CALCULATING BLOCK LOAD

BY

THE MOMENT AREA METHOD

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It is very important for a dockmaster or docking officer to understand how a vessel blocking system behaves under load and to realize how various factors can affect the amount of load taken by a block. The trapezoidal loading equation can be a good approximation of load along a keel line in many instances but you must understand its limitations and resort to more complex calculations if these limitations are not met. Calculating block load by the moment area method uses the same principles as the trapezoidal loading equation but achieves more accurate results if there are different size blocks, irregularly spaced blocks, multiple line of keel blocks or as in the case of drill rigs, blocks spaced over a large rectangular or triangular area.

All blocks act like giant springs and any block under load will compress (squeeze) some amount. The amount of squeeze depends on the pressure on the block and the block's modulus of elasticity (which is the block's degree of stiffness or "squeezability").

Thus, two blocks built of the same materials (having the same size and modulus of elasticity) will compress the same amount under the same load. Two blocks built of different materials or differently sized, will compress varying amount under the same load, Alternatively, it will take a greater load to compress the stiffer block the same amount as the less stiff block.

This fundamental principle enables us to determine the actual load on the blocks under a ship and build a blocking system that adequately distributes the vessel's weight in a manner we can estimate. Knowing the loading on blocks is essential to insuring the blocks, dock and ship are not overloaded.

Many factors can affect the load on a block.

These include:

- Block's initial height relative to other blocks
- Bearing area of the block (hull contact area)
- Types of material the block is constructed of
- Position of block under ship
- Weight & LCG of ship

1 – Block's Initial Height Relative to the Others

Ideally, all block heights under the vessel should be such that the keel and side blocks form a cradle which is the exact shape as the hull of the vessel being docked. If this were the case, and the ship was positioned correctly in the cradle, all blocks would take their portion of the ship's load as determined by their size, relative stiffness and position under the ship.

Unfortunately some blocks result in being higher or lower than their ideal height because of:

- Tolerances required in building and placing blocks
- Irregularities in the shape of the vessel's hull
- Errors in positioning the vessel on the blocks

The higher blocks end up taking greater load than the others since the total squeeze of the high block is greater than the total squeeze of the others.

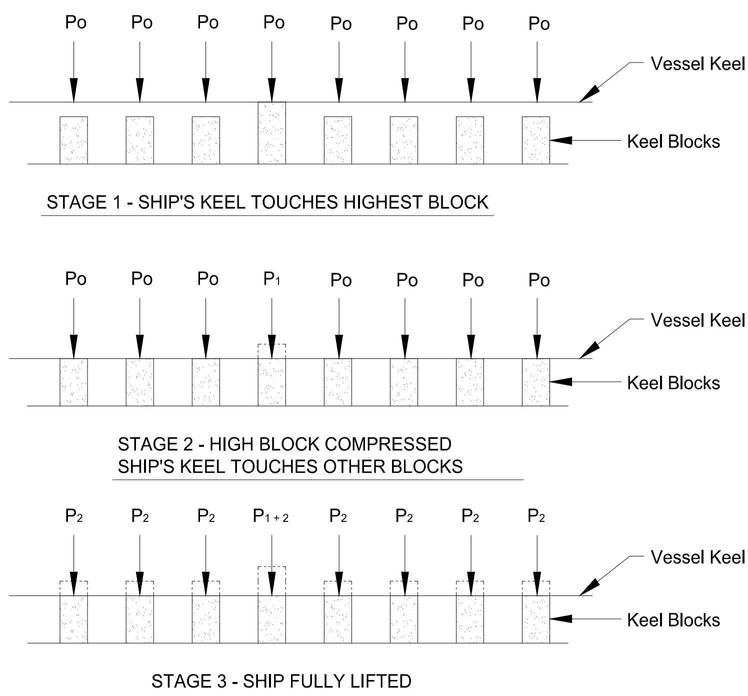


FIGURE 1

In the Figure 1, P_0 is equal to no load on the block, the vessel has not touched, or is just starting to touch the block. This is depicted in Stage 1.

P_1 is equal to the load required to compress the one high block to the correct height of the other blocks. At that point the ship's hull is just starting to contact the other blocks. This is depicted as Stage 2.

P_2 is the load required to compress each block to its final height after the ship has been fully lifted. Because the ship is so rigid, all blocks within a short distance of one another will compress approximately the same amount from this step on. Thus all blocks will have an added load P_2.

It is fairly obvious that the one high block must have an initial load (P_1) to squeeze it down to the correct height, along with its normal portion of the load to lift the ship (P_2). This results in the high block taking a greater total load than the other blocks. The magnitude of the increase in load on the high block is a function of the error in height and the stiffness of the blocks.

Alternatively, if a block is too low in relation to the others, it will take less of a load than the others.

The magnitude of the increase or decrease in load due to errors in height is difficult to calculate. However, if all blocks are built to strict tolerances, and a softwood cap is used to allow crushing of wood that might be too high, the effects of slight variations in height of about ± ¼" can usually be neglected.

Using a 2" softwood cap on top of the blocks is generally sufficient for allowing crush due to errors in height, irregularities in the ship's hull and minor errors in placing the vessel on the blocks.

2 – Bearing Area of the Block Against the Hull

The total load on a block is a function of the pressure on that block times the area of pressure. The pressure on the block is a function of the amount of squeeze the block has taken (and its materials of construction). Thus, a block with smaller bearing area located between two blocks with larger bearing areas will take a smaller total load than the larger blocks. This is because the squeeze of all three blocks must be approximately the same due to the stiffness of the vessel. If the squeeze is the same, then the pressure on the blocks is the same (assuming they are constructed of the same materials).

The total load on each block is it's pressure times it's area, so the block with the smaller area will take a smaller total load. See Figure 2.

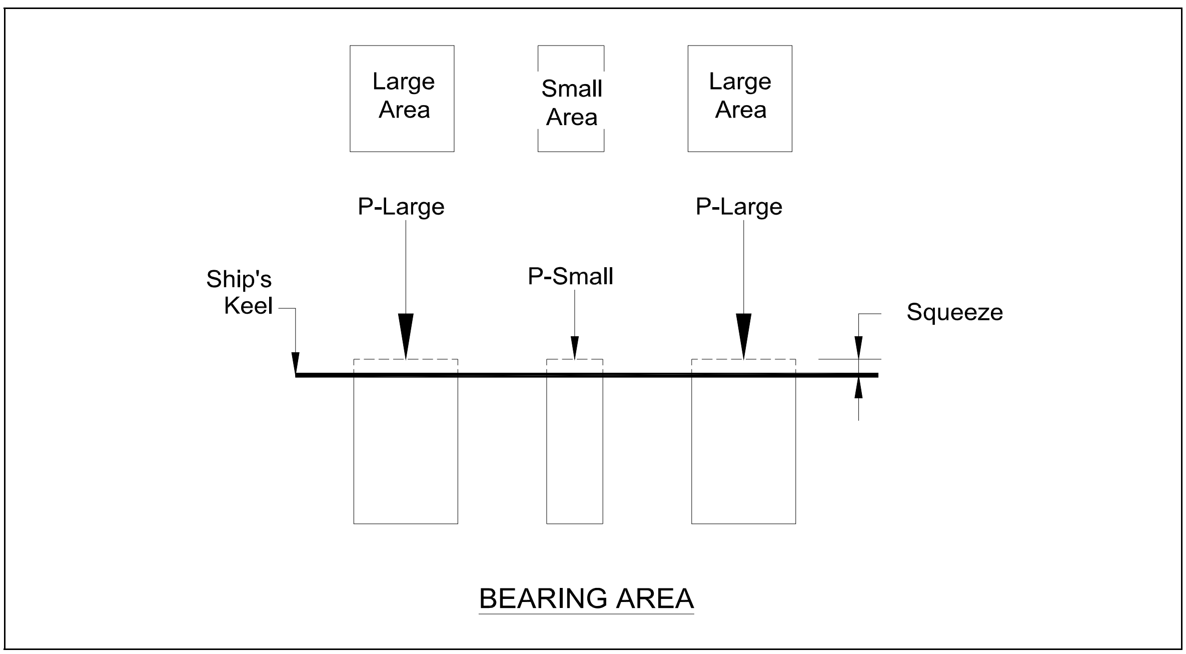


FIGURE 2

Alternatively, for any given load P, a block with a smaller bearing area will squeeze more than one with a larger bearing area. This is important to remember when docking vessels with a bar keel or narrow skeg aft.

The bearing area is the area of contact of the keel on the block (not the full block area).

When the bearing area is small, the pressure on the timber is large, causing a large squeeze and sometimes crushing of the wood.

To prevent localized crushing of the softwood timber cap, a layer of hardwood or a steel plate can be placed on top of the block to distribute the load over a larger area and reduce the pressure on the softwood to acceptable values. The hardwood should be at least 12" thick to prevent breakage and to distribute the load over a larger area of the softwood, which should be placed below the hardwood cap.

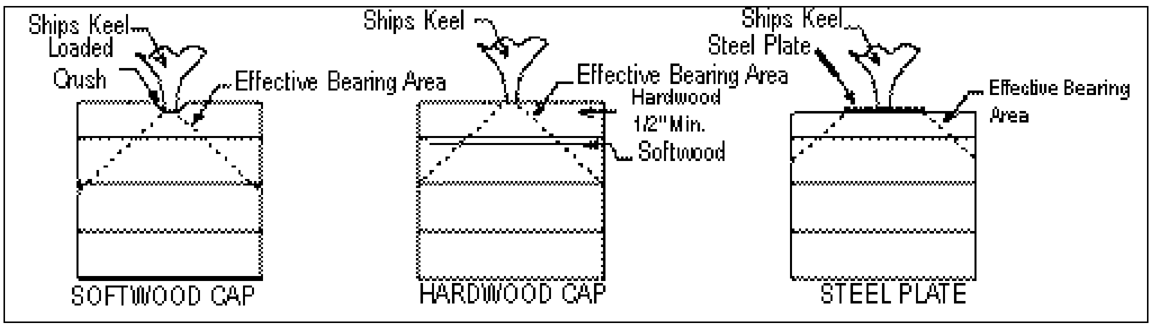


FIGURE 3

In many instances the loading from a narrow keel will overstress even a hardwood cap. In these cases a steel plate can be used on top of the block. The plate must be thick enough to spread the load over a sufficient area of timber to prevent crushing without bending the plate. Typical thicknesses of plate range from 1" to 3" depending on the load, width of plate versus width of keel, and allowable bearing pressure of the timber on which the plate is placed.

3 – Types of Materials

The relative stiffness of the materials the block is constructed of can have an effect on the load the block will take. It takes a larger force to squeeze a stiffer block (such as one constructed with a large concrete or steel base), versus one with a smaller modulus of elasticity (such as one constructed of all timber).

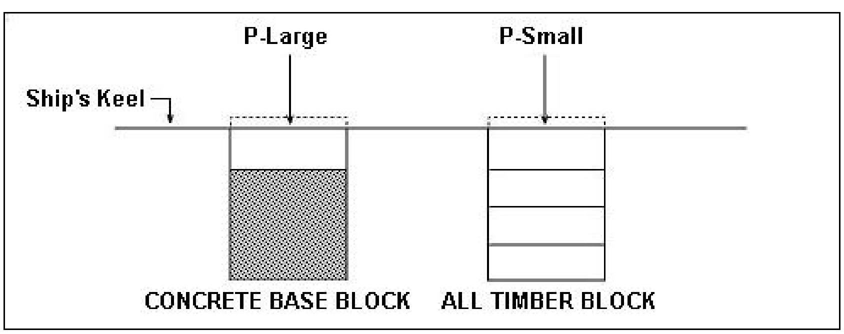


FIGURE 4

From this it can be seen that all blocks in a keel line should usually be built of similar materials. Should a block with concrete (or steel) base be added into a keel track built of all timber blocks, an extremely high load will develop at the concrete block, possibly damaging the block, ship and/or dock. See Figure 5.

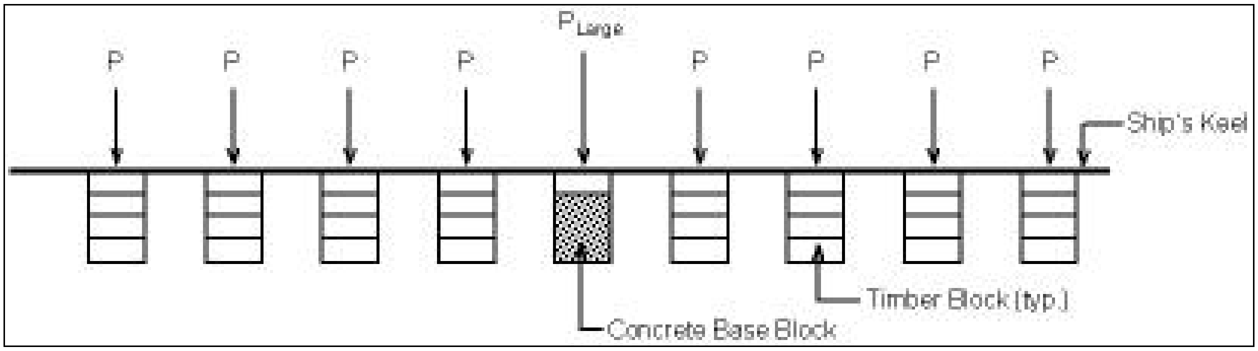


FIGURE 5

Alternatively, if an all timber block is added into a keel track built of blocks with concrete or steel bases, the timber block will take a much smaller load relative to the others.

This same reasoning should be used when building side blocks.

Ideally, the side blocks should never be built stiffer than the keel blocks or else the side blocks will take a larger portion of the load, possibly overloading the vessel. A less stiff side block can be assured by using the same number or, or more, layers of timber in the side blocks than in the keel.

This is usually the case anyway since side blocks are always the same height or higher than the keel.

Problems can arise, however, when alternate, stiffer bases are used for the side blocks but no the keel.

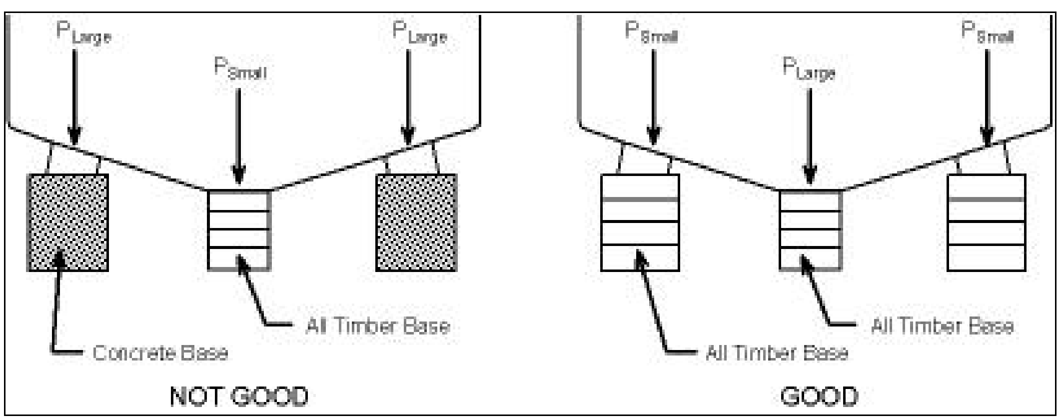


FIGURE 6

4 – Position of Block Under the Ship and Weight of Ship

The preceding sections discussed the effect that block height, bearing area, and materials of construction have on determining the load on the block.

Calculating the actual increase or decrease in load due to these variables is complex and beyond the scope of this paper.

In general, by using blocks of similar design and blocks built to within the proper height tolerances these variables can be neglected and the load on the blocks can be approximated by their position under the vessel and the weight of the vessel.

The weight distribution of a vessel usually resembles a “Skyline” (See Figure 7) with:

- High loads at engine room & machinery compartments
- Lower loads at empty compartments and open spaces.

Once on the blocks, the weight of the vessel must be resisted by the block system.

From the previous section, we know the blocks will squeeze under the load and the amount of squeeze is directly proportional to the amount of load on the block.

The ship is a rigid structure whose keel is a straight line that cannot deflect very much in the distance between keel blocks. Thus for any two blocks next to one another, their squeeze under the weight of the ship must be approximately equal due to the straightness of the ship’s keel and the ship’s rigidity, and hence the load on the two blocks must be approximately equal.

Figure 7 below illustrates this theory. The blocks at points A and B must deflect (squeeze) the same amount (approximately) due to the straight keel and the ship’s rigidity. If the deflection of the blocks is the same, then the load on the blocks must be the same, even though the portion of ship’s weight directly over B is much greater than the portion of ships weight directly over A.

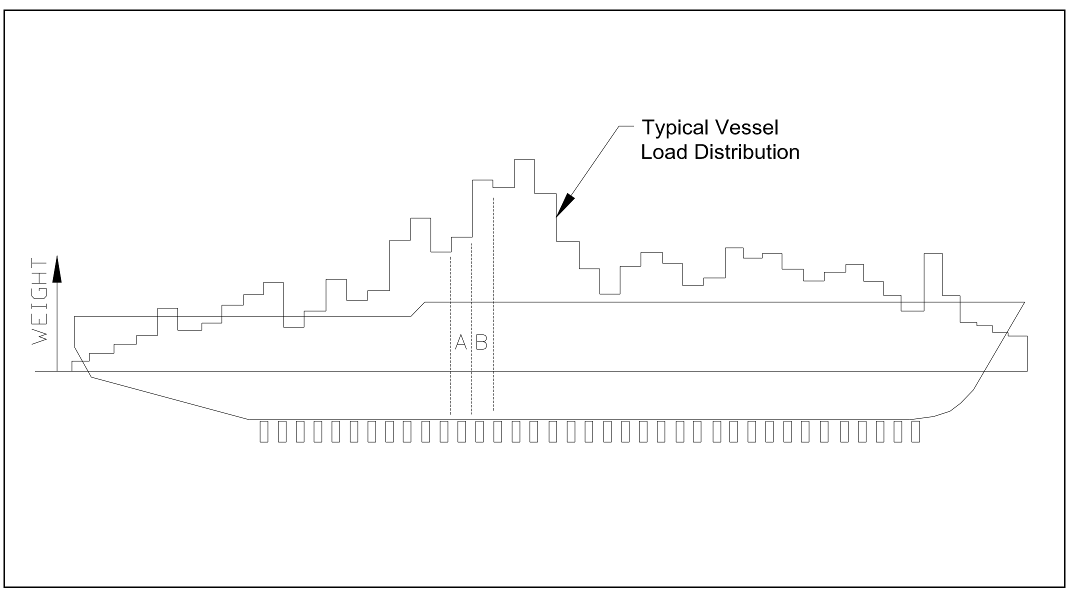


FIGURE 7

Thus, the load on the block line cannot be the irregular “skyline” load but must be a smooth straight line loading.

If the longitudinal center of gravity of the ship, LCG, (the center of all weights on the ship, including the ship’s hull), is located directly over the center of keel line, then the ship will squeeze all blocks equally.

Since all blocks are squeezed equally, all blocks will have the same load and the load distribution diagram will be rectangular in shape, as shown in Figure 8.

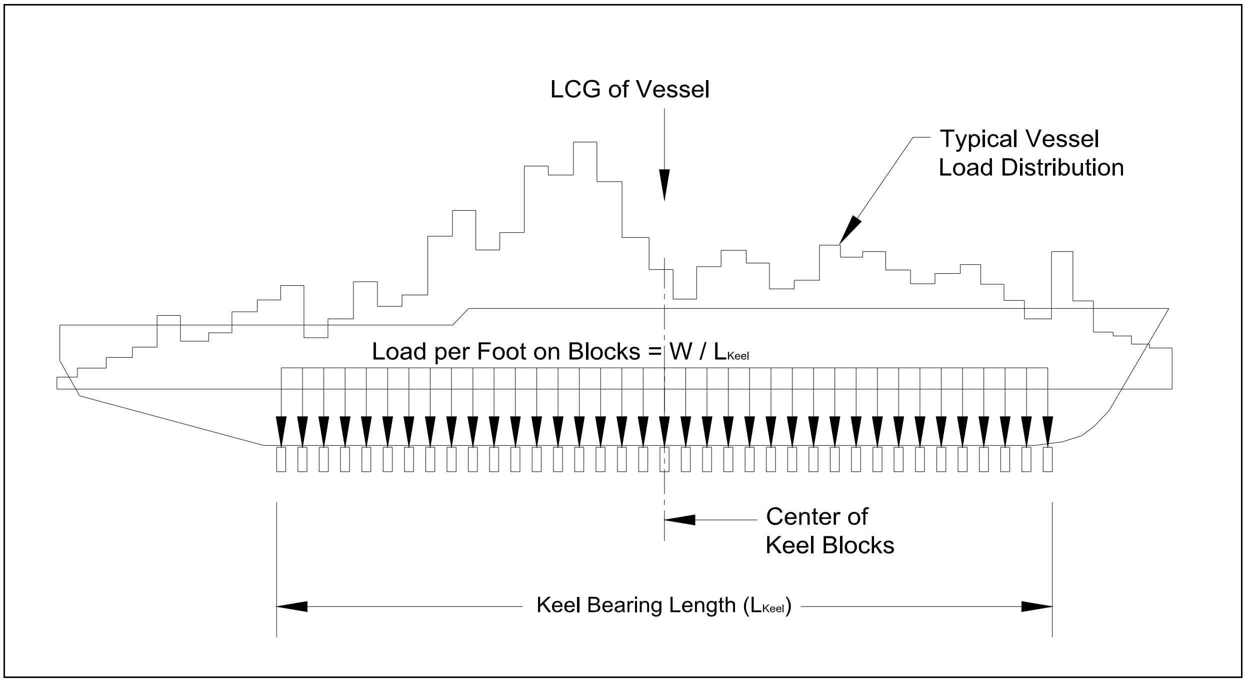


FIGURE 8

In this case the load per linear foot on the block line is constant and equal to the ship weight (W) divided by the keel bearing length (L_{Keel}).

$$\textbf{Load per Foot} = W/\ L_{keel}$$

For most dockings however, the longitudinal center of gravity (LCG) of the vessel does not fall directly over the center of blocks, it falls some distance forward or aft of the center blocks. When this occurs, the load on the blocks is not uniform, but greater at one end than the other. Thus the blocks actually squeeze more at one end than the other.

The ship, being a rigid body with a keel that is assumed a straight line, causes the block line to squeeze in a sloping straight line.

See Figure 9.

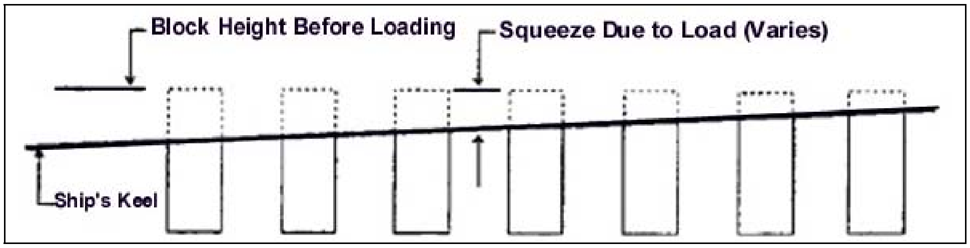


FIGURE 9

Since the load on any block is a function of the squeeze of that block, the load along the keel line must gradually be increasing or decreasing in the same straight line manner.

This results in a trapezoidal shaped loading on the blocks as shown in the Figure 10.

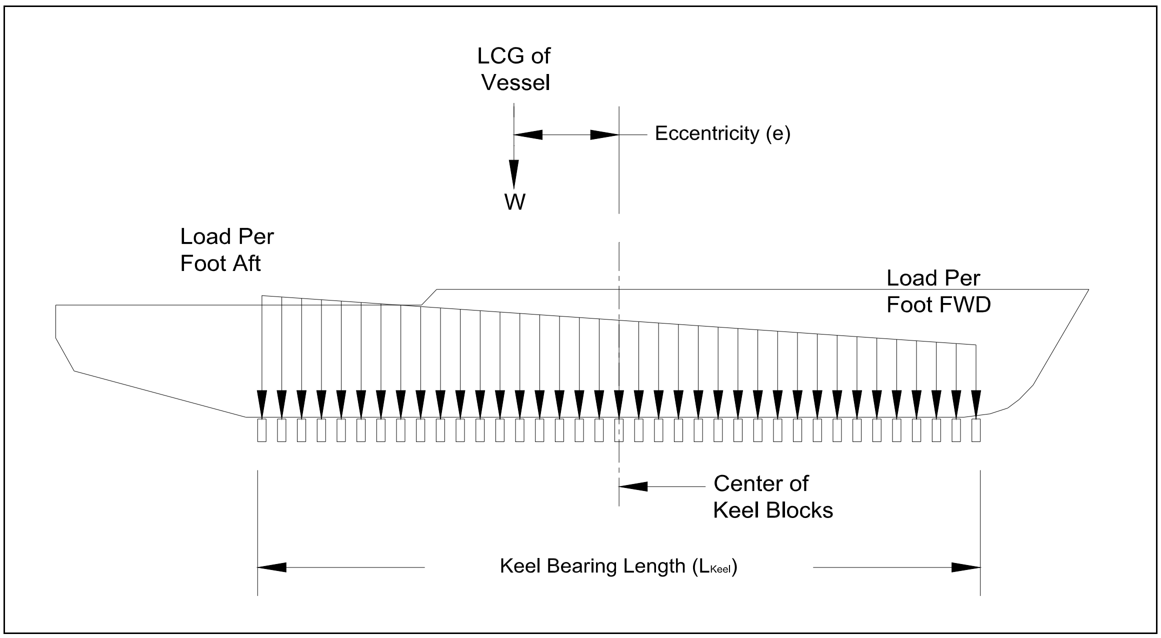


FIGURE 10

The further the vessel's LCG is from the center of keel bearing length, the greater in the increase and decrease of the load per foot at each end of the block line.

5 – Trapezoidal Loading Equation

The magnitude of the load per foot on the keel line can be calculated by the Trapezoidal Loading Equation. The equation determines the load per foot on the keel line at the forward and aft ends.

At the end of the keel line closest to the LCG:

$$\textbf{Load per Foot} = W/L_{keel} + 6 \times W \times e/(L_{keel})^2$$

At the end of the keel line farthest from the LCG:

$$\textbf{Load per Foot} = W/L_{keel} - 6 \times W \times e/(L_{keel})^2$$

Where:

- W = Ship Weight in Long Tons
- L_{keel} = Keel bearing length (distance from first keel block to last keel block)
- e = Distance from centerline of keel bearing length to vessel LCG

This analysis is called the "Trapezoidal Load Equation" and can be used for many typical dockings to determine the load on the blocks and dry dock and to develop pumping plans for floating dry docks.

The analysis assumes the ship is infinitely stiff and the blocks are all of uniform size, materials, and spacing. It also assumes that 100 percent of the load goes into the keel blocks.

These equations are not valid if:

- The longitudinal strength of the ship is impaired due to damage or cutting.
- The blocks are not all constructed similarly.
- The block spacing is not uniform.
- The bearing area varies on top of the block (bar keel at one end, etc.)
- The vessel over hangs the keel blocks by more than twice its molded depth.
- The ship has a large initial hog or sag and the keel line is built straight.
- A floating dock is not dewatered according to the trapezoidal results.

See Figure 11.

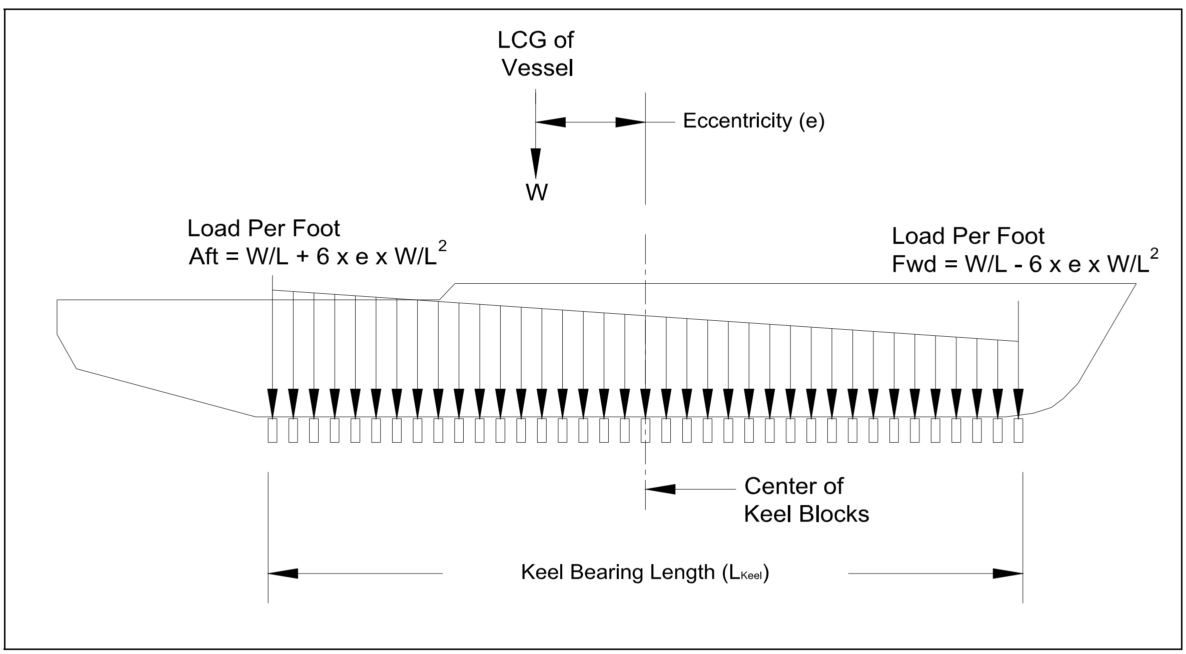


FIGURE 11

This trapezoidal loading equation is derived from the fundamental equation for eccentrically loaded columns:

$$\mathbf{P/A \pm M \times c / I}$$

Where:

- P = Load
- A = Cross sectional area of column
- M = Moment due to eccentric load = P x e
- c = Distance from center of area to edge of column
- I = Moment of inertia of column

For a keel line with regularly spaced, same sized blocks and no large gaps, the keel line can be assumed to be one continuous rectangle with width of 1.

The center of blocks is the center of the rectangle and the moment of inertia of a rectangle about its own axis is the base times the height cubed divided by 12 or:

$I = \text{width} \times L^3 / 12$

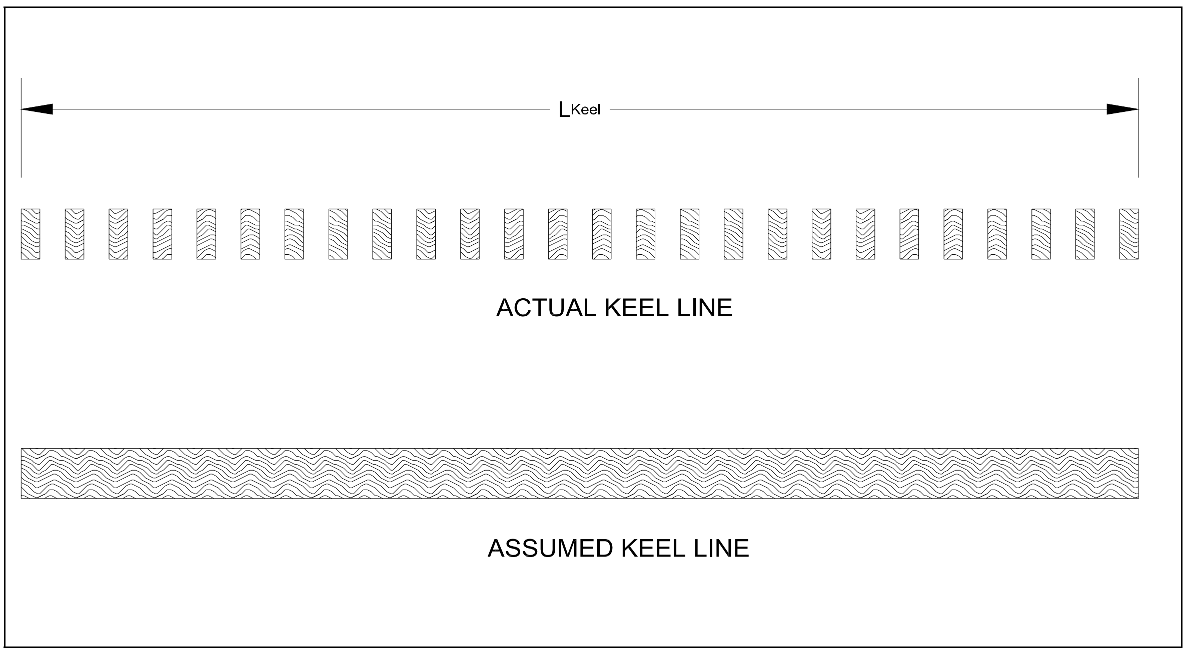


FIGURE 12

Moment (M) is force times distance and the moment on the keel blocks is equal to the ship's weight (W) or (force) times the distance the center of gravity of the ship's weight is from the center of blocks (e) or:

$M = W \times e$

Area of the rectangle is equal to length times width or:

$A = L \times \text{width}$

C is the distance from centre of area to end of the rectangle or:

$C = L/2$

Substituting these values into the equation

$P/A \pm M \times c / I$

You get:

$W / (L \times width) \pm W \times e \times (L/2) / (width \times L^3 / 12)$

If the width of all the blocks is the same, you can use 1 for the width and the result of the equation will be in tons per foot of length (instead of tons per square foot).

Using width = 1 and simplifying results in the trapezoidal equation:

$$\textbf{Load} = W/L \pm 6 \times W \times e / L^2$$

This is a good approximation of the ship's loading along the blocks if the blocks are spaced regularly and block bearing width is constant. If block's are omitted, gaps are created in the keel line, and the assumption that the block line is a single rectangle is no longer valid.

6 – Moment Area Method

In some instances, keel blocks must be omitted to allow clearance for sonar domes or other appendages that hang below the hull or to allow access for repairing that area of the keel. Some vessels will not have a distinct keel line and have multiple lines of blocks at varying spacings. In the case of mat drilling rigs, blocks can be spaced irregularly under the rectangular or triangular mat.

With gaps in the keel line, irregular spaced blocks, different size blocks etc. the block line can not be considered as a single rectangle and each block area must be considered individually. This causes two changes in the analyses method. First, the center of the blocking area is no longer at ½ the keel length (1/2 L) and must be calculated. Second, the moment of inertia about the center of blocks must be calculated for each rectangle segments.

See Figure 13.

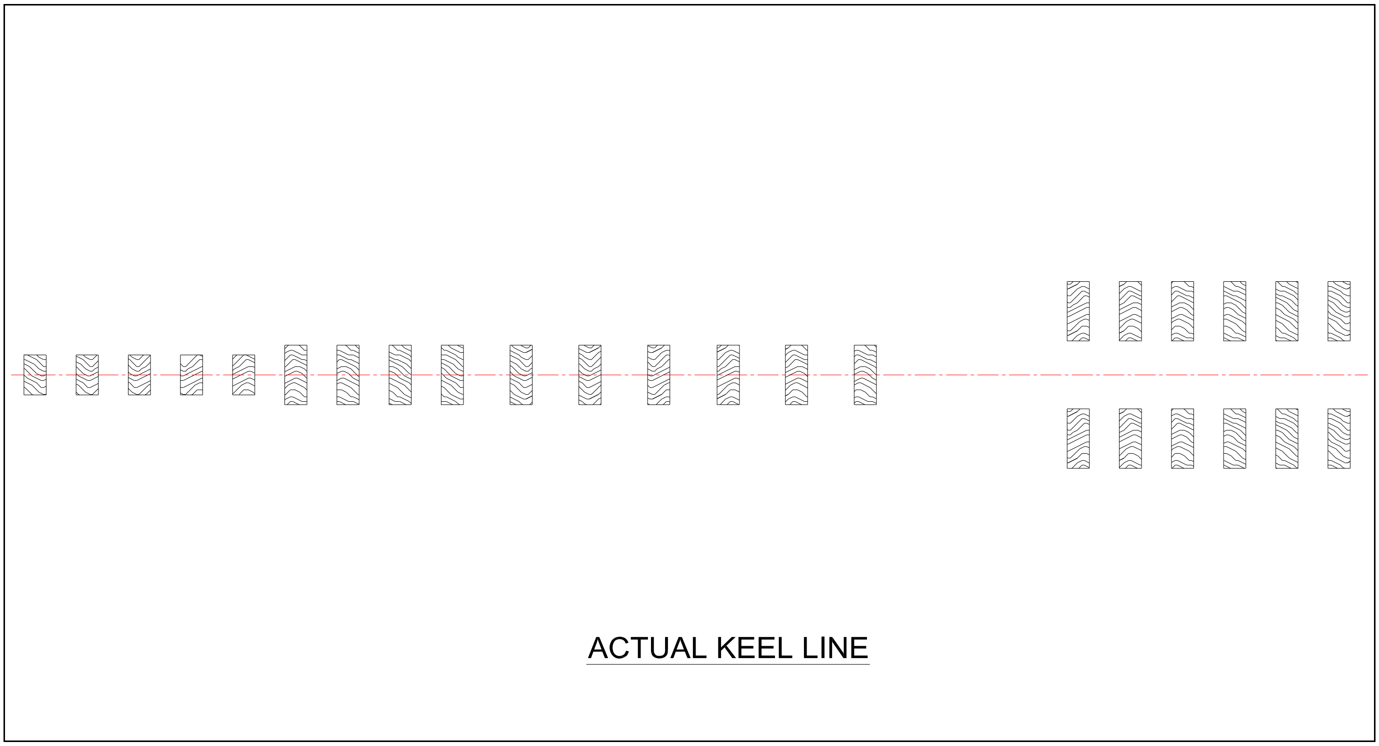


FIGURE 13

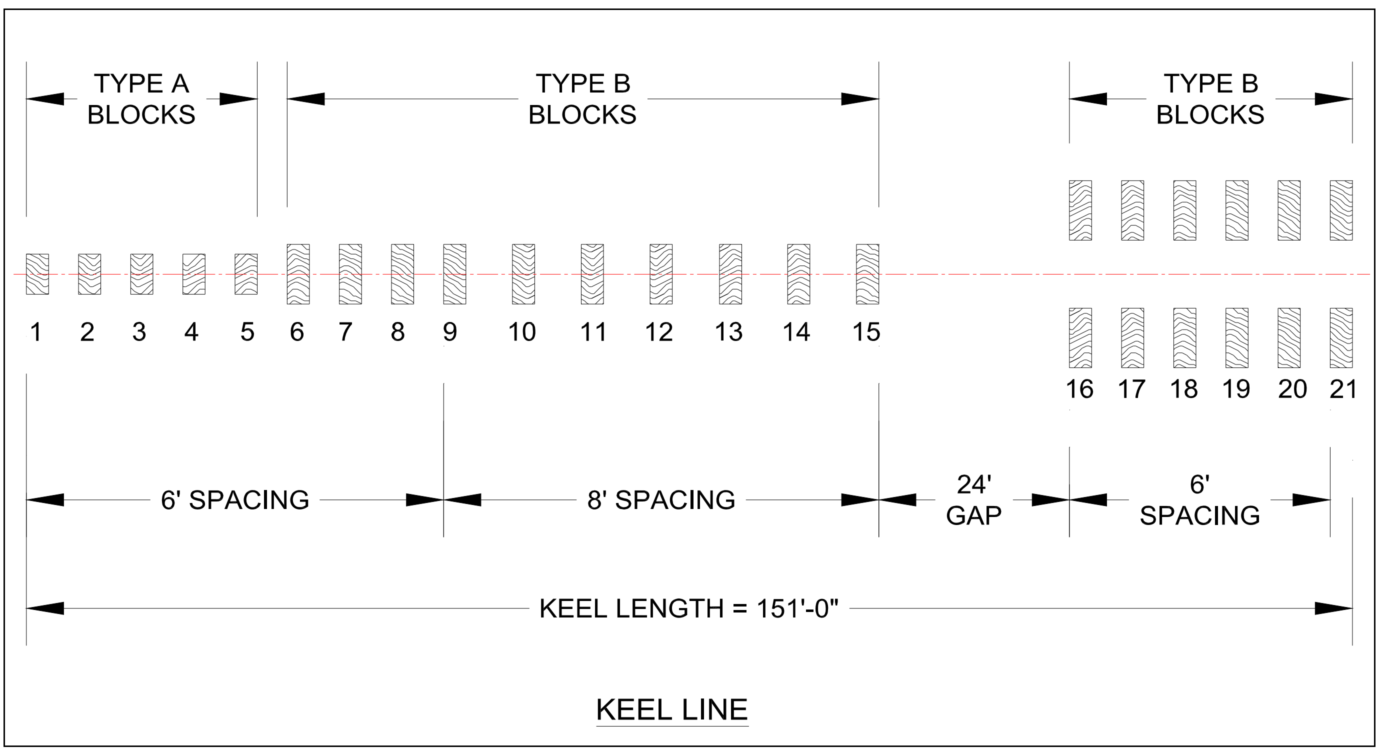


FIGURE 14

Type A blocks are 12” long by 24 Inches wide.

Type B blocks are 12” long by 48 Inches wide.

Calculation of Center of Block Area

First, the center of blocks must be calculated. This can be done by taking the sum of each rectangle's area times it's distance from any arbitrary point and dividing by the total area of all the rectangles. Usually, the arbitrary point is taken as one end of the keel line. With many different type blocks this is best done in an Excel spreadsheet. For this example all distances are referenced to the forward edge of block number 1.

CENTER OF BLOCK AREA					
Block #	Block Length (in)	Block Width (in)	Area (**A**) (in^2)	Distance from Ref. to C.L. block D, (ft)	A x D (in^2-ft)
1	12	24	288	0.50	144
2	12	24	288	6.50	1,872
3	12	24	288	12.50	3,600
4	12	24	288	18.50	5,328
5	12	24	288	24.50	7,056
6	12	48	576	30.50	17,568
7	12	48	576	36.50	21,024
8	12	48	576	42.50	24,480
9	12	48	576	48.50	27,936
10	12	48	576	56.50	32,544
11	12	48	576	64.50	37,152
12	12	48	576	72.50	41,760
13	12	48	576	80.50	46,368
14	12	48	576	88.50	50,976
15	12	48	576	96.50	55,584
16 A	12	48	576	120.50	69,408
16 B	12	48	576	120.50	69,408
17 A	12	48	576	126.50	72,864
17 B	12	48	576	126.50	72,864
18 A	12	48	576	132.50	76,320
18 B	12	48	576	132.50	76,320
19 A	12	48	576	138.50	79,776
19 B	12	48	576	138.50	79,776
20 A	12	48	576	144.50	83,232
20 B	12	48	576	144.50	83,232
21 A	12	48	576	150.50	86,688
21 B	12	48	576	150.50	86,688
Totals			14,112	92.83	1,309,968

The center of the blocking area is calculated by dividing the total moment area (A x D) by the total block area or:

1,309,968 / 14,112 = 92.83 Ft.

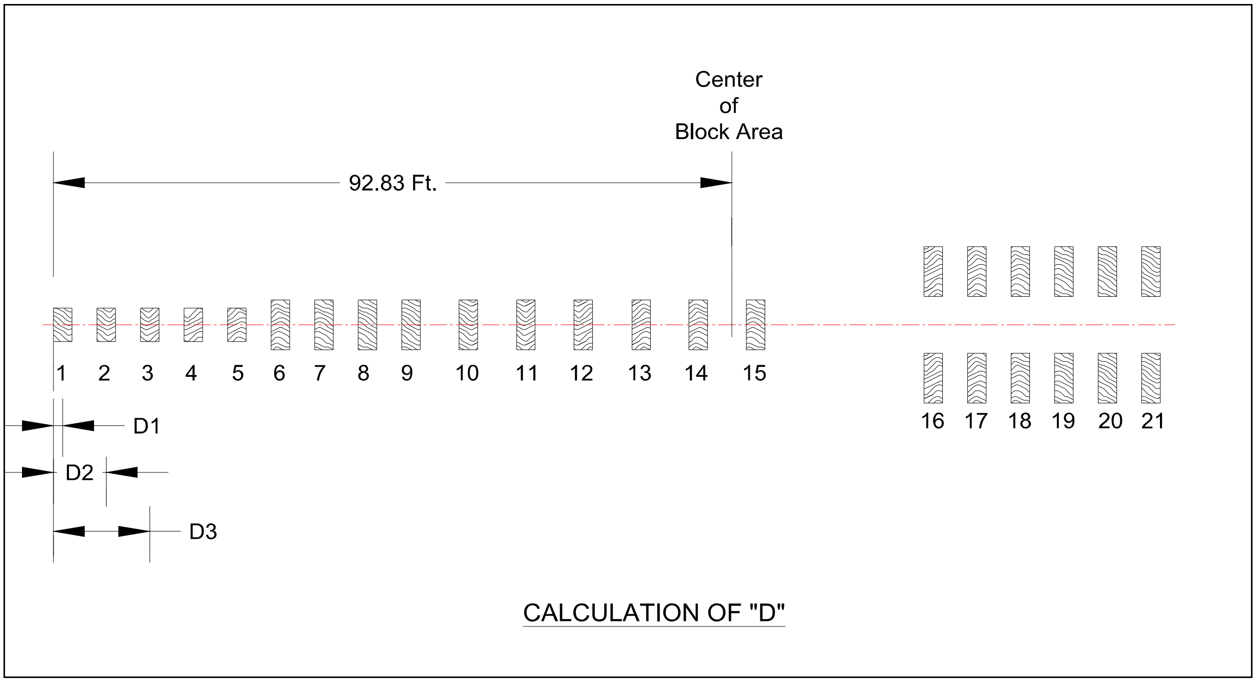


FIGURE 15

Calculation of "d"

Next we have to calculate the distance from the center of block area to the center of each block. This dimension is designated as "d_x".

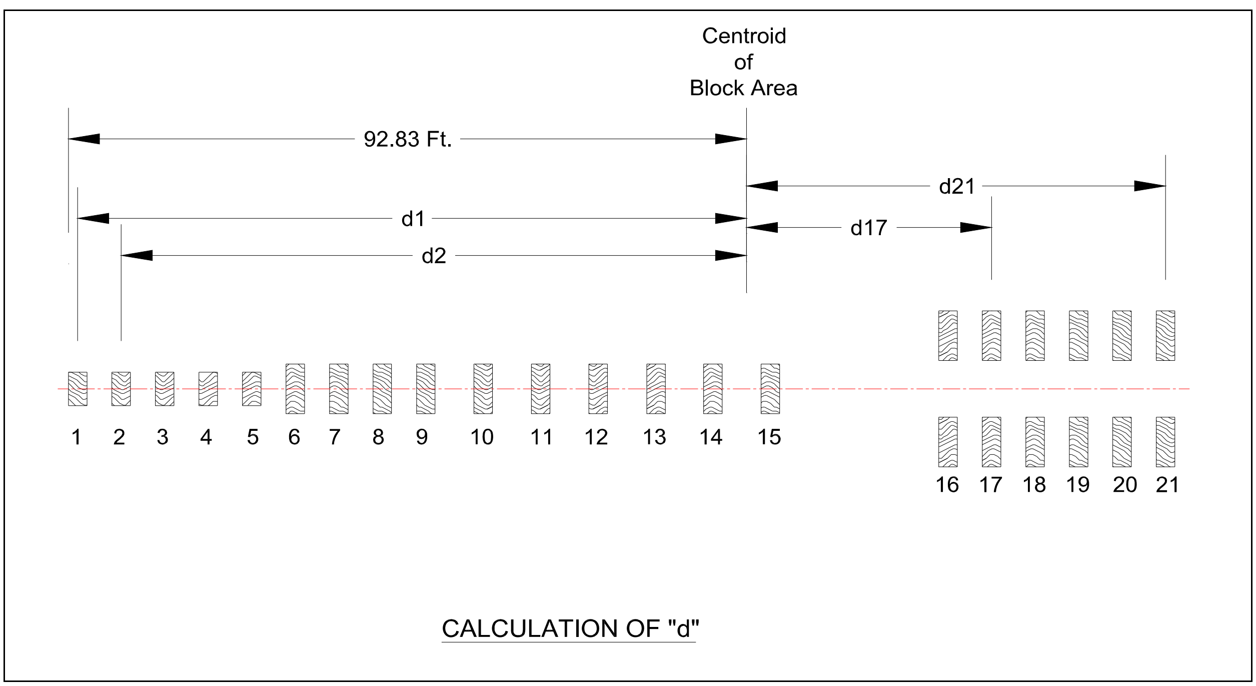


FIGURE 16

CALCULATION OF "d"						
Block #	Block Length (in)	Block Width (in)	Area (**A**) (in^2)	Distance from Ref. to C.L. block D, (ft)	A x D (in^2-ft)	X-D = d (ft)
1	12	24	288	0.50	144	92.33
2	12	24	288	6.50	1,872	86.33
3	12	24	288	12.50	3,600	80.33
4	12	24	288	18.50	5,328	74.33
5	12	24	288	24.50	7,056	68.33
6	12	48	576	30.50	17,568	62.33
7	12	48	576	36.50	21,024	56.33
8	12	48	576	42.50	24,480	50.33
9	12	48	576	48.50	27,936	44.33
10	12	48	576	56.50	32,544	36.33
11	12	48	576	64.50	37,152	28.33
12	12	48	576	72.50	41,760	20.33
13	12	48	576	80.50	46,368	12.33
14	12	48	576	88.50	50,976	4.33
15	12	48	576	96.50	55,584	-3.67
16 A	12	48	576	120.50	69,408	-27.67
16 B	12	48	576	120.50	69,408	-27.67
17 A	12	48	576	126.50	72,864	-33.67
17 B	12	48	576	126.50	72,864	-33.67
18 A	12	48	576	132.50	76,320	-39.67
18 B	12	48	576	132.50	76,320	-39.67
19 A	12	48	576	138.50	79,776	-45.67
19 B	12	48	576	138.50	79,776	-45.67
20 A	12	48	576	144.50	83,232	-51.67
20 B	12	48	576	144.50	83,232	-51.67
21 A	12	48	576	150.50	86,688	-57.67
21 B	12	48	576	150.50	86,688	-57.67
Totals			14,112	92.83	1,309,968	

Each individual "d" is equal to the distance from the reference point to the center of all block area minus D the distance from the reference point to the individual block center or

$92.83 - D_x = d_x$

For Example:

D_1 = 92.83 – 0.5 = 92.33 Feet

D_2 = 92.83 – 6.5 = 86.33 Feet

D_3 = 92.83 – 12.5 = 80.33 Feet

Etc.

Calculation of I

Next the moment of inertia of each individual block with respect to the center of all blocking must be calculated and the results added together to obtain the total moment of inertia of the blocking system about the system's center.

The moment of inertia of a rectangle about an arbitrary axis is

$I = b \times h^3 / 12 + A \times d^2$

Where:

- I = Moment of inertia of individual block
- b = Base of the rectangle which is the width of the block (Dimension transverse to the vessel)
- h = Height of the rectangle which is the length of the block (Dimension longitudinal to the vessel)
- A = Area of the rectangle which is b x h
- d = Distance the center of the rectangle is from the axis being investigated (center of all block area in this case)

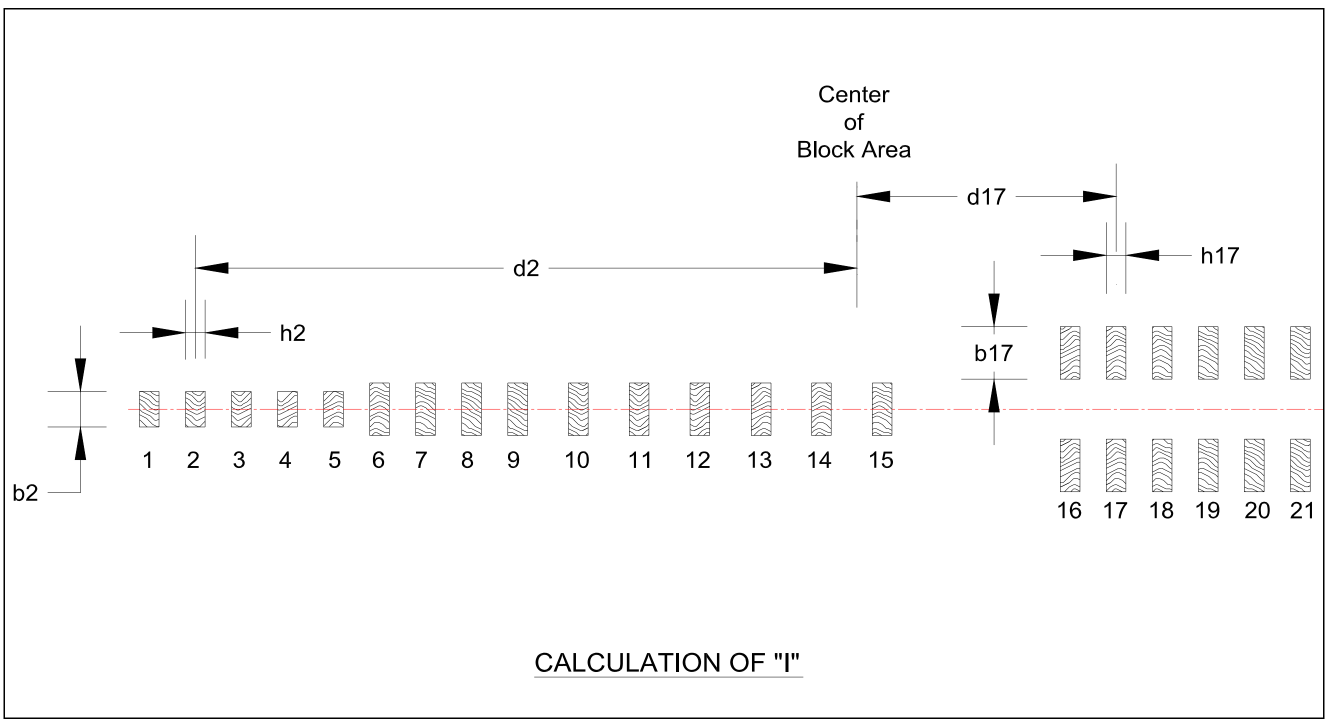


FIGURE 17

CALCULATION OF I							
Block #	Block Length (in)	Block Width (in)	Area (**A**) (in^2)	Distance from Ref. to C.L. block D, (ft)	A x D (in^2-ft)	X-D = d (ft)	Mom. Of Inertia I (in^4)
1	12	24	288	0.50	144	92.33	353,518,591
2	12	24	288	6.50	1,872	86.33	309,063,993
3	12	24	288	12.50	3,600	80.33	267,595,378
4	12	24	288	18.50	5,328	74.33	229,112,748
5	12	24	288	24.50	7,056	68.33	193,616,101
6	12	48	576	30.50	17,568	62.33	322,210,877
7	12	48	576	36.50	21,024	56.33	263,161,520
8	12	48	576	42.50	24,480	50.33	210,084,131
9	12	48	576	48.50	27,936	44.33	162,978,710
10	12	48	576	56.50	32,544	36.33	109,461,210
11	12	48	576	64.50	37,152	28.33	66,560,542
12	12	48	576	72.50	41,760	20.33	34,276,706
13	12	48	576	80.50	46,368	12.33	12,609,702
14	12	48	576	88.50	50,976	4.33	1,559,530
15	12	48	576	96.50	55,584	-3.67	1,126,190
16 A	12	48	576	120.50	69,408	-27.67	63,527,161
16 B	12	48	576	120.50	69,408	-27.67	63,527,161
17 A	12	48	576	126.50	72,864	-33.67	94,057,324
17 B	12	48	576	126.50	72,864	-33.67	94,057,324
18 A	12	48	576	132.50	76,320	-39.67	130,559,455
18 B	12	48	576	132.50	76,320	-39.67	130,559,455
19 A	12	48	576	138.50	79,776	-45.67	173,033,554
19 B	12	48	576	138.50	79,776	-45.67	173,033,554
20 A	12	48	576	144.50	83,232	-51.67	221,479,621
20 B	12	48	576	144.50	83,232	-51.67	221,479,621
21 A	12	48	576	150.50	86,688	-57.67	275,897,656
21 B	12	48	576	150.50	86,688	-57.67	275,897,656
Totals			14,112	92.83	1,309,968		4,454,045,474

For Example:

$I_1 = b \times h^3 / 12 + A \times d^2 = 24 \times 12^3 /12 + 288 \times (92.33 \times 12)^2 = 353{,}518{,}591 \text{ In.}^4$

$I_2 = b \times h^3 / 12 + A \times d^2 = 24 \times 12^3 /12 + 288 \times (86.33 \times 12)^2 = 309{,}063{,}993 \text{ In.}^4$

$I_{17} = b \times h^3 / 12 + A \times d^2 = 48 \times 12^3 /12 + 576 \times (-33.67 \times 12)^2 = 94{,}057{,}324 \text{ In.}^4$

Please note that the dimension “d” must be multiplied by 12 to convert feet to inches.

The total moment of inertia, I, for the block system is the sum of the I for all individual blocks.

Calculation of “c”

In the equation P/A ± M x c / I, the dimension “c” is the distance from the center of all blocking to the point at which you want to calculate the block pressure. We need to calculate the pressure at the center of each block. Thus, the dimension “c” is equal to the dimension “d” for each individual block.

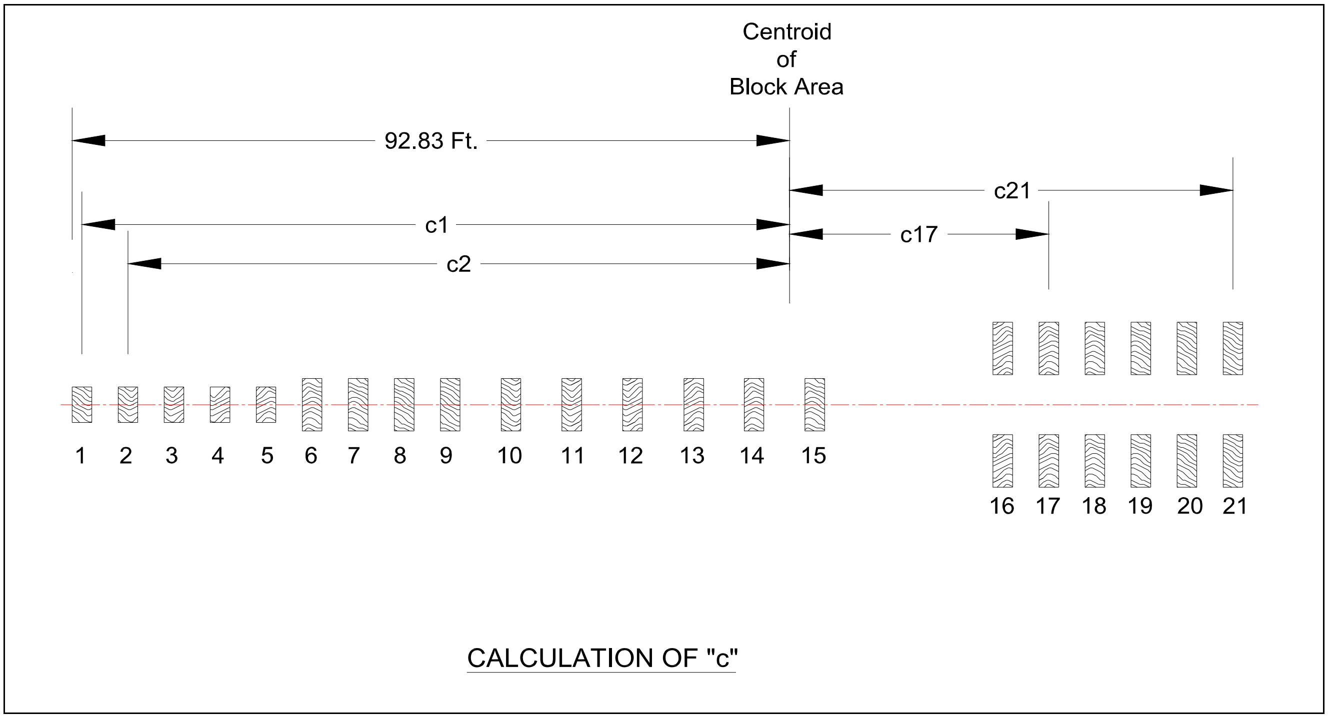


FIGURE 18

Calculation of “e”

We need to calculate the eccentricity (e), which is the distance the longitudinal center of gravity of the vessel (LCG) is from the center of the block area (See Figure 19). The location of the LCG is dependent on how the vessel is loaded and can be determined using the vessel’s drafts and hydrostatic properties of the hull.

In this example the LCG is 84.33 feet aft of the first block. We have previously calculated the center of blocking to be 92.83 feet aft of the first block.

Thus, e = 92.83 – 84.33 = 8.5 feet forward of the center of blocking.

See Figure 19.

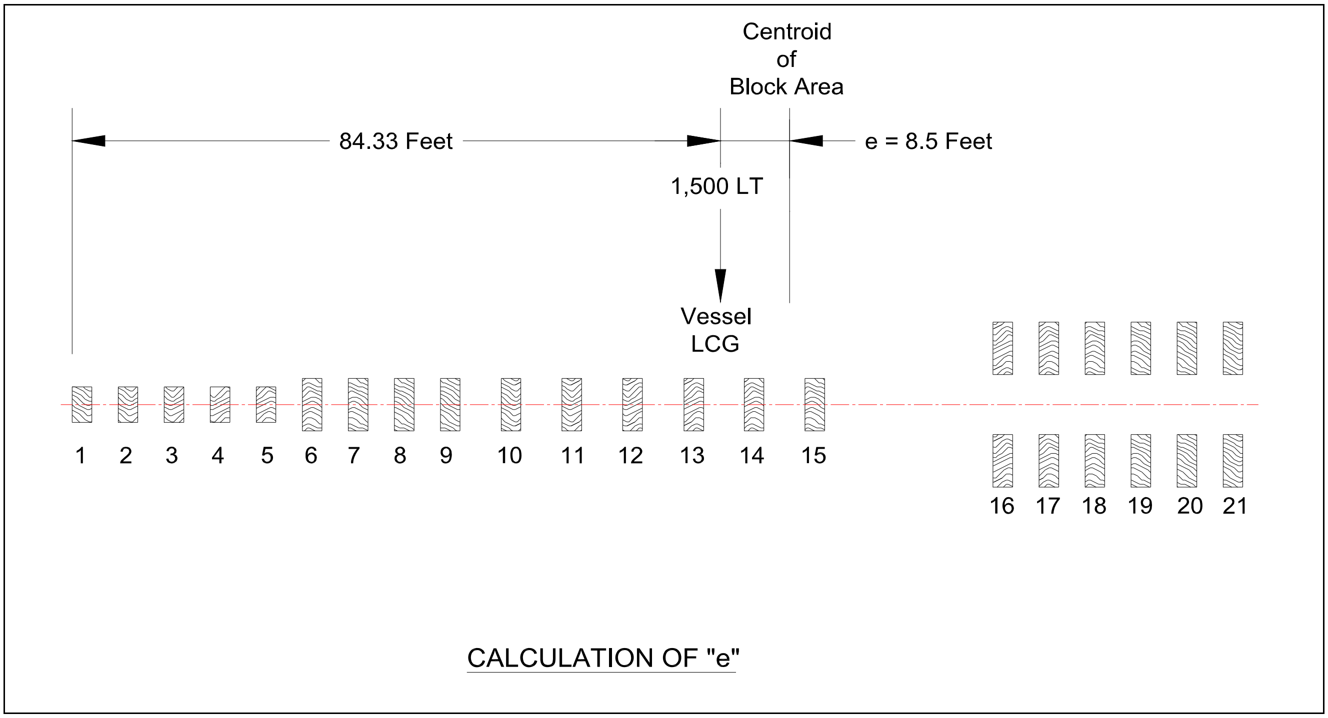


FIGURE 19

Calculation of Block Pressure

We now have all the values needed to plug into the eccentrically loaded column equation and obtain the values of block pressure at the center of each block:

$$P/A \pm M \times c / I \qquad \text{Or} \qquad W/A \pm W \times e \times c / I$$

Where:

- W = vessel wt. = 1,500 LT
- A = block area = 14,112 $In.^2$ = 98 $Ft.^2$
- e = eccentricity = 8.5 Ft.
- I = moment of inertia = 4,454,045,474 $In.^4$ = 214,798 $Ft.^4$
- c = the distance from the center of block area to the point being investigated. Points calculated are usually the center of each block.

The equation produces a result in long tons per square foot block of area (pressure on the block.)

CALCULATION OF BLOCK PRESSURE								
Block #	Block Length (in)	Block Width (in)	Area (**A**) (in^2)	Distance from Ref. to C.L. block D, (ft)	A x D (in^2-ft)	X-D = d (ft)	Mom. Of Inertia I (in^4)	Block Pressure LT/$ft.^2$
1	12	24	288	0.50	144	92.33	353,518,591	20.79
2	12	24	288	6.50	1,872	86.33	309,063,993	20.43
3	12	24	288	12.50	3,600	80.33	267,595,378	20.07
4	12	24	288	18.50	5,328	74.33	229,112,748	19.72
5	12	24	288	24.50	7,056	68.33	193,616,101	19.36
6	12	48	576	30.50	17,568	62.33	322,210,877	19.01
7	12	48	576	36.50	21,024	56.33	263,161,520	18.65
8	12	48	576	42.50	24,480	50.33	210,084,131	18.29
9	12	48	576	48.50	27,936	44.33	162,978,710	17.94
10	12	48	576	56.50	32,544	36.33	109,461,210	17.46
11	12	48	576	64.50	37,152	28.33	66,560,542	16.99
12	12	48	576	72.50	41,760	20.33	34,276,706	16.51
13	12	48	576	80.50	46,368	12.33	12,609,702	16.04
14	12	48	576	88.50	50,976	4.33	1,559,530	15.56
15	12	48	576	96.50	55,584	-3.67	1,126,190	15.09
16 A	12	48	576	120.50	69,408	-27.67	63,527,161	13.66
16 B	12	48	576	120.50	69,408	-27.67	63,527,161	13.66
17 A	12	48	576	126.50	72,864	-33.67	94,057,324	13.31
17 B	12	48	576	126.50	72,864	-33.67	94,057,324	13.31
18 A	12	48	576	132.50	76,320	-39.67	130,559,455	12.95
18 B	12	48	576	132.50	76,320	-39.67	130,559,455	12.95
19 A	12	48	576	138.50	79,776	-45.67	173,033,554	12.60
19 B	12	48	576	138.50	79,776	-45.67	173,033,554	12.60
20 A	12	48	576	144.50	83,232	-51.67	221,479,621	12.24
20 B	12	48	576	144.50	83,232	-51.67	221,479,621	12.24
21 A	12	48	576	150.50	86,688	-57.67	275,897,656	11.88
21 B	12	48	576	150.50	86,688	-57.67	275,897,656	11.88
Totals			14,112	92.83	1,309,968		4,454,045,474	

The pressure distribution is a sloping straight line similar to the trapezoidal loading equation except the line denotes pressure (LT/Ft.^{2}) and not load per foot (LT/Ft.).

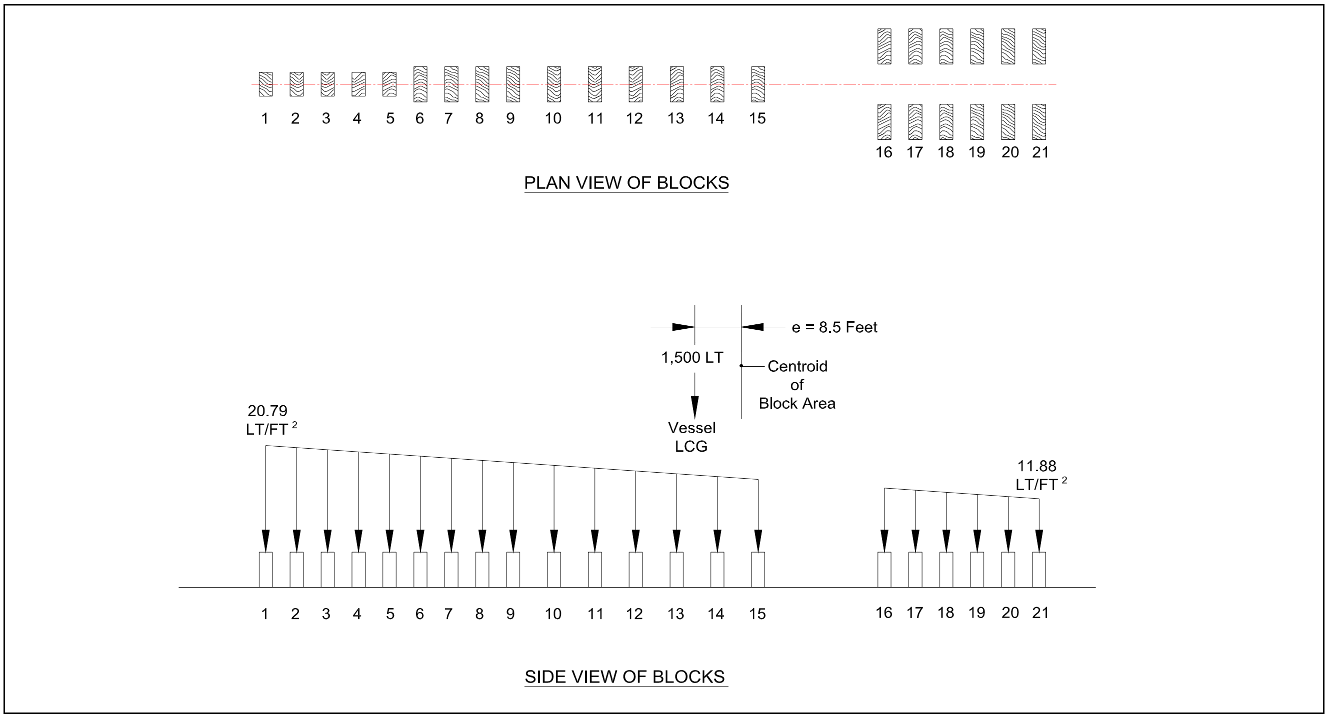


FIGURE 20

Calculation of Block Load

The actual load on each block can be calculated by multiplying the area of the block by the pressure on the block.

For example:

Block 1 has an area of 288 In.^{2} or 288/144 = 2 Ft.^{2} and a pressure of 20.79 LT/Ft^2. Thus the load on the block is 2 Ft. ^{2} x 20.79 LT/Ft.^{2} = 41.58 LT

Block 6 has an area of 576 In.^{2} or 576/144 = 4 Ft.^{2} and a pressure of 19.01 LT/Ft^2. Thus the load on the block is 4 Ft. ^{2} x 19.01 LT/Ft.^{2} = 76.04 LT

Block 16A and 16 B have an area of 576 In.^{2} or 576/144 = 4 Ft.^{2} each and a pressure of 13.66 LT/Ft^2. Thus the load on each block is 4 Ft. ^{2} x 13.66 LT/Ft.^{2} = 54.64 LT. The load on both blocks is 54.64 LT x 2 = 109.28 LT.

CALCULATION OF BLOCK LOAD									
Block #	Block Length (in)	Block Width (in)	Area (**A**) (in^2)	Dist. from Ref. to C.L. block D, (ft)	A x D (in^2-ft)	X-D = d (ft)	Mom. Of Inertia I (in^4)	Block Pres. LT/ft.^{2}	Block Load LT
1	12	24	288	0.50	144	92.33	353,518,591	20.79	41.58
2	12	24	288	6.50	1,872	86.33	309,063,993	20.43	40.86
3	12	24	288	12.50	3,600	80.33	267,595,378	20.07	40.14
4	12	24	288	18.50	5,328	74.33	229,112,748	19.72	39.44
5	12	24	288	24.50	7,056	68.33	193,616,101	19.36	38.72
6	12	48	576	30.50	17,568	62.33	322,210,877	19.01	76.04
7	12	48	576	36.50	21,024	56.33	263,161,520	18.65	74.60
8	12	48	576	42.50	24,480	50.33	210,084,131	18.29	73.16
9	12	48	576	48.50	27,936	44.33	162,978,710	17.94	71.76
10	12	48	576	56.50	32,544	36.33	109,461,210	17.46	69.84
11	12	48	576	64.50	37,152	28.33	66,560,542	16.99	67.96
12	12	48	576	72.50	41,760	20.33	34,276,706	16.51	66.04
13	12	48	576	80.50	46,368	12.33	12,609,702	16.04	64.16
14	12	48	576	88.50	50,976	4.33	1,559,530	15.56	62.24
15	12	48	576	96.50	55,584	-3.67	1,126,190	15.09	60.36
16 A	12	48	576	120.50	69,408	-27.67	63,527,161	13.66	54.64
16 B	12	48	576	120.50	69,408	-27.67	63,527,161	13.66	54.64
17 A	12	48	576	126.50	72,864	-33.67	94,057,324	13.31	53.24
17 B	12	48	576	126.50	72,864	-33.67	94,057,324	13.31	53.24
18 A	12	48	576	132.50	76,320	-39.67	130,559,455	12.95	51.80
18 B	12	48	576	132.50	76,320	-39.67	130,559,455	12.95	51.80
19 A	12	48	576	138.50	79,776	-45.67	173,033,554	12.60	50.40
19 B	12	48	576	138.50	79,776	-45.67	173,033,554	12.60	50.40
20 A	12	48	576	144.50	83,232	-51.67	221,479,621	12.24	48.96
20 B	12	48	576	144.50	83,232	-51.67	221,479,621	12.24	48.96
21 A	12	48	576	150.50	86,688	-57.67	275,897,656	11.88	47.52
21 B	12	48	576	150.50	86,688	-57.67	275,897,656	11.88	47.52
Totals			14,112	92.83	1,309,968		4,454,045,474		1,500

CHECK

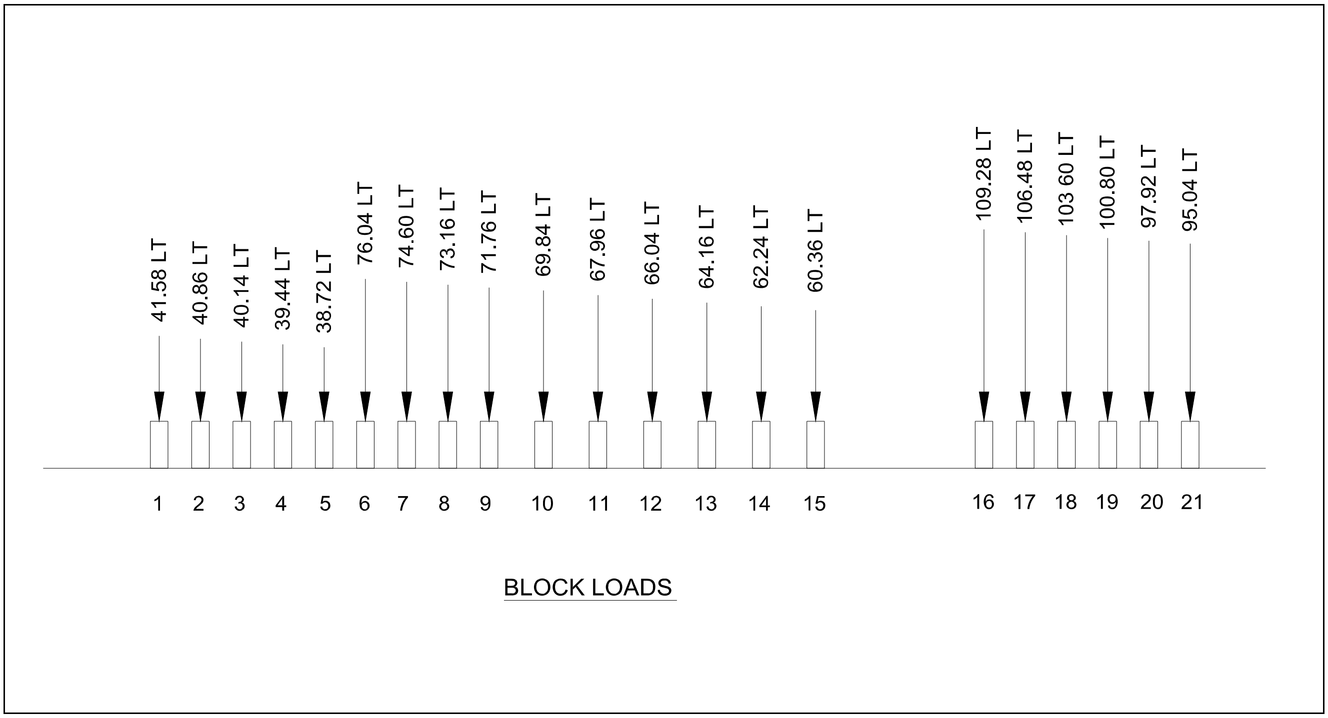


FIGURE 21

Load per foot on the dock floor can be calculated by dividing the block loads by the block spacing.

For example: At Blocks 16 A and B - 109.28 LT / 6 Ft. = 18.21 LT/Ft.

At Block 10 - 69.84 LT / 8 Ft. = 8.73 LT/Ft.

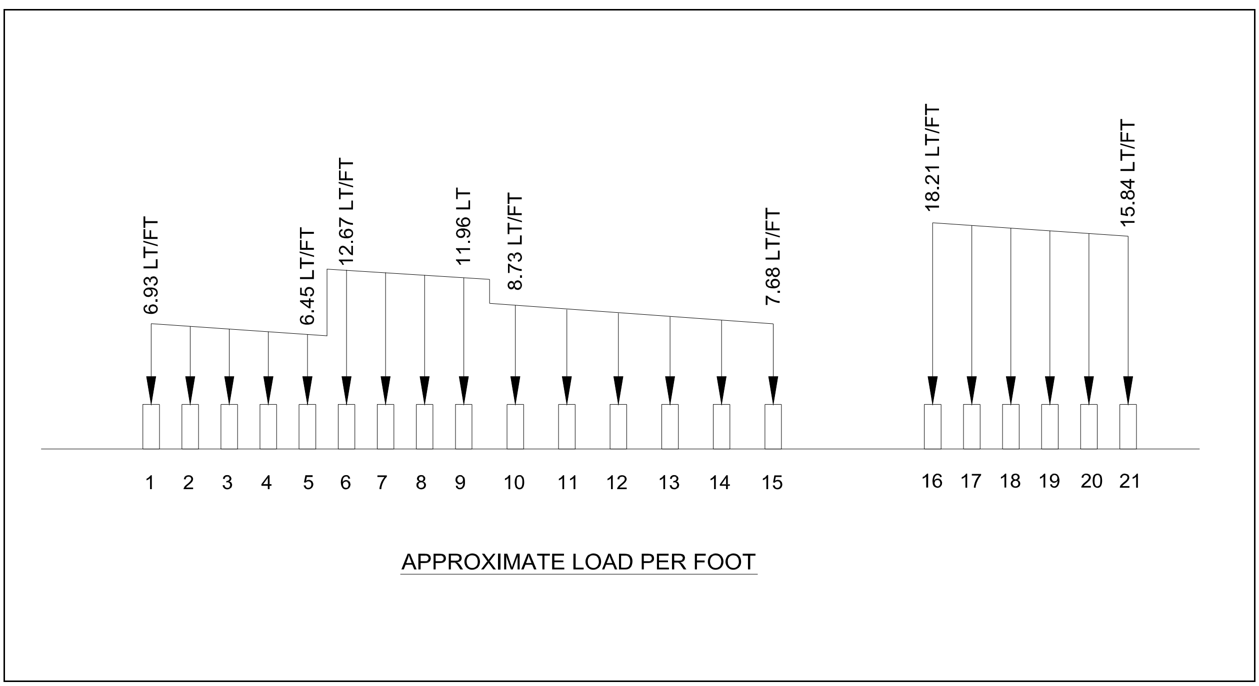


FIGURE 22

7.0 - Comparison with Trapezoidal Load Equation

If the standard trapezoidal loading equation was used to calculate the block loading for this vessel the results would have been different.

The following shows what the results would be if the trapezoidal load equation was used to compute the load per foot instead of the moment area method.

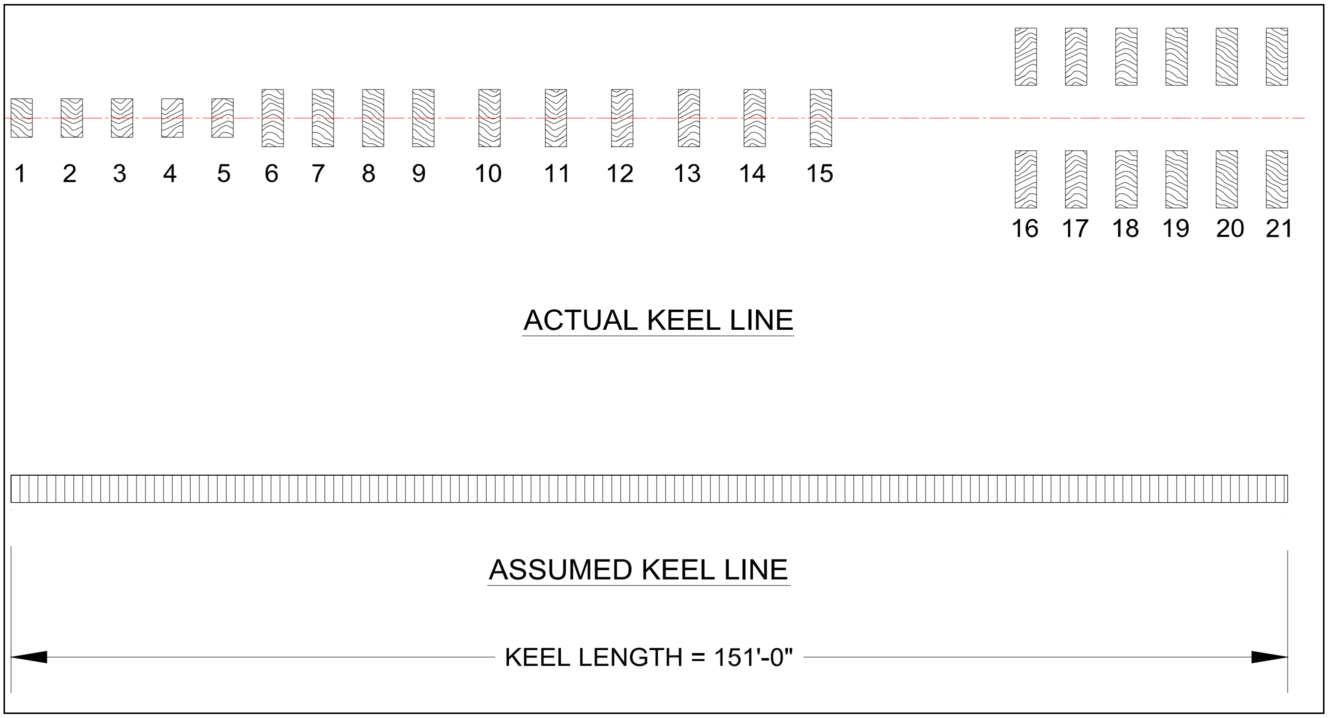


FIGURE 23

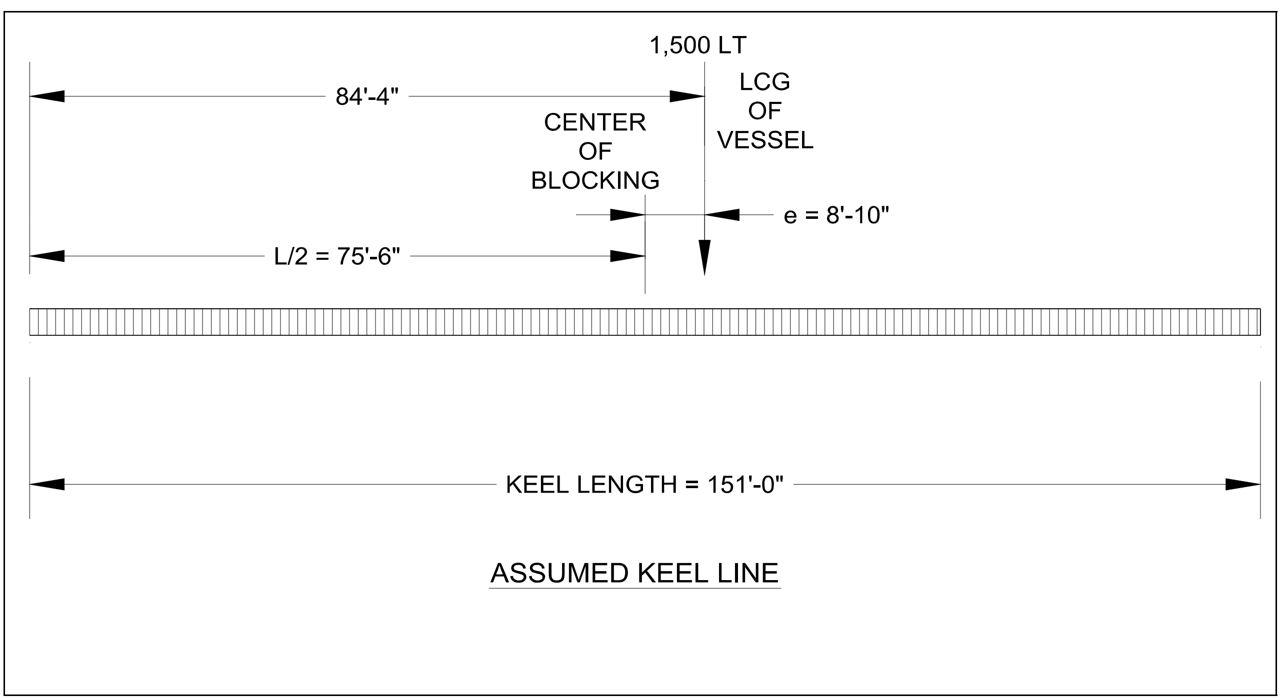


FIGURE 24

Figure 24 shows the assumed keel line with the longitudinal center of gravity of the vessel placed in the same relative location as the previous example.

The block loading is calculated by using the trapezoidal loading equation:

$$\text{Load} = W/L \pm 6 \times W \times e / L^2$$

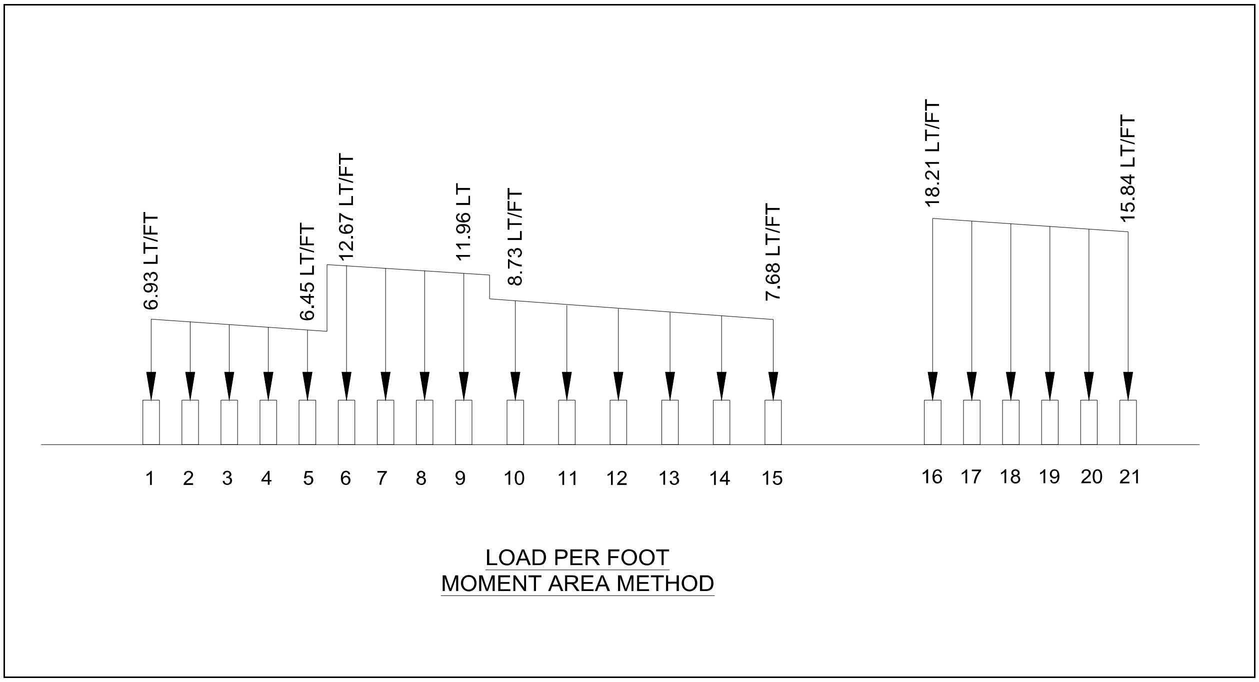
Where:

- W = 1,500 LT
- L = 151 Ft.
- e = 8.83'

Load per foot = $1500/151 \pm 6 \times 1500 \times 8.83 / 151^2$

- = 13.42 LT/Ft. Aft
- = 6.44 LT/Ft. Fwd

Figure 25 compares the loading imposed by the same vessel on a continuous block line and one with a 50' gap in it.



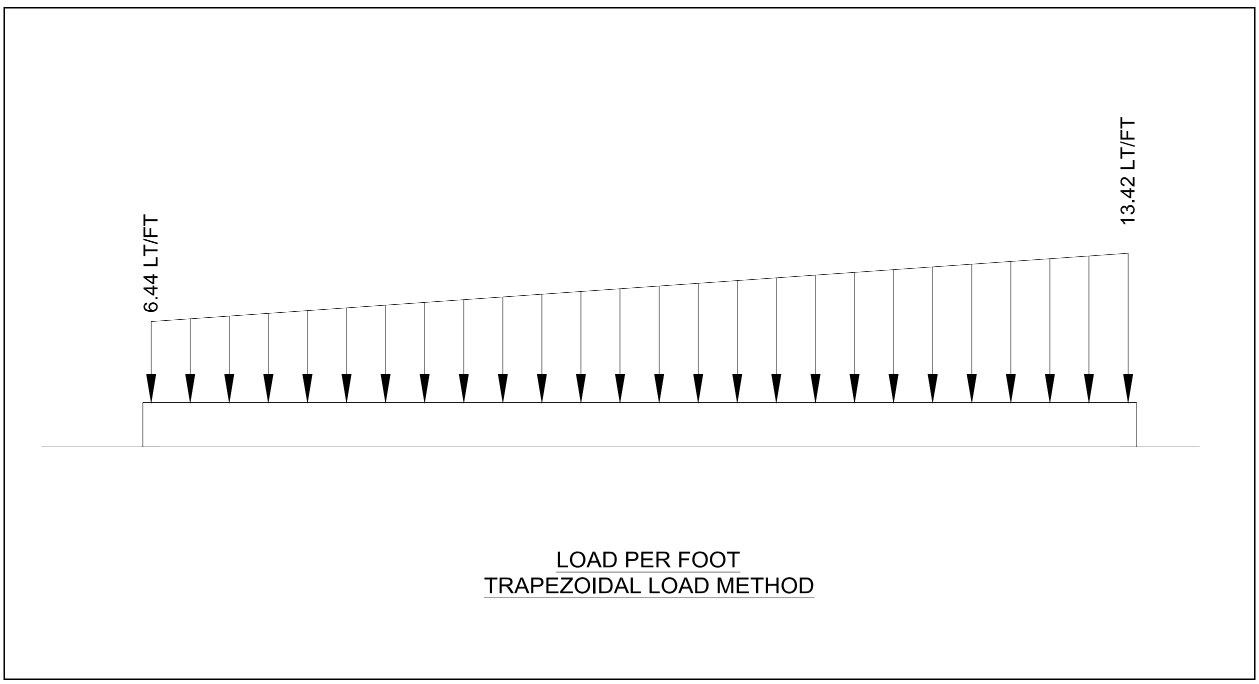


FIGURE 25

8.0 - Conclusions

The Trapezoidal Load Equation can be used for many typical dockings to determine the load on the blocks and dry dock and to develop pumping plans for floating dry docks.

The analysis assumes the ship is infinitely stiff and the blocks are all of uniform size, materials, and spacing. It also assumes that 100 percent of the load goes into the keel blocks.

The Trapezoidal Loading Equation will not be valid if:

- The longitudinal strength of the ship is impaired due to damage or cutting.
- The blocks are not all constructed similarly.
- The block spacing is not uniform.
- The bearing area varies on top of the block (bar keel at one end, etc.)
- The vessel over hangs the keel blocks by more than twice its molded depth.
- The ship has a large initial hog or sag and the keel line is built straight.
- A floating dock is not dewatered according to the trapezoidal results.

Some vessels do not have a singular line of uniformly spaced and sized keel blocks. They may have different size blocks, irregularly spaced blocks, multiple line of keel blocks or as in the case of drill rigs, blocks spaced over a large rectangular or triangular area. In these instances, the Moment Area Method is a much more accurate method of predicting block loads.

The Moment Area Method assumes the vessel is infinitely stiff and that all blocks have the same modulus of elasticity. Thus the method will not be valid if:

- The longitudinal strength of the ship is impaired due to damage or cutting.
- Some blocks are built stiffer than others.
- The vessel over hangs the keel blocks by more than twice its molded depth.
- The ship has a large initial hog or sag and the keel line is built straight.
- A floating dock is not dewatered according to the trapezoidal results.

The example presented here assumes the transverse center of gravity of the vessel is positioned over the transverse center of block area. The Moment Area Method can be used to calculate block loads for vessels (such as drill rigs) that have eccentricity on both the longitudinal and transverse directions but those calculations are beyond the scope of this paper.

Robert Heger
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