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TRABAJO TECNICO

TITULO ANALYSIS OF PIPE CLAMP EAR PLATE

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ABSTRACT

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Pipelines conveying petroleum oil are either buried underground or supported aboveground. This paper deals with an aboveground support structure and describes some considerations necessary for optimizing the design of ear plates provided in order to fasten the heavy pipe clamps which sustain considerable stresses.

In this paper, the following two models of ear plates are considered:

A) Ear plates designed on the basis of conventional plate bending theory (Model A).

B) Ear plates designed on the basis of analysis by two dimensional finite element method (Model B). In this model, modifications were made to Model A described above (1) to reduce the weight by using a plate instead of the bolts at a compression side and (2) to simplify the ear plate compression mechanism by removing stiffeners.

Comparison of the analysis results obtained for Model B with those of Model A indicates that Model B enables steel to be reduced by 14% by weight compared with Model A and that Model B involves less elaborate fabrication. Thus, it has been proved that the two dimensional finite element method, which has come to be widely applied for structural designs of airplanes, ships, buildings and other engineered structures, can be effectively applied for ear plates design. Also, the method is considered effective for design of other parts of pipeline structures.

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Introduction

Pipelines conveying petroleum oil are either buried underground or supported aboveground depending on the climatic, subsurface or other environmental conditions of the site.

Where there is no fear that frozen soil is thawed by heated oil causing large bending stresses in piping elements, pipelines are generally buried underground.

In areas where tawing due to heated oil is liable, pipelines should be raised off ground by means of support structures. In such a system, pipelines must be fully insulated by polyurethane or other appropriate materials in order to minimize temperature fall of heated oil because oil attains high viscosity when its temperature lowers under the influence of low ambient temperature.

Various systems have been devised to absorb stress variation caused by tempeature and pressure changes in aboveground oil pipelines. This paper deals with a support structure so designed as to absorb stress variation by the geometrical change of the pipeline (see Fig. 1) and will describe some considerations necessary for optimizing the design of certain elements of such a support structure.

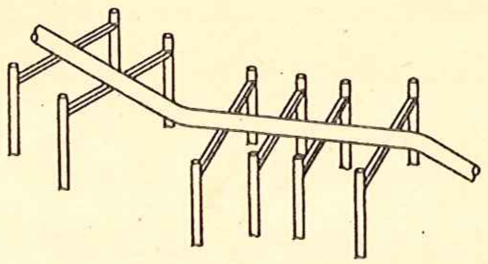

Fig. 1 Pipeline Support System

1. Pipe Clamp Ear Plate

As shown in Fig. 2, the support model is composed of: i) clamps which directly hold the insulated pipe; ii) shoes whose function it is to cope with stresses which vary due to changes in temperature and pressure; and iii) piles and a beam which act as major structural members.

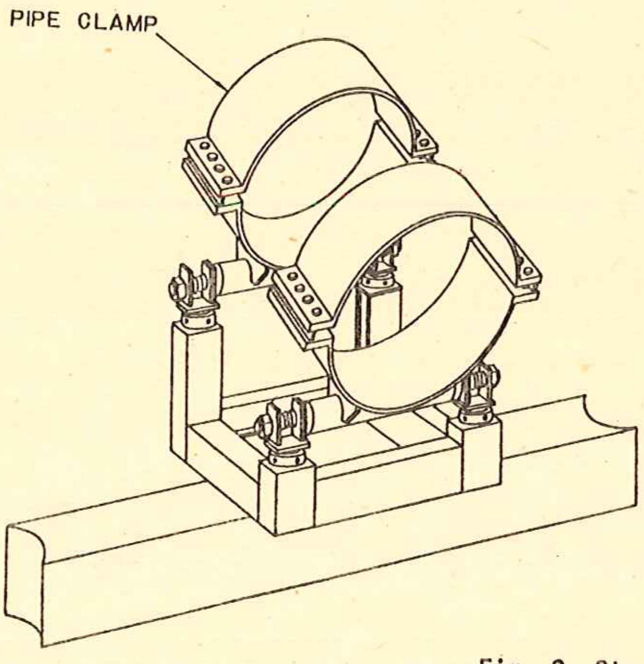

Fig. 2 Structural Member

Of the foregoing components, shoes and pipe clamps may be designed without being much affected by local conditions of the site. Table 1 indicates the weight proportion of various materials which constitute the shoe and clamp assemblies. It should be noted from Table 1 that ear plates account for a substantial portion of the overall weight of these assemblies.

Table 1 Weight Proportion (%) of Shoe and Clamp Elements

	PL.	Bent PL.	Pipe	Bolt, Nut & Washer	Round Bar	Shoe Mechanism
Shoe	18.2 %	0	9.5 %	0.1 %	0.4 %	0.1 %
Clamp	38.0 %*	25.9 %	3.8 %	0	0	0

* Clamp ear plate

In view of above, two types of ear plates were considered as described below:

1) Ear plate designed on the basis of conventional plate bending theory (hereinafter referred to as Model A: see Fig. 3.)
2) Ear plate designed on the basis of analysis by two dimensional finite element method. A modification of Model A (hereinafter referred to as Model B: see Fig. 4.)

These models were studied on a comparative basis to determine their respective advantages.

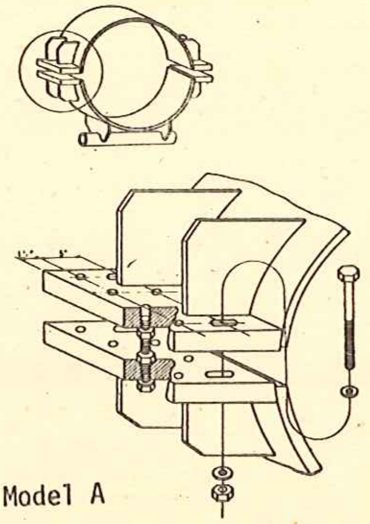

Fig. 3 Model A

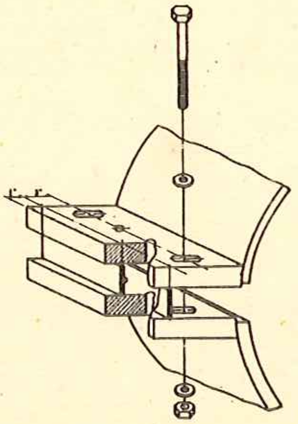

Fig. 4 Model B

2. Method of Analysis

2-1 Design of Model A

Fig. 3 indicates the detail of Model A ear plate as designed by the conventional plate bending theory. The mechanism of this model may be described as follows:

1) Tension bolts (on the inner side) and compression bolts (on the outer side) tighten the upper and the lower ear plates which in turn tighten the clamp holding the pipe.

2) Each plate is provided with stiffeners located between bolts, and ear plate thickness is determined on the assumption that the plate is a rectangular slab fixed at three sides and free at one side, being supported between stiffeners.

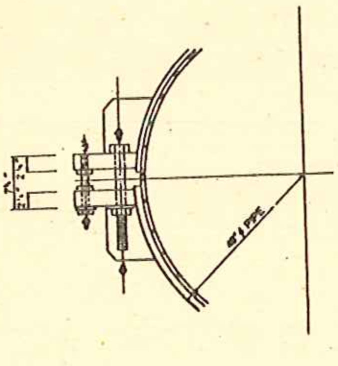

Fig. 5 Detail of Model A

2-2 Design of Model B (Based on the Two Dimensional Finite Element Method Analyses)

Subsequent to the development of Model A ear plates designed by the conventional method, studies were continued to see if it was possible to effect some steel saving by modifying Model A. As can be seen in Fig. 4, the following modifications were proposed:

1) Instead of the bolts at the compression side, a plate would be provided between the ear plates at their outer edge. This should make it possible to eliminate the edge distance for the compression bolts, thereby reducing the ear plate width.

2) The stiffeners in Model A would be removed to simplify the ear plate clamping mechanism and to effect further steel saving. See Fig. 6.

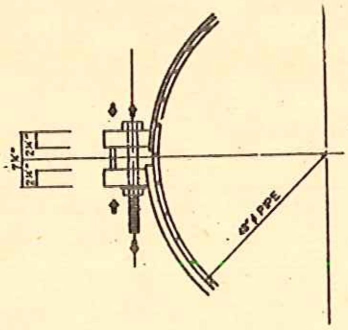

Fig. 6 Detail of Model B

In order to verify the feasibility of the foregoing modifications, a two dimensional finite element method analysis was performed by utilizing an IBM 1130 digital computer so as to obtain optimum design.

As is widely known, the finite element method enables designers to clarify physical behaviors of structures of arbitrary shape by combining force and displacement of buildings into a stiffness matrix and converting the entire structure into a coordinate system. As this method has given a new means for structural analyses which were otherwise impossible, the method has come to be widely applied for structural designs of airplanes, ships, buildings and other engineered structures.

For the present purpose, the ear plates were converted into the following simulated model which was, then, checked as to out-of-plane bending. Analysis procedures adopted were as follows:

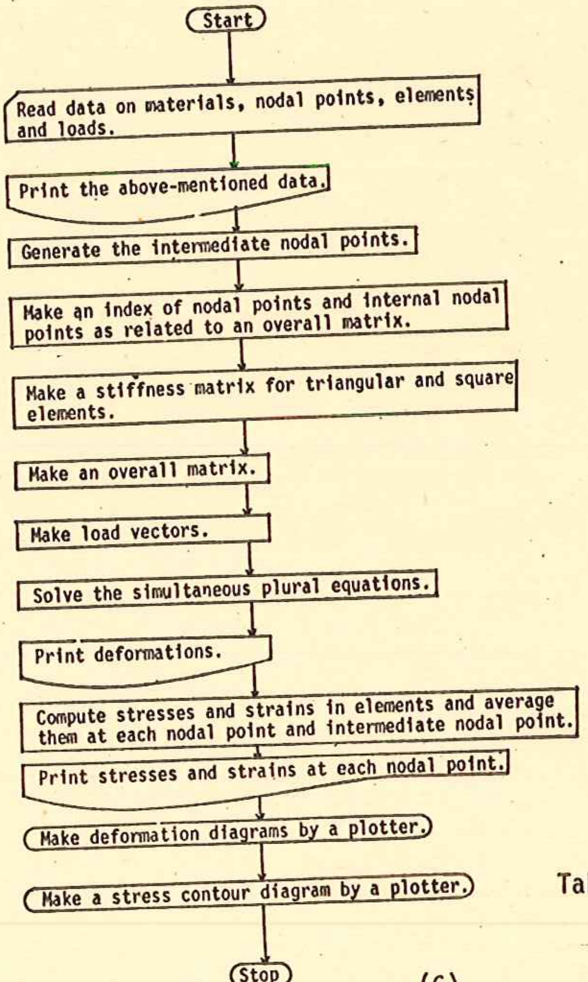

Table 2 Flow Chart of F.E.M.

2-2-1 Analytical Model for Analysis by the Finite Element Method

In this analysis, a model was taken from a partial section through the ear plate, compression plate and upper clamp plate. Then, it was assumed that such a section was subject to a uniformly distributed load applied on the tension bolt. See Fig. 7.

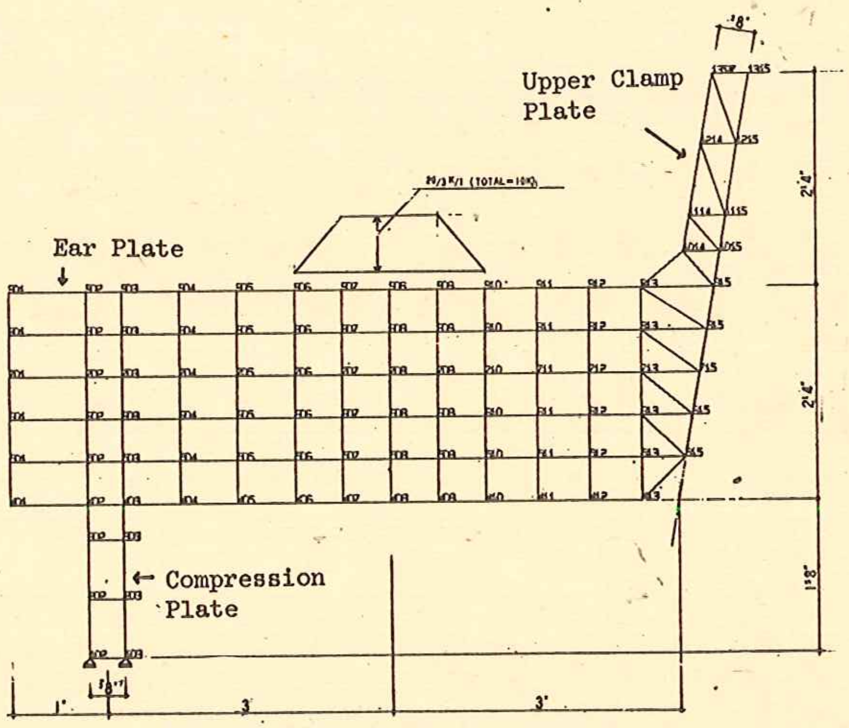

Fig. 7 Analysis Model of F.E.M.

The analysis was conducted by the use of an IBM 1130 digital computer and a program which was developed and owned by the firm of Nikken Sekkei for its exclusive use. The outputs which were obtained are as shown hereinafter.

2-2-2 <u>Results of Analaysis</u>

Fig. 8 shows the analysis results as to the displacement of the frame and Figs. 9 through 12 show those as to the distribution of stresses, σ_X, σ_Y, τ_{xy} and $\bar{\sigma}_X$ in due order. Fig. 13 shows the distribution of normal force on each section.

From these analyses, it was found that under idential stress conditions Model B ear plates were still on the safe side even if stiffeners were eliminated and plates were kept at the same thickness as for Model A.

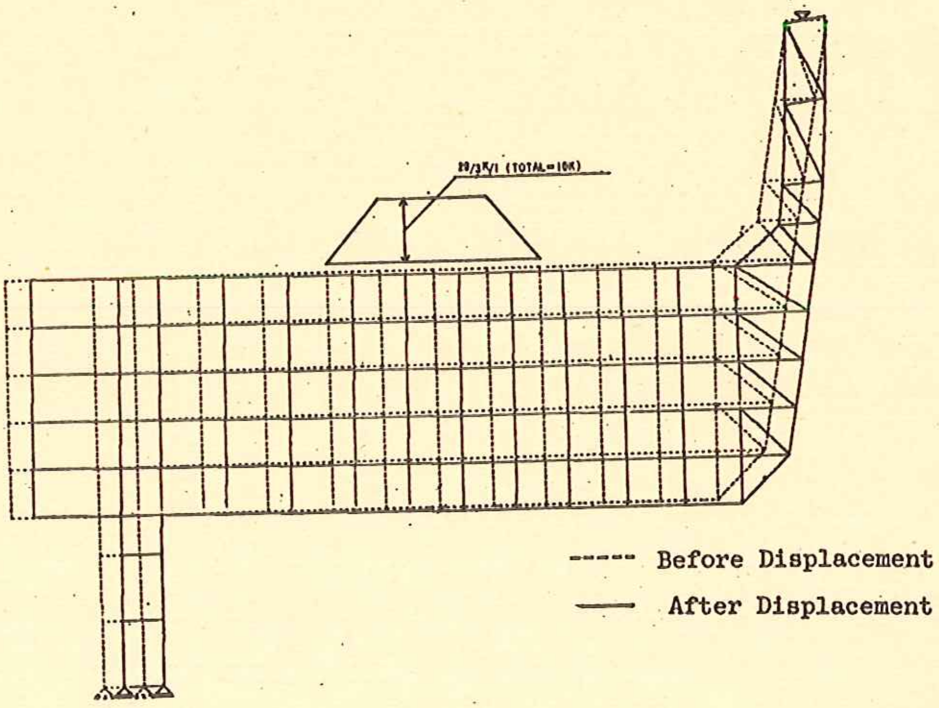

Fig. 8 Displacement

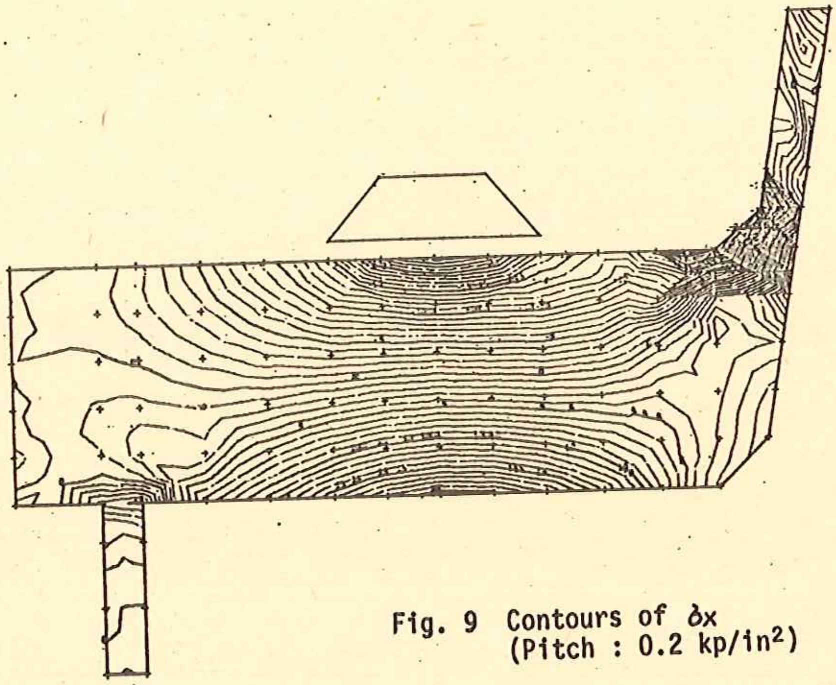

Fig. 9 Contours of σ_x
(Pitch : 0.2 kp/in^2)

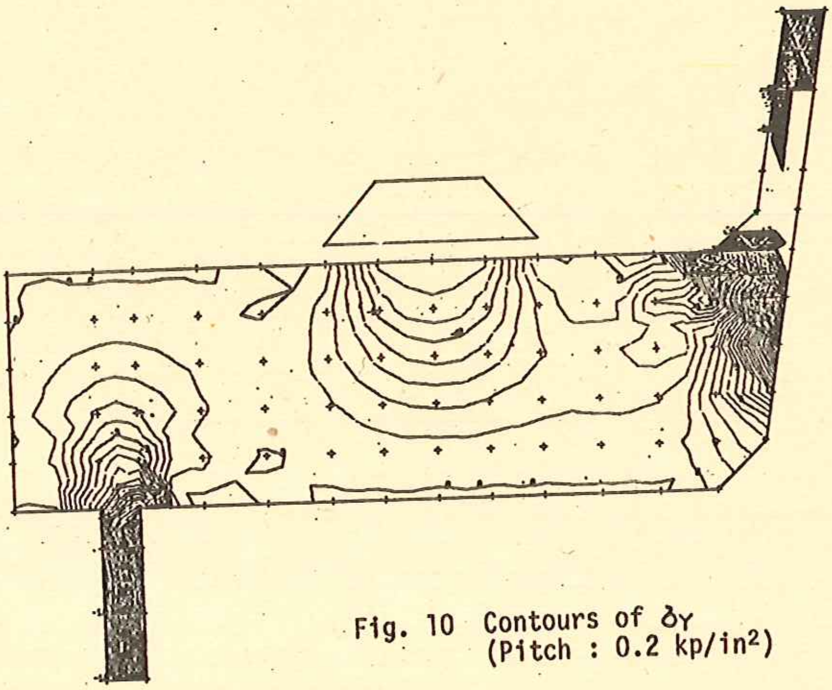

Fig. 10 Contours of σ_Y
(Pitch : 0.2 kp/in^2)

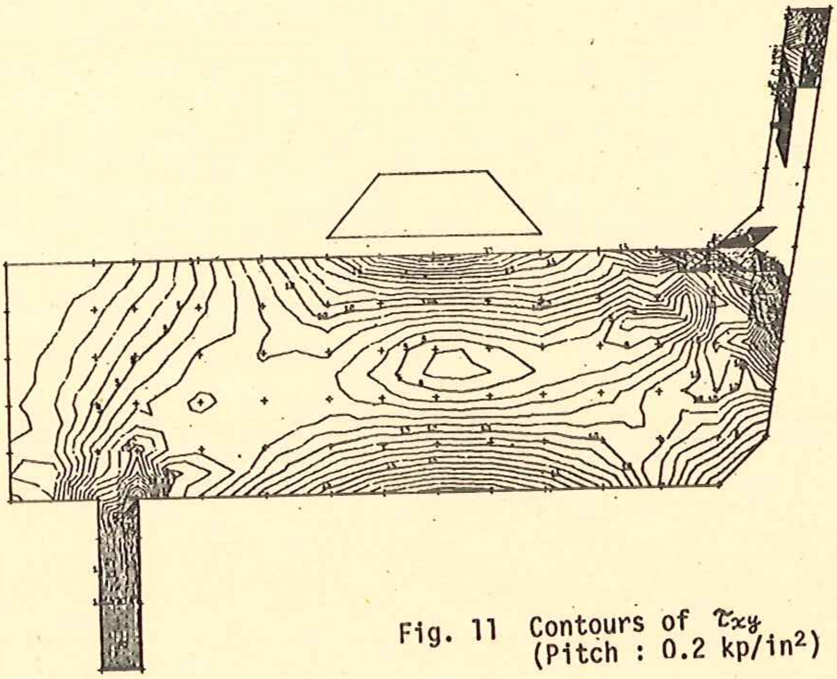

Fig. 11 Contours of τ_{xy}
(Pitch : 0.2 kp/in^2)

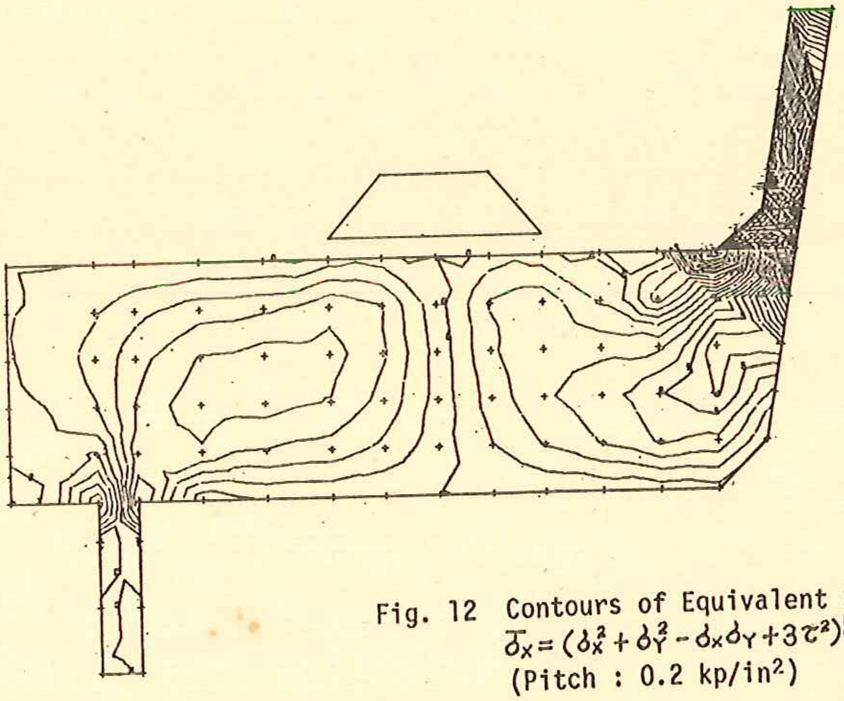

Fig. 12 Contours of Equivalent Stresses
$\bar{\sigma}_x = (\sigma_x^2 + \sigma_Y^2 - \sigma_x \sigma_Y + 3\tau^2)^{1/2}$
(Pitch : 0.2 kp/in^2)

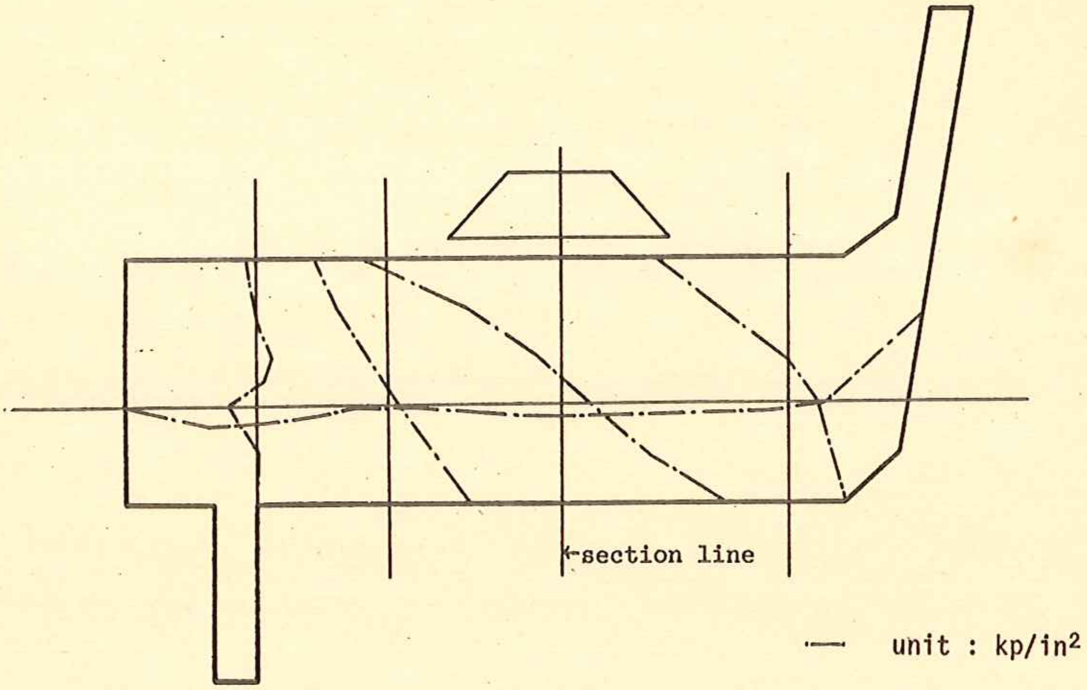

Fig. 13 Distribution of Normal Force

Conclusion

By comparing the analysis results obtained for Model B with those of Model A, the following conclusions were reached:

1) Ear plates in Model B, in which the stiffeners as used in Model A are eliminated, are evidently safe enough without increasing plate thickness over that adopted in Model A. Thus, Model B enables steel to be reduced by 14% in weight compared with Model A because of the elimination of the stiffeners and the reduced ear plate width.

2) Since the ear plate thickness in Model B is the same as that in Model A, the ear plates in these two models are governed by the exactly same conditions as to Charpy values and low-temperature brittleness. Hence, ear plates in Model B are in no way inferior to those in Model A when used under austere climatic conditions.

3) Since Model B is economical as compared with Model A and involves less elaborate fabrication, it may generally be concluded that the design has been optimized by the use of the finite element method analysis.

Table 4

		MODEL A	MODEL B	NOTE
STEEL WEIGHT		100	86	
FABRICATION	EDGE PLATE(UPPER)	100	80	OUTER BOLT HOLES OMITTED WIDTH NARROWED BY 2·½"
	EDGE PLATE(LOWER)	100	105	VERTICAL PLATE TO BE WELDED IN PLACE OF OUTER BOLTS
	STIFFNER PLATE OMITTED	100	0	
	FABRICATION IMPROVEMENT ON BENDING OF CLAMP PLATE	100	85	
CONSTRUCTION SCHEDULE (ASSUMED)		100	90	

In this paper, only ear plates which account for substantial portion of the total steel weight of pipeline support structure have been described; however, the finite element method has also been applied for analyses of clamp plates, pivot pins, and other support elements in order to optimize their designs.

References

1) S. Timoshenko, "Theory of Plate and Shell," McGraw-Hill Publishing Company Limited, 1940

2) O. C. Zienkiewicz & Y. K. Cheung, "The Finite Element Method," McGraw-Hill Publishing Company Limited, 1967

3) T. Teramoto & A. Wada, "Two Dimensional Finite Element Method by the use of Linear Strain Element," 1969 Transaction of Society of Steel Construction of Japan

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TITULO COMPORTAMIENTO DE LAS PLANCHAS DE ACERO ESTRUCTURAL CON LAS VARIACIONES DE TEMPERATURA

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PEDRO BARREDA GRADOS

PAIS PERU

1975