THE INSTITUTION OF ENGINEERS,
SINGAPORE

SEMINAR ON "DESIGN AND CONSTRUCTION OF COASTAL MARINE STRUCTURES"

28 JANUARY 1994

HOLIDAY INN PARK VIEW
CRYSTAL BALLROOM

ORGANISED BY:
CIVIL & STRUCTURAL ENGINEERING TECHNICAL COMMITTEE

MULTI-BERTH WHARF FOR LIQUID CARGO TERMINAL AT PULAU BUSING

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SYNOPSIS

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The development of a nearshore wharf with multiple berth for loading and unloading liquid cargo is rare. This paper briefly describes the design of the wharf, especially the impact of berthing vessel on the wharf structure with the selected fender system.

ACKNOWLEDGEMENT

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The author wishes to acknowledge Tankstore Limited for approval to publish the project information contained in this paper.

MULTI BERTH WHARF FOR LIQUID CARGO TERMINAL AT PULAU BUSING

1.0 INTRODUCTION

The development of the Liquid Cargo Terminal at Pulau Busing began in 1986 infront of the present terminal by using a 350,000 DWT VLLC tanker as a floating storage terminal.

By the end of 1989 a start was made with the development of the terminal on the island, Pulau Busing itself and also with the construction of the berths 1, 2, 3 and 4, nearshore at the north coast of the island.

With the time, however, expansion of the tank storage volume was effected and resulted in demand for extra berthing capacity.

Than in October 1992, in addition to the four existing berths, the construction of the wharf began.

The extend of expansion in berthing capacity in westerly direction was limited due to seabed lease options on the adjacent seabed by other future developers.

This implies that new creative solution had to be developed and led to the construction of a wharf instead of separate island berths, see figure 1 for the situation, to increase the berthing capacity with a maximum for flexible operations.

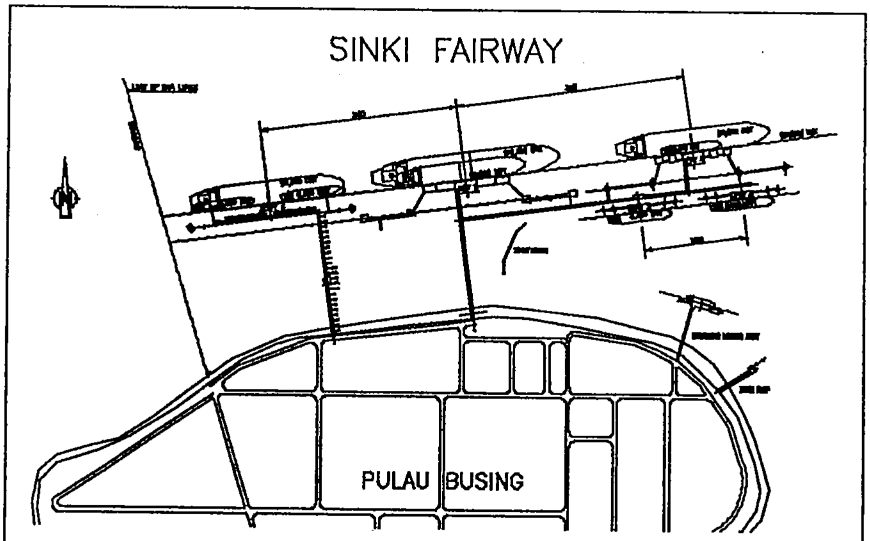


FIGURE 1 – SITUATION

On the wharf three separate unloading facilities are located to cater for loading or unloading two tankers (maximum 6,000 DWT) at both end locations or one tanker (maximum 90,000 DWT) at the center location of the wharf which give a high utilization rate of the new facilities.

The maximum of 90,000 DWT was dictated by the available water depth at the berthing front.

It is expected that the dimensions of the carriers will change.

The width of tankers will increase but the draughts and the lengths are not likely to increase, than the handling capacity may be maximum 8,000 DWT and, 100,000 DWT respectively in the future.

2.0 DESIGN PHILOSOPHY

The dimensions of the two, 6,000 DWT tankers, with a safety clearance between bow and stern or the single 90,000 DWT tanker determines the layout dimensions of the wharf and locations of the moorings.

The design and construction of the wharf has evolved to the construction type as presented in Figure 2.

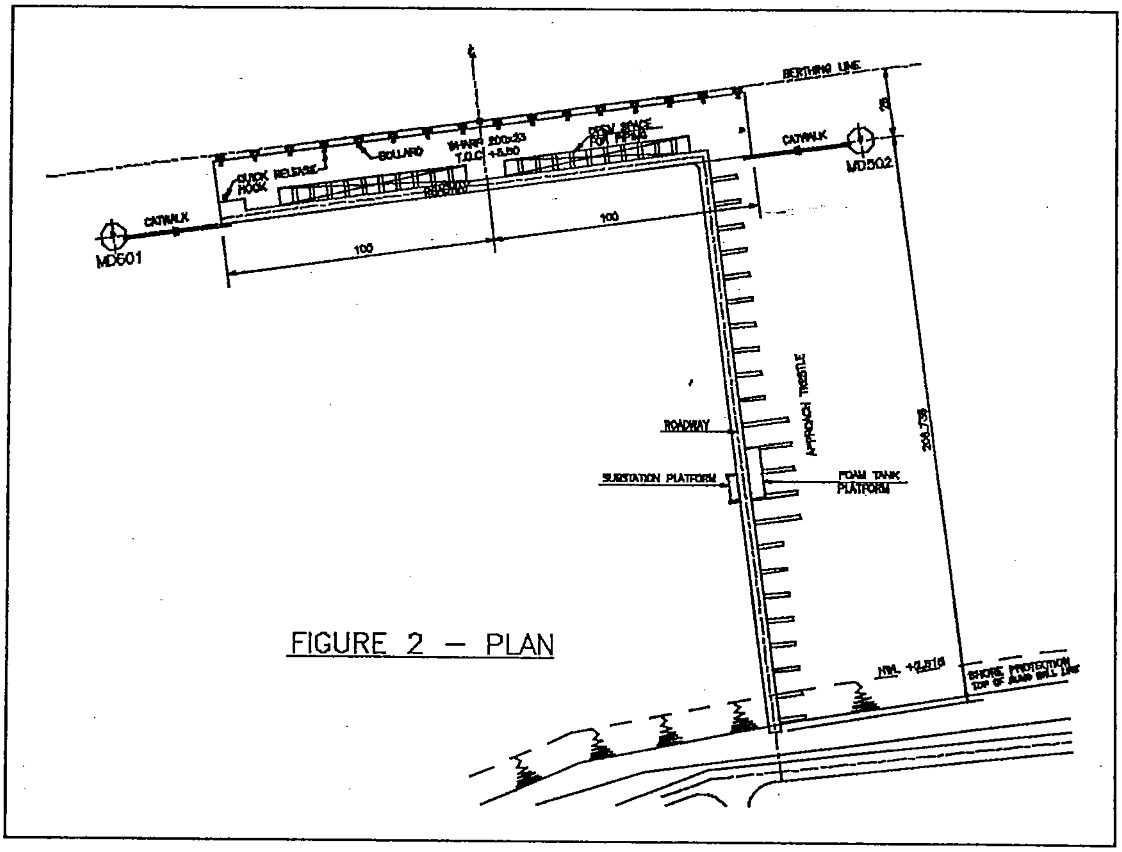


FIGURE 2 – PLAN

This construction was selected on the basis of a study performed by Delta Marine Consultants b.v.

In this study several types of berths have been reviewed and this type of wharf was preferred for the following :

* Accessability of installation
* Flexibility of ship sizes
* Multi berths
* Construction time and costs

The service and berthing loads imposed to the wharf and are transferred via the concrete superstructure to the subsoil via the raker piles.

3.0 **STRUCTURAL ASPECTS**

As can be seen from Figures 3, this construction consist of a concrete superstructure founded on tubular steel piles.

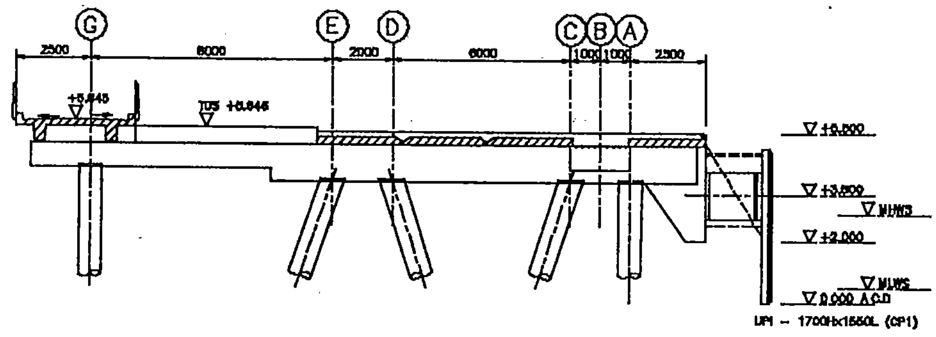


FIGURE 3 –TYPICAL SECTION

3.1 Liquid Cargo Berth

The Liquid Cargo Berth is designed to load or unload oil products from tankers ranging from 1,000 DWT up to 90,000 DWT.

The design of the wharf is a combination of insitu and precast concrete concept.

The construction of the berth followed directly after the piles have been driven in the following sequence :

i) Installation of pile clamps and temporary bracing to secure the position of the piles.

ii) Cutting off the piles at the directed level.

iii) Install the shuttering and pile plug reinforcement and fill the pile top with insitu concrete.

iv) Constructing the cast insitu reinforced concrete beam together with the precast concrete fender support.

v) Installation of precast reinforced concrete slab elements for wharf and roadway elements.

vi) Placing of insitu deck concrete top layer on top of beams, slab elements and between the roadway elements.

vii) Finishing concrete deck with curbs and foundation piers for pipe supports, loading arms and other equipment.

viii) Installation of bollards, quick release hooks, loading arms and rubber fenders.

The sequence of wharf deck construction is shown in Figure 4.

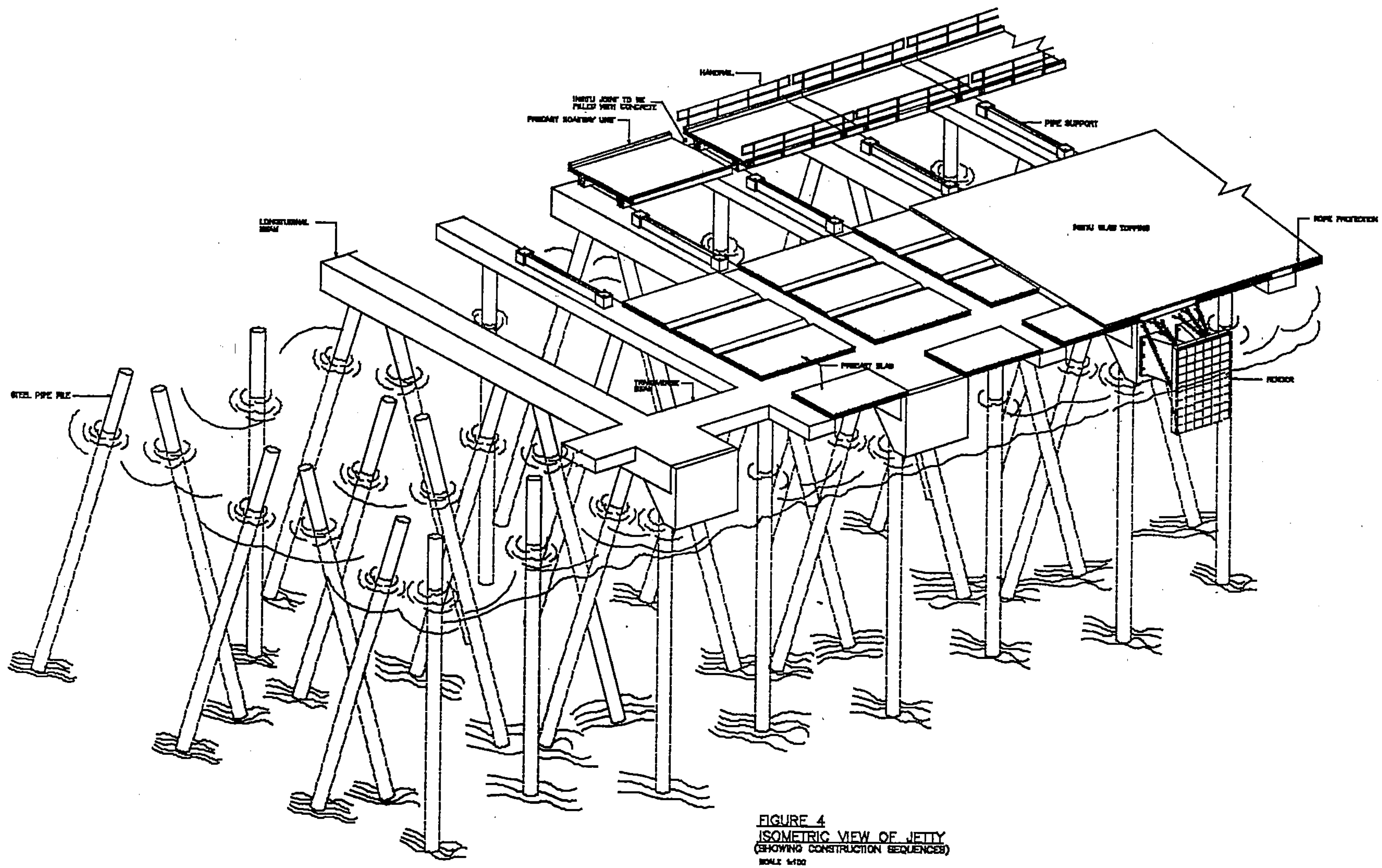


FIGURE 4
ISOMETRIC VIEW OF JETTY
(SHOWING CONSTRUCTION SEQUENCES)
SCALE 1:100

4.0 FENDERING

The fendering is designed for its specific use and location, taking into account factors like ship dimensions, berthing speed, berthing angle and environment.

To adopt the most suitable fender system, therefore, it is important to give priority to the selection of a fender system that can actually reduce the construction cost of the facilities.

From this study it is concluded the total load is the decisive factor in the assessment of the wharf design.

Important factors influencing the choice of fendering are :

* Reaction force on the wharf.
* Type and water displacement of the berthing ships.
* Velocity and angle during berthing.
* Influence of current, waves and wind.
* Permissible surface pressure on the hull of vessel.

The following has been taken in account :

a) Fendering Spacing And Deflection Depth

The fender interval and deflection depth so that the hull (bow and/or stern) will never come into contact with the wharf.

b) Reaction Energy

The fender must have two times the energy absorbtion capacity of the kinetic energy of the berthing vessel with the specified berthing speed as recommended in BS 6349.

c) Reaction Force

The facility must withstand the impact load under extreme condition.

d) Tidal Difference

The difference between tide and variation in draught of the vessels, the fenders must be able to absorb the berthing energy for various conditions, berthing angles and impact levels of the expected ships.

Furthermore, it is very important that the fendering remains visible and that smaller vessels are not berthing below the fender panel.

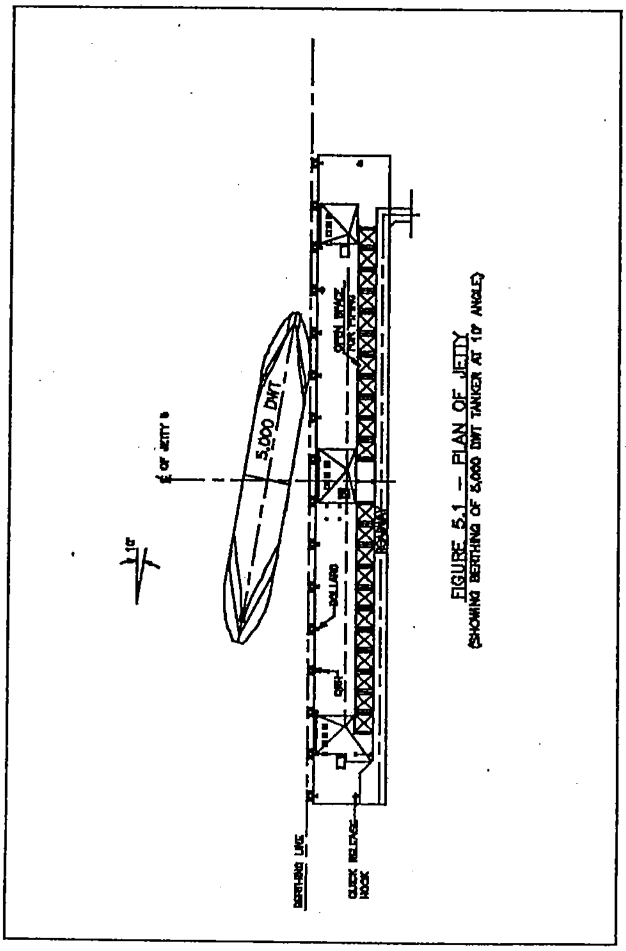


FIGURE 5.1 — PLAN OF JETTY
(SHOWING BERTHING OF 5,000 DWT TANKER AT 10° ANGLE)

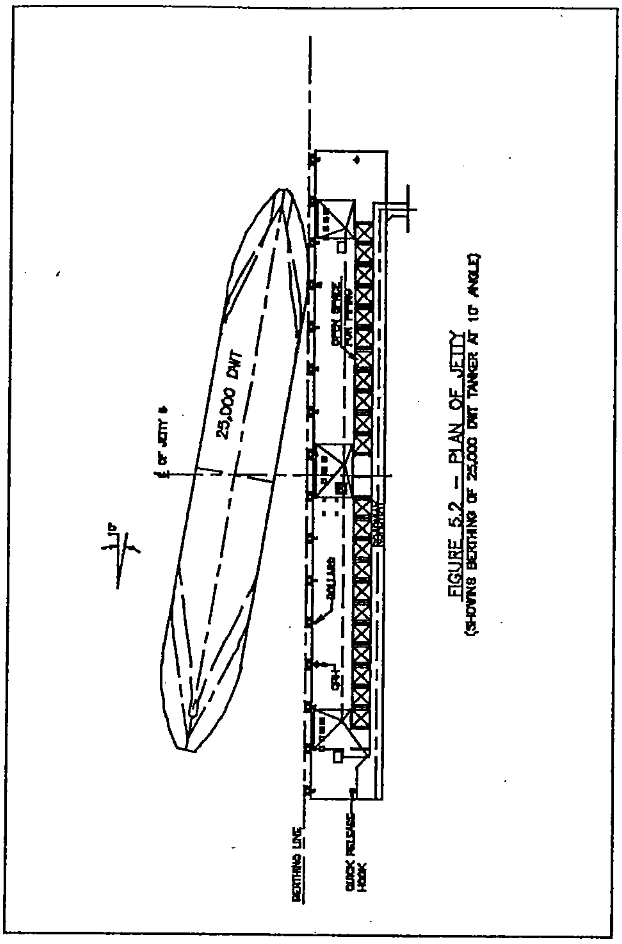


FIGURE 5.2 — PLAN OF JETTY
(SHOWING BERTHING OF 25,000 DWT TANKER AT 10° ANGLE)

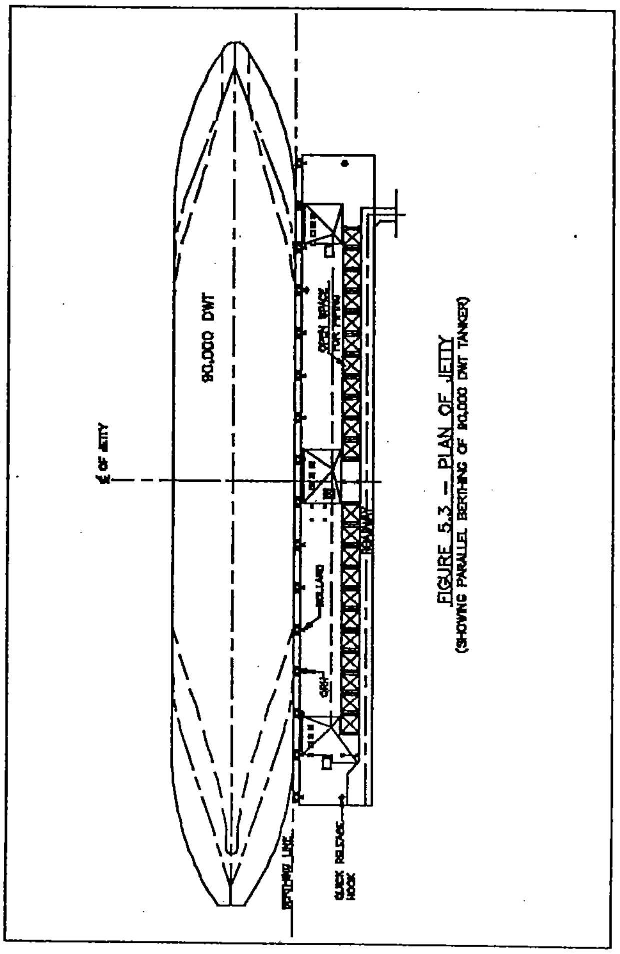


FIGURE 5.3 — PLAN OF JETTY
(SHOWING PARALLEL BERTHING OF 90,000 DWT TANKER)

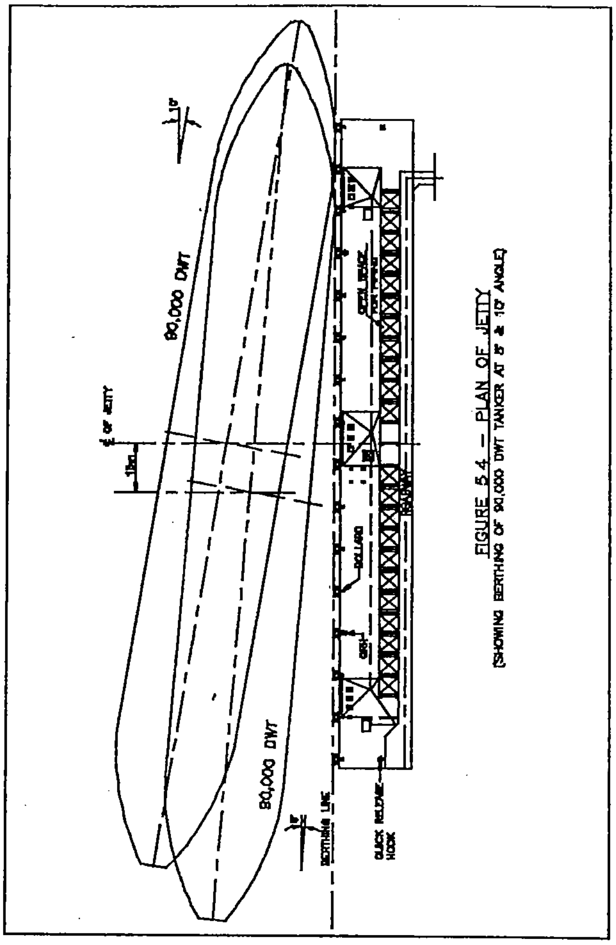


FIGURE 5.4 — PLAN OF JETTY
(SHOWING BERTHING OF 90,000 DWT TANKER AT 5° & 10° ANGLE)

4.1 **BERTHING SITUATIONS**

For the various berthing situations, (see figure 5.1 to 5.4), the capacity of the fenders has been adjusted to suit the most economical solution for fenders and wharf structure.

Consideration has been given to the parallel berthing of the ship which give a high effective berthing energy (C_E = 1.0) which have to be absorbed by all fenders simultaneously.

For this situation all the fenders will deflect 25% only to absorb the total amount of kinetic energy, however, it will still have the maximum fender reaction of all fenders at the same time (see figure 6).

Due varying the fender capacity of the total lateral load reaction on the wharf structure has been reduced.

For the various reactions and loadings (see figure 7.1 and 7.2)

UPI – TYPE CHARACTERISTIC CURVE

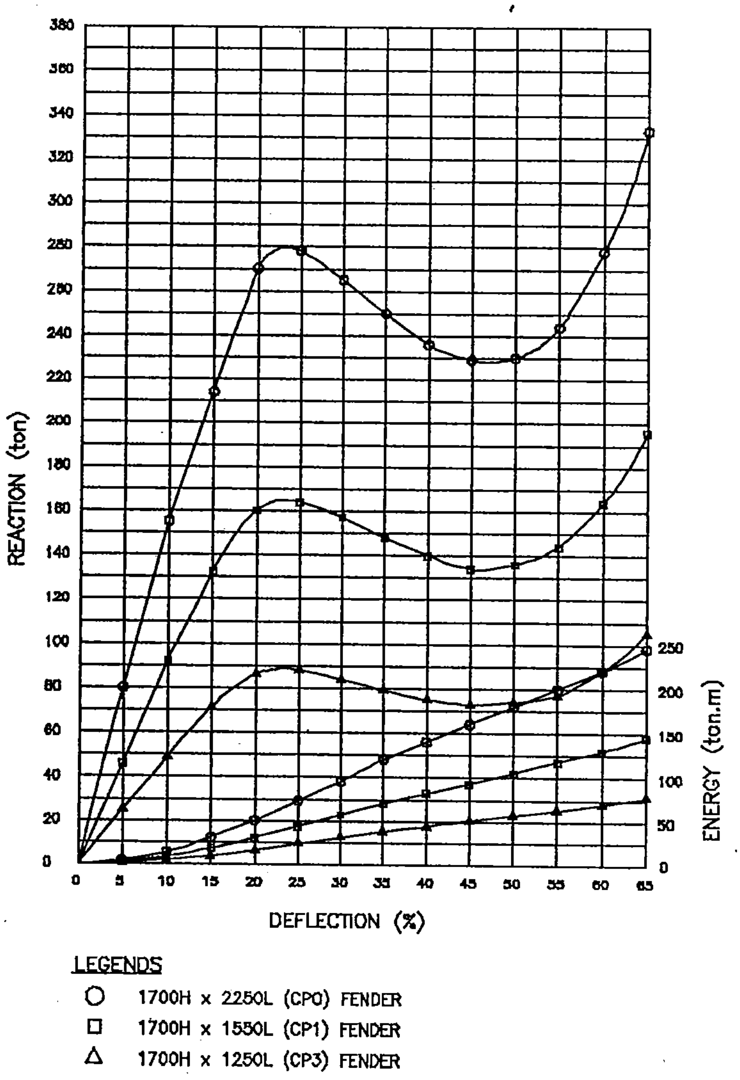


FIGURE 6

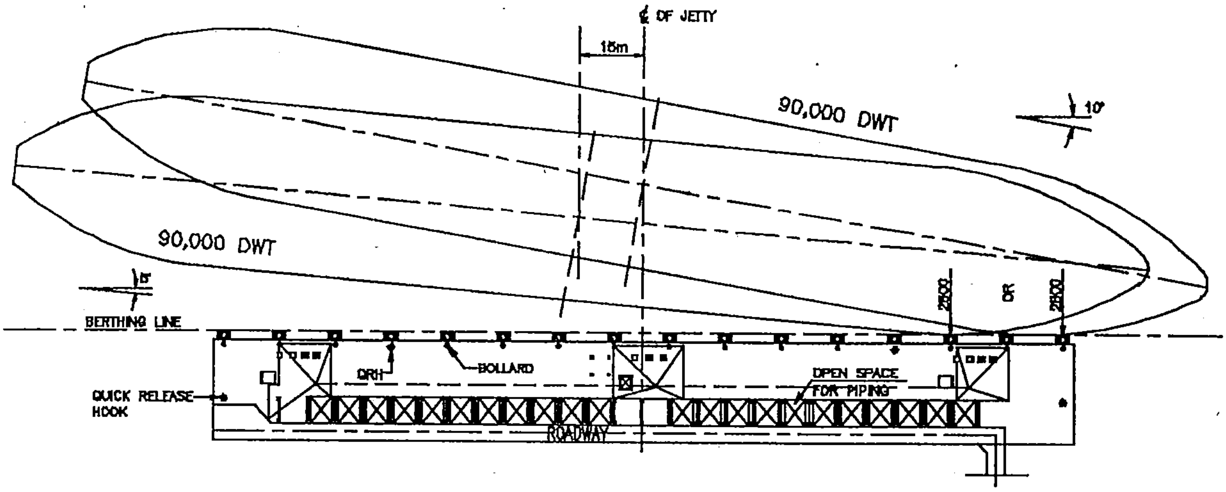


FIGURE 7.1 – PLAN OF JETTY,
(SHOWING BERTHING OF 90,000 DWT TANKER AT 5° & 10° ANGLE)

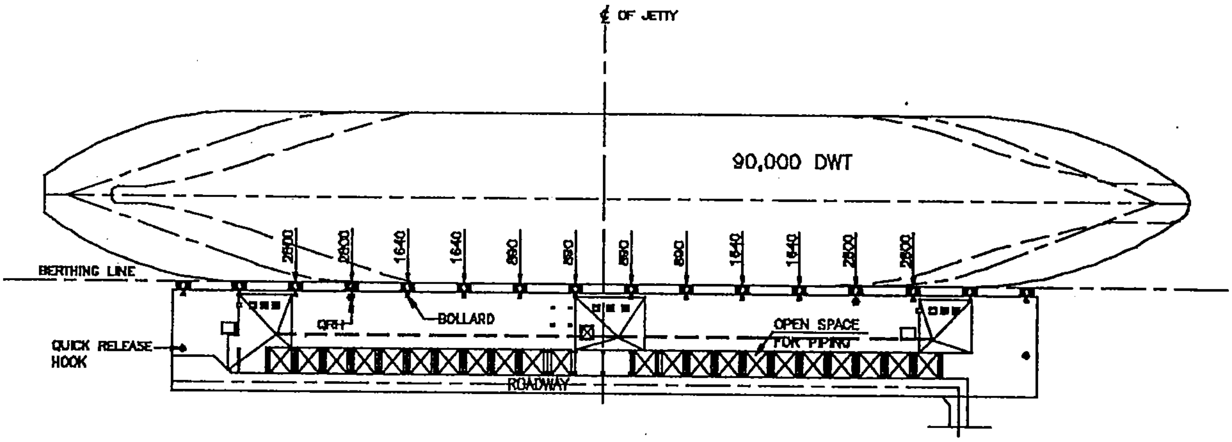


FIGURE 7.2 – PLAN OF JETTY
(SHOWING PARALLEL BERTHING OF 90,000 DWT TANKER)

4.2 ANALYSIS OF KINETIC ENERGY OF SHIP

The energy to be absorbed by the fender is calculated using the formula :

E	=	$0{,}5 \cdot C_E \cdot C_S \cdot C_M \cdot C_C \cdot M \cdot V^2$ (kNm)
C_E	=	Eccentricity Coefficient
C_S	=	Softness Coefficient
C_M	=	Hydrodynamic Mass Coefficient
C_C	=	Berth Configuration Coefficient
M	=	Displacement tonnage of the ship - metric tonnes.
V	=	Berthing speed of the ship. (m/sec)

4.3 FACTOR OF SAFETY

The berthing energy as computed (4.2) is based on normal operations and may be exceeded for accidental occurrences such as :

(a) engine failure of ship or tug;
(b) breaking of mooring or towing lines;
(c) sudden changes of wind or current conditions;
(d) human error.

To provide a margin of safety against such unquantifiable risk the ultimate energy capacity of the installed fenders are double of that calculated for normal condition.

5.0 STRUCTURAL DESIGN

For the design of the whole structure, three dimensional structural analysis (Stress) has been carried out to calculate the main structure and the governing pile loads for the various load combinations.

These analysis give also the displacements of the wharf structure due to the imposed loadings and/or load combinations. These results has been used with the respective displacements to analyze the pile bents, as a two dimensional frame, more detailed to design the reinforcement for the various structural elements.

6.0 FINAL CHECK ANALYSIS

For a final check on the internal forces, distribution of stresses and displacements a similar element programme has been used.

For the similar element analysis the ANSYS programme has been used. This programme runs on a PC-486 processor and 16 MB internal memory.

A complex structural geometry of the wharf structure has been modeled with various elements, such as slab elements for the slab, solid volume elements for the beams and member elements for the piles.

The critical area of the wharf structure was identified to be at the end of the pipe rack opening in the platform slab.

Several loadings were presented on berthing front for analyzing and distributing of the internal forces and stresses through the slab and the pile bents.

The "colar mapping" results from the plotter were very useful for a clear indication of the different stress levels.

Figure 8 - Plot 1	shows the generated elements.
Figure 9 - Plot 1	shows a detailed section of the generated elements.
Figure 10 - Plot 7	shows the stress contours in the concrete slab.

7.0 WHARF STRUCTURE

The wharf structure is of suspended concrete deck.

After driving the tubular steel piles, insitu cross beams where cast together with precast concrete fender supports, than placing precast slab elements onto the beams and finally finishing the insitu concrete top layer.

The precast slab elements for the platform and roadway units have been used to assure a high quality and to expedite the construction works.

8.0 SOIL CONDITION

In general the subsoil could be divided in three sublayers. The toplayer thickness varies from 6.00 to 12.00 m of silt/silty clay and the S.P.T. - N values varies from 20 to 50.

The secondary layer consist of clayey silt with sand and some siltstone fractures and S.P.T. - N values from 100/30 cm to 100/10 cm.

Finally at approximately 12.00 m depth below seabed a medium hard, highly fractured sandstone and/or mudstone is encountered.

In this layer at approximately 6.00 m penetration the borelogs were terminated.

9.0 PILING

Steel tubular steel piles diameter 762 mm and 610 mm, wt 16 mm has been used, the length varies approximately from 34 m to 40 m.

The piles were fabricated on site by automatic welding of standard spool length of 12.00 m.

The toe end of the piles were thick 20 mm to assure enough resistance against local buckling if locally a hard layer should be encountered and had to be driven into this layer.

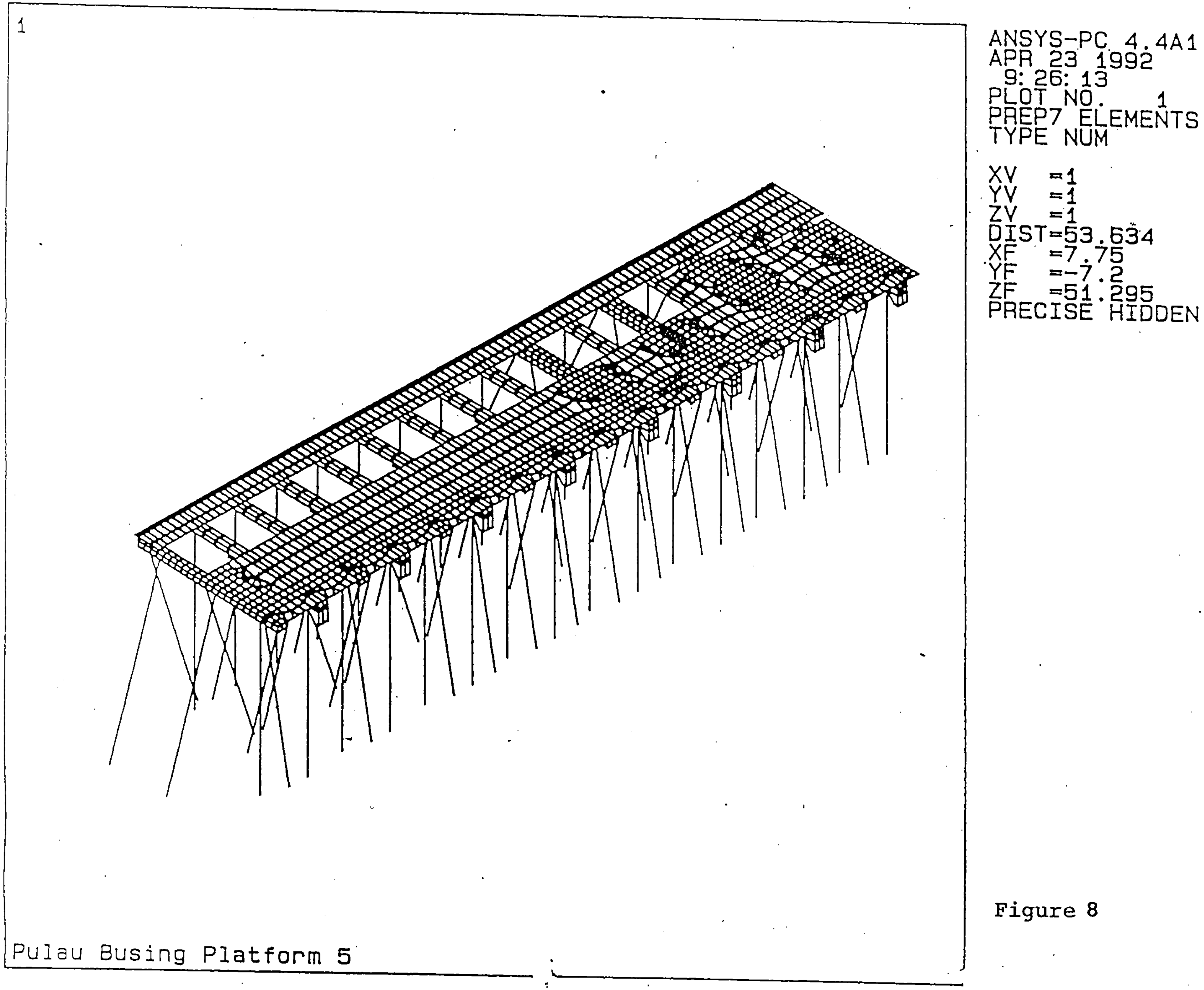
Also a number of piles were subjected to tension (uplift) load and for these piles a minimum penetration was specified to mobilize sufficient shaft friction to develop the required uplift capacity by adhesion between the pile and soil.

A full tension load test has been carried out to proof the uplift capacity of the piles. In general the piles are driven into the sand or sandstone layer respectively.

10.0 CONCLUSION

The design of the wharf with three loading areas adopted at Pulau Busing is considered economical and efficient for flexible loading and unloading operation.

Due to the high repetition and prefabrication of major structural elements the contractor (Wang Coo-Kien & Co.) was able to complete the works ahead of the original construction schedule.


1
ANSYS-PC 4.4A1
APR 23 1992
9:26:13
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ZV =1
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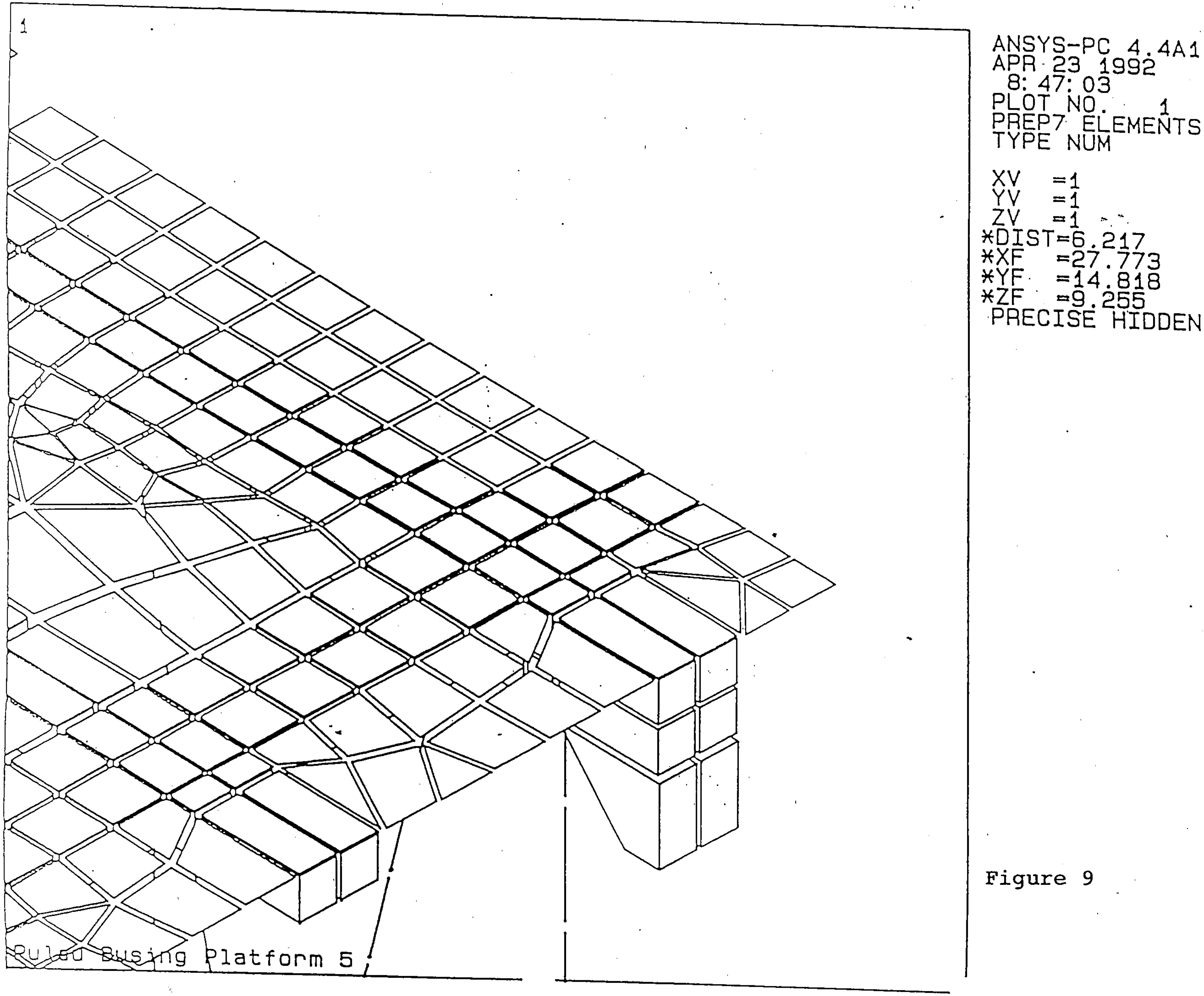
XF =7.75
YF =-7.2
ZF =51.295
PRECISE HIDDEN
Pulau Busing Platform 5

Figure 8


1
Pulsed Busing Platform 5
ANSYS-PC 4.4A1
APR 23 1992
8:47:03
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ZV =1
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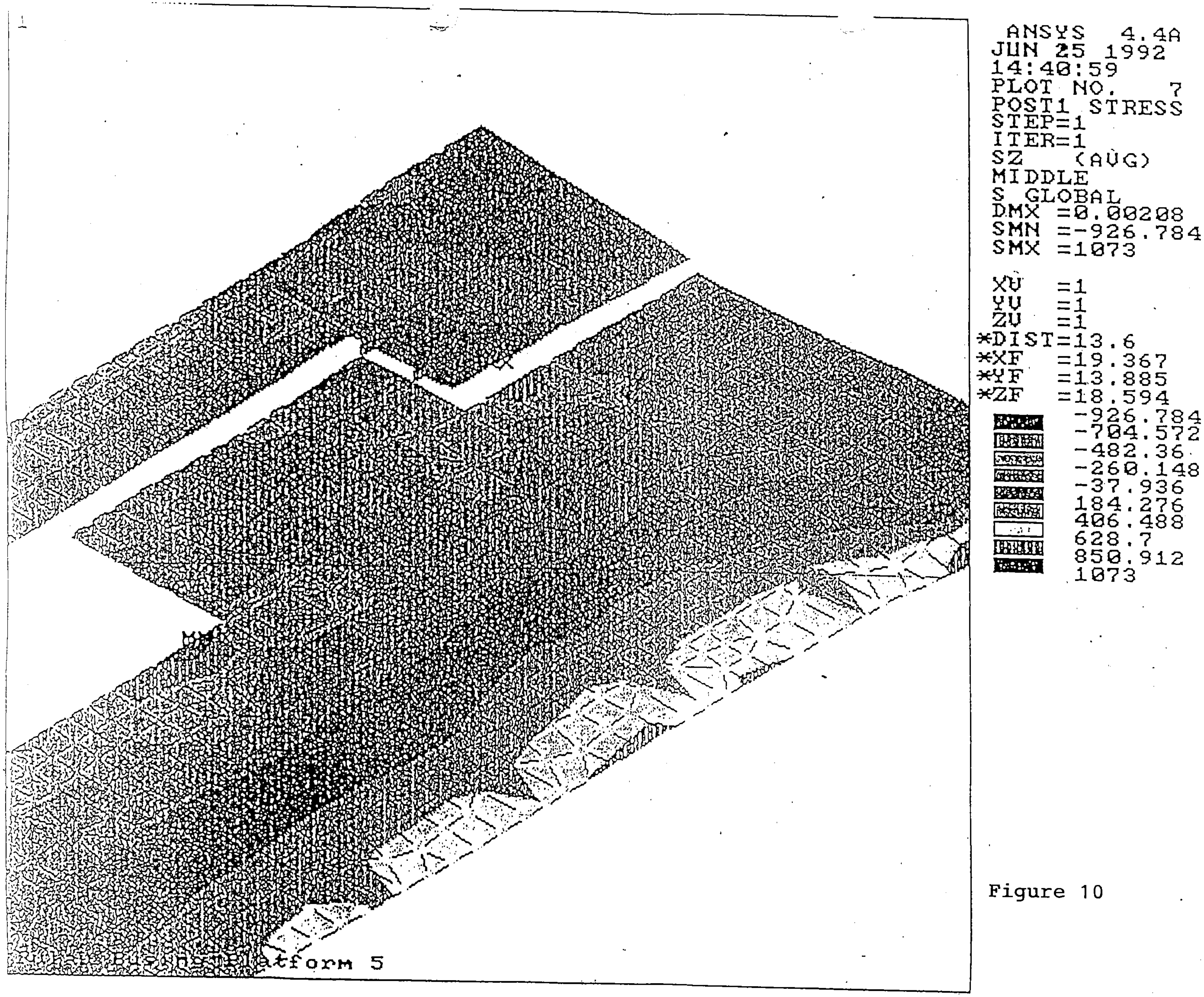
*YF =14.818
*ZF =9.255
PRECISE HIDDEN

Figure 9


ANSYS 4.4A
JUN 25 1992
14:40:59
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POST1 STRESS
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ITER=1
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MIDDLE
S GLOBAL
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SMN =-926.784
SMX =1073
XV =1
YV =1
ZV =1
*DIST=13.6
*XF =19.367
*YF =13.885
*ZF =18.594
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-704.572
-482.36
-260.148
-37.936
184.276
406.488
628.7
850.912
1073

Figure 10