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Effect of Static Load on Work Barge Deck Structure

UGODO GODWIN*[1], ABEKI PULLAR[2]., UTI PRECIOUS[3]
DEPARTMENT OF MARINE ENGINEERING, FACULTY OF ENGINEERING, NIGERIA MARITIME UNIVERSITY, OKENRENKOKO, DELTA STATE, NIGERIA

ABSTRACT
This study assessed the effects of static load on a work barge deck using a Work Barge of 3177 gross tonnage, length 77m, breath moulded 24.03m and depth moulded 6.3m as a case study. The Finite Element Method (FEM) was used to achieve the objectives of this study. Furthermore, five steps were followed to analyse the loads on the work barge deck using MATLAB to compute the Area, stress, strain, and displacement leading to the generations of stress-strain and displacement-force graphs. The graph of displacement (U) against force (F) indicates that a different load placed on the deck of the work barge will make the material plate either deform, embellish, or remain normal. Some of the areas on the work barge which are deformed will required addition of stiffener to rigid the plate making the work barge structure firm or by increasing the plate thickness. When the material selected is below the maximum stress (0.2874 GPA), maximum strain (0.000189), maximum displacement (0.3019MM), and maximum force (2032656N) estimated from the result obtained then the material will fail.
KEY WORD*: Barge, Load, Force, Stress, Strain, Displacement*

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I. INTRODUCTION

1.1 Background of Study

The continuous increment in the universal seaborne trade, we have seen a quick development of the shipping industry in the later decade. Also, with shipping activities becoming more frequent and subsequently more news about work barge collapsing continued to happen. The collapse of a work barge structure can have serious societal and maritime consequences, yet the behaviour of collapsing work barge is not well understood. More investigation is required to completely get the energetic nonlinear behaviour of these ships. According to the work barge accident investigation report. The fundamental reason for these mishaps is the work barge’s basic ultimate quality deficiency to withstand outside loads acting on it in noteworthy oceans. Therefore, the different maritime organization produces rules and regulation relating to progressive collapse and wreck behaviour of work barge structures (waves) on the seaway. The work barge structure has been customarily partitioned into three subcategories, Hull girder, internal structure, and superstructure. The basic component plays different parts in keeping up the astuteness of the ship. Therefore, a numerical and experimental investigation is required to examine the behaviour of the work barge structure under static loading rates and its effect on the collapse process

1.2 Case Study Description

Whilst the immediate maritime problems related to the work barge structure have been well documented, the behaviour of the work barge under static loading rates (collapse loading rate) and its effect on the collapse process is estimated. This study focuses on evaluating the itemize objective which document the state of art with respect to study topic to be achieved. Furthermore, relevant area of study, accurately resolved the mechanism of work barge failure, work barge structure, static loads, different stresses and strain.

1.3 Aim and Objective

The aim of this study is to investigate the collapse effect of static load on the work barge structure (Deck Plate). This aim is accomplished via the following objectives

- To analyse the loads and area of load on work barge deck.
- To determine Displacement, Force, Strain, and Stress on the barge deck using a mathematical model (FEM)
- To Developing a MATLAB program to estimate the Displacement, Forces, Strain and Stress.

II. LITERATURE REVIEW

2.1 Summary of Reviewed Literature

When the blast load acts on the steel frame joints, it produces destructive vibration at the end, part of the structure recovers from deformation after elongating. Work barges made of steel will undergo elongation with more loads increment. Also, the ultimate strength of the plate decreases due to stress creation. in rectangular plates and an arrangement of pits has more effect on reduction of the ultimate strength of cracked-pitted plates than the number of pits. Under loading all the fundamental frequencies of the structural member need to be considered, as they may cause a large contribution on vibrational control and fractural response also, an experimental program is needed to inspect the failure mode of the structural member. With more loads acting in work barge structure the more the draft of the work barge increases and also the more stresses the work barge will experience i.e., load is proportional to stress and draft. Therefore, Load combination factors LCFs and strength assessment calculation is necessary for ship safety. Differences in the geometric shapes and locations of the structure affect the fatigue behaviour, the side-stiffened panel has the lowest the bottom-stiffened panel has the highest fatigue risk based on assessment of ship structure under fatigue loading. The yield strength and fracture toughness must be adjusted to take account of the effects of loading rate. The overall shapes of hull girder vertical bending moment/curvature paths are unaffected by the structural component's ultimate strength, ultimate strain and elastic stiffness. The strength of the hull girder in sagging is generally more sensitive than that in hogging. The estimation and experimental measurements of Load and load distribution on work barge hull structure such as ballast water weight, Structural weight and cargo weight must be taken into account. Under the collapse behaviour of work barge structures in wave it was found that the structures below the still waterline deflect under the effect of lateral pressure so as to produce the bending stress component with the structural buckling and initial yielding occurring earlier. The pressure at any point above mean waterline but below the wave surface profile needs to be accounted for in wave load calculations.

2.2 Stresses Experienced by The Work Barge

Work barge are designed to withstand stresses caused by being balanced on jobs done on the work barge deck of a particular length and height. A work barge floating in unstable water condition has an unevenly distributed weight owing to both cargo distribution and structural distribution. As the wave passes under the hull, owing to the different (oblique, head, following, beam sea) angle of attack.

Below are the stresses experienced by work barge:

- Longitudinal stress: When the vessel hogs and sags in still water or in a seaway, shear forces similar to the vertical shear forces will be present in the longitudinal plane. The magnitude of the longitudinal shear force is greatest at the neutral axis and decreases towards the top and bottom of the girder
- Transverse stress: When a barge experiences transverse forces these tend to change the shape of the vessel's cross-sections and thereby introduce transverse stresses. These forces may be produced by hydrostatic loads and impact of seas or cargo and structural weights, both directly and as the result of reactions due to change of ship motion.
- Torsional stress: When a barge is subject to a twisting moment when riding on a wave, which is commonly referred to as torque, that body is said to be in 'torsion'. A barge heading obliquely (45^{o}) to a wave will be subjected to righting moments of opposite direction at its ends, twisting the hull and putting it in 'torsion'. The greatest effect occurs with decks having large openings.
- Local stress: This occurs as a result of individual weight acting on a segment. This type of stress is experienced in a certain part of barge only.

The effects of the above stresses on ship hull structure include the following; Yielding, buckling including column buckling and Plate Buckling, Slamming, Panting and Fatigue.

III. MATERIALS AND METHODS

3.1. Materials

3.1.1: Work Barge Parameter

The models of this study is a work barge, this study was conducted to determine the effect of static loads on the work barge deck structure on still water condition. The work barge parameter used for this study are shown in table 3.1 below

The table 3.1 below illustrate the work barge parameters

Parameter	Measurement
Length (m.)	71.50

Depth mld. (m.)	6.30
GT	3177
Material of Hull	Steel
Location of machinery space	Aft
Beam mld. (m.)	24.03
Summer draught mld. (m.)	3
NT	953
Nos. * Weight (Kg.) of Anchors	8*8000.00
No. of transverse bulkheads	6

Table 3.1: Work Barge Principal Parameter

3.2: Work Barge Deck Load, Weight and Dimension

A work barge at sea is subjected to a static force causing the deck structure to distort. The loads acting on the barge deck structure when a barge is floating in still (calm) water are the static. It is majorly created by the cargo which induces hogging, sagging and shearing. This can be limited by evenly distribution of load and proper material selection, based on stress calculation.

Table 3.2: Barge and its' Deck Load Weight Distribution

The table 3.2 below describe the load on the work Barge deck and its Load weight Distribution and dimension of the load

S/N	ITEM DESCRIPTION	QUANTITY	WEIGHT (TE)	LENGTH (mm)	WIDTH (mm)	HEIGHT (mm)
1	250Te Under Roller	1	30	7695	6540	1995
2	Under Roller HPU	1	8	4725	2250	8600
3	RL002-33kV Cable Reel	1	197	8600	5400	8600
4	Over Boarding Chute	1	1	1780	400	1190
5	Rigging Container 10ft	1	6	2990	2430	2590
6	Generator 415kVA	2	7	4650	1950	2000
7	Trenching Jet Sled	1	~10	4000	1200	-
9	Water Pump	1	~5	4000	1375	~2380
10	Work Boat	1	~2	~5000	~2200	~2000
11	Winch 10Te	1	~1.5	~1800	~1000	~1200
13	Air Diving LAR 2	1	9	3650	2300	3500
14	20Ft DDC/DCV	1	8	6100	2450	2450
15	Air Diving Dry Storage	1	6	6100	2450	2450
16	Air Diving Machinery	1	7	6100	2450	2450
17	O2 Quad 16cyl	1	~1.6	1100	1100	2200
18	Concrete Mattress	5	-4.6	6000	3000	300
19	Buoy	15	~60	-	-	-
20	Hydraulic Hose Basket	1	~2	2500	1400	~1200
21	Boat Catcher	1	1	1900	1320	~4000
22	Umbilical Frame	2	0.6	2300	1000	2000
23	Air Quad 16cyl	2	3.2	1100	1100	2200
24	Load	1	25	1800	1095	1250
25	,,	1	5	4725	2250	2160
26	,,	1	204	5000	2450	2160
27	,,	1	35	4650	1950	8600
28	,,	1	33	1860	1000	1190
29	,,	1	48	3650	3850	2000
30	,,	1	34	6100	2300	2400
31	,,	1	40	1100	1200	2100
32	,,	1	27	2500	1400	1200
33	,,	1	37	3650	2300	2450

34	,,	1	30	800	1300	4000
35	,,	1	24	3650	3500	2300
36	,,	1	2.5	1111	1100	2210

3.2.1 Work Barge Loading Plan

The description of the Barge and its' Load Distribution in table 3.2 above is shown in Figure 3.1 below.

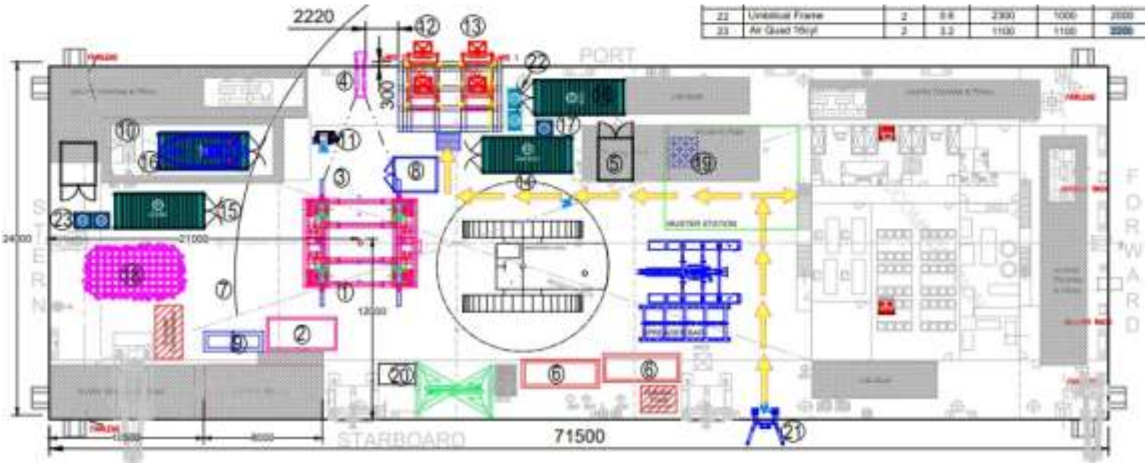

Fig 3.1: Main Deck Plan

3.3 Theoretical Principle

The background and principle of study state that a standard estimation of ship weight distribution ensures that the weight is not concentrated at a point to prevent catastrophe and heavy sea performances. That forces and moment are self-balancing (no force or moment is transfer to the world) ensure optimization of work barge hull strength and even load distribution. The principle has been adopted by several authors and organizations in the past, thus will represent return of proving other calculation from proof test.

3.4 The Study Approach

The approach used in the study is to analyses the gravity load distribution, further derived values for stress, strain, force and displacement. This study utilizes the use of finite element method in order to analyses the static loads, analyses the stress on ship structure and to evaluate a mathematical model for ship strength and stress.
During the conceptual phase of this study, quantitative data was collected from Table 3.2 above.
The steps in this study include the following:

- Identify the CG of the load Δ as a node (force and displacement)
- Link up the node (force and displacement) with element (106 stiffness element)
- A local stiffness matrix, force vector and displacement vector were developed (106 stiffness element matrix)
- Develop a global matrix, force vector and displacement vector (36 by 36 stiffness element matrix)
- Solve the global stiffness matrix, force vector and displacement vector developed in IV using MATLAB
- Result obtained from MATLAB was further used to estimate the stress and strain relationship. Also, the force and displacement relationship with the aid of a graphical representation

3.5 Finite Element Method

A finite element method is a numerical method which can solve such complex engineering problems with an accurate solution. To analyse the stress behaviour of the ship structures FEM analysis has been used. Ship structural collapse, or longitudinal strength, assessment has been a study of interest for a long time to ensure that work barge deck withstand external loads without failure and provide safety for crews and traded cargoes throughout their lifetimes. The prevention of hull collapse is the most critical task in work barge deck structure design and safety assessment. Thus, an accurate and efficient method for computing and analysing the static load, stress and the ultimate hull girder strength is always required in robust work barge structural analysis.

The stress and applied force relation on ship structure can be defined in two ways: engineering stress (σ_E), and true stress (σ_T). The engineering stress is the ratio of the applied force to the original cross-sectional area. The true stress is the ratio of the applied load to area change with respect to the actual cross-sectional area. In situations where gradual increase in the load; significantly changes the sectional area of the work barge deck, the engineering stress type may not hold.

σ_E= applied load/ (original sectional cross) =P/A

σ_T= applied load/ (actual sectional cross) = P/A_0

As the stress is applied, the material elongates. Therefore, the term strain (Ɛ) is used to study material elongation versus stress. Similar to the stress, strain can be determined as engineering strain (ε_E) and true strain (ε_T). In the course of this study, the basic equation for finite element analysis can be presented as

$$\sigma = E\,\varepsilon \qquad (3.1)$$

$$\text{stress} = \sigma = \frac{F}{A} \qquad \text{strain} = \varepsilon = \frac{\Delta L}{L} \qquad (3.2)$$

$$\frac{F}{A} = E\frac{\Delta L}{L} \qquad F = \frac{EA}{L}\Delta L \qquad (3.3)$$

$$\text{Stiffness} = K = \frac{EA}{L} \qquad (3.4)$$

Let the change in length $\Delta L = U$

Therefore, for an element with two nodes in one dimension in one-dimension space

$$F^1 = K\,[U^1 - U^2] \qquad F^2 = K\,[U^2 - U^1] \qquad (3.5)$$

Since the summation of all the forces at a point is equal to zero;

This implies $F^1 + F^2 = 0$ $\quad \Sigma F = 0$

From (3.5)

$$\begin{bmatrix} F^1 \\ F_2 \end{bmatrix} = \begin{bmatrix} K & -K \\ -K & K \end{bmatrix} \begin{bmatrix} U^1 \\ U_2 \end{bmatrix} \qquad (3.6)$$

Where;

F^1 andF^{2} = force vector

K = Stiffness matrix

U^1 and U^2 = displacement vector

For one dimension in one-dimension space

IF = Number of nodes × one column

IK = Number of nodes × Number of nodes

UI = Number of nodes × one column

For one dimension in two-dimension space

IF = Number of nodes × two column

IK = (Number of nodes × 2)^2

UI = Number of nodes × two column

To assemble it to a global force vector, stiffness matrix and displacement vector, it will then become;

$$\begin{bmatrix} F^1 \\ F^2 \\ F^3 \\ F^4 \\ F^5 \end{bmatrix} = \begin{bmatrix} K^{11} & K^{12} & K^{13} & K^{14} & K^{15} \\ K^{21} & K^{22} & K^{23} & K^{24} & K^{25} \\ K^{31} & K^{32} & K^{33} & K^{34} & K^{35} \\ K^{41} & K^{42} & K^{43} & K^{44} & K^{45} \\ K^{51} & K^{52} & K^{35} & K^{54} & K^{55} \end{bmatrix} \begin{bmatrix} U^1 \\ U^2 \\ U^3 \\ U^4 \\ U^5 \end{bmatrix}$$

$$IF = IK.\,UI \qquad (3.7)$$

$$IF = \begin{bmatrix} F^1 \\ F^2 \\ F^3 \\ F^4 \\ F^5 \end{bmatrix} \qquad IK = \begin{bmatrix} K^{11} & K^{12} & K^{13} & K^{14} & K^{15} \\ K^{21} & K^{22} & K^{23} & K^{24} & K^{25} \\ K^{31} & K^{32} & K^{33} & K^{34} & K^{35} \\ K^{41} & K^{42} & K^{43} & K^{44} & K^{45} \\ K^{51} & K^{52} & K^{35} & K^{54} & K^{55} \end{bmatrix} \qquad UI = \begin{bmatrix} U^1 \\ U^2 \\ U^3 \\ U^4 \\ U^5 \end{bmatrix}$$

IF = forces and it will be done for each node

IK = stiffness and it will be done for each element

UI = displacement

3.6 The Work Barge and Load Centre of Gravity (CG)

The description of the Barge and its' Load Distribution in Figure 3.1 above are illustrated with respect to their centroid as shown in figure 3.2 below which is known as node (force and displacement)

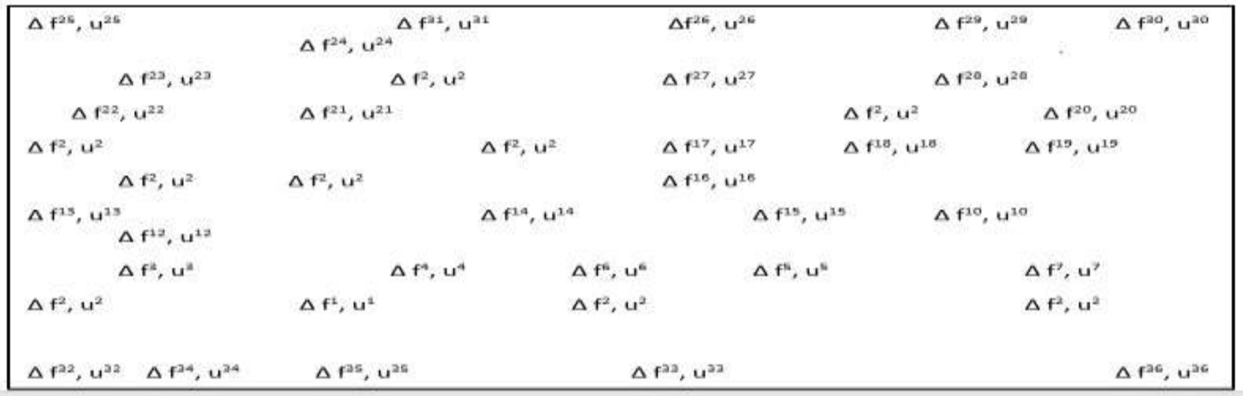

Fig 3.2: Centroid of the Distributed Load

3.7 Element Stiffness

The load in figure 3.2 is see as node link to another node to form an element stiffness as shown in figure 3.3 below thereby discretizing the domain into smaller space in one dimensional element in one dimensional space.

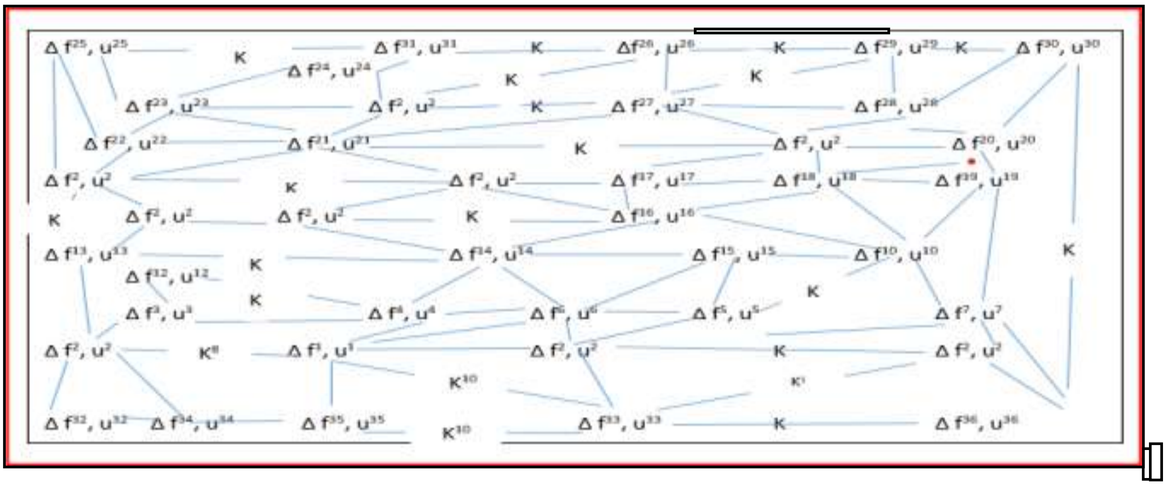

Figure 3.3 Element Stiffness

It implies also stiffness K= Young Modulus (E) * thickness (T) of work barge deck plate material
Where E=200GPA
T=13mm
IF= forces and it will be done for each node
IK= stiffness and it will be done for each element
UI= displacement

3.8 Developing a Local Element Stiffener Matrix

30_____k1____31

$$k = \begin{bmatrix} k^1 & -k^1 \\ -k^1 & k^1 \end{bmatrix} \begin{bmatrix} 30 \\ 31 \end{bmatrix}$$ Element 1

31_______k2_______29

$$k = \begin{bmatrix} k^2 & -k^2 \\ -k^2 & k^2 \end{bmatrix} \begin{bmatrix} 30 \\ 29 \end{bmatrix}$$ Element 2

29_______k3_______20

$$Ik = \begin{bmatrix} k^3 & -k^3 \\ -k^3 & k^3 \end{bmatrix} \begin{bmatrix} 29 \\ 30 \end{bmatrix}$$ Element 3

Continue to element 106

. . . . .

. . . . .

. . . . .

106_______k106______16

Ik = $\begin{bmatrix} k^{106} & -k^{106} \\ -k^{106} & k^{106} \end{bmatrix} \begin{bmatrix} 106 \\ 16 \end{bmatrix}$ Element 106

3.9 Developing a Global Element Stiffener Matrix

The element stiffness local matrix will be place in relation to the number assign to them.

$$\begin{pmatrix} F^1 \\ F^2 \\ F^3 \\ F^4 \\ F^5 \end{pmatrix} = \begin{pmatrix} K^{11} & K^{12} & K^{13} & K^{14} & K^{15} \\ K^{21} & K^{22} & K^{23} & K^{24} & K^{25} \\ K^{31} & K^{32} & K^{33} & K^{34} & K^{35} \\ K^{41} & K^{42} & K^{43} & K^{44} & K^{45} \\ K^{51} & K^{52} & K^{35} & K^{54} & K^{55} \end{pmatrix} \begin{pmatrix} U^1 \\ U^2 \\ U^3 \\ U^4 \\ U^5 \end{pmatrix}$$

IV. RESULTS AND DISCUSSION

4.1 The results obtain from the quantitative findings of the study are shown in table 4.1 below, based on the data collected through study instruments in table 3.2 above

Table 4.1 Result Analysis

The table 4.1 below show the result from the MATLAB evaluation from the developed global element matrix

S/N of Load	Area of Load on Work Barge deck (MM^2)	Stress on Work Barge Deck (GPA)	Load Displacement on Work Barge Deck (MM)	Strain on Work Barge Deck (unitless)	Force on Work Barge Deck (N)
1	50325300	0.00593975594780359	0.0675377890240184	8.77684067888478e-06	298920
2	10631250	0.00749789535567313	-0.864017858720504	-0.000182860922480530	79712
3	46440000	0.0422676141257537	0.252719797164894	2.93860229261505e-05	1962908
4	712000	0.0139943820224719	0.157109225255850	8.82636096942977e-05	9964
5	7265700	0.00822825054709113	-0.0955558423747781	-3.19584757106281e-05	59784
6	9067500	0.00769208712434519	-0.101231514190465	-2.17702181054763e-05	69748
7	4800000	0.0207583333333333	-0.114735977753177	-2.86839944382943e-05	99640
8	4800000	0.0103791666666667	0.00632036178600423	1.58009044650106e-06	49820
9	5500000	0.00905818181818182	-0.0397021828587991	-9.92554571469978e-06	49820
10	11000000	0.00181163636363636	0.105714998776434	2.11429997552868e-05	19928
11	1800000	0.00830333333333333	0.115124275741456	6.39579309674754e-05	14946
12	8395000	0.0106820726622990	0.148861563540838	4.07839900111886e-05	89676
13	8395000	0.0106820726622990	0.115451468696547	3.16305393689170e-05	89676
14	14945000	0.00533369019739043	-0.0285842151977679	-4.68593691766687e-06	79712
15	14945000	0.00400026764804282	-0.0619569950198272	-1.01568844294799e-05	59784
16	14945000	0.00466697892271663	0.141540278704019	2.32033243777081e-05	69748
17	1210000	0.0131755371900826	0.0597229722910614	5.42936111736922e-05	15942.4000000000
18	18000000	0.00254635555555556	0.00545999983237818	9.09999972063030e-07	45834.4000000000
19	10800000	0.0553555555555556	0.0406405314715789	1.01601328678947e-05	597840
20	3500000	0.00569371428571429	-0.0375406959978499	-1.50162783991399e-05	19928
21	2508000	0.00397288676236045	-	-1.04278799685926e-06	9964
22	2300000	0.00259930434782609	0.0934539408812999	4.06321482092608e-05	5978.40000000000
23	1210000	0.0263510743801653	0.0389888156536326	3.54443778669387e-05	31884.8000000000
24	1971000	0.126382546930492	-0.243001085867496	-0.000135000603259720	249100

25	10631250	0.00468618459729571	0.00161176719769200	3.41114750834287e-07	49820
26	12250000	0.165931102040816	0.0744081205270790	1.48816241054158e-05	2032656
27	9021000	0.0386586852898792	0.0466334647192957	1.00287020901711e-05	348740
28	1800000	0.182673333333333	0.0745652258909368	4.14251254949649e-05	328812
29	14052500	0.0340346557552037	-0.195368095373865	-5.35255055818807e-05	478272
30	14030000	0.0241465431218817	0.0513913709426548	8.42481490863194e-06	338776
31	1320000	0.301939393939394	0.0119378256447515	1.08525687679559e-05	398560
32	3500000	0.0768651428571429	0.138945245371934	5.55780981487736e-05	269028
33	8395000	0.0439151876116736	0.00502461379248518	1.37660651848909e-06	368668
34	1040000	0.287423076923077	0.151072429766492	0.000188840537208115	298920
35	8395000	0.0284855270994640	-0.181695228684610	-4.97795147081125e-05	239136
36	1222100	0.0203829473856477	-6.30312609306414	-0.00567338082183991	24910

4.1.1 Graphical Result of Displacement

The results of displacement in table 4.1 above is illustrated in the graph 4.1 below to show the graphical representation of Load displacement on work barge deck

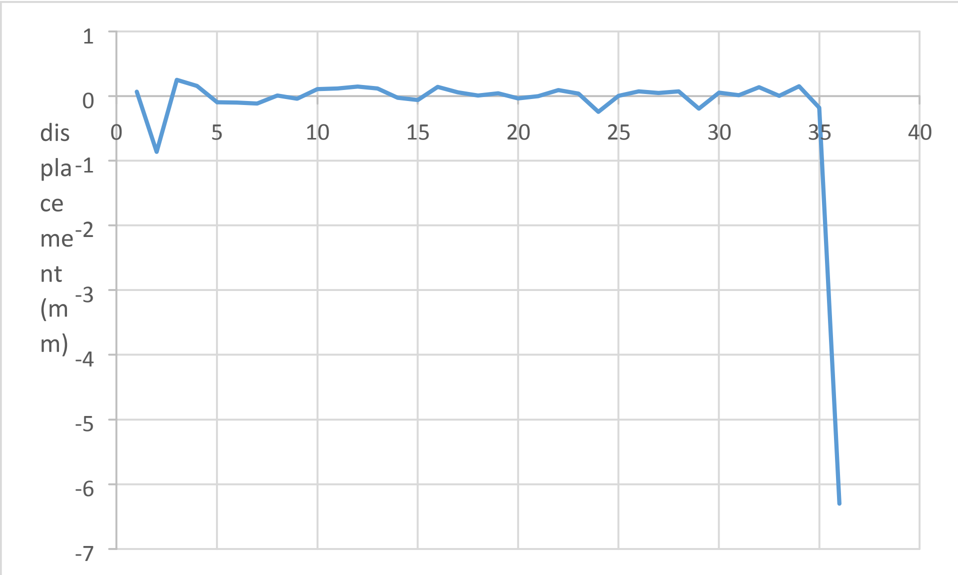

Fig 4.1: Graph of displacement on Work Barge Deck

4.1.2 Graphical Result of Area

The results of area of load acting on the work barge deck in table 4.1 above is illustrated in the graph 4.2 below to show the graphical representation of area of load on work barge deck

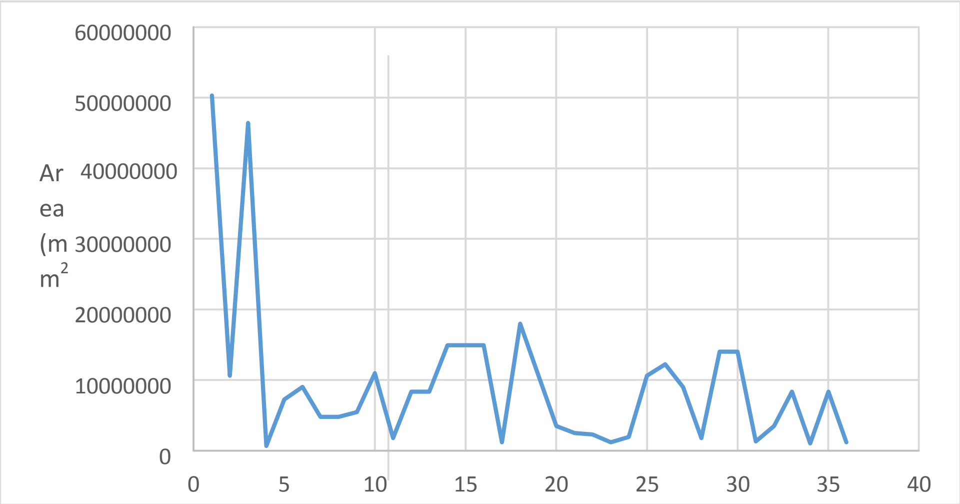

Fig 4.2: Graph of Area of load on Work Barge Deck

4.1.3 Graphical Result of Strain

The results of strain in table 4.1 above is illustrated in the graph 4.3 below to show the graphical representation of strain on work barge deck

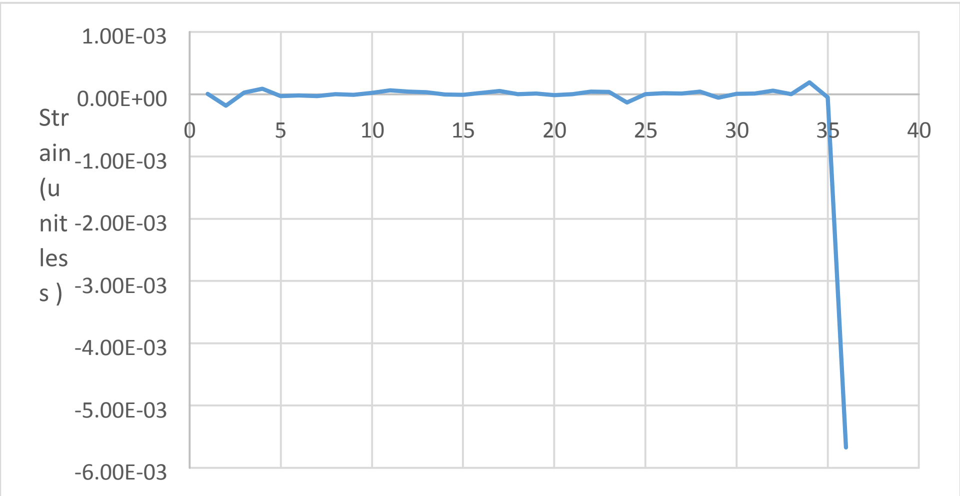

Fig 4.3: Graph of Strain on Work Barge Deck

4.1.4 Graphical Result of Stress

The results of stress in table 4.1 above is illustrated in the graph 4.4 below to show the graphical representation of stress on work barge deck

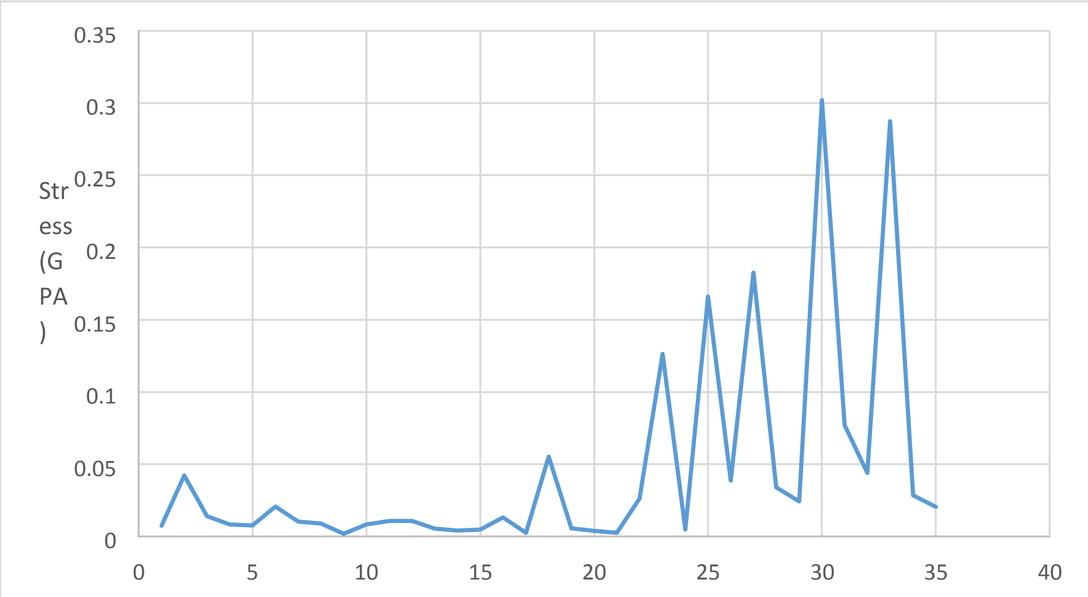

Fig 4.4: Graph of Stress on Work Barge Deck

4.1.5 Graphical Result of Force

The results of Force in table 4.1 above is illustrated in the graph 4.4 below to show the graphical representation of force on work barge deck

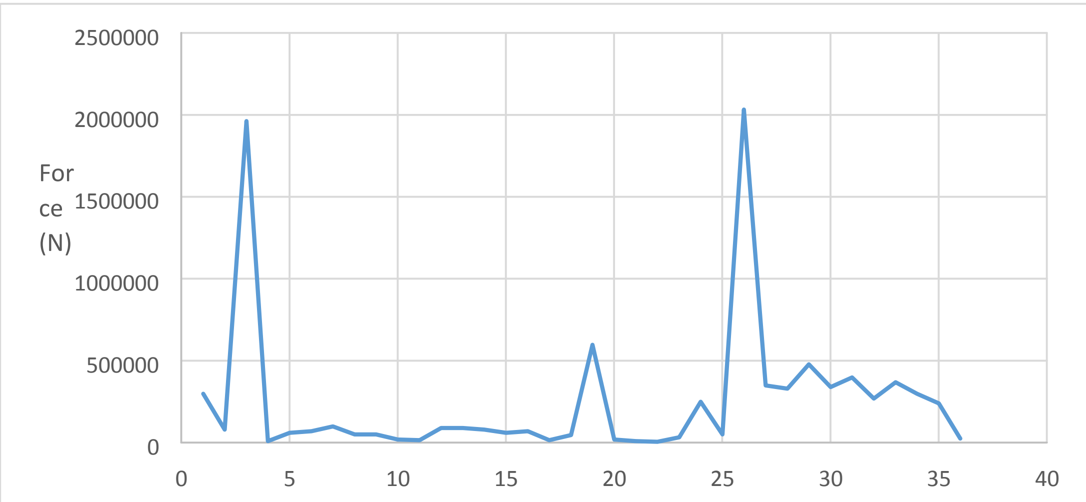

Fig 4.5: Graph of Force on Work Barge Deck

4.1.6 Graphical Result of Strain against Stress

The results of strain against stress in table 4.1 above is illustrated in the graph 4.1 below to show the relationship between stress and strain

area(P,E) %graph of strain against stress

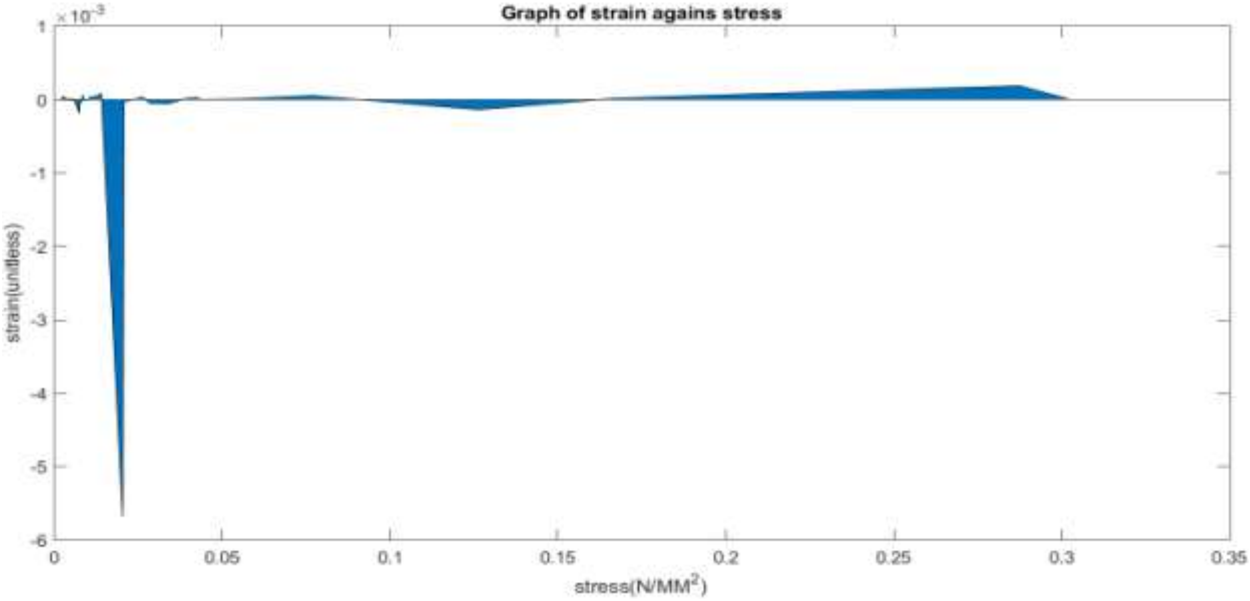

Fig 4.6: Graph of Strain against Stress

4.1.7 Graphical Result of Displacement against Forces

The results of Displacement and force in table 4.1 above is illustrated in the graph of 4.2 below to show the relationship.

```
area(F,U) %graph of displacement against force
```

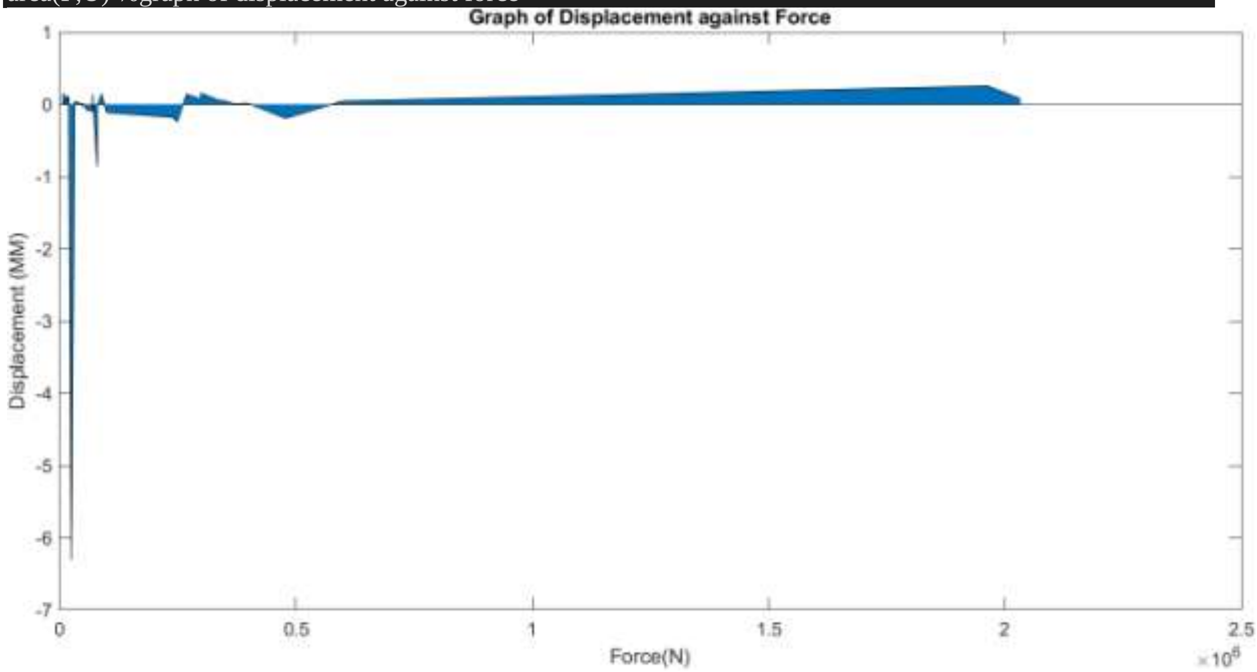

Fig 4.7: Graph of Displacement against Force

4.1.2 Discussions of Results

Displacement and Forces

From the results it was observes that when different load of different weight were placed on the deck of the work barge, displacement were proportional to forces causing the deck plate to under goes tension (negative sign) and making the plate to elongate, hence causing the deck plate to yield at certain points, on the other hand force was inversely proportional to displacement indicate compression (positive sign) is taking place at some point making the plate to buckle which will make the deck plate to deform.

Stress and Strain

From the results it was observes that when different stress at on the deck of the work barge, stress was proportional to strain, elastic limit of the material was not exceeded hence enable the material to with stand the external load, at certain point stress becomes inversely to strain hence the causing the deck plate to elongate and buckle also making the deck plate to yield and exceeds the ultimate strengths of the material at certain points, hence the plate will deform.

V.CONCLUSION

5.1 Conclusion

The study was designed to determine the effect of static load on work barge deck structure at different Loading location on the work barge deck. The behaviour of the barge structure under static loading was found that the stress is proportional to strain obeying Hooke's law but at certain point the law was no longer obeyed. From the study if the stress or displacement is more than the elastic limit meaning it has gotten to a yield point. Therefore, the material will not return to its original state, hence it is expected to be rein enforce or a stiffener should be added to rigid the plate making the work barge deck structure firm or increase the plate thickness. When the material selected is below the maximum stress (0.2874 GPA) estimated then the material will fail and the study had developed a FEM for analysing or estimating stress, strain, force and displacement which helps to eradicate Human error. Hence, the procedure developed is very convenient to use, reliable and very robust it is flexible for modification and shift for time and energy saving

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APPENDIX A

DEVELOPED MATLAB SOURCE CODE FOR THE ESTIMATION FORCE, STRESS, STRAIN AND DISPLACEMENT from the DEVELOPED GLOBAL ELEMENT STIFFENER MATRIX (36 by 36)

K= 200000*13*[4 0 0 0 0 0 0 -1 0 0 0 -1 0 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0; -1 7 -1 0 0 -2 -1 0 -1 0 0 0 0 0 0 -1 -
2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1; 0 1 4 4 0 0 0 0 0 0 -1 -1 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0; 0 0 0 4 0 0 0 0 0 -2 0 -2 -
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 5 0 -1 0 0 0 0 0 0 0 0 0 0 0 -1 0 -1 0 0 -1 0 0 0 0 0 0 0 0 0 0 -1 0; 0 -1 -1 0 0 0 6 2 0 0 0 0 0 0 0 0 0 0 0 0 -3 -2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0; 0 -1 0 0 -1 -2 10 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 -1 0 0 -1 -1 0 0 0 0 0 0 0 -1 0; -
1 0 0 0 0 0 0 4 0 0 0 -1 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0; 0 0 0 0 0 0 0 0 4 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 -1 0 -
1 0 0 0 0 0; 0 0 0 -2 0 0 0 0 0 7 0 0 0 0 -1 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 -1 0 -2 0 0; 0 0 -1 0 0 0 0 0 0 0 3 -1 0 0 -
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0; -1 0 -1 -1 0 0 0 -1 0 0 -1 7 -2 -2 0 -1 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 2 5 0 0 -1 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 -2 0 0 0; 0 0 0 0 -2 0 0 0 -1 0 0 0 0 8 0 0 -1 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0; 0 -1 0 0 0 0 0 0 0 0 -1-
1 0 0 0 0 6 -1 0 -2 0 0 0 -1 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0; 0 -1 -1 -1 -2 0 0 0 0 -1 -1 -1 -1 0 0 0 -1 12 -1 0 0 -1 0 0 0 0 0 0 0 0 0 0 -
1 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 -1 3 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 -1 6 0 0 0 0 -
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1 0 0 0 0 3 0 0 0 0 0 0 0 0 0 -1 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 -2 0 0 0 0 0 0 0 -1 -1 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -
2 0 0 0 0 -1 7 -2 0 0 0 0 0 0 0 -1 0 0 0; 0 0 0 0 0 0 -2 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 -1 -2 6 -2 0 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 -
1 0 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 -2 6 -2 0 0 0 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 -2 3 0 0 0 0 0 0 0 0 0; 0 -
1 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 -2 0 0 0 0 0 0 0 0 0 3 -1 -1 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 3 -
2 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -2 0 0 0 0 0 0 0 0 0 0 0 -1 -2 6 0 0 0 0 0 0; 0 0 0 0 0 0 0 0 0 0 -1 0 0 0 0 0 0 0 -1 0 0 0 0 -
1 0 0 0 0 0 0 0 0 0 4 0 -2 0 0; 0 0 0 0 0 0 0 0 0 0 0 0 -1 0 0 -1 0 0 -1 0 0 0 0 -1 -1 0 0 0 0 0 0 0 0 0 0 6 0 0 0; 0 0 0 0 0 0 0 0 0 -
2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 -2 0 4 0 0; -1 -1 0 0 -1 0 -1 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 5 0; 0 0 2 0 0 0 0 0 0 -1 0 -
2 0 0 0 0 0 0 -2 0 0 0 0 0 1 0 0 0 0 0 -1 0 0 0 0 0 0 0]
F= 9964*[30; 8; 197; 1; 6; 7; 10; 5; 5; 2; 1.5; 9; 9; 8; 6; 7; 1.6; 4.6; 60; 2; 1; 0.6; 3.2; 25; 5; 204; 35; 33; 48; 34; 40; 27; 37; 30; 24; 2.5]

L= [7695; 4725; 8600; 1780; 2990; 4650; 4000; 4000; 4000; 5000; 1800; 3650; 3650; 6100; 6100; 6100; 1100; 6000; 4000; 2500; 1900; 2300; 11 00; 1800; 4725; 5000; 4650; 1800; 3650; 6100; 1100; 2500; 3650; 800; 3650; 1111]
W= [6540; 2250; 5400; 400; 2430; 1950; 1200; 1200; 1375; 2200; 1000; 2300; 2300; 2450; 2450; 2450; 1100; 3000; 2700; 1400; 1320; 1000; 11
00; 1095; 2250; 2450; 1940; 1000; 3850; 2300; 1200; 1400; 2300; 1300; 2300; 1100]

H= [1995; 2160; 8600; 1190; 2590; 2000; 1; 1; 2380; 2000; 1200; 3500; 3500; 2450; 2450; 2450; 2200; 300; 1; 1200; 4000; 2000; 2200;
1250; 2160; 8600; 2340; 1190; 2000; 2440; 2100; 1200; 2454; 4000; 3500; 2210]
A= L.*W %area function
P= F./A %stress function
U= linsolve(K,F)
E= U./L %strain function area(P,E) %graph of stress against strain area(F,U) %graph of force against displacement