The Tiki Express

Design Proposal

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Abstract:

The following project details Prestige Worldwide's final design for the ship the Tiki Express. This ship was designed for the Roto-Nordic Lines to replace their existing fleet of four ro-ro vessels. The TIki Express is 187 meters long, 32.2 meters wide, and 42 meters high ro-ro vessel capable of carrying 1000 40 foot containers and 1721 automobiles

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Introduction

Prestige Worldwide was approached by Rotto Nordic Lines to design a Ro-Ro ship capable of replacing four of their older vessels. The vessel design requires that the ship be able to carry 1,700 Volvo cars, trucks, and buses, as well as 1000 TEUs ISO containers on her decks, with a minimum of two ramps to minimize the time spent in port. The vessel also needs to be able to travel the ports of; Gothenburg, Antwerp, Southampton, Halifax, Baltimore, Galveston, Veracruz, Tacoma.

Other ship requirements are a minimum deadweight capacity of 15,000 metric tons, capabilities of holding heavy cargo such as construction equipment and bulldozers, and capabilities of traveling an 11 day direct route from Gothenburg to Galveston.

The design also requires that the ships dimensions be no larger than the following: 187 m LOA, 7.2 m draft, and 37 m air draft. The ship design also must take into account accommodations for the crew including living units, TV rooms, a reading room, and a meeting room. The vessel should obey all rules and regulations and operate with minimum emissions.

The following paper discusses, through a series of chapters, how Prestige Worldwide began to tackle the task of completing all of these requirements effectively and efficiently.

Chapter1: Ship Design Process and Final Layout

Section 1: Parent Ship

When selecting the parent ship for this design process, many considerations were in place. Did the vessel meet most of our design requirements? Was the vessel capable of traveling the Panama Canal? Was the vessel classed by ABS?

Our team used these preliminary questions to find two potential parent ships: the Alliance Fairfax and the Grande Argentina. Ultimately, it was decided that the Alliance Fairfax was the better candidate due to the cargo layout and the deadweight vs displacement ratio.

By going to marinetraffic.com, our team was able to find all of the basic information of our parent ship as follows:

Length: 179.9 m Draft: 9 m Breadth: 30 m Deadweight: 19,670 t

We were then able to roughly estimate a displacement by getting the product of the length, draft, and breadth, which came out to be 48,573 m^3.

We then did some extensive research on the Alliance Fairfax and were able to find detailed papers on her deck layouts and design specifications at maersklinelimited.com. This helped us vastly when designing our own ship because we could then make educated guesses to help us along the design process.

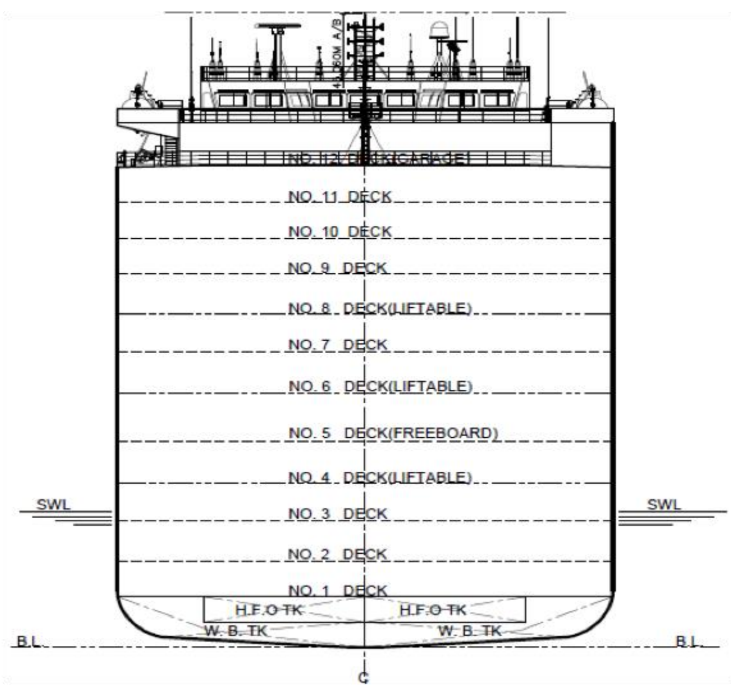

Figure 0 is an example of the detailed information we were able to find on our parent ship that ultimately led us to our final design

Section 2: Engineering Process

The following section lays out Prestige World Wide's design process in laying out the *Tiki Express*. This process lasted over two months and required hundreds of man hours to complete. This report covers only the key points in the design process.

The design of the *Tiki Express* began as an optimization problem. The goal was to hold the minimum desired amount of cargo required by Roto-Nordic lines which was 1,000 forty-foot ISO containers, and Volvo 1,700 automobiles. In order to efficiently optimize the space of Tiki Express the layout was chosen based upon housing the heaviest equipment as low as possible while holding the lighter equipment on the top decks. This would result in the ship being as stable being as possible when fully loaded. The heaviest cargo that the ship is required to carry is the ISO containers which can hold a maximum payload of 26.75 metric tons, which in addition to being heavy, can be densely packed into the ship. The lightest equipment was found to be the Volvo cars which were put on the top decks, the heaviest weight car that Volvo produced was very close to 2 tons and was thus used as the weight when calculating live loads on decks. In order to hold the required amount of cargo an excel document was created to calculate the minimum each deck would have to hold, assuming a roughly box shape. Thus the following figure (figure 1) was generated based upon the project requirement. The red area represents decks designed to hold cars, the yellow was designed to hold larger vehicles such as Volvo trucks, and the green represented the decks on which containers would be double stacked. Finally an accommodations block was generated using the grey area allowing for a 50 meter crew accommodations. This figure is just provided for reference to the ship's initial design process and layout.

Ship Cargo Distibution Loading Plan (used in calculating ship table of offsets and layout)	
Crew Accomidations Block	Crew Accomidations Block
Car Deck	Dimensions 12 Lanes (2.5 m wide each), 2.5 m high, 5m per, Total number of cars held : 427 Cars
Car Deck	Dimensions 12 Lanes (2.5 m wide each), 2.5 m high, 5m per, Total number of cars held : 427 Cars
Car Deck	Dimensions 12 Lanes (2.5 m wide each), 2.5 m high, 5m per, Total number of cars held : 427 Cars
Heavy Equipment Deck	Dimensions 9 Lanes (3.5 m wide each), 4 m high, 12m per Total number of cars held : 427 Cars or 135 Heavy Trucks
Heavy Equipment Deck	Dimensions 9 Lanes (3.5 m wide each), 4 m high, 12m per Total number of cars held : 427 Cars or 135 Heavy Trucks
Container Deck	Triple Stacked Container Deck 336 Containers per Deck or 427 Cars or 135 Heavy Trucks
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Figure 1 Showing initial cargo layout as determined by Prestige World Wide

Note that this ship model included three, 3m car decks, two 4m truck decks for the customer to haul heavy trucks and mining equipment, and three, 6m container decks. After the excel table was created a 3D Model was generated (Figure 2) to give the design some form as shown. This model was only 166 meters long, 32.2 meters wide, and had a height of only 36 meters, as the model developed these dimensions would grow much wider.

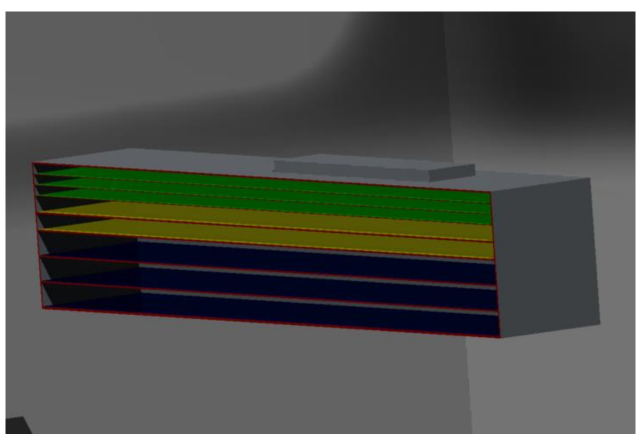


Figure 2 showing the Excel file turned into a 3D rendered modeled.

Prestige World Wide found later that it was more efficient not to include truck decks and instead hold the equipment on the lower decks, nicknamed “container decks.” The layout of the ship was refined into seven decks spaced three meters apart designed to hold lightweight automobiles and three decks separated 6 meters apart designed to hold heavy ISO containers in a double stacked arrangement. These design changes can be seen in the evolution of the outside of the hull. The ship was changed from a ship with a block coefficient of one and made narrower and narrower to make the ship more hydrodynamic. As the ship's hull was refined it had to be made longer and taller to hold all the cargo. The ships final dimensions ended at 187 meters long, 32.2 meters wide to meet the maximum Panamax requirements, a draft of 7 meters, and a height from keel of 42 meters. Figure 3 shows this evolution from start to end product.

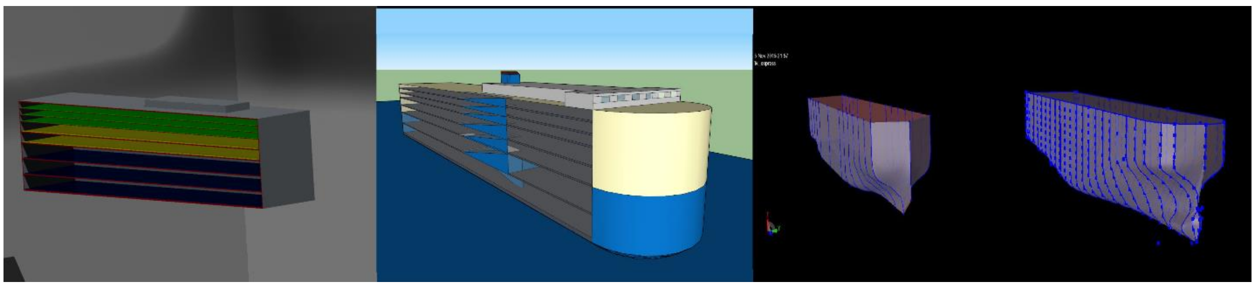


Figure 3 shows the development of the outer hull in the 3D modeling software: CreoParametric, GoogleSketchup, and Seasam.

Section 3: Table of Offsets and Hull Plans

The Tiki Express's table of offsets was largely inspired by her parent ship the Alliance Fairfax. After several iterations of the table offsets were drawn by our team we consulted the *Alliance Fairfax's* deck layout scheme (*Hoegh Autoliners – Hoegh Kyoto General Arangment, Knud E. Hansen A/S*). Using a copy of their deck layout each deck was manually measured over 22 intervals for every deck, which were then used to create a table of offsets after being scaled up to the size of the Alliance Fairfax. This final set of table of offsets was then further modified to take into considerations a bulbous bow. The final table of offsets is displayed below in Figure IV. Note that in the Tiki Express has all of its decks fall on its waterlines. Waterlines that contain decks are waterlines 1, 3, 5, 7, 8, 9, 10, 11, 12, and 13. The following table displays the table off offsets of the *Tiki Express*. Decks labeled with cargo are optimized to hold double stacked containers while those labeled with cars can hold containers single stack and cars.

Table I Displays the table of Offsets for the Tiki Express.

Table of Offsets Tiki Express															
Height of Waterlines:		0.000	3	6	9	12	15	18	21	24	27	30	33	36	39
Station from Aft	Stations	WL 0	WL 1	WL 2	WL 3	WL 4	WL 5	WL 6	WL 7	WL 8	WL 9	WL 10	WL 11	WL 12	WL 13
0	0				0.000	15.573	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
4.25	AP			0.000	9.269	15.878	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
8.5	1		0.000	0.170	11.506	16.065	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
17	2	0	2.003	2.567	13.997	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
25.5	3	0	3.791	6.168	15.150	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
34	4	0	6.134	10.778	15.794	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
42.5	5	0	8.960	13.930	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
51	6	0	11.811	15.311	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
59.5	7	0	14.050	15.980	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
68	8	0	15.336	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
76.5	9	0	15.877	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
85	10	0	15.912	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
93.5	11	0	15.539	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
102	12	0	14.854	15.928	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
110.5	13	0	13.692	15.302	16.041	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
119	14	0	12.159	14.218	15.506	15.963	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
127.5	15	0	10.320	12.659	14.366	15.361	16.068	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
136	16	0	8.324	10.674	12.625	14.082	15.336	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
144.5	17	0	6.389	8.371	10.388	12.150	14.116	15.997	16.100	16.100	16.100	16.100	16.100	16.100	16.100
153	18	0	4.465	5.872	7.710	9.744	12.371	15.302	16.100	16.100	16.100	16.100	16.100	16.100	16.100
161.5	19	0	3.154	3.721	4.935	6.973	10.337	14.387	16.100	16.100	16.100	16.100	16.100	16.100	16.100
170	20	0	3.500	2.118	2.334	4.440	7.897	12.828	16.100	16.100	16.100	16.100	16.100	16.100	16.100
178.5	21	0	3.500	1.779	0.404	1.483	4.675	9.437	13.815	13.815	13.815	13.815	13.815	13.815	13.815
182.75	FP	0	1.574	1.898	0.000	0.000	1.669	6.219	10.399	10.399	10.399	10.399	10.399	10.399	10.399
187	22		0.000	0.000					0.000	0.000	0.000	0.000	0.000	0.000	0.000
			Engines	Cargo	Cargo		Cargo		Cars	Cars	Cars	Cars	Cars	Cars	Cars

From the table of offsets the body plan, sheer plan, and half-breadth plan were created. These plans were created using ACAD 2012. These plans give a detailed view of all of the Tiki Expresses’ exterior features. These plans are displayed below in figures 4, 5, and 6.

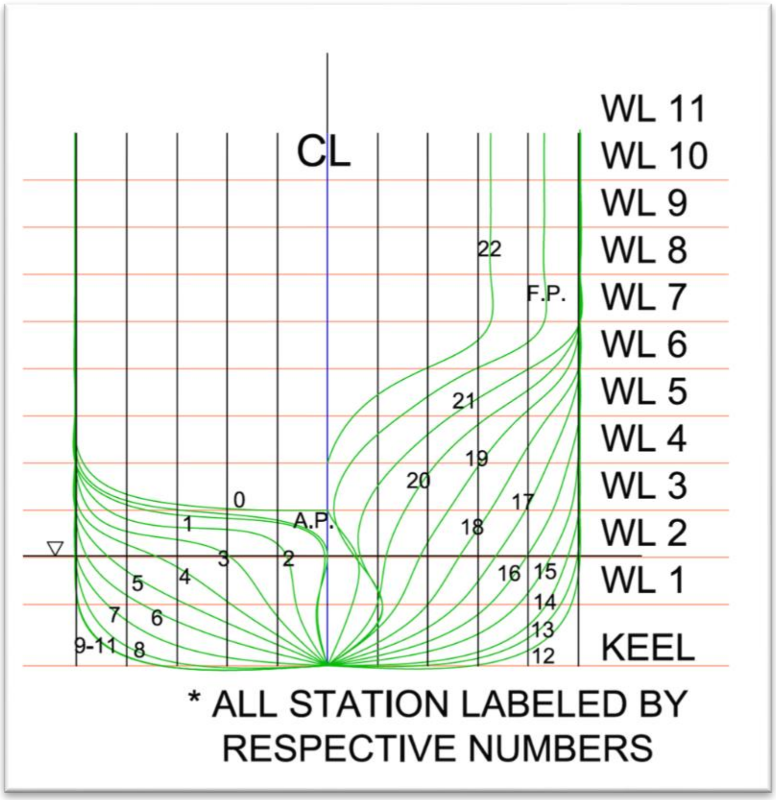
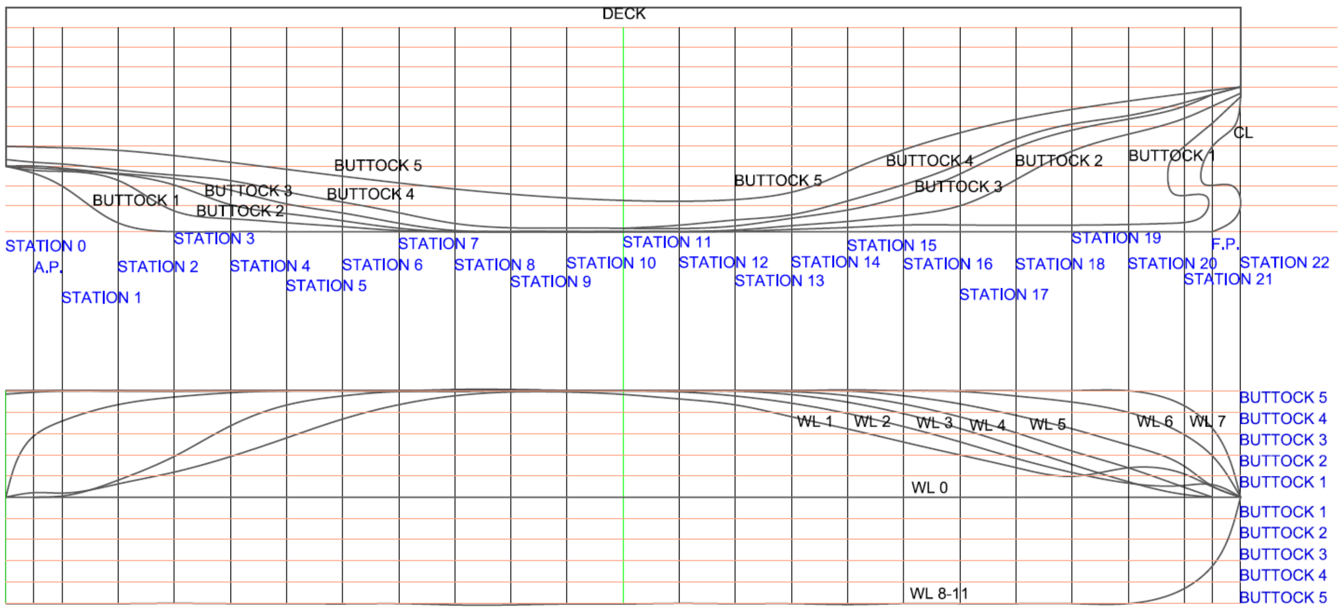


Figure 4 shows the Tiki Expresses' body plan.

The body plan is laid out with the forward stations of the ship displayed on the right side of the centerline and the aft stations displayed on the left side of the centerline. Observe key features of the body plan such as the bulbous bow which is 3.5 meters at its widest.



Figures 5 shows the sheer and body plan of the Tiki Express This figure is blown up on the proceeding page for reference.

The sheer and body plan show the ship at every waterline and every buttock line. These help give a better idea of what the ship looks like from the side and from the top. The Bulbous bow can clearly be seen in these figures as well as the spaced allotted astern for the propeller and the rudder.

Section 4: Ramp, Bulkhead, and Traffic Flow Layout

One of the next design considerations made was how to layout the internal and external ramps. One of the most important layout considerations when designing a RO-RO is how to quickly load on cargo, and discharge cargo. The Tiki Express's deck layout was chosen specifically to allow for fast roll on fast roll off capabilities. This entailed the ship being designed so that the cars can be driven on quickly as possible, while allowing them to quickly be discharged. In order to accomplish this a two-up-two-down configuration of ramps was chosen. Observe figure six and figure seven below.

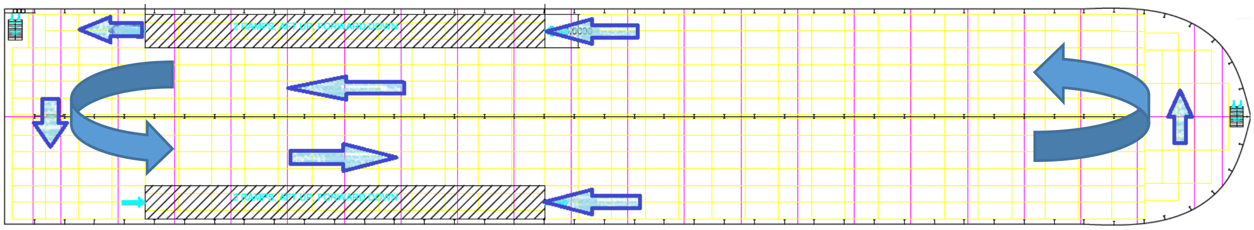


Figure 6 showing the offloading clockwise flow.

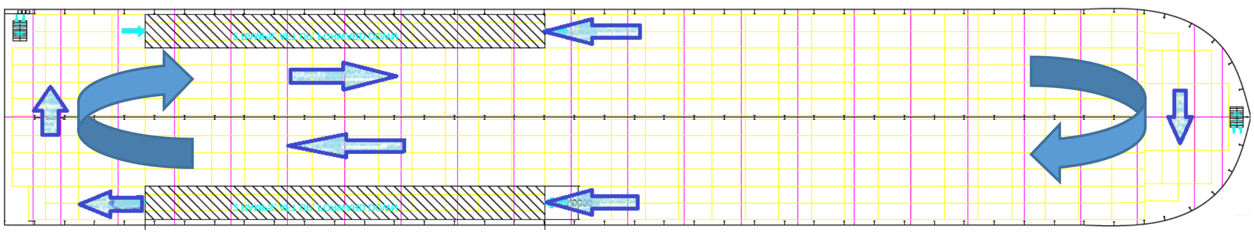


Figure 7 showing the loading clockwise flow

Traffic flows in a counter clockwise direction when loading and a clockwise direction when loading. The forward two ramps lead to the deck below, while the aft two ramps lead to the upper deck. This allows cargo, specifically cars, not to be concerned with directions that they face when offloading (Meaning that no car will ever needed to be backed into, or jockeyed into position saving time.) This deck layout however, only applies to automobile traffic and was thus only used for the uppermost decks were cars would be held. Decks below this went with a single ramp layout as these are designed to primarily hold bulk cargo such as 20 foot and 40 foot containers. For all decks, cargo was stored on the ramps as well as the deck itself. All ramps were fixed and made water tight.

Ramps, in addition to being in a two-up-two-down configuration were also walled off with steel plates and closable on both ends with hatches on either end to prevent water due to flooding from passing from one deck to another effectively making sure that every deck was watertight. Ramps were also made long, wide, and tall, to allow easy passage up and down them with large 40 foot containers as requested by Roto-Nordic Lines. In order to accommodate such large cargo the ramps were made to be 60 M in length so that containers could be rolled up and down between decks double stacked (which is the maximum height that containers can be transported on and off a ship). By allowing such design considerations the Tiki express decreases time to load large bulk cargo by 50% since only one trip must be made carrying double stacked containers instead of two. The containers double stacked came to a height of 5.243 meters. The sled that 40 foot containers ride on is assumed to be 0.4 meter based upon (*Toolwell North America JUNG Machine Skates and Hydraulic Toe Jacks Made in Germany*). Thus the total height of an ISO container rolling up a 60 meter ramp to a deck 6 meter above would be 5.64256 meters tall which would fit on the deck. Allowing for a 0.4 meter double stacked dolly meant that the maximum angle of attack for the container ramps was 7.4 degrees. From this we chose a ramp angle of 5.71°. This limit was based off the minimum ramp calculations, observe Figure 8 to see. Note that only the bottom three decks store containers double stacked, the remaining decks store containers single stacked. Note that dollies less than 0.3 meters in height and without a supporting center wheel in the middle of the 40 foot containers will bottom out and cannot be used. In total using 0.4 meter dollies the containers have 0.1 meters of clearance.

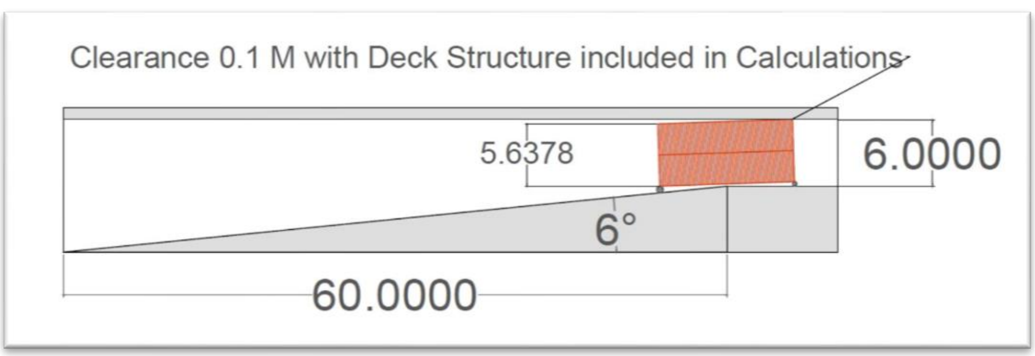


Figure 8 shows two containers being brought up an internal ramp on a 0.4 meter dolly.

In order to ensure that the ship remained stable when flooding occurred, all ramps were made water tight. To do this all ramps were enclosed with steel panels on all sides with a lift able hatch on the end. Prestige World Wide selected Macgregor hydraulically movable doors and hatches. These hatches are attached to the end to every ramp were the ramp meets the deck. Figure 9 below displays a Macgregor hydraulically lift-able hatch on a ramp similar to a ramp and hatch that will be used by the Tiki Express (*MacGregor, Ramps, Hatches, Bulkheads*).

Figure 9 displays an internal ramp with a closable hatch (MacGregor, Ramps, Hatches, and Bulkheads).

For decks with bulk heads *TTSGroup* retractable bulkheads were chosen as the best option for bulkheads in the way of cargo loading routes. These bulkheads can be retracted out of the way of vehicles to allow cargo to be quickly on loaded and offloaded. Then once the cargo has been fully loaded the bulkheads can be swiveled back into place. A picture of a *TTSGroup* RORO bulkhead is displayed below. Again theses bulkheads mean that the loading offloading time of our RORO is greatly reduced. Note that collision bulkheads and the bulkhead protecting the engine room are solid bulkheads and cannot swivel.

Figure 10 showing a swivel-able bulkhead (The Online Boating and Maritime Exhibition, Bulkheads/TTSGroup Bulkheads)

The final consideration that had to be taken in choosing a ship layout was the primary loading ramp. The ramp that Prestige World Wide selected was again a Macgregor brand 30 meter ship-to-shore stern ramp. These ramps are mechanically winched up and down to raise and lower and have an excellent industry reputation. This ramp meets the ship at waterline five and loads directly on to the third cargo deck. Note that there is also a side ramp at waterline 7 designed to help assist in the offloading in automobiles.

F*igure 11 shows a Macgregor brand 30 meter ship-to-shore stern ramp with a 10 M extension added on to the end (MacGregor, Ramps, Hatches, and Bulkheads).*

Section 5: Crew Manifest

The *Tiki Express* being a modern ships is designed to hold only a minimal crew. This saves the operator a large operation cost. The crew size was chosen to be 12, in order to fall under ABS guidelines of a non-passenger ship. Which allows a vessel to carry a maximum number of 12 crew before requiring the ship to meet additionally safety standards (ABS Rules & Guides). Since the ship only has a crew of two it is required only to have two companion ways between each deck. The ship thus only saves space for more cargo. In order to properly operate the ship the following crew are required. These crew members were based upon several RORO crews. This number is design to have a three watch rotation, with each watch running for 8 hours, due to this all crew members must be capable of standing a watch. At minimum there must be two crew manning the bridge at all times, one with a current USCG license, and one engineering watch officer with license, and one other crew member monitoring the engine room and engine facilities. The crew minimum manifest is as follows:

1. A Ship's Master (Captain)

   Chief Officer in charge of the ship, must have USCG license.

2. A Chief Mate (Second in command)

   Second officer in charge of the ship, must have USCG license.

3. A Second Mate (Second Officer)

   Third officer in charge of the ship, must have USCG license.

4. A Third Mate (Third Officer)

   Fourth officer in charge of the ship, must have USCG license.

5. Chief Engineer

   First engineering watch officer, must have an approved engineering USCG license.

6. Second engineer/first assistant engineer

Second in command engineering watch officer, must have an approved engineering USCG license

7. Third engineer/second assistant engineer

   Third in command engineering watch officer, must have an approved engineering USCG license.

8. Third engineer/third assistant engineer

   Third in command engineering watch officer, must have an approved engineering USCG license

9. Chief Electrician

   Must be a licensed electrician.

10. Electrician's Mate

    Must be a licensed electrician.

11. Chief Cook (Chief Steward)

    Will cook, and maintain the ships accommodations, would be preferred if he/she can stand a watch.

12. Extra deckhand

    Extra hand to stand bridge and engine watches as well as to perform routine maintenance.

Section 6: Final Layout of Ship

After all the design considerations were taken into account and the ships structure had been designed the ship was then built in Sesam and had its deck layout, and amidships section drawn in ACAD. The following figures display these seas am drawings

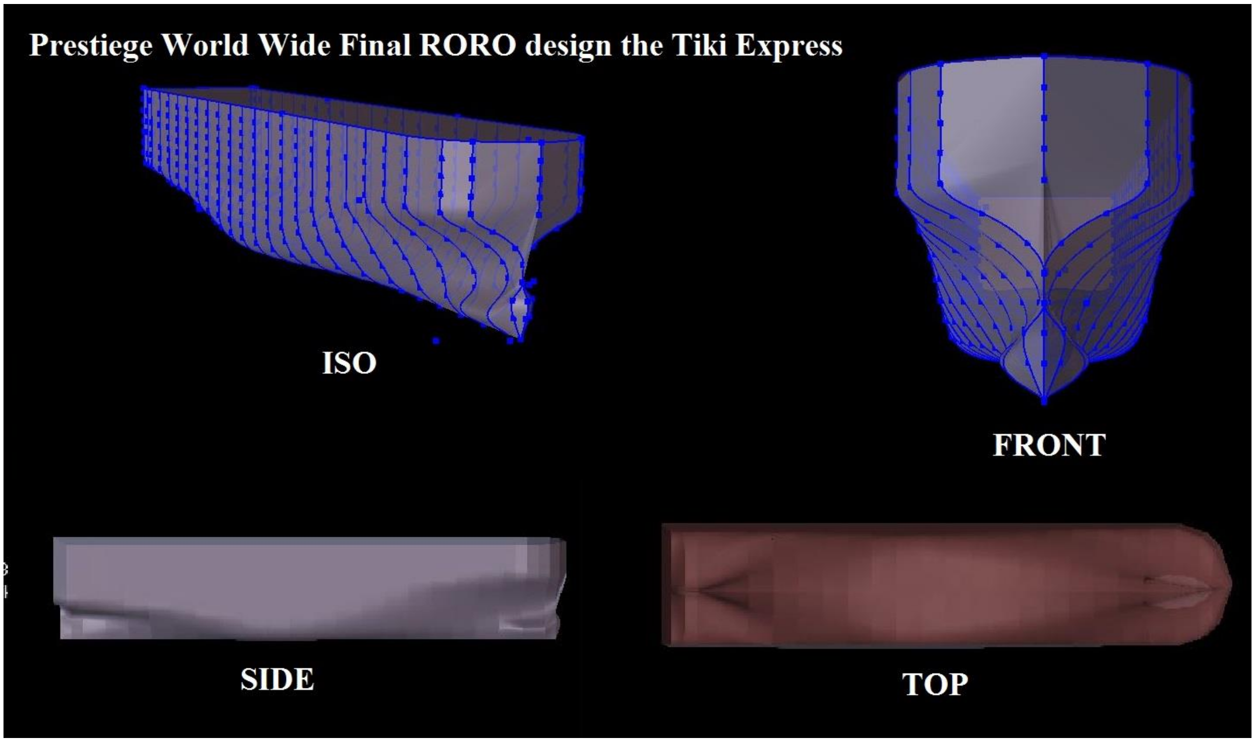


Figure 12 shows the Tiki Express hull only, with all structural elements hidden. This figure shows standard isometric, front, top, and side view of the ship's hull.

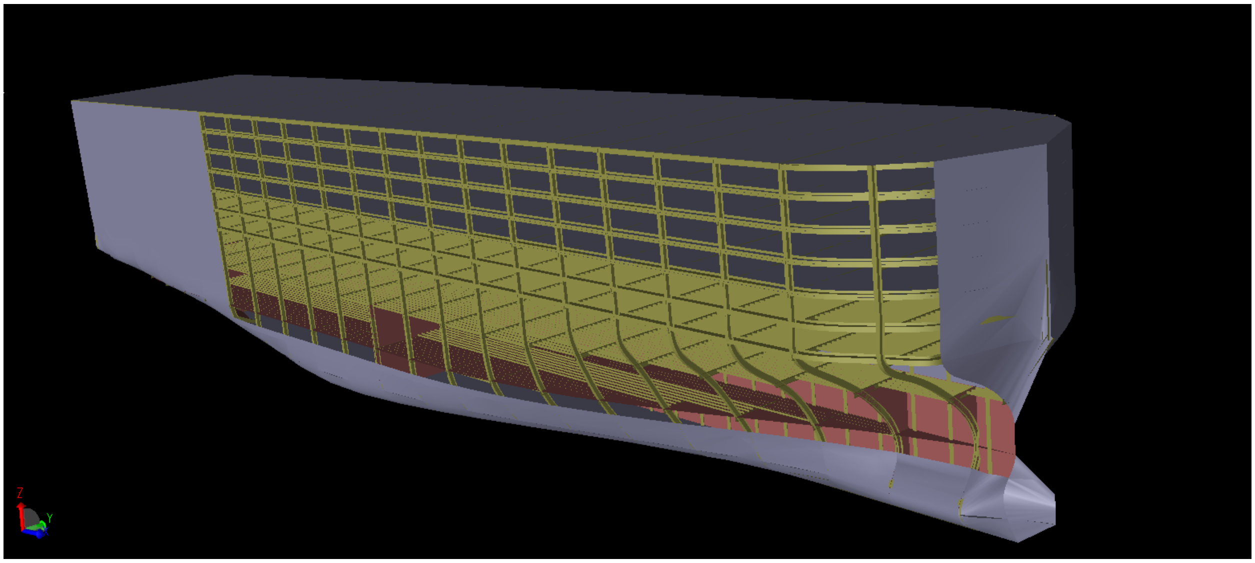


Figure 13 shows the interior structure, deck layout, and bulkheads in the Tiki Express.

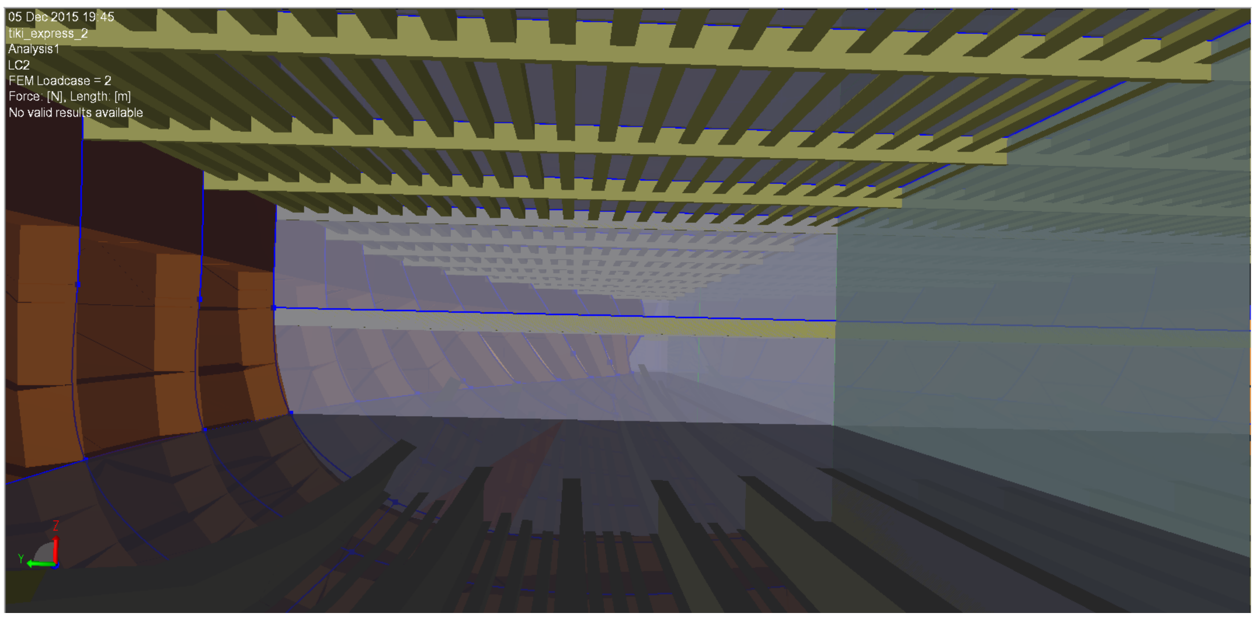


Figure 14 shows the inside the ship at waterline one with bulkheads made transparent so that the deck structure can be seen, Observe the longitudinal stiffeners from the cargo deck above.

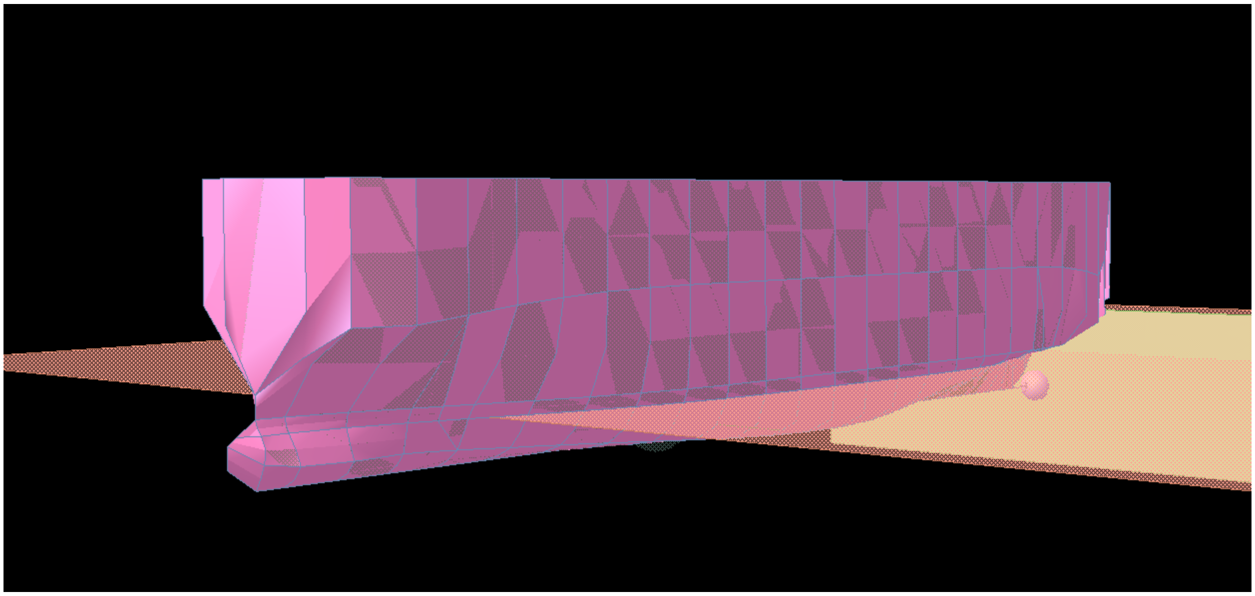


Figure 15 shows the hydrodynamic mesh used to evaluate the ship in HydroD. Also displayed is the water at draft.

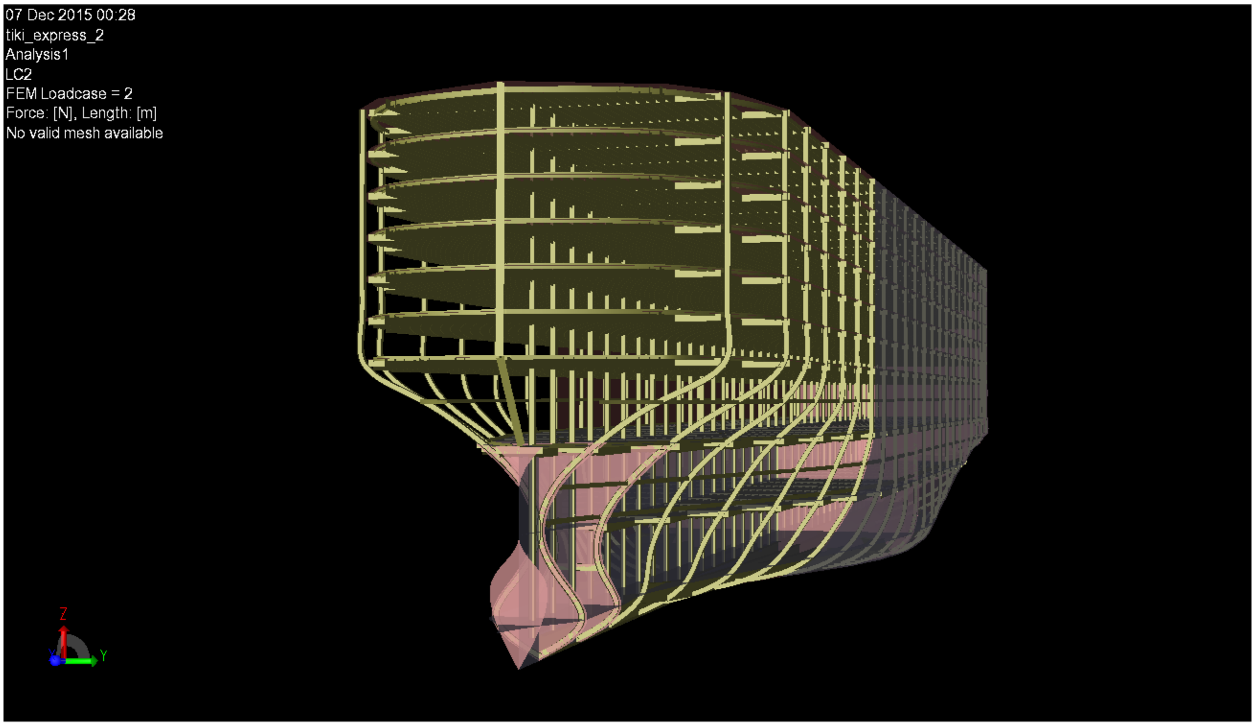


Figure 16 shows all of the ships structural elements, these will be discussed later in this paper.

The layout of the ship was divided out by waterlines; the reason for this was all decks fell only on waterlines. Note that there are some air gaps some waterlines. In the following figures the ship is shown with its general layout, and with the cargo held in the decks as required by Rotto-Nordic lines. Rotto-Nordic desires to have their RORO's hold 1,000 40 foot containers or 12.192 meters in the metric system, and 1700 Volvo Cars. Note that this is not the only possible cargo layout but just one of many. The following pages show the Tiki Expresses fully loaded with a maximum payload of 1,000 40 foot containers, and 1721 cars. The Tiki Expresses was laid out with 12 Car lanes at her widest breadth with each lane being divided into CEUs (Car Equivalency Units). These units are slightly wider than the largest car that Volvo produces (2.42 meters wide and 4.13 meters long, available in project description). Each CEU allows room for the car and the moorings holding the car. For the Tiki Express each CEU is 2.5 meters by 5 meters which is the same CEU standard used on the Alliance Fairfax. Containers were given a much tighter box to occupy. Each one needed to fit into a 2.5 meters wide, and 12.5 meters long which left 38.1 cm on the ends of containers for moorings. Overall this cost 2 containers per deck in storage space. Figure 17 below shows the Tiki Express's amidships section.

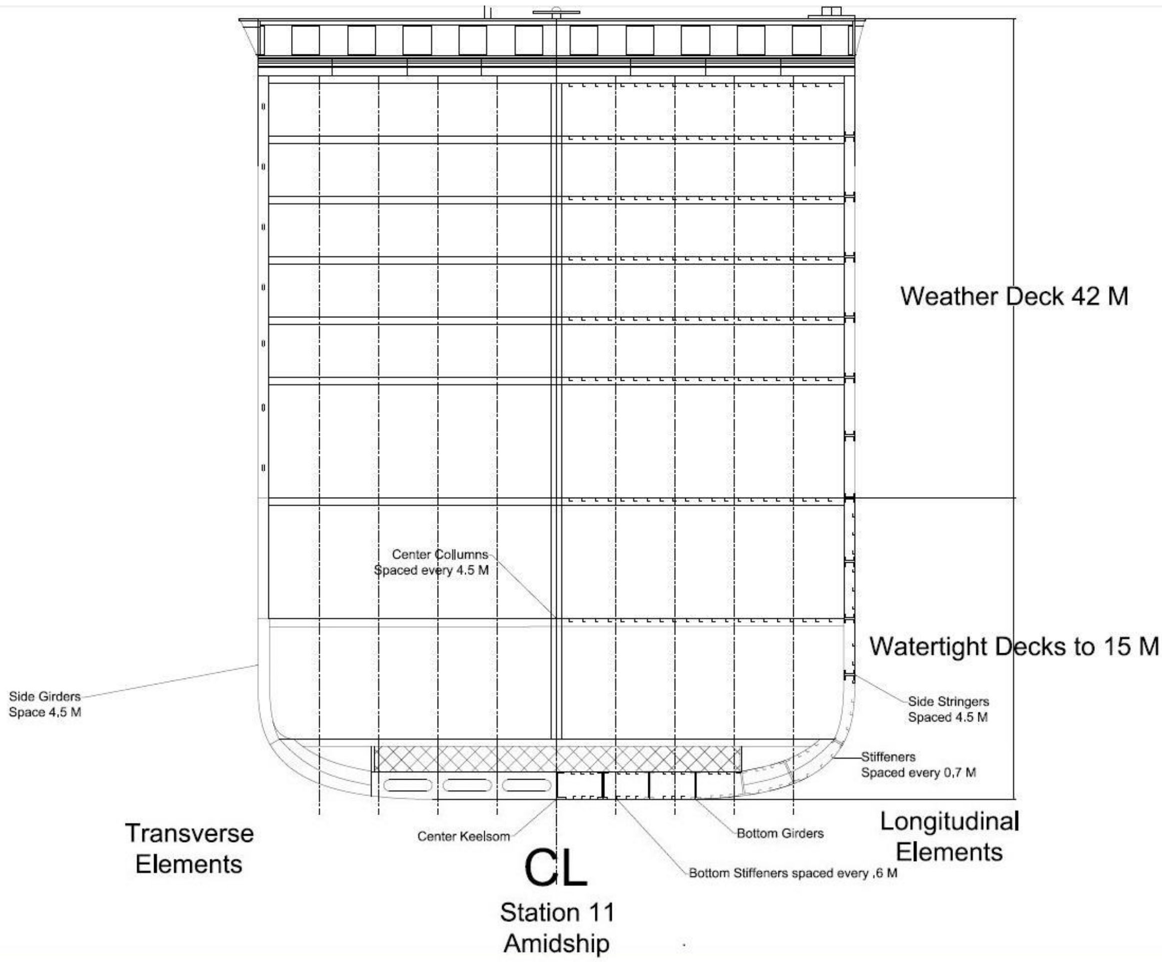


Figure 17 Shows the Tiki Express' amidships with the bridge included.

Inside the amidships section all the transvers and longitudinal elements can be seen. These elements are further explained in the structural chapter of this report. Key features of this figure is the weather deck which is 42 meters above the keel, the uppermost watertight decks located at waterline five were the primary loading ramp at the stern is located, the ballast tanks are represented by the cross hatching section of the amidships section which can hold 3110 tons of seawater. Another notable feature is the longitudinal bulkhead centered amidships. This bulkhead is placed amidships to prevent cargo from sliding from one side of the ship to the other. This can create huge tipping moments and can cause the RORO to capsize. This can occur if one piece of the cargo brakes its moorings and begins to roll freely during extreme weather condition, this can ram in to other cargo and cause all the cargo to break their moorings in a domino effect.

The longitudinal bulkhead follows a row of columns placed amidships. This layout of center columns was chosen to that the structure supporting each deck could be reduced in size since the center columns reduced the span of the decks from 32.2 meters to 16.1 meters, meaning that the material weight was greatly reduced. These columns were space 4.5 meters apart reducing the weight, by reducing the maximum required resistance to bending moment and maximum required section modulus by ABS.

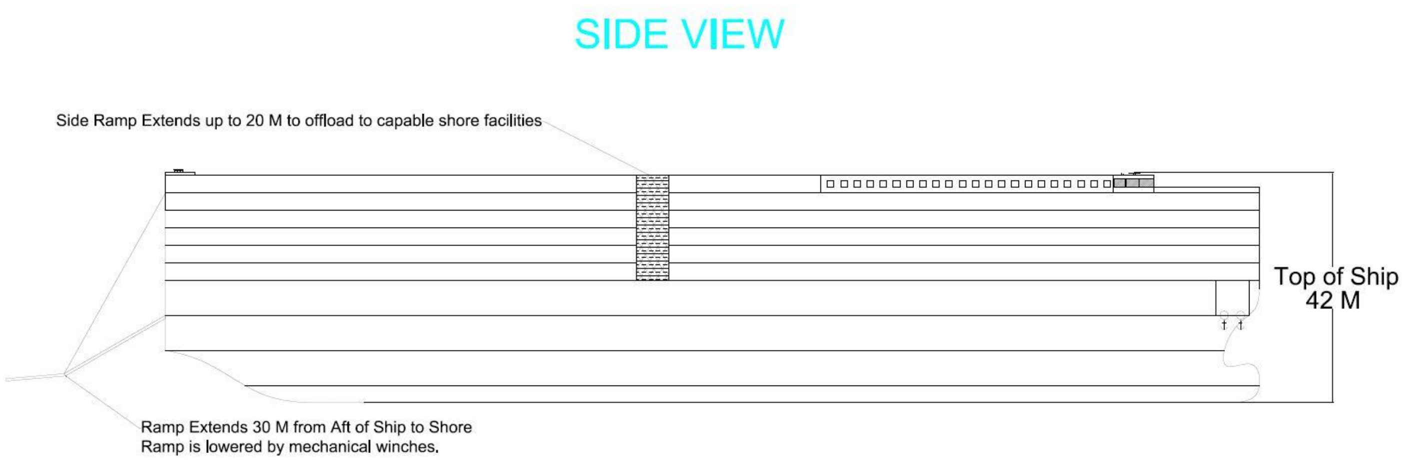


Figure 18 shows the side view of the Tiki Express

The side view shows the location of the bridge on the ship as well as the location of the stern and side ramps. These ramps are both designed by Macgregor. The aft ramp can extend 30 Meters with and the Side ramp can extend 20 meters. Take note that these two ramps are located on two separate waterlines. The stern ramp is located at waterline five while the side ramp is located on waterline six. The reason for this was the side ramp is primarily used to load cars and not heavy equipment, so it is make sense for it to go to decks that are specifically meant to hold cars. The smoke stack is placed on the aft portion of the ship to accommodate the shortest distance for the engine exhaust to travel. The smoke stack is located on the port side of the ship.

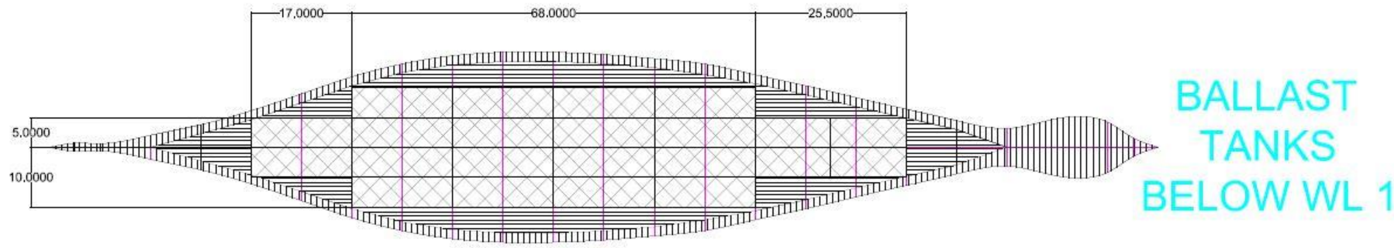


Figure 19 showing the ballast tank tops directly below waterline one.

Figure 19 shows the tank tops, outer and inner hull, and hull representing the outer full with vertical lines and the inner hull with vertical lines. The ballast tanks are represented by the cross hatching. The tanks run for 110.5 meters and are divided into four rows separated by walls. Each tank is 5 meters wide and17 meters long. The tank closest to the front is slightly shorter being only 8.5 meters long, again these tanks can hold 3110 tons of seawater.

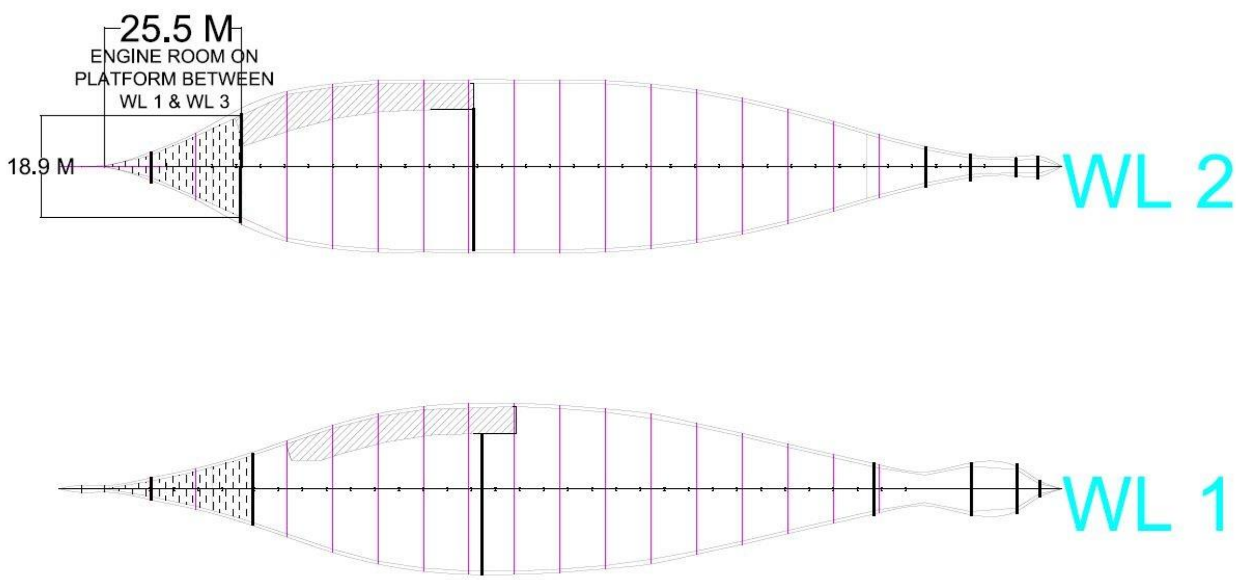


Figure 20 shows water lines one and two which hold the engine room.

Figure 20 shows the bottom deck. Waterline two is the air gap above the deck situated at waterline one. The engine room is located to the aft of the ship and is 25.5 meters long and 18.9

meters wide. It is situated between two bulkheads .The purple lines in this figure show the station lines on the ship. Each station line is 4.5 meters apart and serves to help the reader measure the ship. Other key features in this drawing are the bulkhead located amidships and the car ramp. The ramp lets out towards the aft of the ship and is 5 meters wide and 60 meters long. The bulbous bow is visible in this drawing as well. No cargo is held in the bulbous bow.

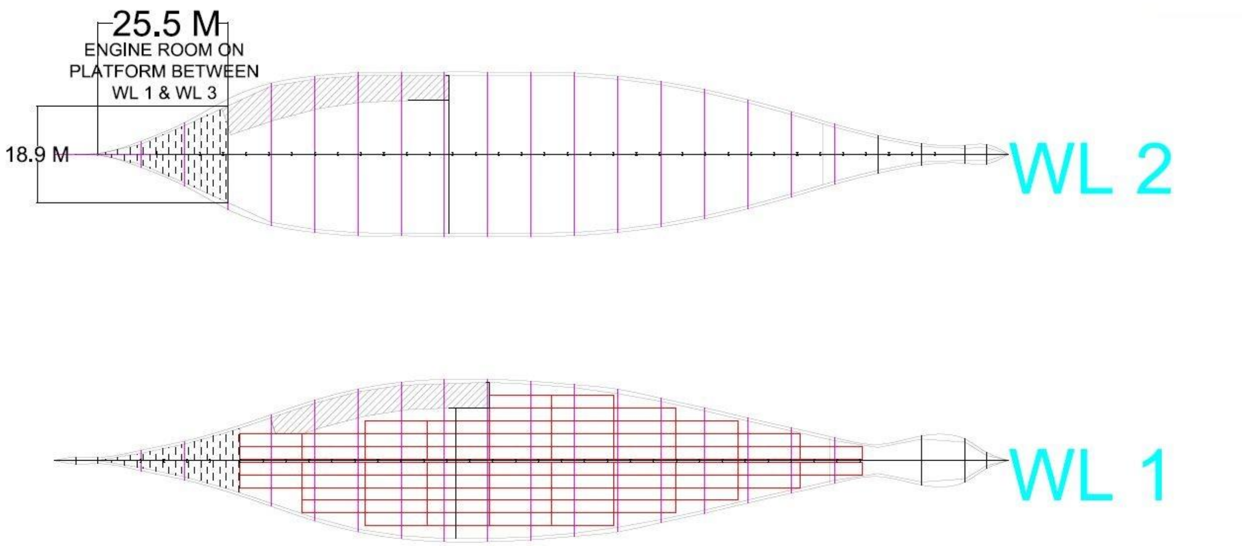


Figure 21 shows the waterlines one and two with cargo held on them.

Figure 21 shows the containers distributed amongst the bottom deck. These containers are double stacked and total 108 in number resulting in a total live load on the deck of 1,115.4 tons.

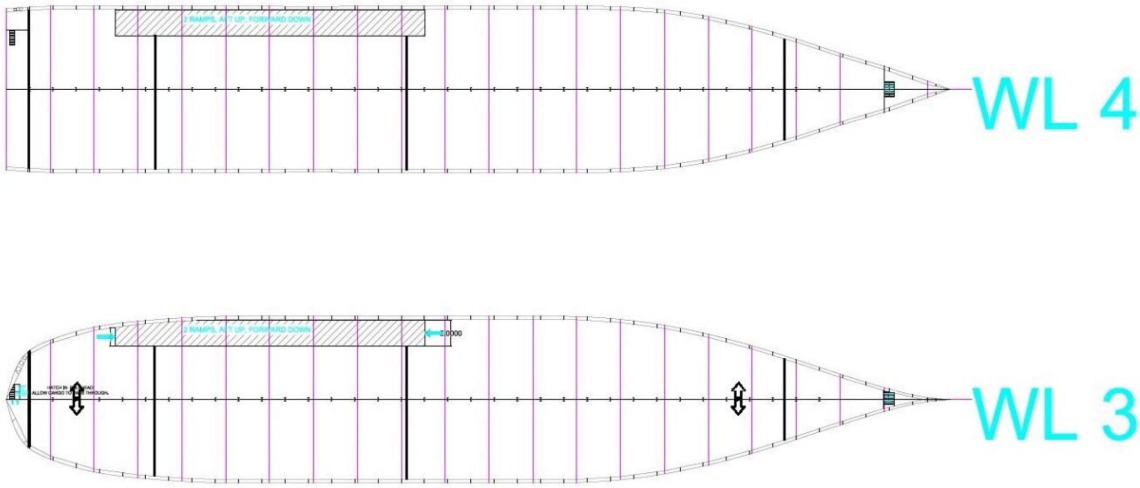


Figure 22 shows the layout at waterlines three and four.

The deck waterline three and the air gap above it at waterline four are displayed above. Notable features in this drawing are the stairways included forward and aft which as well as the ramp with arrows indicating the direction of traffic flow when loading the vessel. The two black arrows located on centerline indicate were an opening in the longitudinal bulkhead is allowing for cargo to be passed through. The transverse bulkheads are nearly completely retractable and are manufactured by *TTSGroup* and are swivel type. This type of bulkhead allows the ship to move the bulkheads out of the way while loading the ship, and then swivel them back into place when fully loaded. The only two transverse bulkheads that are not swivel type are the two collision bulkheads located forward and aft.

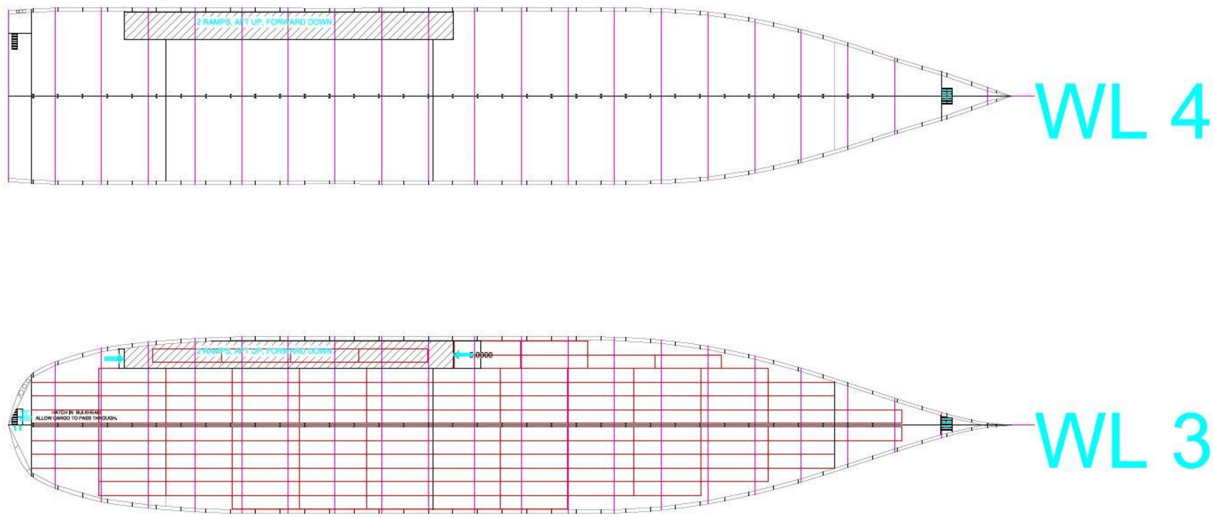


Figure 23 shows the cargo laid out on the deck of waterline 3.

The deck at waterline three is capable of holding 238 containers in a double stacked format, this comes out to a total live load on this deck of 2459 tons.

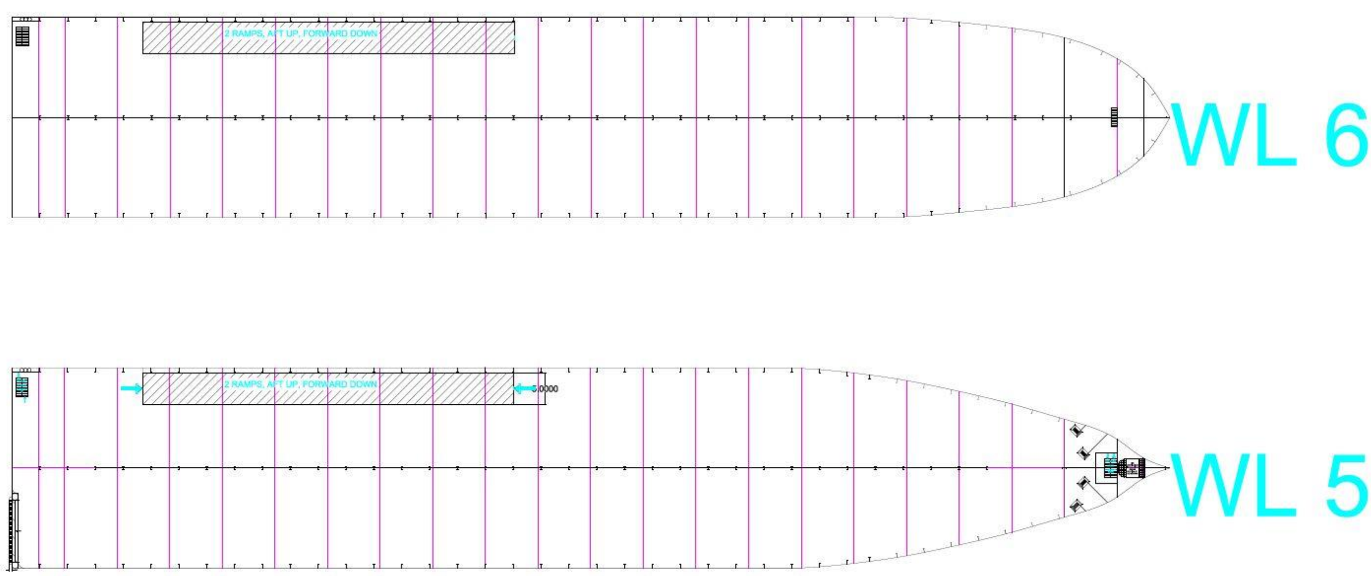


Figure 24 shows the cargo deck layout on the deck of waterline five with the air gap above it at waterline six.

There are several very important observations that need to be made on waterline five. First off this deck is the primary loading decks were the 10 meter wide 30 meter long loading ramp meets the ship. Additionally the stairwell to the engine room is located on the stern on the port side of the ship. Located next to the stairwell running through what was the double hull is the engine exhaust running along the side of the ship. Note that the double hull of the Tiki Express only runs up to waterline five. All decks below waterline five are watertight decks and have water tight ramps. Additionally take note that waterline five also houses the mooring equipment and anchor winches which are located forward of the from collision bulkhead. In addition to this the forward stair well is located here and the primary air intake is on the forward most part of the deck. The air intake has a 3X3 m foot print as well as a nine meter squared air intake to provide the ship with fresh air. Note that this deck is located 8 meters above draft to help prevent this portion of the ship from being flooded. Additionally take note that this is the last deck to include transverse bulkheads.

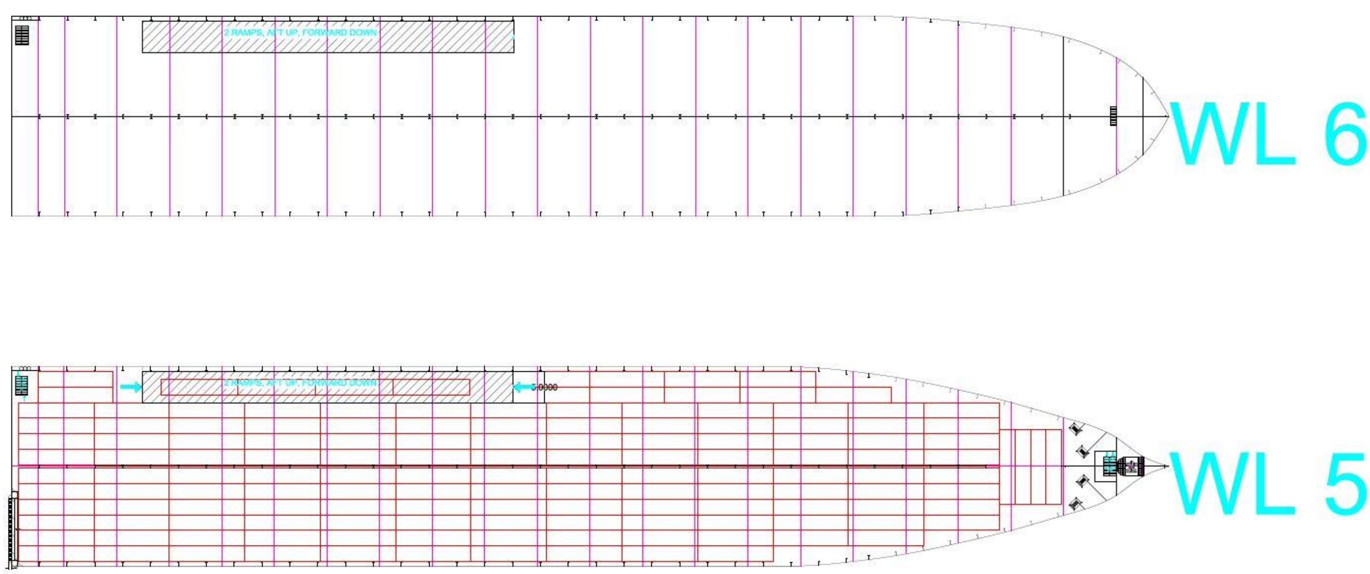


Figure 25 shows the cargo deck layout on the deck of waterline five with the air gap above it at waterline six with cargo placed on the deck

The third cargo deck located at waterline five is shown here holding 290 containers, or a total live load of 2996.3 tons of cargo. Containers on this deck are again double stacked as in the previous decks. Not those decks above this will only be separated by three meters instead of six thus limiting the height at which containers are stacked.

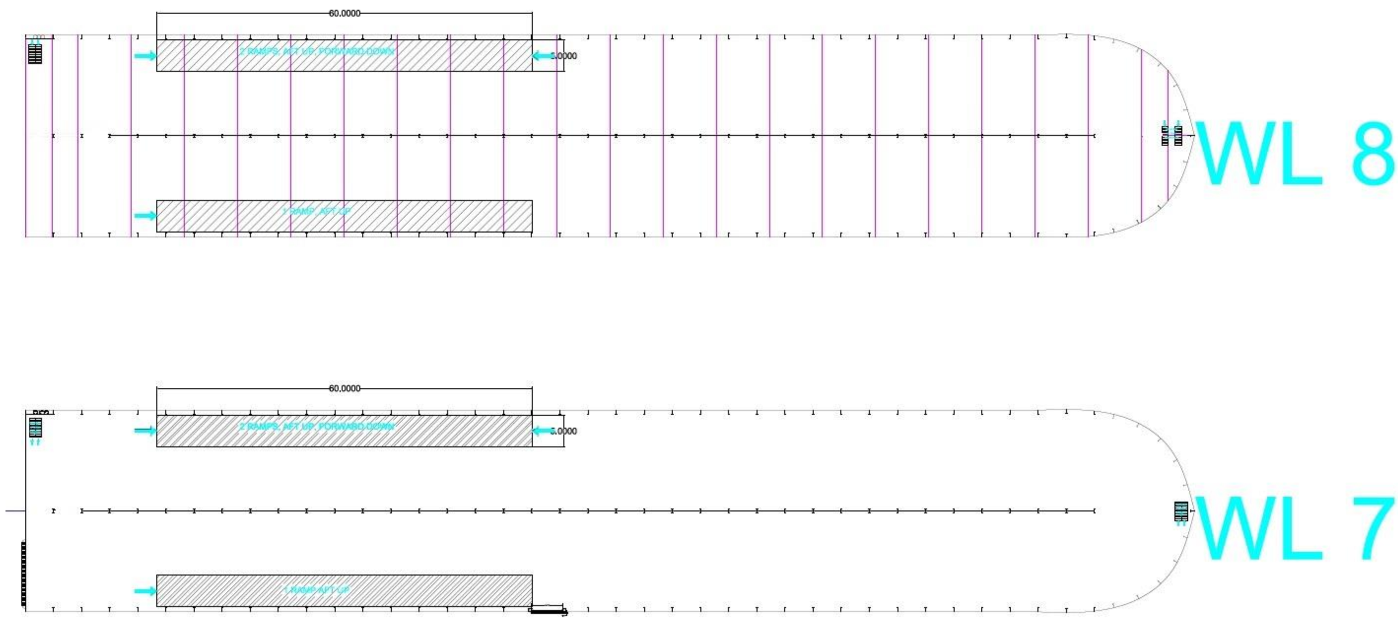
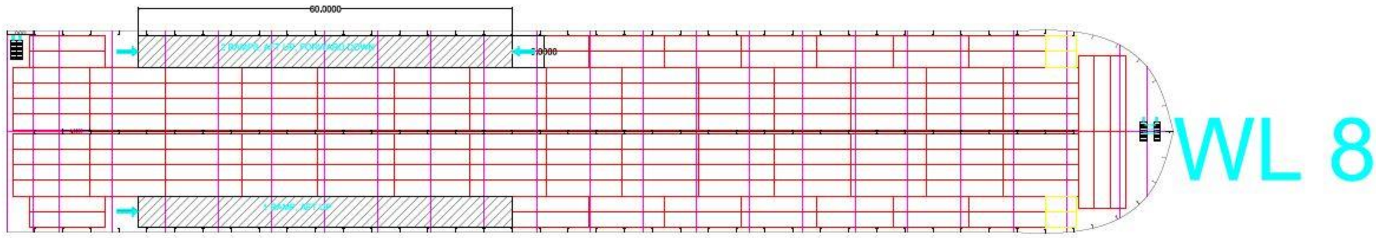


Figure 26 shows waterline seven and six.

Note that above waterline six the ship is roughly the same at every waterline. For waterline seven the station lines have been removed only for this deck to give the viewer a better understanding of how the ship is again laid out. Waterline seven is where the second ramp is included. As mentioned earlier in the paper the Tiki Express uses a two up in the aft and a two down loading scheme, or in short both entrances to the ramps in the front lead down while the back leads up. Also take note of the stairwells in the forward and aft portions of the ship meeting ABS standards of the at least two companion ways between decks. Amidships on waterline seven is where the side ramp is located, it is five meters wide and three meters tall and extends out from the ship 20 meters to a shore facilities.



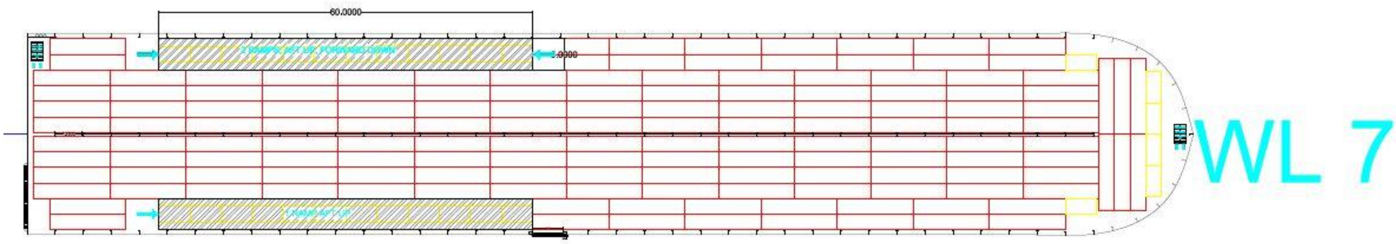


Figure 27 shows the cargo deck layout on the deck of waterline seven and the deck above it located at waterline eight.

Unlike the previous deck waterline seven is primarily optimized for carrying cars however, in order to meet Rotto-Nordics Lines desire of holding 1,000 containers and 1,700 automobiles, these two decks thus carry both containers and cars. These decks in the figure are currently holding 150 containers, and waterline seven is holding and additional 30 cars. With containers the total live load comes out as 1,983.8 tons. These can also carry 30 cars stored in-between these containers.

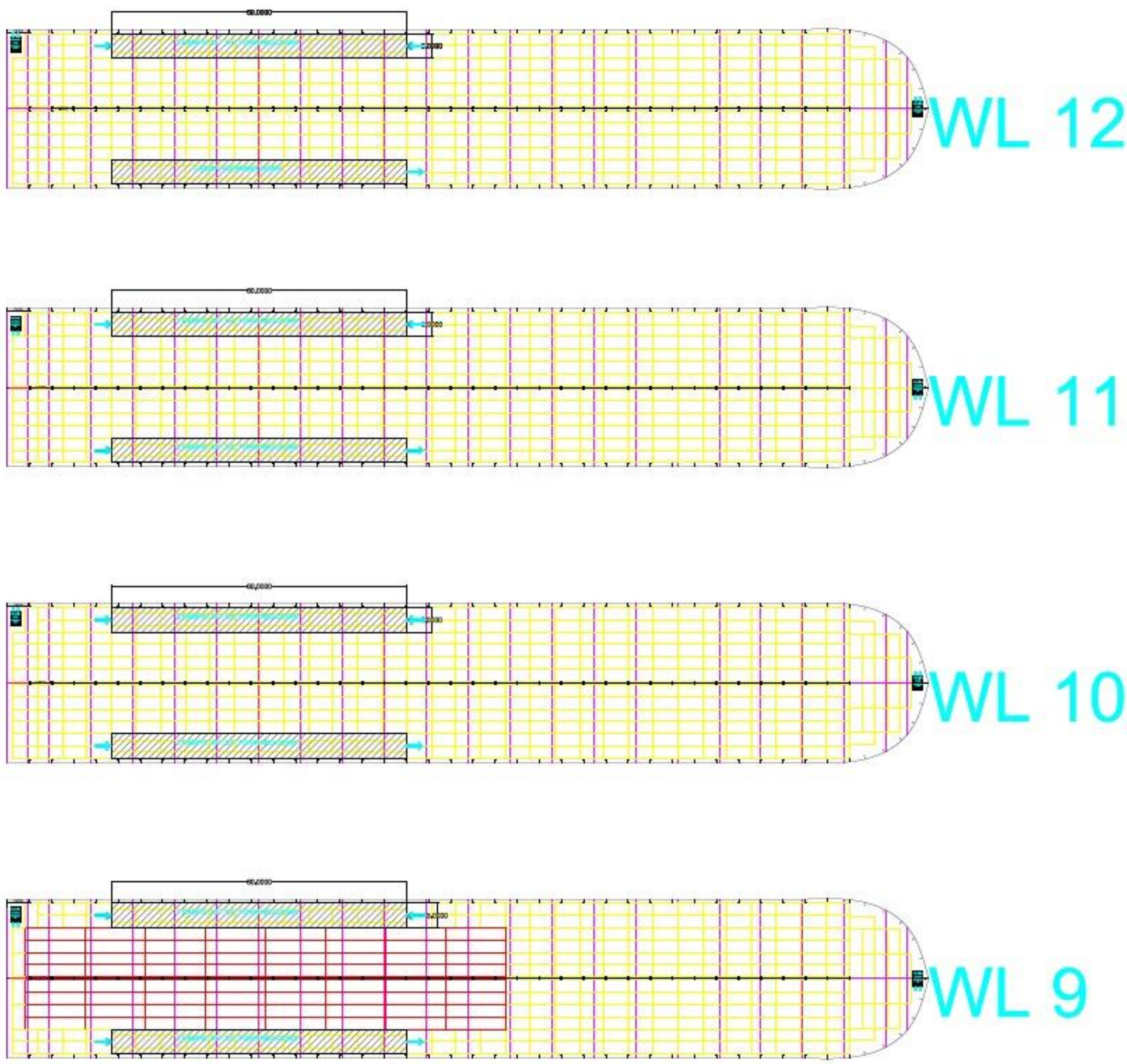


Figure 28 shows waterlines nine through twelve fully loaded as desired by Rotto-Nordic Lines.

The above figure shows the remaining decks fully loaded. All of the decks have the same design and shape with two ramps going down and two ramps going up they are all shown here together. In conclusion the live loadings with the Rotto-Nordic cargo layout is as follows; waterline nine with 243 cars held with 64 containers and a live load of 1,147.2 tons. Waterline ten holds 403 cars, with a total live load of 806 tons, waterline eleven holds 403 cars with a total live load of 806 tons, and waterline twelve also holds 403 cars with a total live load of 806 tons of cargo.

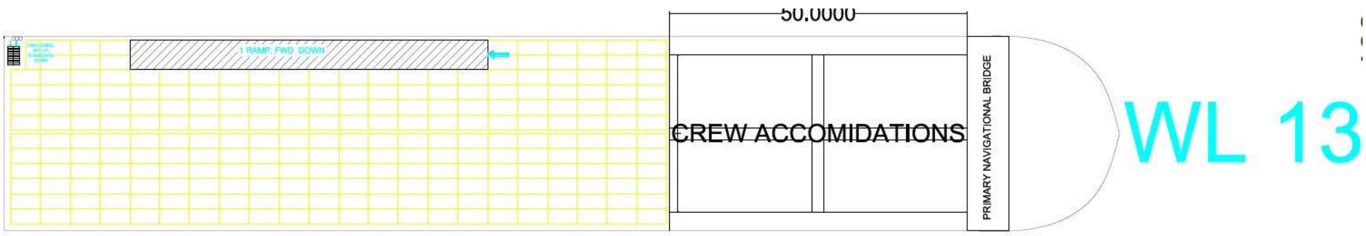


Figure 29 displays the uppermost deck of the ship

Figure 29 shows the very top of the ship. This deck is split into four categories; the open bow, and the primary navigation bridge, a crew accommodations block, and cargo storage. The primary navigation bridge is eight meters by 32.2 meters in size. The crew accommodations block is split into four sections and was designed for 12 crew. The block is 50 meters, by 28 meters in size, and is divided into four sections, crew berthing and living facilities, crew mess and recreations area, an office space for crew to work in including a small gym, and a control room. The rest of the top deck is enclosed and holds 239 cars which at the standard weight of two tons per each car comes out to a total live load of 478 tons.

Chapter 2: Ship Stability

Section 1: Curves of Form

From the table of offsets, the Simpson's method for numerical integration was used to find the area of each water plane. Table 2 shows the steps to calculate the area of water plane. This formula is:

$$A = h\left(\frac{1}{2}y_0 + y_1 + y_2 \ldots y_{n-1} + \frac{1}{2}y_n\right) \qquad \text{(EQ 1)}$$

Table 2 shows the calculations to find the water plane area at waterline one

Sections	Ordinat	Station	1/2 y (m)	x	SM	Ai (m^2	Myi (m^3
Section 1	0	0	0	0	1	0	0
	1	AP	0.6778	4.25	4	2.7112	11.5226
	2	1	0.6153	8.5	1	0.6153	5.23005
Section 2	2	1	0.6153	8.5	1	0.6153	5.23005
	3	2	2.003	17	4	8.012	136.204
	4	3	3.791	25.5	2	7.582	193.341
	5	4	6.1344	34	4	24.5376	834.2784
	6	5	8.9603	42.5	2	17.9206	761.6255
	7	6	11.8113	51	4	47.2452	2409.5052
	8	7	14.0499	59.5	2	28.0998	1671.9381
	9	8	15.3361	68	4	61.3444	4171.4192
	10	9	15.877	76.5	2	31.754	2429.181
	11	10	15.9122	85	4	63.6488	5410.148
	12	11	15.5394	93.5	2	31.0788	2905.8678
	13	12	14.854	102	4	59.416	6060.432
	14	13	13.6923	110.5	2	27.3846	3025.9983
	15	14	12.1587	119	4	48.6348	5787.5412
	16	15	10.3201	127.5	2	20.6402	2631.6255
	17	16	8.3242	136	4	33.2968	4528.3648
	18	17	6.3886	144.5	2	12.7772	1846.3054
	19	18	4.4653	153	4	17.8612	2732.7636
	20	19	3.154	161.5	2	6.308	1018.742
	21	20	3.5	170	4	14	2380
	22	21	3.5	178.5	1	3.5	624.75
Section 3	22	21	3.5	178.5	1	3.5	624.75
	23	FP	1.5743	182.75	4	6.2972	1150.8133
	24	22	0	187	1	0	0
Section 1 Sum	3.3265	16.75265					
Section 2 sum	565.6573	51565.26105					
Section 3 sum	9.7972	1775.5633					

Table 3 shows the calculations to find the water plane area at water line 1

Station intervals, h=Lpp/22			8.5	
h1 =	0.5*h =		4.25	4.25
h2 =	1*h =		8.5	8.5
h3 =	0.5*h =		4.25	4.25
S1 Integral =	(1/3)*h1*(S1 Sum)		4.71254	23.73292083
S2 Integral =	(1/3)*h2*(S2 Sum)		1602.7	146101.573
S3 Integral =	(1/3)*h3*(S3 Sum)		13.8794	2515.381342
Total =			**3242.58**	**297281.3745**
			A (m^2)	My (m^3)
Xc =			91.6806	m, from AP

In order to calculate the water plane area at our designed draft of 7m, offset values were extracted from the body plan. A line was drawn up 7m from the keel on the center line and then lines were drawn out to each station and measured. These values were then put into a similar format as Table 3. The area of the water plane at the designed draft is shown in Table 3.

Table 4 Shows the calculations for the area of the water plane at draft.

Sections	Ordinate	Station	1/2 y (m)	x	SM	Ai (m^2)	Myi (m^3)
Section 1	0	0	0	0	1	0	0
	1	AP	0.0167	4.25	4	0.0668	0.2839
	2	1	0.1773	8.5	1	0.1773	1.50705
Section 2	2	1	0.1773	8.5	1	0.1773	1.50705
	3	2	2.6149	17	4	10.4596	177.8132
	4	3	6.4	25.5	2	12.8	326.4
	5	4	11.0563	34	4	44.2252	1503.6568
	6	5	14.1055	42.5	2	28.211	1198.9675
	7	6	15.311	51	4	61.244	3123.444
	8	7	16	59.5	2	32	1904
	9	8	16.1	68	4	64.4	4379.2
	10	9	16.1	76.5	2	32.2	2463.3
	11	10	16.1	85	4	64.4	5474
	12	11	16.1	93.5	2	32.2	3010.7
	13	12	16.1	102	4	64.4	6568.8
	14	13	15.9455	110.5	2	31.891	3523.9555
	15	14	15.3341	119	4	61.3364	7299.0316
	16	15	14.2782	127.5	2	28.5564	3640.941
	17	16	12.7329	136	4	50.9316	6926.6976
	18	17	10.7634	144.5	2	21.5268	3110.6226
	19	18	8.4247	153	4	33.6988	5155.9164
	20	19	5.9252	161.5	2	11.8504	1913.8396
	21	20	3.7464	170	4	14.9856	2547.552
	22	21	2.0642	178.5	1	2.0642	368.4597
Section 3	22	21	2.0642	178.5	1	2.0642	368.4597
	23	FP	1.6846	182.75	4	6.7384	1231.4426
	24	22	1.8615	187	1	1.8615	348.1005
		Section 1 Sum				0.2441	1.79095
		Section 2 sum				703.5583	64618.80455
		Section 3 sum				10.6641	1948.0028
		Station intervals, h=Lpp/22					8.5
		h1 =		0.5*h =		4.25	4.25
		h2 =		1*h =		8.5	8.5
		h3 =		0.5*h =		4.25	4.25
		S1 Integral =		(1/3)*h1*(S1 Sum)		0.345808333	2.537179167
		S2 Integral =		(1/3)*h2*(S2 Sum)		1993.415183	183086.6129
		S3 Integral =		(1/3)*h3*(S3 Sum)		15.107475	2759.670633
		Total =				**4017.736933**	**371697.6414**
						A (m^2)	My (m^3)
		Xc =				92.51418089	m, from AP

In order to calculate the water plane area at our designed draft of 7m, offset values were extracted from the body plan. A line was drawn up 7m from the keel on the center line and then lines were drawn out to each station and measured. These values were then put into a similar format as table %%%. The area of the water plane at draft is 4017.737 m2.

To find volume at the designed draught, another Simpson's approximation was used. The areas of the water planes at 0, 3.5, and 7m were found, and put into a similar table as table.

Table 5 Shows the steps to calculate the volume at draft.

DWL 7m			
Water line number	Water plane area	SM	FA
0	0	1	0
1	2715.777483	4	10863.11
2	3394.817833	2	6789.636
3	3795.054783	4	15180.22
4	4017.736933	1	4017.737
		Total =	36850.7
		Volume =	21496.24

This process was repeated for different drafts. By finding the volume at different drafts a graph was produced showing different curves of form for this ship design. The block coefficient was calculated using this formula:

$$C_B = \frac{\nabla}{LBT} \tag{EQ 2}$$

Where

$\nabla = volume$

$L = length\ on\ the\ designed\ water\ line$

$B = breadth\ amidships\ at\ the\ designed\ water\ line$

$T = draft\ to\ the\ designed\ water\ line$

The block coefficient for the ship was calculated by a combination of hand calculations and measuring from AutoCAD. A sample calculation for the designed draft is:

$$C_B = \frac{21496.24}{(32.2 * 187 * 7)} = 0.530$$

This value for the block coefficient is relatively low for a Ro-Ro, however, we based our design off of the general arrangement of our parent ship, the Alliance Fairfax. The prismatic coefficient was calculated using:

$$C_P = \frac{\nabla}{A_m L} \qquad \text{(EQ 3)}$$

where,

$A_m = area\ of\ the\ midship\ section\ at\ draft\ T$

The area of the amidships section was calculated at the designed draft by using the area tool on AutoCAD on the body plan for the ship design. A sample of this calculation is:

$$C_P = \frac{21496.24}{(211.2294 * 187)} = 0.542$$

The vertical prismatic coefficient was calculated using this formula:

$$C_{vp} = \frac{\nabla}{T A_w} \qquad \text{(EQ 4)}$$

The water plane area coefficient was calculated using:

$$C_{wp} = \frac{A_w}{L_{WL} B} \qquad \text{(EQ 5)}$$

Where

$L_{WL} = length\ of\ the\ water\ plane\ area$

The amidships section coefficient was found using:

$$C_M = \frac{A_m}{BT} \qquad \text{(EQ 6)}$$

These calculations were repeated for a draft of 1.75, 3.5, and 6m. These values are plotted on a graph shown in Figure 30.

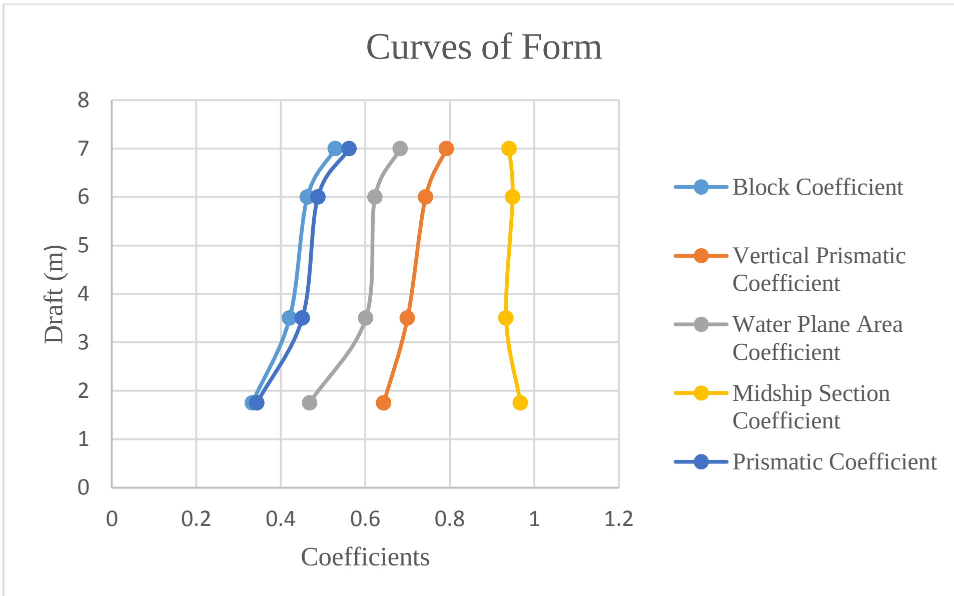


Figure 30 A graph showing the Curves of Form for the Tiki Express.

The displacement of the Tiki Express at draft is 21496.24 tons. By knowing the displacement and its relationship to light weight and dead weight, different stability conditions were calculated. A deadweight of 15000 tons was assumed, and a light weight of 7,850 tons and was calculated using this formula:

$$\Delta = Lightweight + deadweight$$

The draft for light weight, full load, half load, and ballast were calculated using the formula of a trend line of a graph of the draft versus the underwater volume shown in Figure 31.

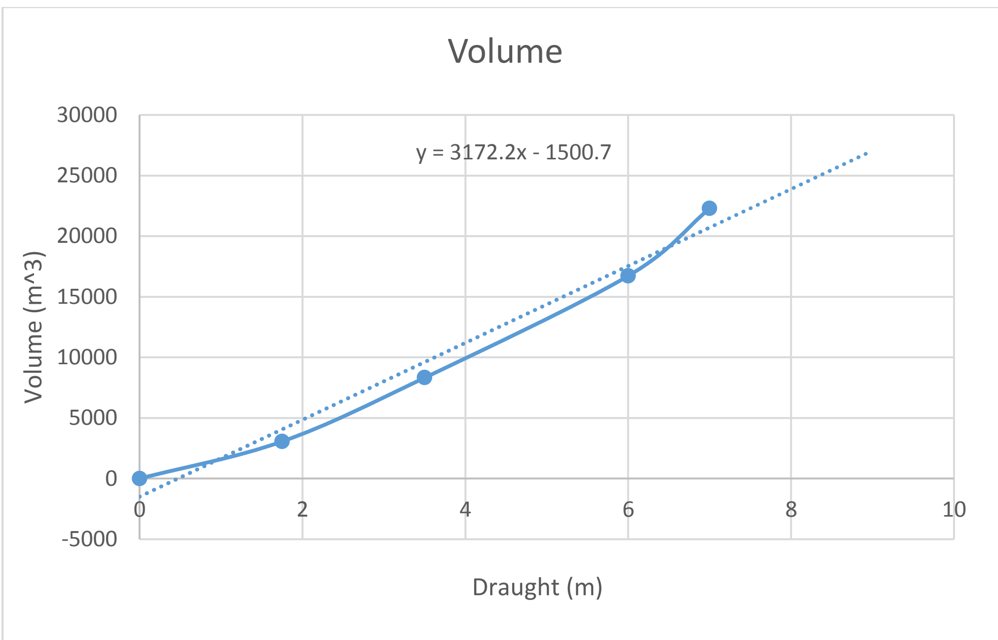


Figure 31 shows the relationship between draught and volume.

The draughts for full load, half load, light ship, and ballast condition are 7, 4.94, 2.64, 1.43m respectively. Applying Simpson's rule to our table of offsets, the water plane areas associated with these draughts were calculated. The center of buoyancy for these drafts were estimated using this formula:

$$\overline{KB} = T\left(\frac{A_W}{A_W + (\nabla/_T)}\right) \tag{EQ 7}$$

The center of buoyancy was found to be 4.09, 2.81, 1.47, 0.8m for full load, half load, light ship, and ballast conditions, respectively. The metacentric radius is found using this equation:

$$\overline{BM} = \frac{I}{\nabla} \tag{EQ 8}$$

These values were found by applying Simpson's method to the table of offsets to obtain the moment of inertia of the water plane and the volume at each respective draught. The distance from the keel to the metacenter was found using this equation:

$$\overline{KM} = \overline{BM} + \overline{KB} \tag{EQ 9}$$

Section 2: Center of Gravity

The center of gravity was found using this equation:

$$\overline{KG} = \frac{\sum w_i \overline{Kg_i}}{\sum w_i} \tag{EQ 10}$$

We calculated $\overline{KG}$ values for full load, half load, and ballast conditions by using the light ship weight and light ship $\overline{Kg}$ obtained from Genie. The light weight of the ship is $7850\ tons$ at a $\overline{Kg}$ of $18.53\ m$.

Table 5 Cargo Loading Conditions for Full Load and Half Load

Deck	Full Load (tons)	Half Load (tons)	Height (m)
10	478	239	40.5
9	806	403	37.5
8	806	403	34.5
7	806	403	31.5
6	1234	573.6	28.5
5	1815	774.9	25.5
4	1755	991.9	22.5
3	3393	1498.15	18
2	2784.6	1229.5	12
1	1263.6	557.7	6
Light ship	7850	7850	18.53
Ballast	3110	3110	1.5

$\overline{KG}$ under full loading conditions is calculated using equation 10.

$$\overline{KG} full\ load = (6 * 1263.6 + 12 * 2784.6 + 18 * 3393 + 22.5 * 1755 + 25.5 * 1815 + 28.5 * 1234 + 31.5 * 806 + 34.5 * 806 + 37.5 * 806 + 40.5 * 478 + 7850 * 18.53) * (1263.6 + 2784.6 + 3393 + 1755 + 1815 + 1234 + 806 + 806 + 806 + 478)^{-1} = \frac{471273 tons * m}{22992 tons} = 20.50\ m$$

Despite heavier cargo being placed on lower decks, the majority of the cargo weight is distributed above the $\overline{Kg}$ of the light ship weight. Thus, a $\overline{KG}$ value of $20.69\ m$ is reasonable.

$\overline{KG}$ for half loading conditions is calculated as follows:

$$\overline{KG}\,half\ load = (6 * 631.8 + 12 * 1392.3 + 18 * 1696.5 + 22.5 * 877.5 + 25.5 * 907.5 + 28.5 * 617.4 + 31.5 * 403 + 34.5 * 403 + 37.5 * 403 + 40.5 * 239 + 7850 * 18.53) * (631.8 + 1392.3 + 1696.5 + 877.5 + 907.5 + 617.4 + 403 + 403 + 403 + 239 + 7850)^{-1} = \frac{308369 tons * m}{15421 tons} = 19.99\ m$$

Since the only load within the ship that was not halved was the light weight of the ship itself, $\overline{KG}$ at half loading conditions is less than $\overline{KG}$ at full loading conditions.

For ballast conditions, the only weights within the ship are the ballast water and the lightweight of the ship. $\overline{KG}$ for the ballast condition is calculated as follows:

$$\overline{KG} ballast = \frac{3110 * 1.5 + 7850 * 18.53}{1.5 + 18.53} \frac{tons * m}{tons} = 13.70\ m$$

This is a reasonable $\overline{KG}$ since almost a third of the load is distributed near the very bottom of the ship.

The metacentric height was found using this equation:

$$\overline{GM} = \overline{KM} - \overline{KG} \qquad \text{(EQ 11)}$$

Table 6 shows the results for the transverse stability of the Tiki Express at four different conditions.

Table 6 Stability for the Tiki Express.

	Full Load	Half load	Light ship	Ballast
Draught	7	4.94	2.64	3.59
KB	4.13	2.81	1.47	1.98
BM	18.19	24.53	37.911	28.18
KM	22.32	27.34	39.381	30.16
KG	20.7	20.13	18.53	13.7
GM	1.62	7.21	20.851	16.46

The positive values for GM indicate a stable ship. The GM values also go up as the load on the ship gets lighter. The longitudinal stability was calculated similarly. The center of buoyancy and the center of gravity did not change, but the metacentric radius grew. Table 7 shows the longitudinal stability for the Tiki Express.

Table 7 Longitudinal stability for the Tiki Express.

	Full Load	Half load	Light ship	Ballast
Draught	7	4.94	2.64	3.59
KB	4.13	2.81	1.47	1.98
BML	912.4	1355.98	2316.59	1818.7
KML	916.53	1358.79	2318.06	1820.7
KG	20.7	20.13	18.53	13.7
GML	895.83	1338.66	2299.53	1807

The positive values indicate a stable ship. The metacentric height increases as the load on the ship goes down.

Section 3 Genie/HydroD

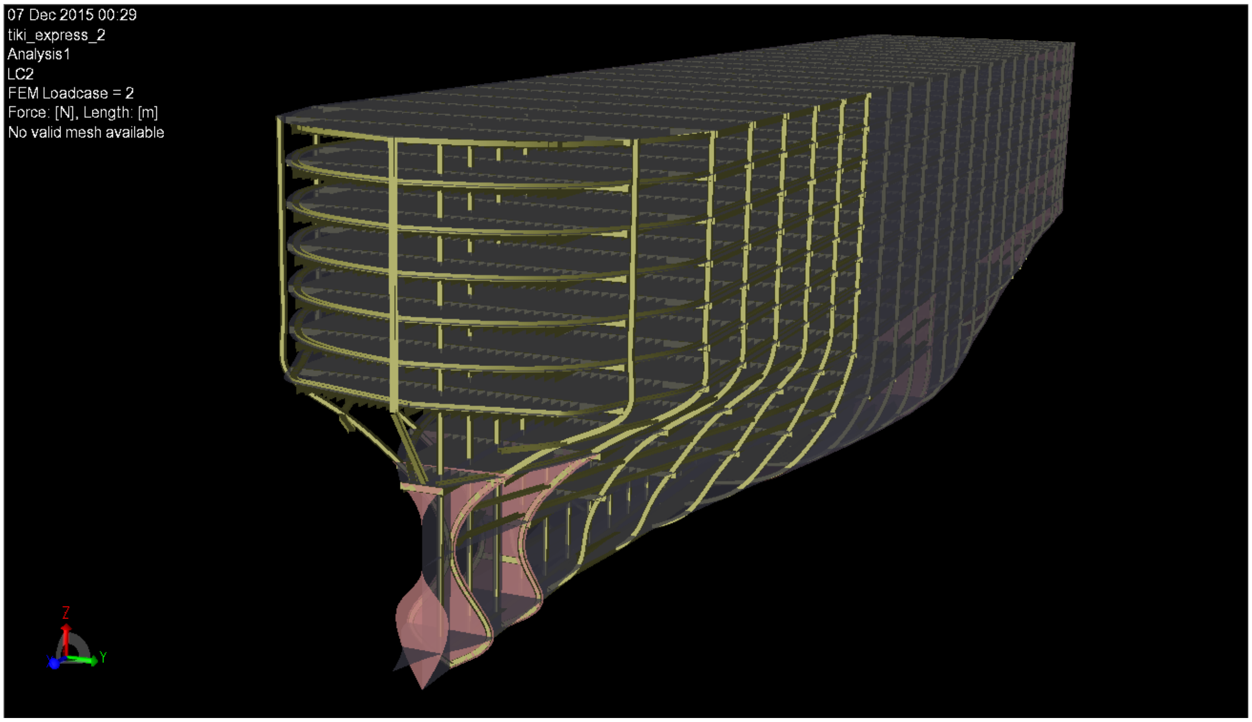


Figure 32 A Drawing in Genie

Genie and HydroD are naval design and analysis programs developed by DNV-GL. Figure 32 represents one of our models created in Genie. Genie is used for generating models of ships that will be used in HydroD, which calculates stability and hydrodynamics. Genie provided an essential role in obtaining the lightweight $\overline{KG}$ and displacement of the *Tiki Express* while HydroD generated hydrostatic and hydrodynamic information.

The preliminary Genie drawing was generated in order to learn how Genie operates. This model was expanded upon throughout the design process. The second Genie drawing was generated without any beams or internal structures. This model was based on an updated table of offsets with waterlines set at 3.5 meters apart. The bulbous bow was included as well. Once the table of offsets was completed, the third iteration of the Genie drawing was generated. The preliminary bottom structural elements, which included the center keelsome, bottom girders, and bottom stiffeners, were incorporated into this design, as seen in Figure 33.

Figure 33: Bottom Structure for the Third Iteration

The focus of the fifth iteration was to create a structure that fit light ship requirements, as seen in Figure 34.

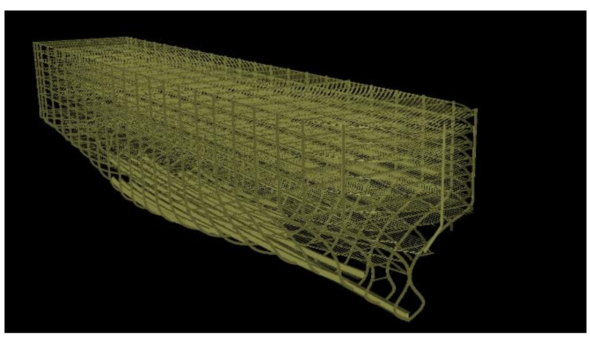


Figure 34 Structure of the Tiki Express

Critical errors prevented this design from being imported into HydroD. The final iteration of the Genie model was then designed to prevent the same errors. The structure of the final design is shown in Figure 35.

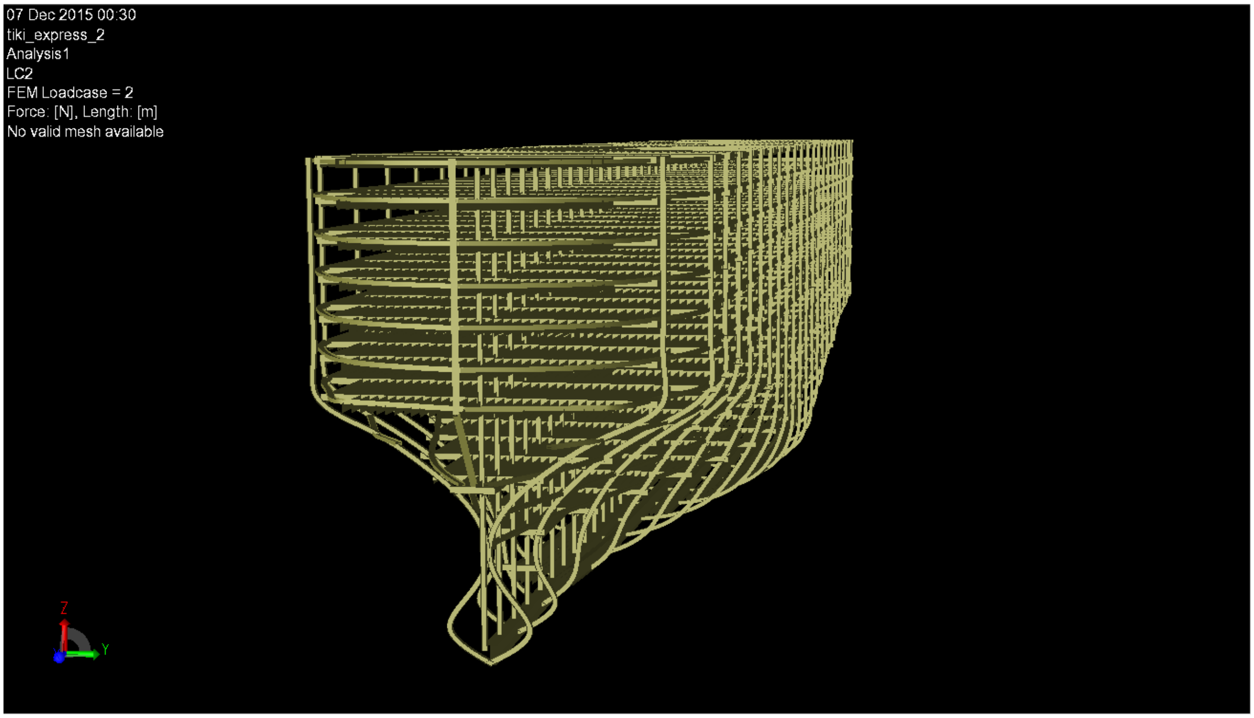


Figure 35 Final Version of Ship Structure in Genie

After creating the final iteration of the ship, a panel model and structural model were generated. After running a mesh analysis on each, FEM files were generated and imported into HydroD. HydroD then calculated the center of buoyancy, total mass, metacentric height, center of floatation, trim moment, and deck immersion angles. Standard wind velocity and water density conditions of $1\frac{m}{s}$ and $1025\frac{kg}{m^3}$, were applied.

Section 4 HydroD Data

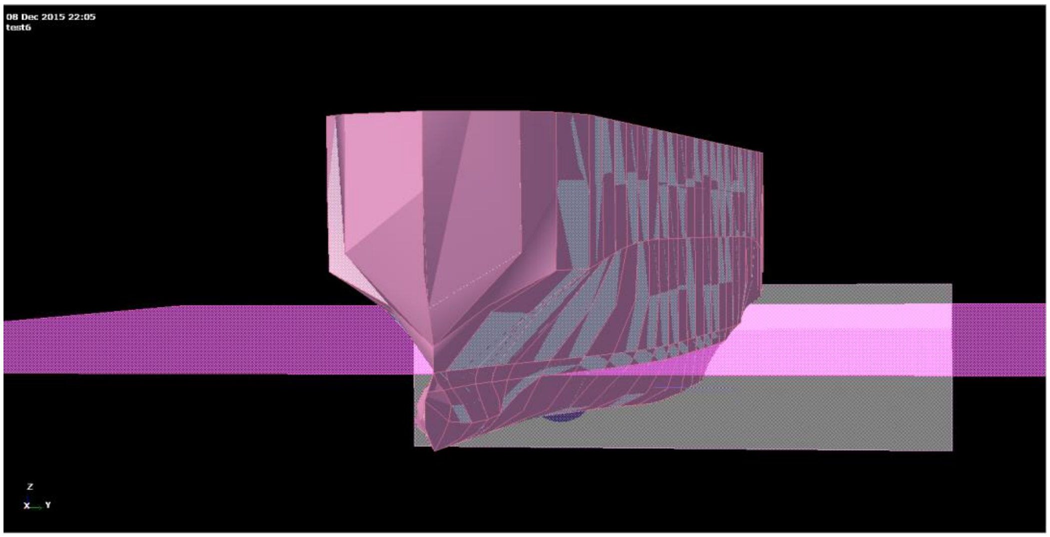


Figure 36: The Tiki Express in HydroD

The final model in HydroD is shown in Figure 36 where the pink plane represents the $7\ m$ draft. The GZ curve found through HydroD is displayed in Figure 37. This curve indicates that the ship will have a maximum righting arm of 1.8 meters which occurs at 42^{o} and -42^{o} respectively. Despite the ship being symmetric, there is a stability error of 0.1415^{o}. This is due to slight, non-symmetric variances within the generated mesh for the wetted surface by Genie.

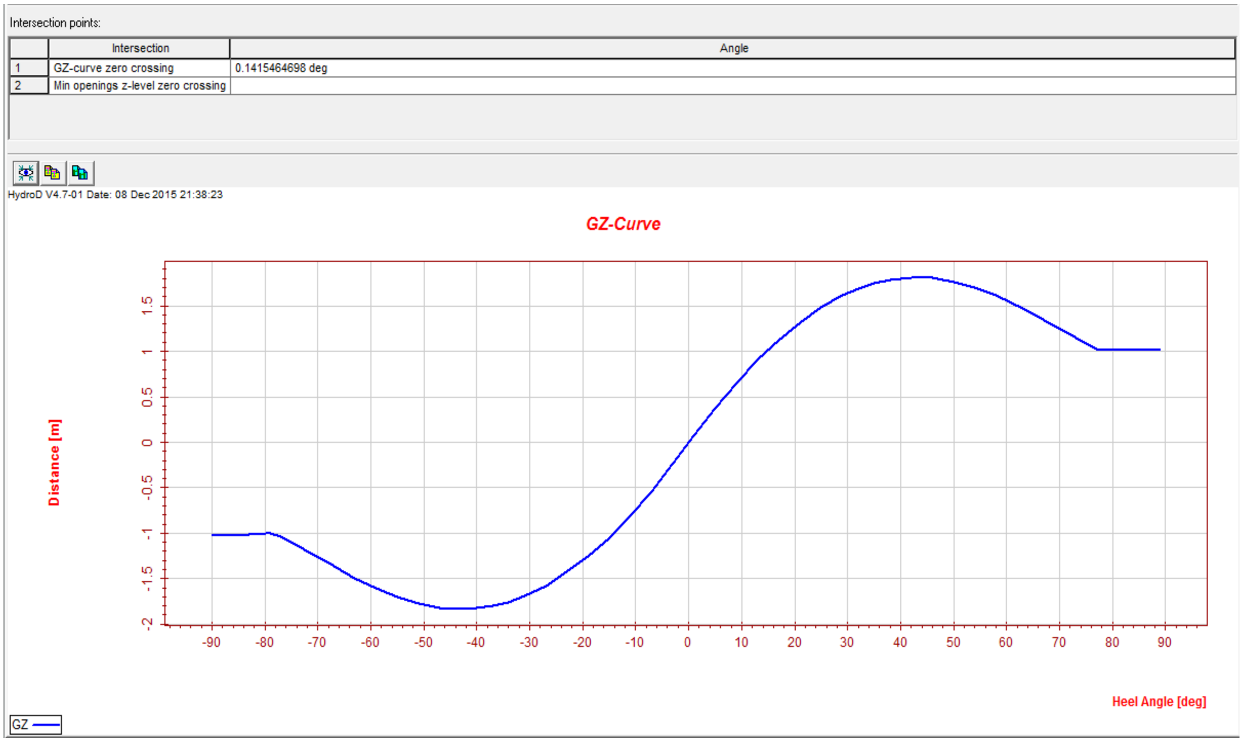


Figure 37: GZ Curve at Draft of 7 *m*

According to HydroD, the top starboard deck breaks the water surface when a heeling angle of 90 degrees is encountered. The top port deck does not touch the water surface until a heeling angle of 89 degrees is reached. This variation of one degree of heel is due to the slight error in the mesh generation mentioned previously.

The HydroD analysis of the final Genie model produced hydrostatic stability values that are listed in Table X:

Table 7: Results of HydroD Analaysis

Center of Floatation	82.79 m from AP
Center of Bouyancy	85.57 m from AP
KB	3.89 m
GM_T	4.68 m
∇	21422 m^3
Δ	21,958 $tons$
Trim Moment	$2.978 * 10^5$ $Kn * m$

The values for ∇ and Δ obtained through Simpson's rule are compared to those obtained through HydroD:

$$\nabla\ Error = \frac{\nabla\text{Simpson's} - \nabla HydroD}{\nabla\text{Simpson's}} = \frac{21422 - 22289}{21422} * 100\% = 4.0\%$$

$$\Delta\ Error = \frac{\Delta\text{Simpson's} - \Delta HydroD}{\Delta\text{Simpson's}} = \frac{22846 - 21598}{22846} * 100\% = 5.5\%$$

This error is expected since Simpson's rule is a numerical method of obtaining the volume and displacement while HydroD is an exact method. From Genie, we were able to find the total tonnage of the light ship and its $\overline{Kg}$:

Table 8: Genie calculations

Light Ship Tonnage	7,850 $tons$
Light Ship $\overline{Kg}$	18.53 m

These values are appropriate since the lower half of the ship contains the heaviest structural elements, such as the center keelsome, and the ship's engine.

Chapter 3: Ship Structure

Symbols:

a: wheel imprint parallel to longer edge

B: Breadth of vessel

b: wheel imprint perpendicular to longer edge

c: coefficient

C: constant coefficient

C_b: block coefficient (not to be less than .6)

d: draft of vessel

D_{DB}: depth of double bottom

h=distance to top watertight deck from keel

I: moment of interia

k: constant coefficient

K: constant coefficient

l: distance between girders

L: Length of vessel

n: constant coefficient

q=235/yield strength

S: spacing

s: stiffener spacing

SM: section modulus

t: thickness

Chapter 2 Symbols for Damage Stability

∇: underwater volume

a: area of flooded section

b: change in bilge

BM_l: longitudinal metacentric radius

BM_t: transverse metacentric radius

I_l: longitudinal moment of inertia

I_t: transverse moment of inertia

KB: center of buoyancy

KG: center of gravity

S: parallel sinkage

V_{co}: volume of flooded region

X_a: center of flooded region with respect to midship

X_F': Center of floatation movement to aft

Y_a: center of flooded region with respect to centerline

Y_F': Center of floatation movement to port

Z_{co}: center of flooded region with respect to keel

Ө: angle of trim

μ: volume permeability

μ_s: surface permeability

Φ: angle of heel

General

The ship structure section of this report will be discussed in seven separate sections consisting of the bottom structure, deck structure, side structure, mid-ship section, bow and stern structure, bulkheads, and finally stiffener and girder dimensions.

Section 1 Bottom structure:

The following information in Table 9 shows the assumptions made for the bottom structure of the ship. These assumptions were made with information from the Tiki Express design or the ABS manual in order to maximize or minimize spacing or lengths to fit all sections of the ship to have a consistent ship structure. All calculations made in this section regarding thickness and section modulus are minimum value requirements by ABS and therefore can be increased at our discretion.

Table 9: Bottom structure values and calculations

Assumptions:	
stiffener spacing [m]	0.6
distance between supports [m]	2.5
draft [m]	7
breadth [m]	32.2
overall length [m]	187
length for open floors [m]	2.5

1.1 *Center Keelson:*

This center girder is to be continuous .75L in the middle of the ship. When approaching the bow and stern of the ship the thickness of the structure changes. The following equations were used to calculate the center keelson:

1.1(a) *Thickness amidships*

$t=56*L*10^{-3}+5.5$ [mm]

$t=15.972$ [mm]

1.1(b) *Thickness at bow and stern*

$t=.85*(56*L*10^{-3}+5.5)$ [mm]

$t=13.5762$

1.1(c) *Depth of double bottom*

$D_{DB}=32*B+190\sqrt{d}$ [mm]

$D_{DB}=1533$ [mm]

1.2 *Side Girders:*

These girders run next to the center keelson and help support the structure around it and at a spacing of 3 [m] from the center keelson, see figure 1.

Thickness:

$t=.036*s+4.7$ [mm]

$t=4.808$ [mm]

1.3 *Floors:*

1.3.1 *Solid Floors:*

This consists of the plating on the double bottom between the inner and outer bottom of the double bottom tank. These run from the mid-ship to the side of the ship and can contain manholes and hatch ways.

Thickness

$t=.036*L+4.7+c$ [mm]

**c=1.5 for boilers (this coefficient was used for the entire ship to remain consistent)*

$t=11.432$ *[mm]*

1.3.2 *Open Floors:*

Open floors are placed where solid floors are not fitted on every frame. These floors are fitted at each frame between the solid floors. A section modulus equation is used to determine the necessary strength of that floor:

Section Modulus

$SM=7.8*c*h*s*l^2$ *[cm³]*

$SM= 102.375$ *[cm³]*

1.4 *Inner Bottom Plating:*

This is the plating on the inner side of the double bottom structure.

Thickness:

t=37*L*10^(-3)+.009*s*10^(3)-c [mm] *c=.5 for transverse framing

t=11.819 [mm]

1.5 *Immersed Bow Plating:*

This is the side plating of the section of the ship that will be underwater towards the bow section of the ship.

Thickness:

$t = 0.05*(L + 20) + 0.009*s$ *[mm]*

t=15.84 [mm]

1.6 *Stiffeners:*

Stiffeners for all sections of the ship are calculated based on a section modulus requirement and then sized from there.

Section Modulus:

SM=7.8*c*h*s*l^2 *c=.715 since struts will be located on the ship

SM=460.1025 [cm^3]

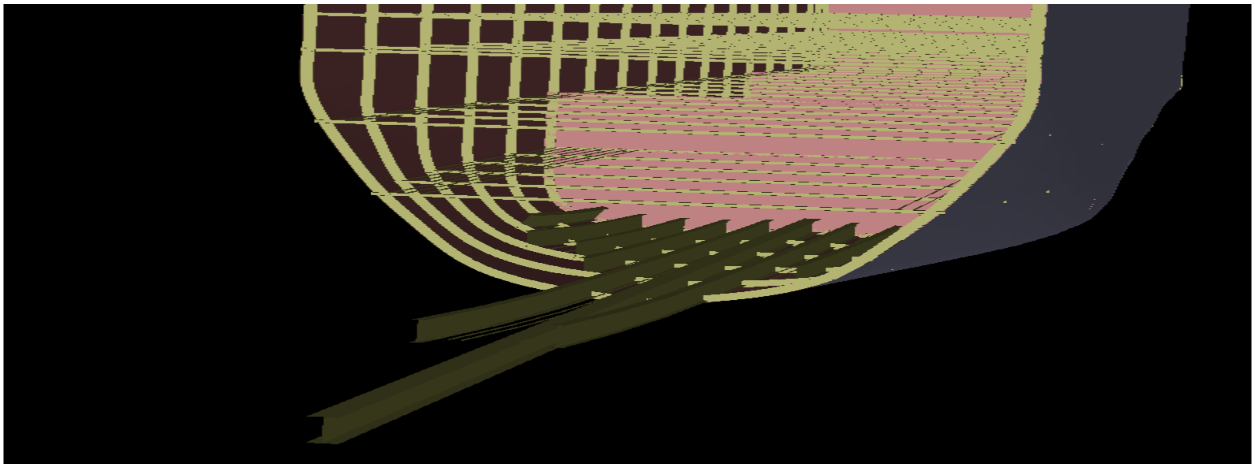


Figure 38 Ship Bottom structure based on section 1

Section 2 Side Structure:

Table 2 shows values for the side structure of the ship along with the calculations. As mentioned in the bottom structure section, the assumptions portion remained consistent for the entire ship thus no values changed from one section to the next, however some assumptions were added for this particle section of the ship.

Table 10: Side structure values and calculations

Assumptions:	
length overall [m]	187
draft [m]	7
depth [m]	35
stiffener spacing [m]	0.7
u=material conversion factor	1

2.1 *Shell Plating*

Shell plating is the ships outer hull and increases as the ship goes towards the bottom, therefore these calculations will be split into two separate thickness calculations.

2.1(a) *Thickness 2.3 meters above draft:*

$$t = (\frac{s}{645})\sqrt{(L-15.2)(\frac{d}{Ds})} + 2.5 \ \text{[mm]}$$

t= 7.92 [mm]

2.1(b) *Thickness below 2.3 meters above draft:*

$$t = (\frac{s}{508})\sqrt{(L-62.5)(\frac{d}{Ds})} + 2.5 \ \text{[mm]}$$

t= 7.95 [mm]

2.2 Sheer Strake:

This is the plating on the outside of the ship near the top portion of the ship near the weather deck. This thickness is not to be less than the shell plating for 2.3 meters above draft however it must have a certain width. This calculation is shown below.

Width, b:

b=5L+800 [mm]

b= 1735 [mm]

2.3 *Cant Framing*

Cant framing is framing that is not perpendicular to the midship line. This requires a certain spacing that varies from ship to ship. Our ship calculation is shown below.

Spacing

S=2.08*L+438 [mm]

S=826.96 [mm]

2.4 *Tween Deck Framing:*

A tween deck is the decks in between the upper most deck and the bottom most deck. This framing for these decks is the framing that goes between deck levels to entire structural stability. A section modulus is calculated to size the frames. This modulus is usually fairly large since decks are open spaces that cannot be opened to water.

Section Modulus:

SM=(7+45/l^3)*s*l^(2)*K [cm^3]

SM= 8237.668 [cm^3]

2.5 *Ship Girders:*

Girders for the ship were calculated using a section modulus and moment of inertia formula from the ABS manual and then sized accordingly to meet design criteria.

2.5(a) *Section Modulus:*

$SM = C1*C2*L^2*B\,(Cb + 0.7)$ [cm^2-m]   *Where $C_1=10.75-\left(\frac{300-L}{100}\right)^{1.5}=9.54$

$C_2= .01$

SM=139775.463 [cm^2-m]

2.5(b) *Moment of Inertia amidships*:

I=L*SM/33.3 [cm^2-m^2]

$I=784925.2729$ [cm^2-m^2]

2.6 *Transverse frames:*

The transverse frames on the ship below the lowest deck on the ship was obtained using a section modulus equation from ABS.

Section Modulus

$SM = s\square^2(h + bh1/30)\,(7 + 45/\square^3)$ [cm^3]

$SM=544.95$ [cm^3]

2.7 *Side Stringers:*

The side stringers on a ship are taken based off of the transverse frame section modulus by using a reduction factor of 20% from the section modulus obtained above.

$SM=435.96$ [cm^3]

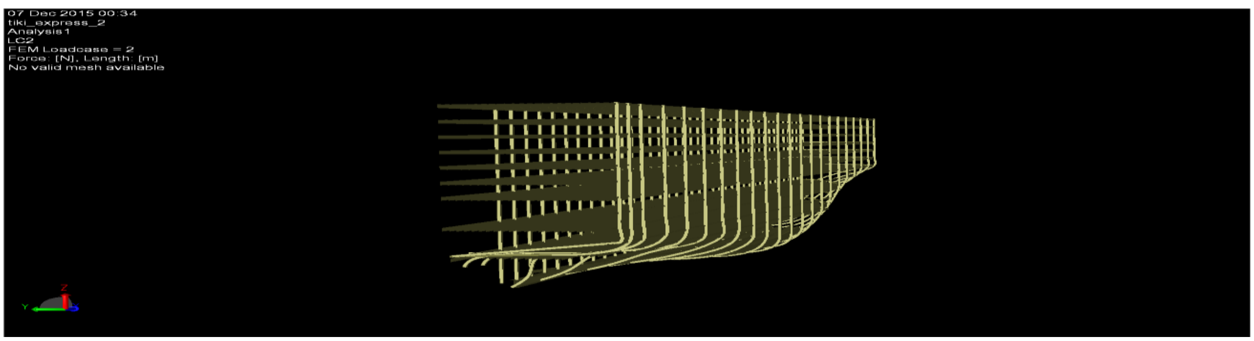


Figure 39: Side structure based on section 1 and 2

Section 3 Deck Structure*:*

Table 11 shows the values calculated for decks on the ship. All calculations made were minimum required thickness for those decks. Each deck calculation is for a certain section of the ship depending on what the deck is intended to hold. The tire dimensions used are for a new Volvo XC90 which was selected since the car is the biggest car in the Volvo lineup which allows for the biggest tire dimensions.

Table 11 Stating initial assumptions for tire loadings

Assumptions:	
tire length [mm]	739.14
tire width [mm]	264.16
stiffener spacing [m]	0.7

3.1 *Wheel Loading Deck:*

These decks are designed to hold ordinary Volvo cars. These calculations from the ABS manual require the tire dimensions that will be on the vehicle that is intended to be loaded on that deck.

Thickness:

$t = k*K*n*\sqrt{C * W}$ *[mm]*

**where*

k=8.05

$K=[21.99 + 0.316(a/s)^2 – 5.328(a/s) + 2.6(a/s)\ (b/s) – 0.895(b/s)5 – 7.624(b/s)]10^{-2}$

a=739.14 [mm]

b= 264.16 [mm]

s= stiffener spacing

n=1

C= 1.5 for vehicles stored at sea

W=static wheel load (9.559 KN based on tire used)

t= 4.53 [mm]

3.2 *Container Deck:*

These decks are intended to hold standard TEU containers along with heavy equipment that Volvo may want to load.

Thickness:

*t=.01*s_b +2.3 [mm]*

t= 9.3 [mm]

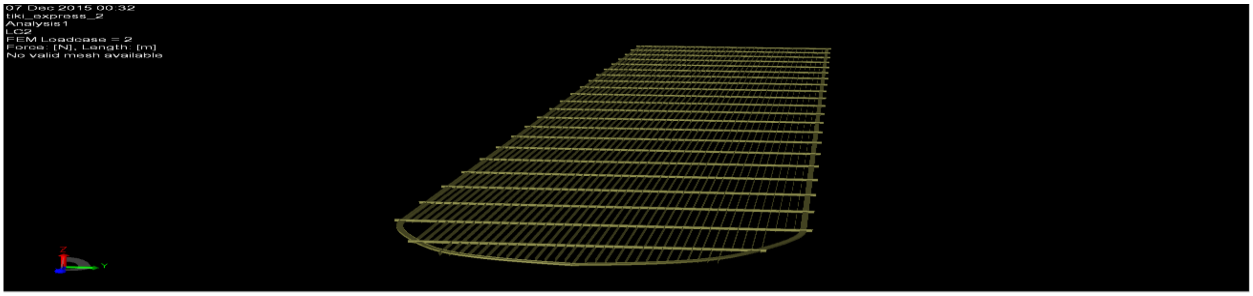


Figure 40: Deck Structure based on values calculated in sections 1-3

Section 4 Mid-ship section

The mid-ship drawing shows below lays out sections 1-3 and their respective calculations.

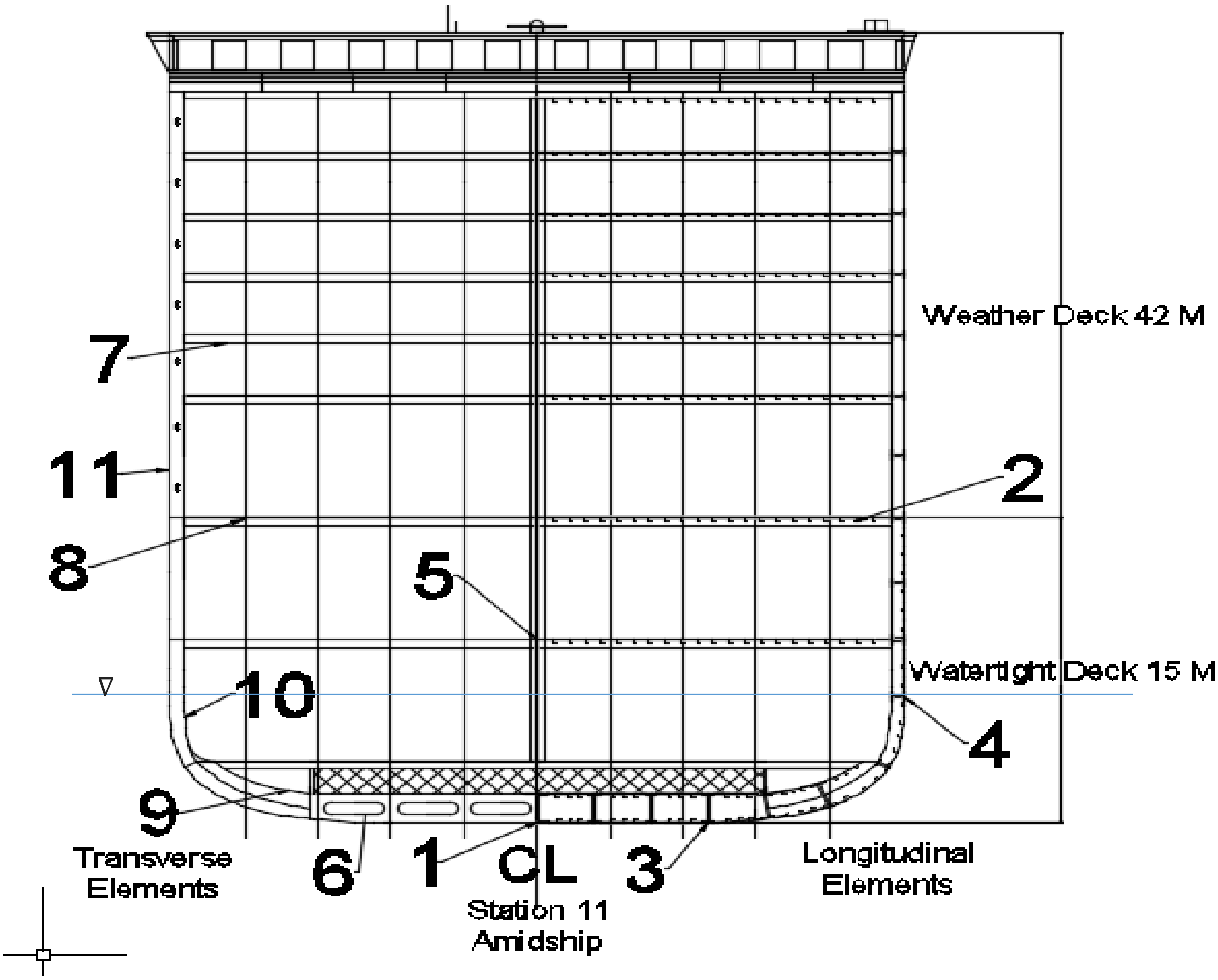


Figure 41: Mid-Ship Section

1. Center Keelson
2. Stiffeners
3. Girders
4. Side Stringers
5. Longitudinal Bulkhead
6. Manhole
7. Wheel Loading Deck
8. Container Deck

9. Inner Bottom Plate
10. Immersed Bow Plate
11. Shell Plating

Section 5 Bow and Stern Structure

5.1 *Fore/Aft Frame Thickness:*

The thickness for the fore and aft of the ship changes compared to the frame amidship based on the following equation.

Thickness:

*t=.036*s+4.7+1.5 [mm]*

t=12.9 [mm]

5.2 *Fore/Aft Stringer Plate thickness:*

The stringers that run on the sides of the fore and aft portion of the ship must maintain a thickness using the following equation.

Thickness:

*t=.007*s+8.6 [mm]*

t= 9.9 [mm]

Section 6 Bulkheads

Bulkheads are to be placed in 6 specific points on the ship. The first is the collision bulkhead which is placed at a location of .05*L from the front of the ship. The second bulkhead is the forward cargo bulkhead which will allow for increase structural stability and allow for the cargo area to be enclosed in case the collision bulkhead fails. This bulkhead was placed 34.9 meters back from the front of the ship. The third bulkhead is the mid-ship bulkhead, this bulkhead was placed with intension to increase structural stability and to contain water in the event of flooding and placed 101 meters back. The fourth and fifth bulkhead were placed around the engine room to so that the engine compartment can still run in case of flooding. The final bulkhead is the longitudinal bulkhead that will run the length of the ship down the middle to allow for increase in structural stability and to separate compartments to minimize damage potential. All bulkhead locations are shown in figure two below.

6.1 *Bulkhead thickness:*

Bulkhead plate thickness is separate for collision bulkhead, however all other bulkheads will allow for similar thickness using the ABS equation below.

Thickness:

$$t=s * k * \frac{\sqrt{q * h}}{c} + 1.5 \text{ [mm]}$$

**where*

s=stiffener spacing

k=1

q=235/yield strength

h=distance to top watertight deck

c= 254 and 290 for collision and other water tight bulkheads respectively

t= 15.28 [mm] for collision bulkheads

t= 13.57 [mm] for all other bulkheads

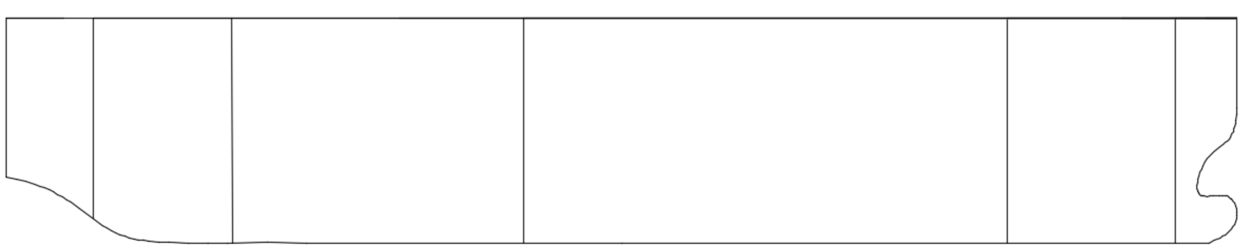


Figure 42: Bulkhead layout

Section 7 Beam Sizing

After calculating the section modulus for the stiffeners and the different girders needing to go on the ship the following figures show what the dimensions will be. Not all the girders are the same for reasons of needed to meet certain height requirements such as the bottom girders needed to be as tall as the center keelson and the deck girders could not exceed a certain height or else 40 ft containers would hit the top of the deck and damage it.

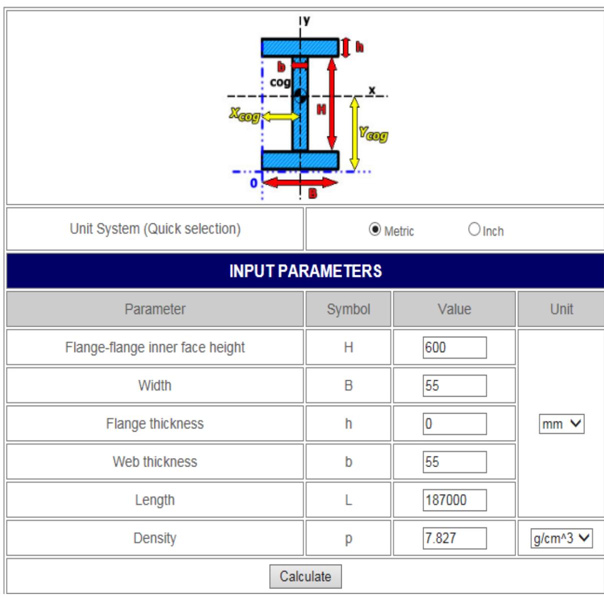


Figure 43: Side Stringer Dimensions

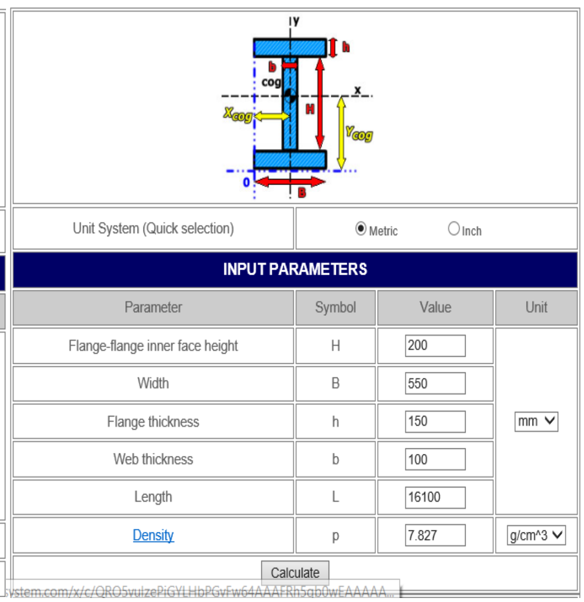
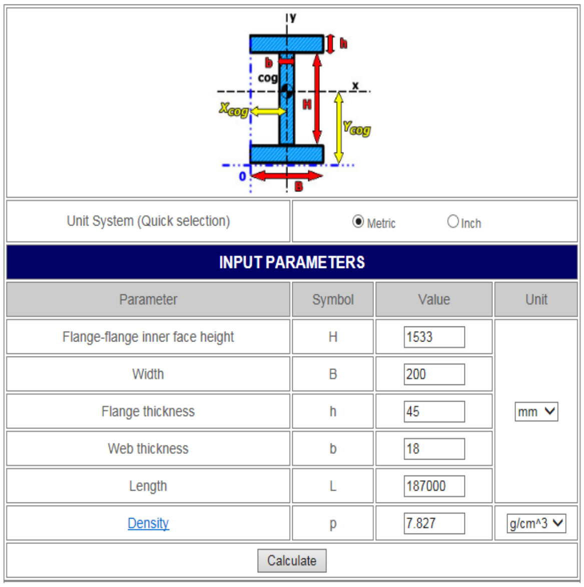


Figure 44: Deck Girder Dimensions



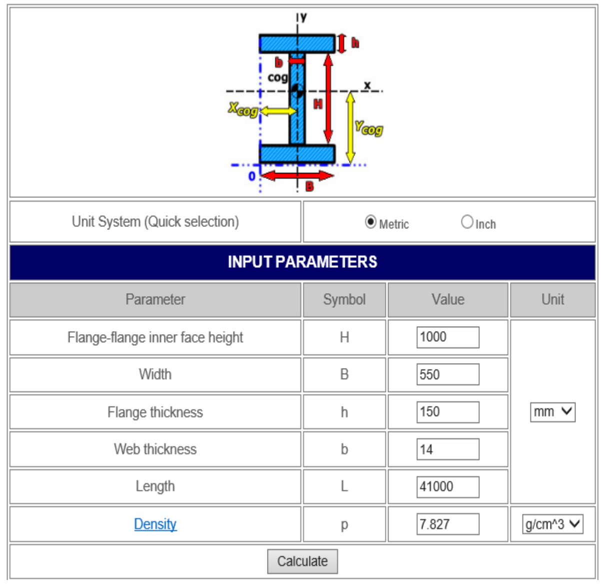


Figure 45: Bottom Girder Dimensions *Figure 46: Side Girder Dimensions*

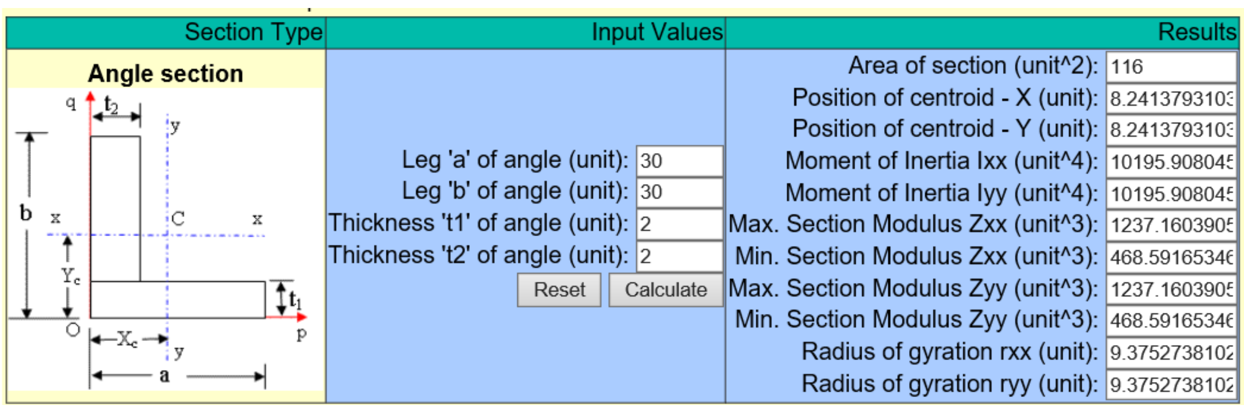


Figure 47: Stiffener Dimensions

Chapter 4: Damage Stability:

Initial values:

The initial values for this portion are as follows:

- ∇= 22288.86
- BM_t=18.19 [m]
- BM_L= 912.57 [m]
- KB=4.13 [m]

- KG= 18.53 [m]
- I_t= 405406.71 [m^4]
- I_l= 20336344.69 [m^4]
- μ=.85
- μ_s=1
- A_{wp}=4626.403

These values were taken from hydrostatics and the KG was used because this value is at lightship and if the ship was damaged this would allow for maximum water to enter the region.

Section 1 Flooded Sections:

1.1 *Container Deck on WL 1*

This section was flooded in order to obtain data for the largest watertight compartment on the ship that could potentially flood. The following values were taken from CAD and hydrostatics.

- a=708 [m^2]
- V_{co}=4248 [m^3]
- Y_a=8.05 [m]
- X_a=21.9 [m]
- Z_{co}=6 [m]

Next a new waterplane area was found with the equation:

A_{wp}-a* μ= $A_{wp\ new}$

4626.403-708*.85= 3918.4 [m^2]

Next the new center of floatation was calculated using the following equation:

C.F. movement to aft: $\frac{a * \mathrm{Xa}}{\mathrm{Awp\ new}} = X_F' = \frac{708*21.9}{3918.4} = 3.95\ [m]$

C.F. movement to port: $\frac{a*\mathrm{Ya}}{\mathrm{Awp\ new}} = Y_F' = \frac{708*8.05}{3918.4} = 1.45$ [m]

These values are negative since they move towards the negative side of the respected axis in the middle of the ship. The rest of the calculations shown take place after bilging occurs, the steps are as follows:

1. Calculate parallel sinkage:
   a. $S = \frac{\mathrm{Vco}*\mu}{\mathrm{Awp\ new}}$
      i. $= \frac{4248*.85}{3918.4} = .92$ [m]
2. Calculate rise in bilge:
   a. $b = \mu * V_{co} * \frac{(7+\frac{S}{2}-\mathrm{KB})}{\nabla}$
      i. $= .85 * 4248 * \frac{(7+\frac{.92}{2}-4.13)}{22288.86} = .76$ [m]
3. Calculate new transverse moment of inertia:
   a. $I_T' = I_T + A_{wp}*(y_F - y_F')^2 - \mu_s*(i_t + a*(y_a - y_f')^2)$
      i. $= 405406.71+4626.403*(0+1.45)^2 - 1*(\frac{73.5*16.1^3}{12}+708*(8.05+1.45)^2) = 325675.3$ [m^4]
4. Calculate new longitudinal moment of inertia:
   a. $I_L' = I_L + A_{wp}*(X_F - X_F')^2 - \mu_s*(i_l + a*(x_a - x_f')^2)$
      i. $= 20336344.69+4626.403*(1+3.95)^2 - 1*(\frac{16.1*73.5^3}{12}+708*(21.9+3.95)^2) = 19443937$ [m^4]
5. Calculate new BM_t':
   a. $BM_t' = \frac{\mathrm{IT'}}{\nabla}$
      i. $= \frac{325675.3}{22288.86} = 14.6$ [m]

6. Calculate new $BM_l^{'}$:

    a. $BM_l^{'} = \frac{IL'}{\nabla}$

        i. $= \frac{19443937}{22288.86} = 872.36$ [m]

7. Calculate change in buoyancy:

    a. $BB' = \mu * V_{co} * \frac{(7+\frac{S}{2})}{\nabla} - \mu * V_{co} * \frac{Zco}{\nabla}$

        i. $= .85 * 4248 * \frac{(7+\frac{.92}{2})}{22288.86} - .85 * 4248 * \frac{6}{22288.86} = .24$ [m]

8. Calculate new $GM_t^{'}$:

    a. $GM_t^{'} = KB + BB' + BM_t^{'} - KG$

        i. =4.13+.24+14.6-18.53=.45 [m]

9. Calculate new $GM_L^{'}$:

    a. $GM_L^{'} = KB + BB' + BM_l^{'} - KG$

        i. =4.13+.24+872.4-18.53=858.2 [m]

10. Calculate angle of heel:

    a. $\Phi = \frac{\mu * Vco}{\nabla * GMt'} * (y_a - y_f^{'}) =$

        i. $\frac{.85*4248}{22288.86*.45} * (8.05+1.45) = 3.44^0$

11. Calculate angle of trim:

    a. $\Theta = \frac{\mu * Vco}{\nabla * GML'} * (x_a - x_f^{'}) =$

        i. $\frac{.85*4248}{22288.86*.45} * (1 + 5.61) = .003^0$

12. Calculate change of heel:

    a. angle of heel*B

        i. = 3.44*pi/180*32.2= 3.44 [m]

13. Calculate change of trim:
    a. angle of trim*L
        i. = .003*pi/180*187= 1.85 [m]
14. Calculate change of heel:
    a. Immersed Side: $\frac{16.1+2.06}{32.2} * 3.44 = 1.63\ [m]$
    b. Emerged Side: $\frac{16.1-2.06}{32.2} * 3.44 = 1.26\ [m]$
15. Calculate change of trim:
    a. Immersed side: $\frac{93.5+5.61}{187} * 1.85 = .003\ [m]$
    b. Emerged side: $\frac{93.5-5.61}{187} * 1.85 = .002\ [m]$

After all of this the final drafts at each point of the ship are as follows:

- Aft-Port: 7+1.31-1.26-.002= 7.04 [m]
- Aft-Starboard: 7+1.31+1.26-.002= 9.929[m]
- Bow-Port: 7+1.31-1.26+.002= 7.05 [m]
- Bow-Starboard: 7+1.31+1.26+.002= 9.934 [m]

1.2 *Aft section of ship at WL 1*

This section was flooded to see how the ship would act if the very front or back were damaged and took on water. Just as before the following values were taken from CAD and hydrostatics.

- a=122.37 [m^2]
- V_{co}=734.22 [m^3]
- Y_a=0 [m]
- X_a=89.16 [m]

- Z_{co}=6 [m]

A new waterplane area had to calculated just as before.

A_{wp}-a* μ= $A_{wp\ new}$

4626.403-122.37*.85= 4504.033 [m^2]

Next the new center of floatation was calculated using the following equation:

C.F. movement to aft: $\frac{a*\text{Xa}}{\text{Awp new}} = X_F{}' = \frac{122.37*89.16}{4504.033} = 2.422\ [m]$

C.F. movement to port: $\frac{a*\text{Ya}}{\text{Awp new}} = Y_F{}' = \frac{122.37*0}{4504.033} = 0\ [m]$

Just as before the same steps were used in calculations.

1. Calculate parallel sinkage:
   a. $\frac{\text{Vco}*\mu}{\text{Awp new}}$
      i. $=\frac{734.22*.85}{4504.033}$ = .139 [m]=S
2. Calculate rise in bilge:
   a. b= μ* V_{co}*$\frac{(7+\frac{S}{2}-\text{KB})}{\nabla}$
      i. = .85* 734.22*$\frac{(7+\frac{.139}{2}-4.13)}{22288.86}$ = .08 [m]
3. Calculate new transverse moment of inertia:
   a. $I_T{}' = I_T + A_{wp}*(y_F - y_F{}')^2 - \mu_s*(i_t + a*(y_a - y_f{}')^2)$
      i. = 405406.71+4626.403*$(0+0)^2$-1*($\frac{73.5*16.1^3}{12}$+708*$(0+0)^2$)=

         381257.3 [m^4]
4. Calculate new longitudinal moment of inertia:
   a. $I_L{}' = I_L + A_{wp}*(X_F - X_F{}')^2 - \mu_s*(i_l + a*(x_a - x_f{}')^2)$

i. $= 20336344.69+4626.403*(1-2.422)^2-1*(\frac{32.2*8.68^3}{12}+122.37*(89.16-2.422)^2)=19423310\ [m^4]$

5. Calculate new $BM_t{}'$:

   a. $BM_t{}' = \frac{IT'}{\nabla}$

      i. $= \frac{381257.3}{22288.86} = 17.1\ [m]$

6. Calculate new $BM_l{}'$:

   a. $BM_l{}' = \frac{IL'}{\nabla}$

      i. $= \frac{19423310}{22288.86} = 871.4\ [m]$

7. Calculate change in buoyancy:

   a. $BB' = \mu * V_{co} * \frac{(7+\frac{S}{2})}{\nabla} - \mu * V_{co} * \frac{Zco}{\nabla}$

      i. $= .85 * 4248 * \frac{(7+\frac{.92}{2})}{22288.86} - .85 * 4248 * \frac{6}{22288.86} = .03\ [m]$

8. Calculate new $GM_t{}'$:

   a. $GM_t{}' = KB + BB' + BM_t{}' - KG$

      i. $=4.13+.24+14.6-18.53= 3.605\ [m]$

9. Calculate new $GM_L{}'$:

   a. $GM_L{}' = KB + BB' + BM_l{}' - KG$

      i. $=4.13+.24+872.4-18.53=857.9\ [m]$

10. Calculate angle of heel:

    a. $\Phi = \frac{\mu * Vco}{\nabla * GMt'} * (y_a - y_f{}')$

       i. $= \frac{.85*734.22}{22288.86*.45} * (0+0)=0^0$

11. Calculate angle of trim:

a. $\Theta = \frac{\mu * Vco}{\nabla * GML'} * (x_a - x_f^{'})$

i. $= \frac{.85*734.22}{22288.86*3.6} * (89.16+2.422) = .003^0$

12. Calculate change of heel:

a. angle of heel*B

i. = 0*pi/180*32.2= 0 [m]

13. Calculate change of trim:

a. angle of trim*L

i. = .003*pi/180*187= .01 [m]

14. Calculate change in heel:

a. Immersed Side: $\frac{16.1+0}{32.2} * 0 = 0\ [m]$

b. Emerged Side: $\frac{16.1-0}{32.2} * 0 = 0\ [m]$

15. Calculate change in trim:

a. Immersed side: $\frac{93.5+2.41}{187} * .01 = .005\ [m]$

b. Emerged side: $\frac{93.5-2.41}{187} * .01 = .0047\ [m]$

After all of this the final drafts at each point of the ship are as follows:

- Aft-Port: 7+.139+0+.0047= 7.14 [m]
- Aft-Starboard: 7+1.31+0+.002= 7.14[m]
- Bow-Port: 7+1.31-0-.005= 7.13 [m]
- Bow-Starboard: 7+1.31-0+.005= 7.13 [m]

Chapter 5: Voyage Specific Stability Analysis

Using a constant displacement of 22846.1 tons and an air draft of 35 meters, the Tiki express will be required to visit certain regions where the draft of the ship may change and she has to be able to fit under certain bridges at the entrance to ports. A few of the values are shown below.

- Water density through panama canal: .9954 [tons/m^3]
- Water density at port of Gothenburg: 1.011 [tons/m^3]
- Water density of freshwater: 1.000 [tons/m^3]
- Water density at port of Houston: 1.010 [tons/m^3]
- Bridge height at port of Gothenburg: 45 meters
- Bridge height at port of Houston: 41 meters
- Bridge height at port of Tacoma: 57.3 meters
- Bridge height at port of Halifax: 46.9 meters
- Bridge height at port of Baltimore: 56.7 meters

Through use of the formula: $\Delta = p * L * B * T * C_b$, the displacement remained constant for each calculation along with length, breadth, and block coefficient. By changing the water density for each of the values stated above, the following drafts were found:

- Draft through panama canal: 7.16 [m]
- Draft through port of Gothenburg: 7.06 [m]
- Draft through freshwater: 7.16 [m]
- Draft through port of Houston: 7.09 [m]

The ship also forms an air draft of 35 [m] which fits well below the bridges for the ports the ship is required to go to even with a change in draft. The panama cannel is where the ship will hold the biggest draft however it will still meet the owners requirements of having a draft less than 7.2 [m]. The Panama Canal asks that ships do not have a draft exceeding 15 [m] which will be plenty of space for the Tiki Express to travel through the locks.

Chapter 6 Ship Resistance

Calculating the ship's resistance was approached with hand calculations. This was done by making four initial assumptions and then following a series of calculations to arrive at the total resistance of our ship, the Tiki Express.

We decided to take the model-prototype approach where we used our parent ship as the model and our ship design as the prototype.

Section 1 Assumptions and Calculations

1.1 Assumptions

The four assumptions we had to make were the Estimated Horsepower of our model, the total resistance of our model, the wetted surface area of the prototype, and the temperature of the water that the model is traveling in.

1.1.2 Estimated Horsepower

The Estimated Horsepower of the model was found by looking up the Alliance Fairfax engine specifications and finding the maximum continuous rating (MCR). We found this to be 18,900 HP at 20 knots. From there, we took a value that was 82.5% of the MCR called the normal service rating and used this as our EHP. This was done because the normal service rating is the economic speed at which the engine consumes the least fuel. This gave us an EHP of 15,592.5 HP for our model.

1.1.3 Total Resistance of Model

Next, we were able to plug this value into a formula to give us our total resistance for the model:

$EHP = R_T * V$

$R_{T =}$ (15,529.5 HP)/(20 knots)

= (11.627E6 W)/(10.288 m/s)

= 11.302E5 N

1.1.4 Wetted Surface Area

To find the wetted surface area of our prototype, we had to use Mumford's Formula which was found at http://www.skibstekniskselskab.dk .

$S = 1.025(L_{pp})[(C_b*B) + 1.7(T)]$

This value was found at 5293.8 m^2 for our prototype. From this we were able to find the wetted surface area of our model because of a 1:1.0395 length scale between our model and prototype.

1.1.5 Density and Kinematic Viscosity

Finally, we had to assume a temperature of the water at which the model ship was traveling. This was done in order to find the density and kinematic viscosity of the water for the model. We assumed a temperature of 25 degrees Celsius in order to move forward with our calculations. We then referred to a document titled "ITTC – Recommended Procedure" and used the table below (Table 12) to find the density and kinematic viscosity for the model.

Table 12 Water Properties in increments of 1 degree Celsius

Temp t (°C)	Density ρ (kg/m^3)	$\partial\rho/\partial t$ (kg/m^3·°C)	Viscos μ (Pa·s)	$\partial\mu/\partial t$ (Pa·s/°C)	$\nu = \mu/\rho$ (m^2/s)	$\partial\nu/\partial t$ (m^2/s·°C)	Pressure p_v (MPa)	$\partial p_v/\partial t$ (MPa/°C)
1	1028.0941	-0.0680	0.001843	-6.186E-05	1.7926E-06	-6.005E-08	6.4363E-04	4.639E-05
2	1028.0197	-0.0810	0.001783	-5.862E-05	1.7341E-06	-5.689E-08	6.9153E-04	4.944E-05
3	1027.9327	-0.0930	0.001726	-5.561E-05	1.6787E-06	-5.395E-08	7.4256E-04	5.265E-05
4	1027.8336	-0.1050	0.001671	-5.282E-05	1.6262E-06	-5.122E-08	7.9689E-04	5.604E-05
5	1027.7225	-0.1170	0.001620	-5.021E-05	1.5762E-06	-4.867E-08	8.5471E-04	5.962E-05
6	1027.6000	-0.1280	0.001571	-4.777E-05	1.5288E-06	-4.630E-08	9.1620E-04	6.340E-05
7	1027.4662	-0.1390	0.001524	-4.549E-05	1.4836E-06	-4.408E-08	9.8157E-04	6.738E-05
8	1027.3214	-0.1500	0.001480	-4.337E-05	1.4406E-06	-4.200E-08	1.0510E-03	7.156E-05
9	1027.1659	-0.1605	0.001438	-4.137E-05	1.3995E-06	-4.006E-08	1.1248E-03	7.597E-05
10	1027.0000	-0.1710	0.001397	-3.950E-05	1.3604E-06	-3.823E-08	1.2030E-03	8.061E-05
11	1026.8238	-0.1815	0.001359	-3.774E-05	1.3230E-06	-3.652E-08	1.2861E-03	8.550E-05
12	1026.6376	-0.1915	0.001322	-3.609E-05	1.2873E-06	-3.492E-08	1.3741E-03	9.063E-05
13	1026.4416	-0.2010	0.001286	-3.454E-05	1.2532E-06	-3.341E-08	1.4674E-03	9.601E-05
14	1026.2360	-0.2105	0.001252	-3.308E-05	1.2205E-06	-3.198E-08	1.5662E-03	1.017E-04
15	1026.0210	-0.2195	0.001220	-3.170E-05	1.1892E-06	-3.064E-08	1.6709E-03	1.076E-04
16	1025.7967	-0.2290	0.001189	-3.040E-05	1.1592E-06	-2.938E-08	1.7816E-03	1.139E-04
17	1025.5633	-0.2380	0.001159	-2.918E-05	1.1304E-06	-2.819E-08	1.8987E-03	1.204E-04
18	1025.3210	-0.2470	0.001131	-2.801E-05	1.1028E-06	-2.706E-08	2.0225E-03	1.272E-04
19	1025.0700	-0.2555	0.001103	-2.692E-05	1.0763E-06	-2.599E-08	2.1533E-03	1.344E-04
20	1024.8103	-0.2640	0.001077	-2.588E-05	1.0508E-06	-2.498E-08	2.2914E-03	1.419E-04
21	1024.5421	-0.2725	0.001051	-2.489E-05	1.0263E-06	-2.402E-08	2.4373E-03	1.498E-04
22	1024.2656	-0.2805	0.001027	-2.396E-05	1.0027E-06	-2.312E-08	2.5912E-03	1.581E-04
23	1023.9808	-0.2890	0.001004	-2.307E-05	9.8002E-07	-2.226E-08	2.7535E-03	1.667E-04
24	1023.6881	-0.2970	0.000981	-2.223E-05	9.5818E-07	-2.144E-08	2.9247E-03	1.757E-04
25	1023.3873	-0.3050	0.000959	-2.143E-05	9.3713E-07	-2.066E-08	3.1050E-03	1.851E-04
26	1023.0788	-0.3125	0.000938	-2.067E-05	9.1683E-07	-1.993E-08	3.2950E-03	1.949E-04
27	1022.7626	-0.3200	0.000918	-1.995E-05	8.9726E-07	-1.922E-08	3.4950E-03	2.052E-04
28	1022.4389	-0.3275	0.000898	-1.926E-05	8.7837E-07	-1.856E-08	3.7056E-03	2.159E-04
29	1022.1078	-0.3345	0.000879	-1.860E-05	8.6014E-07	-1.792E-08	3.9271E-03	2.271E-04
30	1021.7694	-0.3420	0.000861	-1.798E-05	8.4253E-07	-1.731E-08	4.1600E-03	2.388E-04

1.2 Calculations

After all four of those assumptions were made, we were able to go through a series of calculations found in figures 48 and 49 in order to arrive at a total resistance of 1.39 E 06 N. This then gave us an EHP of 19,572.2 HP traveling at 20.4 knots

	Model - Alliance Fairfax	Prototype - Tiki Express
Length (m)	179.9	187
Temperature (°C)	25	20
Density (kg/m^3)	1023.3873	1025
Kinematic Viscosity (m^2/s)	9.37E-07	1.06E-06
Wetted Surface Area (m^2)	To be calculated	5293.8
Roughness Allowance	N/A	4.00E-04
Velocity (m/s)	10.288	To be calculated
Total Resistance (kg*m/s^2)	1.13E+06	To be calculated

Figure 48 All variables needed prior to hand calculations

Variable	Calculated Value
Re_m	1.98E+09
C_{fm}	1.41E-03
S_m	4.90E+03
C_{tm}	4.26E-03
C_{rm}	2.85E-03
F_{rm}	2.45E-01
V_p	1.05E+01
Re_p	1.85E+09
C_{fp}	1.42E-03
C_{tp}	4.67E-03
R_{tp}	1.39E+06

Figure 49 All variables calculated with values from Figure Blah

Chapter 7 Engine and Generators

The Tiki Express decided to go with the B&W 6S60ME-C X engine which can be seen in figure 50 as well as a set of 3 B35:40V generators found in figure 51. This specifies that our engine will have 6 cylinders, super long stroke, 60 cm diameter piston, will be electronically controlled, and will be a compact engine. The design specs of the three generators consist of a 400mm stroke and a bore of 350mm which will provide the ship with a combined minimum 22,014.21 hp and a maximum 22,931.49 hp. This engine and generators allow for our estimated horsepower and also happen to be the same engine that is in our parent ship. According to http://www.mandieselturbo.com/ which lists all of the manufacturer specifications, our engine will meet all IMO regulations including: MARPOL Annex I: Protected fuel oil tanks, MARPOL Annex VI: NOx emissions, MARPOL Annex VI: SOx emissions, and MARPOL Annex VI: Energy Efficiency Design Index.

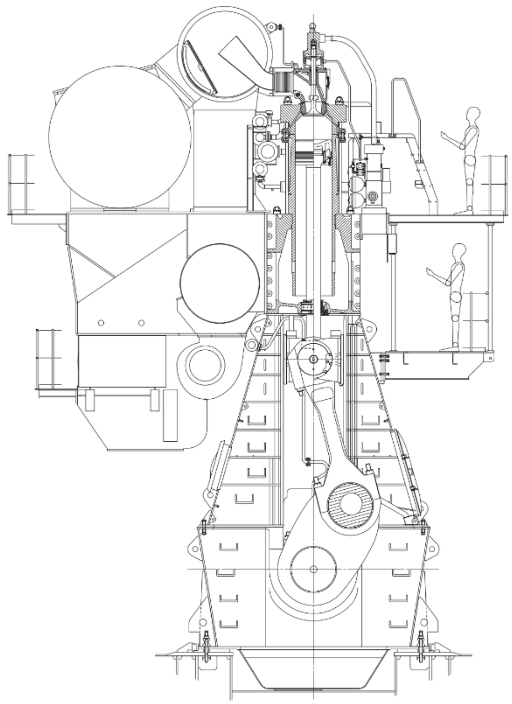


Figure 50 A cross section of the B&W 6S60ME-C X engine

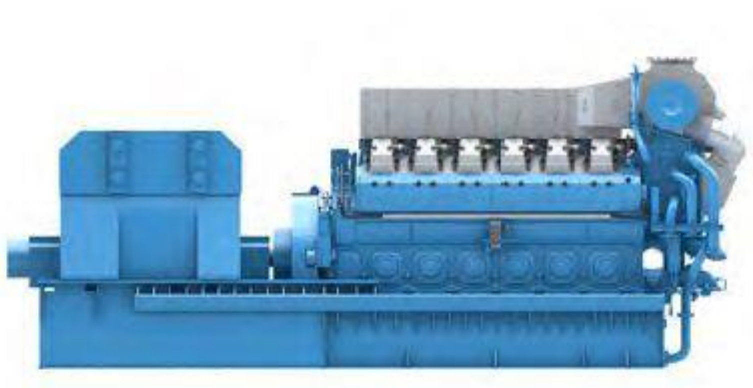


Figure 51 A rendering of the generators that will be used on the Tiki Express

Conclusion:

The final design for the Tiki Express is a ship that is 187 meters long, 32.2 meters wide and 42 meters tall with a draft of 7 meters. She will hold 1721 units of automobiles and 1000 40ft TEU ISO containers across her 11 decks. All requirements set by the owner and MARPOL have been met by the vessel traveling at 21 knots and having a maximum deadweight capacity of 15156.7 tons. This vessel corresponds with all ABS rules and regulations and meets Panamax requirements.

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