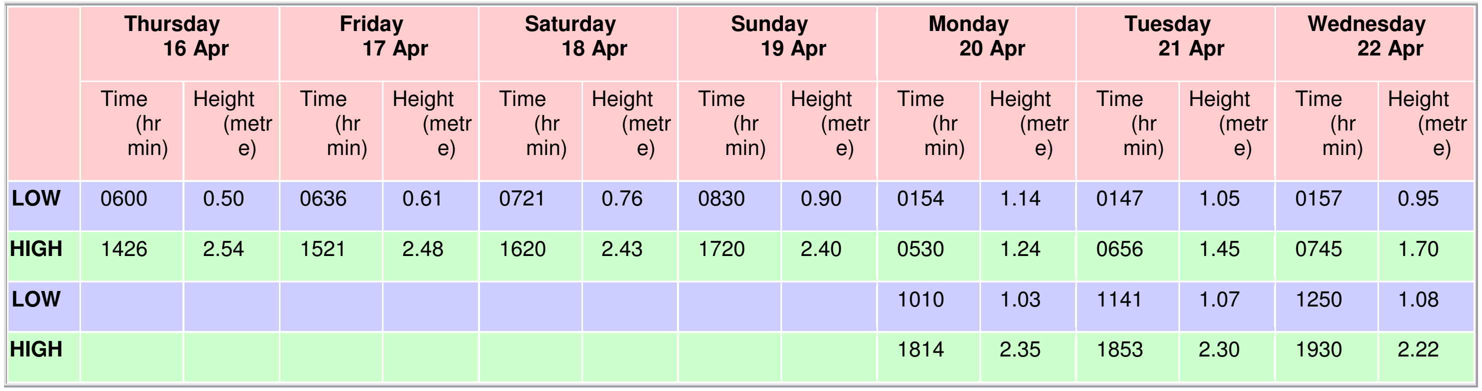
	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0330	1.02	1500	1.93	1606	1.78								
LOW	0550	0.99	2306	0.69			0130	0.67	0230	0.61	0302	0.56	0330	0.55
HIGH	1419	2.08					1747	1.69	1045	1.42	1013	1.49	1008	1.59
LOW	2130	0.60							1418	1.29	1503	1.07	1541	0.84
HIGH									1922	1.70	2045	1.74	2146	1.78

Table B-17: High and low tide levels for Sejingkat



	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH											0059	3.76	0203	4.05
LOW	0225	0.77	0305	1.01	0357	1.25	0503	1.43	0616	1.49	0724	1.44	0823	1.32
HIGH	0921	4.53	1013	4.33	1113	4.21	1218	4.20	1315	4.30	1405	4.44	1445	4.60
LOW	1502	1.91	1558	2.12	1707	2.23	1821	2.16	1926	1.94	2019	1.62	2103	1.25
HIGH	2026	4.05	2116	3.80	2224	3.61	2346	3.60						

Table B-18: High and low tide levels for Tanjung Gelang



	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
LOW	0600	0.50	0636	0.61	0721	0.76	0830	0.90	0154	1.14	0147	1.05	0157	0.95
HIGH	1426	2.54	1521	2.48	1620	2.43	1720	2.40	0530	1.24	0656	1.45	0745	1.70
LOW									1010	1.03	1141	1.07	1250	1.08
HIGH									1814	2.35	1853	2.30	1930	2.22

Table B-19: High and low tide levels for Tanjung Keling

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH			0009	1.76	0130	1.59	0342	1.54	0500	1.63	0543	1.72		
LOW	0557	0.87	0640	1.04	0800	1.16	1050	1.11	1130	0.98	1157	0.82	0012	0.50
HIGH	1108	1.45	1137	1.35	1200	1.25	1510	1.21	1654	1.42	1749	1.68	0613	1.79
LOW	1734	0.34	1824	0.47	1938	0.60	2145	0.65	2310	0.57			1225	0.65
HIGH													1824	1.93

Table B-20: High and low tide levels for Tanjung Sedili

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)	Time (hr min)	Height (metre)
HIGH	0037	1.56	0110	1.49	0154	1.41								
LOW	0756	0.28	0839	0.36	0930	0.48	0018	1.25	0120	1.14	0200	1.00	0235	0.85
HIGH	1526	2.10	1625	2.03	1720	1.99	0330	1.32	0518	1.32	0656	1.44	0803	1.63
LOW	2130	1.30	2250	1.31			1036	0.59	1152	0.69	1312	0.73	1416	0.74
HIGH							1824	1.96	1915	1.94	1957	1.92	2030	1.90

Table B-21: High and low tide levels for Tawau

	Thursday 16 Apr		Friday 17 Apr		Saturday 18 Apr		Sunday 19 Apr		Monday 20 Apr		Tuesday 21 Apr		Wednesday 22 Apr	
	ime r min)	leight (metr e)	ime (hr min)	leight (metr e)	ime (hr min)	leight (metr e)	ime (hr min)	leight (metr e)	ime (hr min)	leight (metr e)	ime (hr min)	leight (metr e)	ime (hr min)	leight (metr e)
HIGH							0015	1.78	0340	1.98	0415	2.27	0443	2.57
LOW	0235	0.89	0257	1.13	0319	1.39	0530	1.67	0903	1.49	0956	1.18	1032	0.87
HIGH	0933	2.77	1009	2.54	1112	2.32	1313	2.22	1517	2.36	1614	2.58	1655	2.78
LOW	1537	1.06	1625	1.32	1845	1.50	2103	1.37	2151	1.14	2223	0.90	2251	0.68
HIGH	2138	2.14	2217	1.93										

APPENDIX C

MICROSOFT EXCEL WORKSHEET FOR BEAMS COMBINATION FOR TELESCOPIC WALKWAY STRESS ANALYSIS

		T-T BEAM													
		Reaction Forces (N)		*Telescopic Section*					*Main Walkway*						
Length (m)	*Distance(Ny2-Ny1)*	*Ny1*	*Ny2*	*Shear Force (N)*	*Bending Moment (Nm)*	*Shear Stress (N/m2)*	*Tensile Stress due to Bending (MPa)*	*Compressive Stress due to Bending (MPa)*	*Ny3*	*Ncounter balance(N)*	*Shear Force (N)*	*Bending Moment (Nm)*	*Shear Stress (N/m2)*	*Tensile Stress due to Bending (N/m2)*	*Compressive Stress due to Bending (N/m2)*
0.0000	5.0000	7654.0886	7654.0886	7654.0886	0.0000	325705.8989	0.0000E+00	0.0000E+00	-40962.2659	68270.4431	-40962.2659	0.0000	#DIV/0!	#DIV/0!	#DIV/0!
0.2500	4.7500	7251.2419	8056.9354	6485.8330	1717.1344	275992.8933	1.0323E+00	-9.2015E-03	-44789.3102	72097.4874	-45389.3102	-11272.3275	#DIV/0!	#DIV/0!	#DIV/0!
0.5000	4.5000	6803.6343	8504.5429	5272.8166	3019.1127	224375.1748	1.8150E+00	-1.6178E-02	-48616.3545	75924.5318	-49816.3545	-24608.1773	#DIV/0!	#DIV/0!	#DIV/0!
0.7500	4.2500	6303.3671	9004.8101	4007.1405	3866.4404	170516.6177	2.3244E+00	-2.0719E-02	-52443.3988	79751.5761	-54243.3988	-40007.5491	#DIV/0!	#DIV/0!	#DIV/0!
1.0000	4.0000	5740.5665	9567.6108	2678.9310	4209.7487	113997.0646	2.5308E+00	-2.2558E-02	-56270.4431	83578.6204	-58670.4431	-57470.4431	#DIV/0!	#DIV/0!	#DIV/0!
1.2500	3.7500	5102.7258	10205.4515	1275.6814	3986.5045	54284.3165	2.3966E+00	-2.1362E-02	-60097.4874	87405.6647	-63097.4874	-76996.8593	#DIV/0!	#DIV/0!	#DIV/0!
1.5000	3.5000	4373.7649	10934.4123	-218.6882	3116.3075	-9305.8828	1.8735E+00	-1.6699E-02	-63924.5318	91232.7090	-67524.5318	-98586.7976	#DIV/0!	#DIV/0!	#DIV/0!
1.7500	3.2500	3532.6563	11775.5210	-1825.2057	1494.0192	-77668.3297	8.9818E-01	-8.0059E-03	-67751.5761	95059.7533	-71951.5761	-122240.2581	#DIV/0!	#DIV/0!	#DIV/0!
2.0000	3.0000	2551.3629	12756.8144	-3571.9080	-1020.5452	-151996.0862	-6.1353E-01	5.4687E-03	-71578.6204	98886.7976	-76378.6204	-147957.2408	#DIV/0!	#DIV/0!	#DIV/0!

Table continued

2.2500	2.7500	1391.6525	13916.5248	-5497.0273	-4618.5467	-233916.0547	-2.7766E+00	2.4749E-02	-75405.6647	102713.8419	-80805.6647	-175737.7455	#DIV/0!	#DIV/0!	#DIV/0!
2.5000	2.5000	0.0000	15308.1773	-7654.0886	-9567.6108	-325705.8989	-5.7519E+00	5.1269E-02	-79232.7090	106540.8863	-85232.7090	-205581.7725	#DIV/0!	#DIV/0!	#DIV/0!
2.7500	2.2500	-1700.9086	17009.0858	-10120.4061	-16254.3076	-430655.5775	-9.7718E+00	8.7101E-02	-83059.7533	110367.9306	-89659.7533	-237489.3216	#DIV/0!	#DIV/0!	#DIV/0!
3.0000	2.0000	-3827.0443	19135.2216	-13011.9507	-25258.4925	-553700.0282	-1.5185E+01	1.3535E-01	-86886.7976	114194.9749	-94086.7976	-271460.3929	#DIV/0!	#DIV/0!	#DIV/0!
3.2500	1.7500	-6560.6474	21868.8246	-16510.9626	-37491.3662	-702594.1534	-2.2539E+01	2.0090E-01	-90713.8419	118022.0192	-98513.8419	-307494.9863	#DIV/0!	#DIV/0!	#DIV/0!
3.5000	1.5000	-10205.4515	25513.6288	-20921.1756	-54471.5974	-890262.7904	-3.2747E+01	2.9189E-01	-94540.8863	121849.0635	-102940.8863	-345593.1019	#DIV/0!	#DIV/0!	#DIV/0!
3.7500	1.2500	-15308.1773	30616.3545	-26789.3102	-78932.7889	-1139970.6463	-4.7453E+01	4.2297E-01	-98367.9306	125676.1078	-107367.9306	-385754.7396	#DIV/0!	#DIV/0!	#DIV/0!
4.0000	1.0000	-22962.2659	38270.4431	-35208.8077	-116342.1471	-1498247.1351	-6.9943E+01	6.2343E-01	-102194.9749	129503.1521	-111794.9749	-427979.8995	#DIV/0!	#DIV/0!	#DIV/0!
4.2500	0.7500	-35719.0803	51027.2575	-48731.0309	-179456.4862	-2073660.8899	-1.0789E+02	9.6164E-01	-106022.0192	133330.1964	-116222.0192	-472268.5815	#DIV/0!	#DIV/0!	#DIV/0!
4.5000	0.5000	-61232.7090	76540.8863	-75010.0685	-306546.2494	-3191917.8096	-1.8429E+02	1.6427E+00	-109849.0635	137157.2408	-120649.0635	-518620.7858	#DIV/0!	#DIV/0!	#DIV/0!
4.7500	0.2500	-137773.5953	153081.7725	-152316.3636	-688963.6524	-6481547.3888	-4.1419E+02	3.6919E+00	-113676.1078	140984.2851	-125076.1078	-567036.5121	#DIV/0!	#DIV/0!	#DIV/0!
5.0000	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

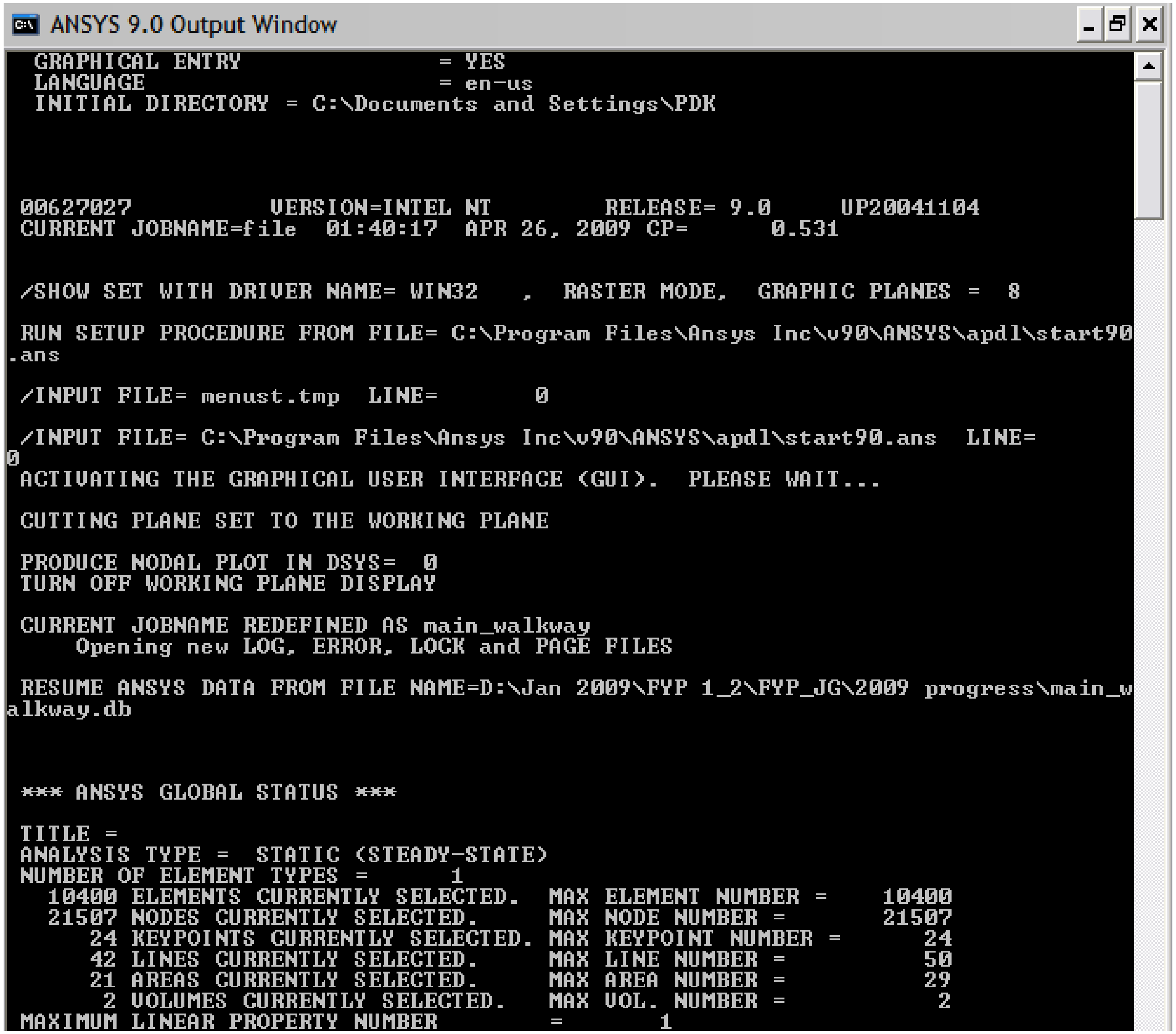
		T-I BEAM													
		Reaction Forces (N)		***Telescopic Section***					***Main Walkway***						
Length (m)	***Distance(Ny2-Ny1)***	***Ny1***	***Ny2***	***Shear Force (N)***	***Bending Moment (Nm)***	***Shear Stress (N/m2)***	***Tensile Stress due to Bending (MPa)***	***Compressive Stress due to Bending (MPa)***	***Ny3***	***Ncounter balance (N)***	***Shear Force (N)***	***Bending Moment (Nm)***	***Shear Stress (N/m2)***	***Tensile Stress due to Bending (N/m2)***	***Compressive Stress due to Bending (N/m2)***
0.0000	5.0000	6000.0000	6000.0000	6000.0000	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	-36000.0000	60000.0000	-36000.0000	0.0000	#DIV/0!	#DIV/0!	#DIV/0!
0.2500	4.7500	5684.2105	6315.7895	5084.2105	1346.0526	#DIV/0!	#DIV/0!	#DIV/0!	-39000.0000	63000.0000	-39600.0000	-9825.0000	#DIV/0!	#DIV/0!	#DIV/0!
0.5000	4.5000	5333.3333	6666.6667	4133.3333	2366.6667	#DIV/0!	#DIV/0!	#DIV/0!	-42000.0000	66000.0000	-43200.0000	-21300.0000	#DIV/0!	#DIV/0!	#DIV/0!
0.7500	4.2500	4941.1765	7058.8235	3141.1765	3030.8824	#DIV/0!	#DIV/0!	#DIV/0!	-45000.0000	69000.0000	-46800.0000	-34425.0000	#DIV/0!	#DIV/0!	#DIV/0!
1.0000	4.0000	4500.0000	7500.0000	2100.0000	3300.0000	#DIV/0!	#DIV/0!	#DIV/0!	-48000.0000	72000.0000	-50400.0000	-49200.0000	#DIV/0!	#DIV/0!	#DIV/0!
1.2500	3.7500	4000.0000	8000.0000	1000.0000	3125.0000	#DIV/0!	#DIV/0!	#DIV/0!	-51000.0000	75000.0000	-54000.0000	-65625.0000	#DIV/0!	#DIV/0!	#DIV/0!
1.5000	3.5000	3428.5714	8571.4286	-171.4286	2442.8571	#DIV/0!	#DIV/0!	#DIV/0!	-54000.0000	78000.0000	-57600.0000	-83700.0000	#DIV/0!	#DIV/0!	#DIV/0!
1.7500	3.2500	2769.2308	9230.7692	-1430.7692	1171.1538	#DIV/0!	#DIV/0!	#DIV/0!	-57000.0000	81000.0000	-61200.0000	-103425.0000	#DIV/0!	#DIV/0!	#DIV/0!
2.0000	3.0000	2000.0000	10000.0000	-2800.0000	-800.0000	#DIV/0!	#DIV/0!	#DIV/0!	-60000.0000	84000.0000	-64800.0000	-124800.0000	#DIV/0!	#DIV/0!	#DIV/0!

Table continued

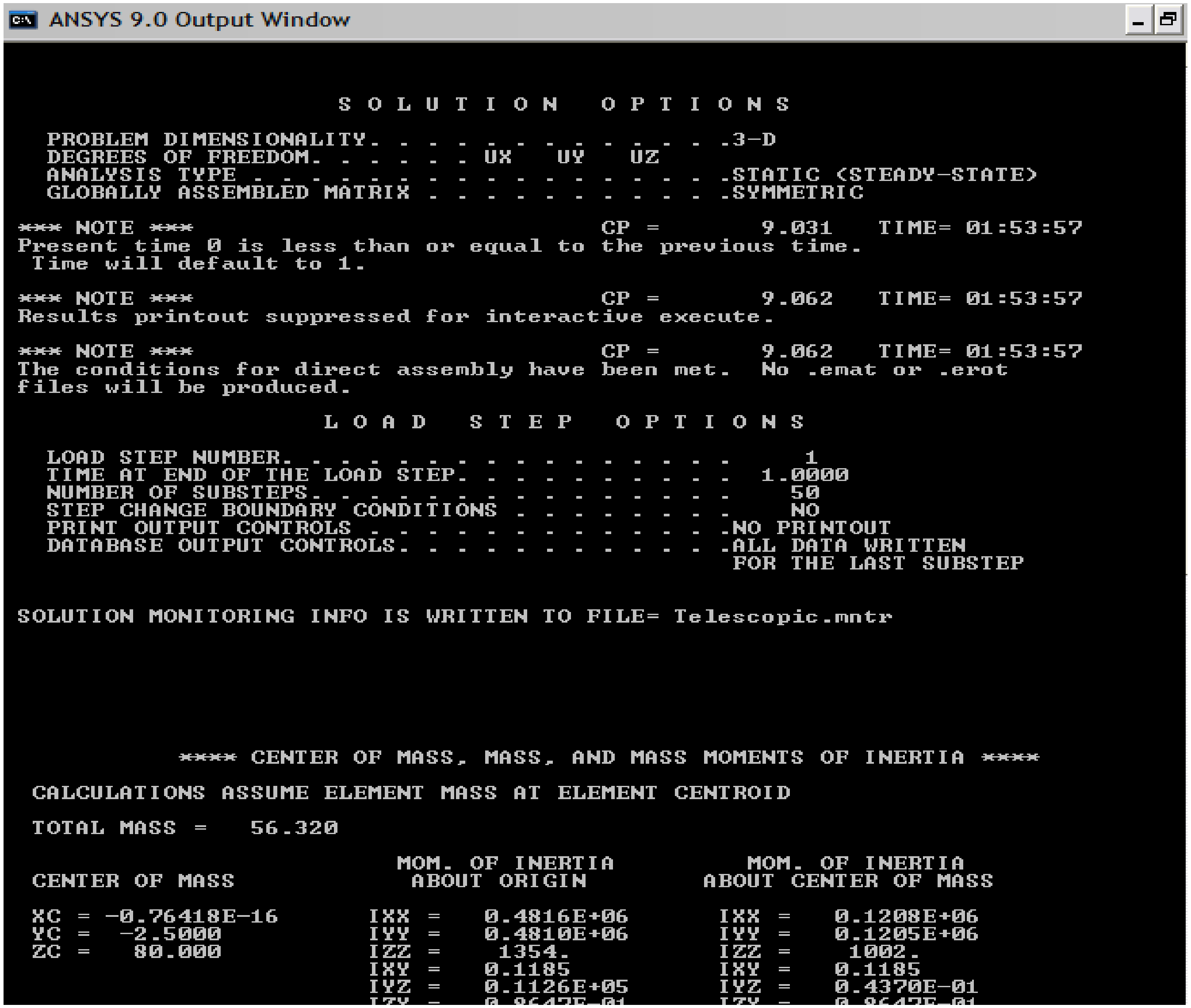
2.2500	2.7500	1090.9091	10909.0909	-4309.0909	-3620.4545	#DIV/0!	#DIV/0!	#DIV/0!	-63000.0000	87000.0000	-68400.0000	-147825.0000	#DIV/0!	#DIV/0!	#DIV/0!
2.5000	2.5000	0.0000	12000.0000	-6000.0000	-7500.0000	#DIV/0!	#DIV/0!	#DIV/0!	-66000.0000	90000.0000	-72000.0000	-172500.0000	#DIV/0!	#DIV/0!	#DIV/0!
2.7500	2.2500	-1333.3333	13333.3333	-7933.3333	-12741.6667	#DIV/0!	#DIV/0!	#DIV/0!	-69000.0000	93000.0000	-75600.0000	-198825.0000	#DIV/0!	#DIV/0!	#DIV/0!
3.0000	2.0000	-3000.0000	15000.0000	-10200.0000	-19800.0000	#DIV/0!	#DIV/0!	#DIV/0!	-72000.0000	96000.0000	-79200.0000	-226800.0000	#DIV/0!	#DIV/0!	#DIV/0!
3.2500	1.7500	-5142.8571	17142.8571	-12942.8571	-29389.2857	#DIV/0!	#DIV/0!	#DIV/0!	-75000.0000	99000.0000	-82800.0000	-256425.0000	#DIV/0!	#DIV/0!	#DIV/0!
3.5000	1.5000	-8000.0000	20000.0000	-16400.0000	-42700.0000	#DIV/0!	#DIV/0!	#DIV/0!	-78000.0000	102000.0000	-86400.0000	-287700.0000	#DIV/0!	#DIV/0!	#DIV/0!
3.7500	1.2500	-12000.0000	24000.0000	-21000.0000	-61875.0000	#DIV/0!	#DIV/0!	#DIV/0!	-81000.0000	105000.0000	-90000.0000	-320625.0000	#DIV/0!	#DIV/0!	#DIV/0!
4.0000	1.0000	-18000.0000	30000.0000	-27600.0000	-91200.0000	#DIV/0!	#DIV/0!	#DIV/0!	-84000.0000	108000.0000	-93600.0000	-355200.0000	#DIV/0!	#DIV/0!	#DIV/0!
4.2500	0.7500	-28000.0000	40000.0000	-38200.0000	-140675.0000	#DIV/0!	#DIV/0!	#DIV/0!	-87000.0000	111000.0000	-97200.0000	-391425.0000	#DIV/0!	#DIV/0!	#DIV/0!
4.5000	0.5000	-48000.0000	60000.0000	-58800.0000	-240300.0000	#DIV/0!	#DIV/0!	#DIV/0!	-90000.0000	114000.0000	-100800.0000	-429300.0000	#DIV/0!	#DIV/0!	#DIV/0!
4.7500	0.2500	-108000.0000	120000.0000	-119400.0000	-540075.0000	#DIV/0!	#DIV/0!	#DIV/0!	-93000.0000	117000.0000	-104400.0000	-468825.0000	#DIV/0!	#DIV/0!	#DIV/0!
5.0000	0.0000	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

APPENDIX D

ANSYS OUTPUT WINDOW



```
  GRAPHICAL ENTRY              = YES
  LANGUAGE                     = en-us
  INITIAL DIRECTORY = C:\Documents and Settings\PDK



 00627027          VERSION=INTEL NT        RELEASE= 9.0     UP20041104
 CURRENT JOBNAME=file  01:40:17  APR 26, 2009 CP=      0.531


 /SHOW SET WITH DRIVER NAME= WIN32    ,  RASTER MODE,  GRAPHIC PLANES =  8

 RUN SETUP PROCEDURE FROM FILE= C:\Program Files\Ansys Inc\v90\ANSYS\apdl\start90
.ans

 /INPUT FILE= menust.tmp  LINE=       0

 /INPUT FILE= C:\Program Files\Ansys Inc\v90\ANSYS\apdl\start90.ans  LINE=
0
 ACTIVATING THE GRAPHICAL USER INTERFACE (GUI).  PLEASE WAIT...

 CUTTING PLANE SET TO THE WORKING PLANE

 PRODUCE NODAL PLOT IN DSYS=  0
 TURN OFF WORKING PLANE DISPLAY

 CURRENT JOBNAME REDEFINED AS main_walkway
     Opening new LOG, ERROR, LOCK and PAGE FILES

 RESUME ANSYS DATA FROM FILE NAME=D:\Jan 2009\FYP 1_2\FYP_JG\2009 progress\main_w
alkway.db



 *** ANSYS GLOBAL STATUS ***

 TITLE =
 ANALYSIS TYPE =  STATIC (STEADY-STATE)
 NUMBER OF ELEMENT TYPES =       1
   10400 ELEMENTS CURRENTLY SELECTED.  MAX ELEMENT NUMBER =    10400
   21507 NODES CURRENTLY SELECTED.     MAX NODE NUMBER =       21507
      24 KEYPOINTS CURRENTLY SELECTED. MAX KEYPOINT NUMBER =      24
      42 LINES CURRENTLY SELECTED.     MAX LINE NUMBER =          50
      21 AREAS CURRENTLY SELECTED.     MAX AREA NUMBER =          29
       2 VOLUMES CURRENTLY SELECTED.   MAX VOL. NUMBER =           2
 MAXIMUM LINEAR PROPERTY NUMBER       =       1
```



```
                       S O L U T I O N   O P T I O N S

   PROBLEM DIMENSIONALITY. . . . . . . . . . . . .3-D
   DEGREES OF FREEDOM. . . . . . UX   UY   UZ
   ANALYSIS TYPE . . . . . . . . . . . . . . . . .STATIC (STEADY-STATE)
   GLOBALLY ASSEMBLED MATRIX . . . . . . . . . . .SYMMETRIC

 *** NOTE ***                            CP =       9.031   TIME= 01:53:57
 Present time 0 is less than or equal to the previous time.
  Time will default to 1.

 *** NOTE ***                            CP =       9.062   TIME= 01:53:57
 Results printout suppressed for interactive execute.

 *** NOTE ***                            CP =       9.062   TIME= 01:53:57
 The conditions for direct assembly have been met.  No .emat or .erot
 files will be produced.
                      L O A D   S T E P   O P T I O N S

   LOAD STEP NUMBER. . . . . . . . . . . . . . . .     1
   TIME AT END OF THE LOAD STEP. . . . . . . . . .  1.0000
   NUMBER OF SUBSTEPS. . . . . . . . . . . . . . .    50
   STEP CHANGE BOUNDARY CONDITIONS . . . . . . . .    NO
   PRINT OUTPUT CONTROLS . . . . . . . . . . . . .NO PRINTOUT
   DATABASE OUTPUT CONTROLS. . . . . . . . . . . .ALL DATA WRITTEN
                                                  FOR THE LAST SUBSTEP


 SOLUTION MONITORING INFO IS WRITTEN TO FILE= Telescopic.mntr






            **** CENTER OF MASS, MASS, AND MASS MOMENTS OF INERTIA ****

  CALCULATIONS ASSUME ELEMENT MASS AT ELEMENT CENTROID

  TOTAL MASS =   56.320

                           MOM. OF INERTIA         MOM. OF INERTIA
  CENTER OF MASS            ABOUT ORIGIN         ABOUT CENTER OF MASS

  XC = -0.76418E-16       IXX =   0.4816E+06       IXX =   0.1208E+06
  YC =  -2.5000           IYY =   0.4810E+06       IYY =   0.1205E+06
  ZC =   80.000           IZZ =    1354.           IZZ =    1002.
                          IXY =   0.1185           IXY =   0.1185
                          IYZ =   0.1126E+05       IYZ =   0.4370E-01
                          IZX =   0.8647E-01       IZX =   0.8647E-01
```