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Analytical Study of
Concrete Pavement Behavior

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By

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CHAPTER 1
INTRODUCTION

1a. Background

The performance of rigid pavements has been for a long time a matter of concern for the U.S. Air Force. Many air force bases features such as runways, taxiways, and aprons have been constructed as rigid pavements and have structurally failed before the end of its design service live. These failures have been attributed primarily to increase in traffic loadings, changes in the geometrics of the main landing gear of new aircraft combined with the interaction of inadequate soil support, poor drainage, temperature gradients, use of marginal aggregates and inadequate load transfer at the joints. In addition, the rigid pavement design methodologies that have been developed in the past that have been used since recently, have certain limitations that were imposed by the state of the art at the particular stage of development.

The advances in computer technology during the last decade has permitted the application of techniques such as finite element method to analyze very complicated problems in a more rational manner. In rigid pavements in particular, a more comprehensive analysis of the state of stresses at pavement joints, cracks, and edges due to dynamic gear loadings, taking into account the non-linear behavior of soils can be more efficiently analyzed.

1b. Purpose

The purpose of this research study is to develop an analytical tool to analyze the performance of rigid pavements taking into account the non-linear behavior of soils using the finite element method. The end result is a computer program named Dynamic Non-Linear Pavement Analysis Program (DYNOPAV), a crack visualization and interpretation program (CRACK) and a user-friendly graphical input program of pavement features (GRINPAV).

1c. Scope

The research study will focus on the development of an analytical tool for analyzing the state of stresses due to dynamic gear loadings taking into account the non-linear behavior of soils. The analysis will concentrate on one plain slab without reinforcement, ties, or dowels and with a fixed length.

The report will include a description of the computer programs developed complemented with an input guide. Case study examples illustrating input procedures for the programs will also be included as well as outputs of the example problems.

CHAPTER 2

LITERATURE REVIEW

The literature review associated with the analytical study of concrete pavement behavior was concentrated on two major areas:

- ♦ non-linear analysis of stress and strains in soils and its applicability to pavement design and performance.
- ♦ state of the art in the analysis of concrete pavements with emphasis on the application of finite element formulation and modeling the dynamic effect of wheel loads configurations typically applied to pavement structures.

2.a Non-linear Analysis of Stress and Strain in Soils

The stress-strain behavior of any type of soil depends of a number of different factors including density, moisture, pore structure, drainage conditions, strain conditions, duration of loading, stress history, confining pressure, and shear stresses [5]. Non-linear analysis of stress and strains in fine-grained subgrades and granular materials have been used to model the behavior of concrete pavements subjected to different types of wheel loading configurations. A review of the literature related to non-linear analysis of stress and strain in soils is presented in the following paragraphs.

In its initial conception, the classical rigid pavement design and analysis methodologies assume that the subgrade is an elastic Winkler foundation represented by a bed of closely

spaced, independent, linear springs [35]. The stiffness of the springs, known as the modulus of subgrade reaction (k), relates the reactive pressure (p) to the deflection (w) at a given location in the subgrade. The value obtained is often termed the spring or the dense liquid constant. The equation is expressed as follows:

$$p = kw \tag{1}$$

The assumption relative to k is valid as long as the pavement slab is in complete contact with the supporting medium, (i.e. subgrade).

Several models are being developed to represent an elastic soil medium considering the non-linearity of the springs which more accurately approximate the stress softening behavior of fine-grained subgrade. The Ramberg-Osgood model [14] is specially suited for cyclic loading situations, where both loading and unloading curves are of interest.

The model for first loading is expressed in the following form:

$$\frac{w}{w_y} = \frac{p}{p_y} + a \left| \frac{p}{p_y} \right|^r \tag{2}$$

For reloading, the model is expressed as follows:

$$\frac{w-w_0}{2w_y} = \frac{p-p_0}{2p_y} + a \left| \frac{p-p_0}{2p_y} \right|^r \tag{3}$$

where:

- w_y = deflection at yielding, inch
- p_y = plate pressure at yielding, psi
- w₀ = extreme deflection value of w for the cycle, inch
- p₀ = extreme pressure value of p for the cycle, psi
- a&r = constants determined experimentally

Butterfield and Georgiadis [2] developed an empirical equation to account for the non-linearity of the subgrade springs. The model shown in equation 4 takes into account the initial stiffness (k_0), a final stiffness (k_f) and a pressure axis intercept (q_u).

$$q = q_u (1 - \exp \{-(k_0 - k_f) w / q_u\}) + k_f w \quad (4)$$

The major drawback of the Winkler and non-linear springs model is the inability to adequately describe the behavior of the half space. In other words, it implies that no deflection response is feasible outside the loaded area, which in terms reflects that the deflection at any location is only a function of the pressure at that location. In reality, some deflection always occur outside the loaded area in terms of other models to describe elastic foundation response.

Filonenko-Borodich foundation [14] considers, in addition to the vertical springs, a stretched elastic membrane. The elastic membrane which is subjected to a constant tension field is connected to the top end of the springs to develop interaction among them. The amount of interaction is a direct function of the tension field. The formula used to relate subgrade stress and deflection is shown below:

$$q = kw - T\nabla^2 - w \quad (5)$$

where:

- q = subgrade stress, psi
- w = deflection, inches
- T = tension field
- ∇^2 = Laplace operator in x and y.

Pasternak [14] developed a two parameter model which takes into account the existence of shear interactions between the springs elements by tying the springs together at the top with a plate consisting of incompressible vertical elements that deform only by transverse shear. The relationship between subgrade stress and deflection is shown below:

$$q = kw - GV^2w \tag{6}$$

where:

- q = subgrade stress, psi
- w = deflection, inches
- k = subgrade modulus, psi
- G = plate shear modulus, psi

With the exception of the Ramberg-Osgood model all the previous models were developed for static loading conditions.

Repeated unconfined compression or triaxial testing procedures are used to evaluate the resilient moduli of fine-grained soils and granular materials [33]. Resilient moduli are stress dependent: fine-grained soils experience resilient modulus decreases with increasing stress, while granular materials stiffen with increasing stress levels.

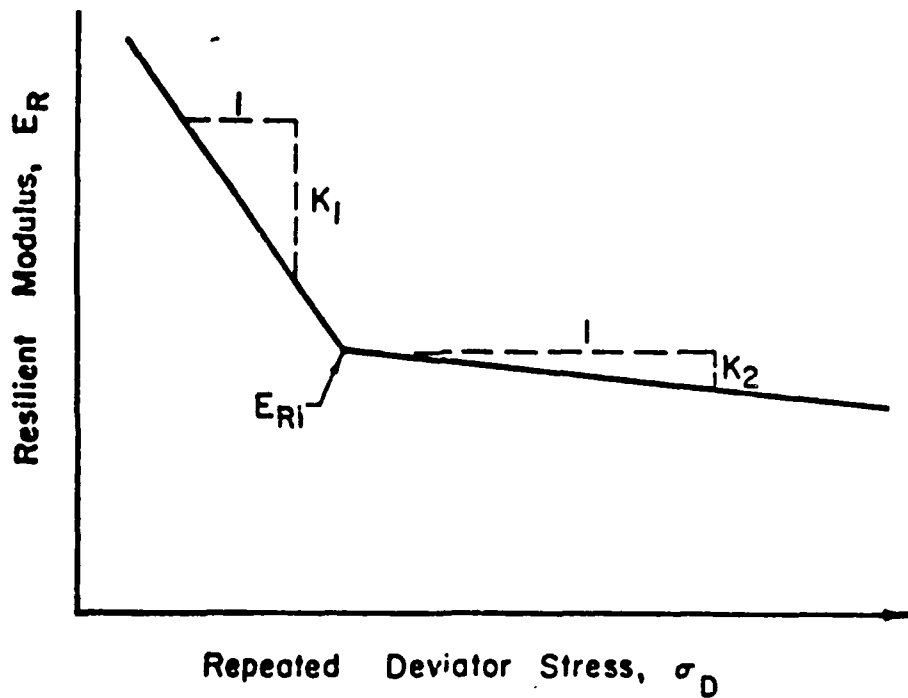
The general formula for measuring the resilient response is shown below:

$$E_R = \sigma_D / \epsilon_R \tag{7}$$

where:

- E_R = resilient modulus, psi
- σ_D = repeated deviator stress, psi
- ϵ_R = recoverable axial strain

A graphical representation of the stress dependent resilient behavior of fine-grained soils is shown below. The value of the resilient modulus at the breakpoint in the bilinear curve, E_{Ri} , is a good indicator of a soils of the subgrade resilient behavior. The slope values, K_1 and K_2 , display less variability and influence pavement structural response to smaller degree that E_{Ri} .



Repeated load triaxial testing is used to characterize the resilient behavior of granular materials and is a function of the applied stress tape. The mathematical relationship to determine the resilient modulus for granular materials is as follows:

$$E_R = K_1 \theta^{K_2} \tag{8}$$

where:

- E_R = resilient modululus for granular materials, psi
- K_1 and K_2 = regression coefficients
- θ = sum of principal stresses ($\sigma_1 + \sigma_2 + \sigma_3$)

Duncan and Chang [5] presented a simplified, practical stress-strain relationship which takes into account the non-linearity, stress dependency, and inelasticity of soil behaviors.

Wang, Sargious, and Cheung [34] used a finite element method to determine the deflections and stresses in rigid pavement slabs with the subgrade acting as semi-infinite, elastic, homogeneous continuum. The slab is divided into individual, rectangular elements which are jointed at the spring final numbers of nodal points. The foundation is considered as consisting of a series of rectangular pressure areas whose centers coincide with and remain in contact with the nodal point of the slab. The pressure is assumed to be constant within each rectangle. He showed that the deflection for the foundation considered as an elastic continuum are much higher than those obtained by the Winkler assumption.

Duncan and Chang [5] analyzed the non-linear stress-strain relationship of soils using six parameters which includes the Mohr-Coulomb stress parameters (soil cohesion, c and friction angle, θ) and four parameters that can be evaluated using the stress-strain curves of the same tests used to determine the values of c and θ . The procedure to analyze the shear in loading is incremental in nature which essentially approximates the non-linear stress-strain relationship by a series of straight lines. The shortcoming of the iterative procedure is that it is very difficult to take into account non-zero initial stresses, which play an important role in many applications in soil mechanics. The principal advantage of the incremental procedure is that

initial stresses may be readily accounted for. It also has the advantage that, in the process of analyzing the effects of a given loading, stresses and strains are calculated for smaller loads as well. The accuracy of the incremental procedure may be improved if each load increment is analyzed more than once, in this way it is possible to improve the degree to which the linear increments approximates the non-linear soil behavior.

2.b. Concrete Pavement Analysis

The behavior of rigid pavements has been for a long time a matter of concern for the U.S. Air Force. In 1926, H.M. Westergaard published a report in the Highway Research Board Proceedings which contain mathematical equations to analyze stresses in concrete pavements [35]. The equations developed assumed that the slab is infinite in both x and y directions and the analysis of stresses at slab edges and corners had not been developed. He further assumed the modulus of subgrade reaction, k , to be a constant at each point, independent of the deflections and to be the same at all points within the area which is under consideration.

In 1951 Pickett and Ray [20] developed influence charts for the solution of two cases of loading: (1) assuming that the subgrade acts as a dense liquid (i.e. conventional k), and (2) based upon the elastic solid case. The stresses could be determined for several wheel configurations. A computerized version of the Pickett and Ray influence charts has been developed and incorporated in the computer program H51ES [6].

This program, essentially, incorporates an analytical method for calculating the bending stress at the free edge of a loaded semi-infinite slab resting on a dense liquid or elastic solid foundation. The original computerized procedure was developed for the dense liquid subgrade and was later expanded to include the elastic solid idealization. The most significant limitations of the program are that the effects of thermal and moisture gradients as well as the loss of support beneath the slab are not considered. Base and subbase are not directly considered and only edge stresses can be calculated. Wheel configurations must be symmetrical about two perpendicular axles and jointing including slab sides and load transfer systems are not considered. The stresses are computed only for a semi-infinite plane PCC slab.

Both Westergaard analysis for liquid foundations [35] and Pickett's and Ray analysis for solid foundations [20] are based on the assumption that the slab and foundation are in full contact. This assumption is valid if there are no gaps between the slab and foundation, because the weight of the slab naturally imposes a large pre-compression on the foundation, which will keep the slab and foundation in full contact. However, this is not true when the slab is subjected to warping or pumping, which results in a separation between slab and foundation. Finite elements techniques are very useful for evaluating the effect of contact condition on the design and analysis of concrete pavements.

In 1966 the Portland Cement Association [21] developed a mechanistic procedure for design of rigid pavements based on Miner's hypothesis which considers the accumulative damage of the ratio of the stress associated with a particular wheel loading with respect to the flexural strength of the concrete.

In the last two decades, several models have been developed to analyze concrete pavement behavior using finite element techniques. ILLI-SLAB [28,29] developed by the University of Illinois, JSLAB [31] developed by the Portland Cement Association, WESLIQID [4] and WESLAYER [4] developed by the U.S. Corps of Engineers, and RISC [16] are examples of operational rigid pavement analysis models that have incorporated finite element formulations. A brief description of these models including their limitations are discussed in the following sections.

2.b.1 ILLI-SLAB

ILLI-SLAB was originally developed for structural analysis of one or two layer concrete pavements with or without mechanical load transfer systems at joints and cracks [28]. The finite element formulation is based on the classical theory of a medium-thick plate resting on a Winkler foundation. The model employs the 4-noded, 12 degrees of freedom plate bending element, and analyzes the subgrade as a uniform distributed subgrade through an equivalent mass formulation. The program uses a work equivalent load vector.

The current version of ILLI-SLAB incorporates partial slab-subgrade contact and thermal gradient modeling techniques.

In terms of limitations, ILLI-SLAB does not have the ability:

- a. to consider all types of pavements or all factors that affect a pavement, specifically it considers a maximum of two slab layers in addition to the subgrade;
- b. considers only a single slab, layer, and subgrade model when considering temperature gradients through the slabs and gaps between slab and subgrade;
- c. does not consider the effects of drainability of the pavement section;
- d. does not consider volume of vehicle traffic;
- e. considers longitudinal and transverse joints and/or cracks with identical connections and load transfer mechanisms.

2.b.2 JSLAB

JSLAB is a finite element program that has very similar assumptions and derivations as compared to ILLI-SLAB. The subgrade is modeled as a Winkler type dense liquid, through an equivalent mass formulation as in ILLI-SLAB. JSLAB has identical capabilities as ILLI-SLAB with the exception of the partial contact with initial gap option [31]. In addition, JSLAB has the ability to consider nonuniformly spaced dowel bars across the longitudinal or transverse joints as well as considerations of noncircular load transfer devices.

In terms of limitations, JSLAB does not calculate the principal bending stresses as well as vertical stresses on the subgrade. Furthermore, only a one layer pavement system with a uniform thickness can be analyzed when a moisture gradient through the slab is considered. If the user specifies a vertical

slab displacement, it is not feasible to locate the applied loads at that particular node or over any element adjacent to that node. In terms of computer time, there is a significant amount of time required when the thermal gradient analysis is performed.

2.b.3 WESLIQID

The WESLIQID finite element computer program was developed for the analysis of concrete pavements subjected to both multiple wheel load arrangements as well as temperature gradients [4]. The subgrade is characterized as a dense liquid Winkler foundation in which the vertical forces and deformations are considered proportional to the corresponding vertical deflection. This technique can accommodate any number of rectangular shaped slabs arranged in any arbitrary pattern, connected by dowel bars or any other load transfer devices at the joints. The program can also handle cracks perpendicular or parallel to the joints.

In terms of limitations, the program is limited to a maximum of two pavement layers, in addition to the subgrade, and to a maximum of nine slabs and eleven joints of cracks with 200 nodes and 130 elements. Furthermore, temperature gradients are only considered for a slab with uniform thickness.

2.b.4 WESLAYER

The WESLAYER finite element program was developed to compute the state of stresses in a rigid pavement supported on an elastic solid or layered elastic foundation [4]. This program in terms of the method of solution and general input and output is very

similar to WESLIQID previously defined. In terms of capabilities, WESLAYER is essentially identical to WESLIQID with the exception that only two slabs uniformly thick may be modeled with one joint between them; this is due to the fact that large computer storage capacity is required by the elastic solid representation of the subgrade. The program uses as input and output essentially the same requirements as WESLIQID with the additional input of layered data, namely, modulus of elasticity and poisson ratio for the layered elastic representation of the subgrade.

In terms of limitations, WESLIQID is limited to a maximum of two slabs, one joint with 70 nodes and 60 elements, and limited to a maximum of 5 layers in the subgrade. Furthermore, temperature gradients may only be considered for uniformly thick slab configurations.

2.b.5 RISC

RISC is part of a mechanistic design procedure for rigid pavements and is based on the coupling of a finite element slab resting on a multilayer elastic solid foundation of up to 3 discrete layers [16]. The program considers up to 3 slabs in a row with or without shoulders as well as joint spacing, joint width, the effect of dowel bars and tie bars, load location, and thermal curling stresses.

In terms of limitations, the program requires a large amount of high speed computer time, essentially 30 to 50 minutes of CPU time for a single run, therefore, is quite expensive to use for

certain types of investigations. In terms of additional limitations, this program is limited to a standard dual wheel loading at a choice of three determined locations. All transverse joints must have identical load transfer mechanisms, and load transfer across longitudinal shoulder joint is not calculated. Unit weight and coefficient of thermal expansion of concrete slab as well as bending condition between layers are assumed in program and are not direct inputs. Flexural stresses in base and/or other support layers are not calculated neither subgrade stresses when more than one-layered pavements are modeled. Critical tension stress location in slabs (i.e. top or bottom) is not indicated, and only maximum displacements and stresses are output. Finally, the fatigue and faulting models presented are quoted in the literature as "questionable".

2.b.6 Other Finite Element Methodologies

Larralde and Chen [15] conducted a research study at Purdue University to develop a method for structural analysis of rigid pavements which considers the damage produced in the pavement structures by the repetitive actions of traffic loads. The damage is represented as a function of the reduction in concrete strength, deterioration in load transfer efficiency and pumping action.

Wang, Sargious, and Cheung [34] used the elastic solid methodology in the analysis of rigid pavements. The major difficulty they encountered in the use of solid foundations was in terms of the large computer storage required, because the

coefficient matrix for the large set of simultaneous equations is not banded, in contrast to the banded matrix when considering the subgrade as a dense liquid.

Chou [3] analyzed stress conditions in concrete pavements using the finite elements methods for slabs on liquid and elastic subgrades. In this study he found that the efficiency of load transfer accross a joint has an insignificant effect on the stresses and deflections in the slab when the load is placed at the center of the slab, but has a significant effect when the load is placed next to the joint. In addition, he showed that when the slab is in partial contact with the subgrade due to temperature warping, the assumption of the elastic response, as assumed by the Westergaard solution is not longer valid, even though the slab stresses are still within the elastic range.

Finally, he showed that the most critical condition in a rigid pavement occurs when there is no transverse joint or crack in the pavement, and also when the load is moving along its edge. Under the edge load, the presence of joints and cracks can reduce pavements stresses near the joints and the cracks, but increase the deflections in the same area. In a jointed pavement, the critical stress occurs when the load is half-way between the joints and the stress can have a magnitude close to that of a pavement with no transverse joint. Therefore, the presence of a joint does not reduce the maximum stress in a pavement. When the load is moving along the center of the pavement, the stresses are smaller, and are nearly independent of whether the load is at the center or next to the pavement joint.

Under both center and edge loads, maximum deflection occurs when the load is next to the transverse joint; corner deflection induced by the corner load is much greater. In terms of the theoretical deflection basin of the concrete slab, he demonstrated that is much flatter when the assumed subgrade is elastic than when it is liquid.

In 1986 the National Cooperative Highway Research Program awarded a research project to develop calibrated mechanistic structural analysis procedures for pavements using finite element methods. In 1989, the Federal Highway Administration [6] sponsored a research project to characterize and compare currently available rigid pavement analysis models and design methods and to develop new rigid pavement designs to be evaluated in full-scale experimental projects in an actual environment. The finite element formulations previously described in this chapter were analyzed in a great detail as part of this study.

The methodologies that have been used for analyzing concrete pavement behavior have had several drawbacks. The inability to simulate the dynamic effect of wheel loadings combined with the assumption of continuous support at the slab-subbase interface is by far the most critical drawback.

In the next chapter a description of the analytical methodology that was developed to model this drawback is presented.

CHAPTER 3

DESCRIPTION OF FINITE ELEMENT METHODOLOGY

3.a Finite Element Formulation

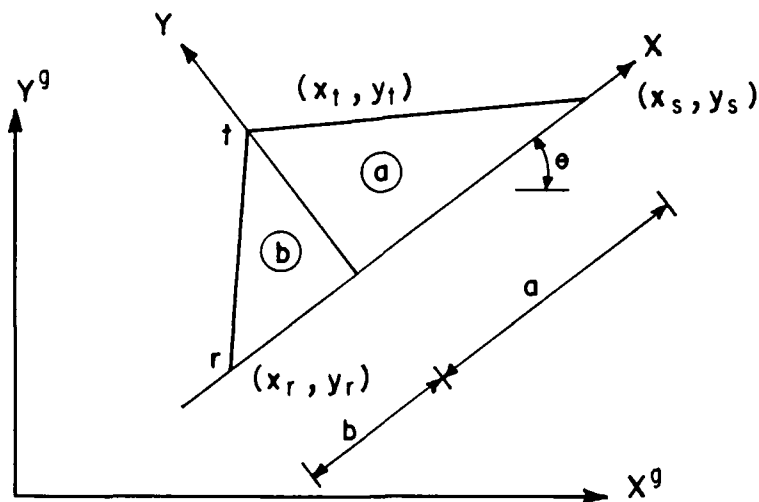
A triangular finite element with three nodes and three coordinates at each node was used as the basic element formulation. This element, developed by Rodriguez [25] in 1968, was selected because the computation of its stiffness matrix could be simplified reducing the amount of computing time required for the solution. As illustrated in Figure 1, there is a displacement function for each subelement. Originally the displacement formulation had a total of thirty-two constants which were reduced to fifteen by imposing compatibility. The element exhibits lack of compatibility in some specific cases, but even so, it converges and has been proved to give good results.

The general element stiffness matrix is given by:

$$K_e = t^3/12 [C^{-1}]^T \left\{ \int_{A_A} [Ba]^T [D][Ba]dA + \int_{A_B} [Bb]^T [D][Bb]dA \right\} [C^{-1}] \quad (1)$$

The element stiffness matrix is rotated to global coordinates and added to the total pavement stiffness matrix.

In Appendix A, the matrices [C], [Ba] and [Bb] are given. The material rigidity matrix is discussed and presented in section 3.g where the concrete behavior representation is explained.



$$W_a = \alpha_1 + \alpha_2 X + \alpha_3 Y + \alpha_4 X^2 + \alpha_5 XY + \alpha_6 Y^2 + \alpha_8 (mX^3 + XY^2) + \alpha_9 (mX^3 + Y^3)$$

$$W_b = \alpha_1 + \alpha_2 X + \alpha_3 Y + \alpha_4 X^2 + \alpha_5 XY + \alpha_6 Y^2 + \alpha_8 (m'X^3 + XY^2) + \alpha_9 (n'X^3 + Y^3)$$

where:

$$m = [2 - (h/a)^2]/3 \qquad n = -h/a$$

$$m' = [2 - (h/b)^2]/3 \qquad n' = h/b$$

Figure 1 - Element Displacement Expansion.

3.b Matrix Condensation

For the dynamic analysis it is convenient to condense the stiffness matrix to eliminate all rotational coordinates of the general dynamic solution. To simplify the matrix condensation, rotational coordinates are enumerated consecutively after the displacement and vehicle coordinates. This condensation is performed using the following matrix relations:

$$\{F_{TOT}\} = \{K_{TOT}\} \{U_{TOT}\} \quad (2)$$

$$\{F_V/F_R\} = \begin{bmatrix} K_{VV} & K_{VR} \\ K_{RV} & K_{RR} \end{bmatrix} \begin{Bmatrix} U_V \\ U_R \end{Bmatrix} \quad (3)$$

where subscript V represents vertical plus vehicle coordinates and subscript R represents rotational coordinates.

$$\{F_V\} = [K_{VV}] \{U_V\} + [K_{VR}] \{U_R\} \quad (4)$$

$$\{F_R\} = [K_{RV}] \{U_V\} + [K_{RR}] \{U_R\} \quad (5)$$

From equation five we can solve for $\{U_R\}$

$$\{U_R\} = [K_{RR}]^{-1} \{F_R\} - K_{RV} \{U_V\} \quad (6)$$

Substituting in four, equation six and simplifying we have:

$$\{F_V\} - [K_{RR}]^{-1} \{F_R\} = [[K_{VV}] - [K_{VR}][K_{RR}]^{-1}[K_{RV}]]\{U_V\} \quad (7)$$

$$[K_V] = [K_{VV}] - [K_{VR}] [K_{RR}]^{-1} [K_{RV}] \quad (8)$$

$$\{F_V\}_{Red} = \{F_V\} - [K_{RR}]^{-1} \{F_R\} \quad (9)$$

The reduced stiffness matrix (8) and the load vector (9) are used in the step by step dynamic analysis. Formula six is used to compute the rotational displacement at each step to be able to compute the flexural moment and stresses at each element.

3.c Vehicle Representation

The vehicle representation is done by assuming a rigid body supported in n axles or gears. Each axle or gear can have two pavement contact points or tires. There are three coordinates of motion at the rigid body, two vertical coordinates at each axle or gear and two vertical coordinates at the contact points between the tires and the pavement. A graphical representation of the vehicle is shown in Figure 2 and the corresponding stiffness matrix is included in Appendix A.

The percent of mass concentrated at the main body is given as input and the center of gravity of the vehicle mass is computed by statics using the magnitude of the axle or gear loads.

3.d General Dynamic Formulation

The general dynamic formulation is given by the following equations:

$$[M_V] \{\ddot{Y}_V\} + [K_V] \{Y_V\} + [K_T] \{\{Y_V\} - \{Y_O\}\} = \{F_V\} \quad (10)$$

$$[M_V] \{\ddot{Y}_V\} + [[K_V] + [K_T]] \{Y_V\} = \{F_V\} + [K_T] \{Y_O\} \quad (11)$$

In this equation $[M_V]$ corresponds to the mass matrix, $[K_V]$ to the global reduced stiffness matrix, $[K_T]$ to the vehicle stiffness matrix, $\{F_V\}$ to the reduce force vector, $\{\ddot{Y}_V\}$ to the displacement acceleration, $\{Y_O\}$ to the roughness vector and $\{Y_V\}$ to the vertical displacement vector for pavement and vehicle coordinates.

The force vector is reduced in two components; the static initial force due to temperature and pavement slab weight and the

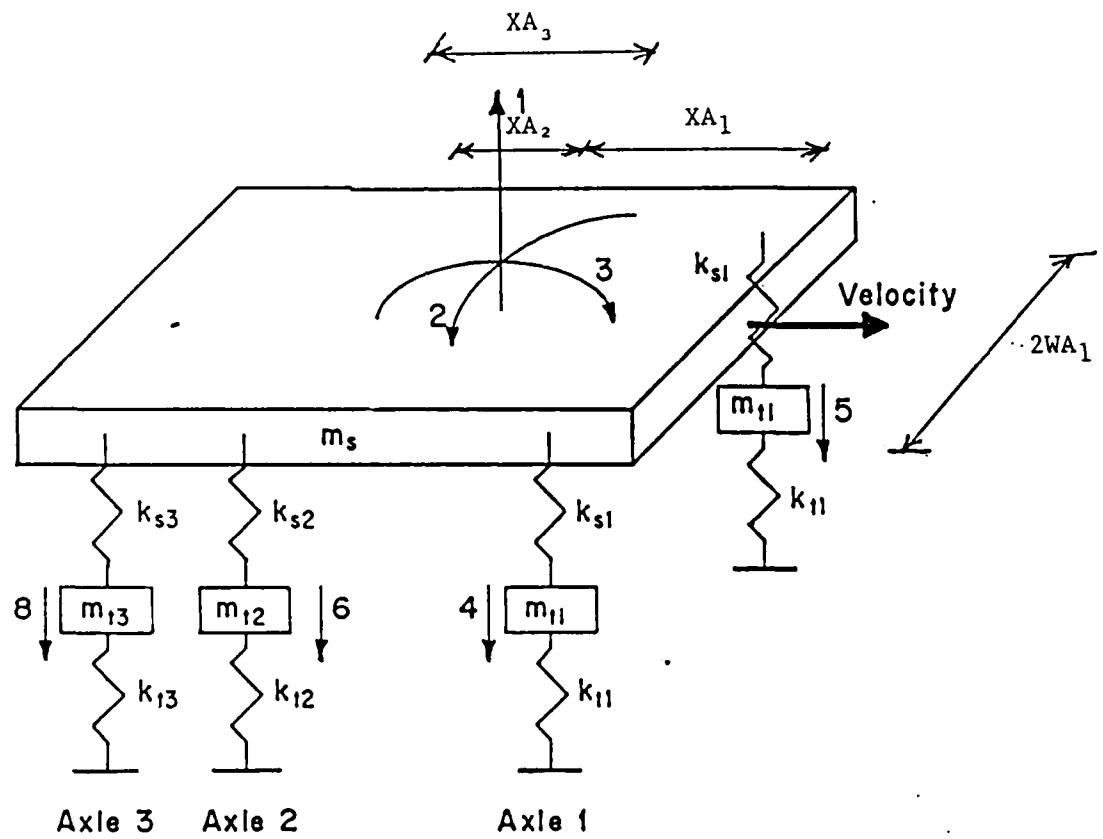


Figure 2 - Vehicle Representation.

dynamic force induced by the vehicle as it moves along the pavement.

At each step the location of each axle or gear contact point is determined. The vehicle stiffness matrix and the vehicle forces are added to the total pavement stiffness matrix and total force vectors at the coordinates in which the axles or gears are in contact. In most of the cases the axle or gear tire location does not coincide exactly with the coordinate location, thus a linear interpolation is made between the four corresponding coordinates. (See Figure 3).

3.e Numerical Integration

At each interval the dynamic equation given in section 3.d is solved using lumped-impulse numerical integration. First, the acceleration is computed with the displacement of the previous step using the dynamic equation that follows:

$$\{\ddot{Y}_V\}(s) = \{F_V\}(s) + [K_T] [Y_O] - \{[K_V] + [K_T](s)\}(Y_V)^s \begin{bmatrix} 1/M_1 & 0 & 0 & 0\dots \\ 0 & 1/M_2 & 0 & 0\dots \\ 0 & 0 & 1/m_3 & 0\dots \end{bmatrix} \quad (12)$$

The displacements for the following steps are then computed using the following recurrence formula.

$$\{Y_V\}(s+1) = 2\{Y_V\}(s) - \{Y_V\}(s-1) + \{\ddot{Y}_V\}(s) (\Delta t)^2 \quad (13)$$

For the first step a special procedure is required.

The acceleration is assumed to vary linearly up to the first step and the displacements are given by the following formulas:

$$\{Y\}(1) = 1/6 \{\ddot{Y}\}(1) (\Delta t)^2 \quad (14)$$

$$\text{or } \{\ddot{Y}\}(1) = 6/\Delta t^2 \{Y\}(1) \quad (15)$$

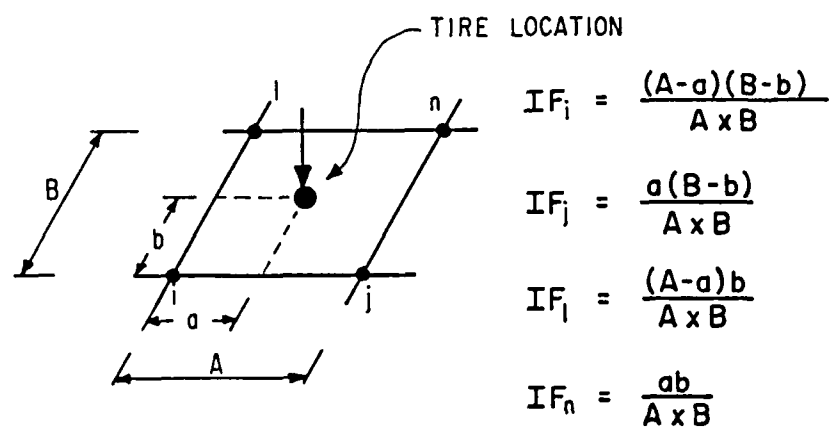


Figure 3 - Interpolation Factor for Axle Contribution.

If the expression for the acceleration is substituted in the general dynamic equation (11), then it can be solved directly for the first step displacement. After obtaining the first step displacement, the first step acceleration is obtained and the normal numerical integration procedure is performed in the subsequent steps.

3.f Vehicle Approach

Two vehicle approaches have been implemented. The first corresponds to the case in which the vehicle enters the slab coming from a previous slab.

In this case, three hundred steps of the vehicle moving over a rigid pavement at the input velocity and corresponding time interval are analysed prior to the vehicle entering the pavement. The vehicle acceleration and displacement coordinates at the end of the approach procedure are the initial conditions for the step by step dynamic analysis.

The second approach corresponds to the case in which the front vehicle axle makes a sudden contact with the pavement at a given distance from the starting edge. In this case, the initial condition is the sudden application of all the axles or gear loads within the pavement.

3.g Concrete Behavior (Crack Development Procedure and Stiffness Variation)

The general concrete stiffness matrix for the plate flexure formula is defined as recommended by Darwin and Pecknold:

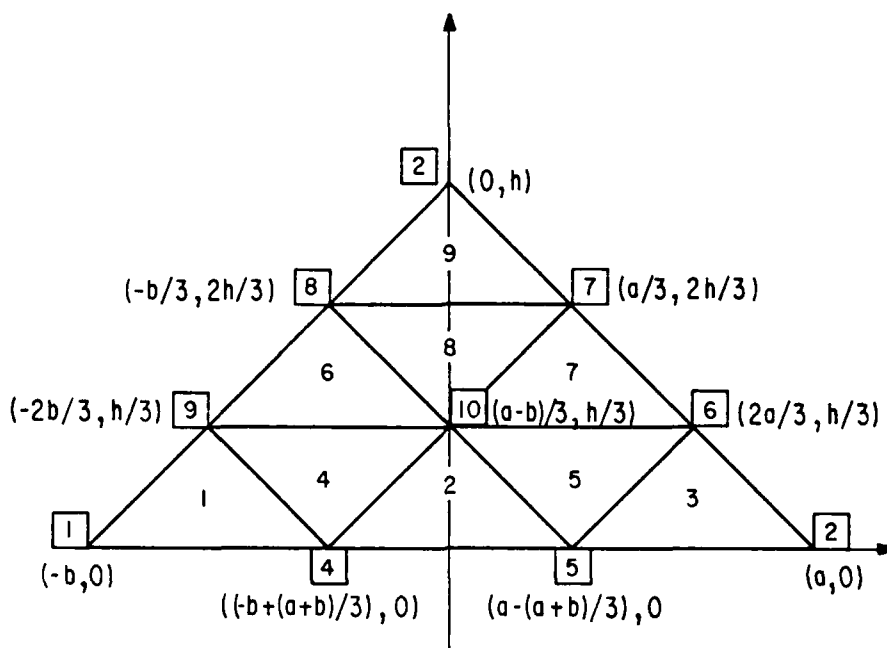
$$[D] = \frac{1}{1 - \nu^2} \begin{bmatrix} E_1 & \nu \sqrt{E_1 E_2} & 0 \\ \nu \sqrt{E_1 E_2} & E_2 & 0 \\ 0 & 0 & 1/4(E_1 + E_2 - 2\nu \sqrt{E_1 E_2}) \end{bmatrix} \quad (16)$$

The behavior of the concrete in tension and compression up to cracking is considered essentially linear and the uncracked rigidity matrix is given by:

$$[D] = \frac{1}{1 - \nu^2} \begin{bmatrix} E_T & \nu E_T & 0 \\ \nu E_T & E_T & 0 \\ 0 & 0 & \frac{(1-\nu)}{2} E_T \end{bmatrix} \quad (17)$$

In order to determine and consider the crack formation, the principal stresses were computed for each step in nine locations within each triangular element as shown in Figure 4. A crack index was stored and updated at each step for each of the nine points of each element depending of the stress conditions at the given point. A vector with the direction of the crack with respect to local axis is also stored and modified at each step for each point within each element. At each of the nine points within an element the material rigidity matrix is modified to consider the formation of cracks in a given direction or in both directions.

If a crack is active at a given interval in a given direction the modulus of elasticity in that direction is set to zero and the rigidity matrix is rotated to the local element



TRIANGLE	COORDINATES IN X	COORDINATES IN Y
1	$1/9(a-7b)$	$1/9h$
2	$4/9(a-b)$	$1/9h$
3	$1/9(7a-b)$	$1/9h$
4	$1/9(2a-5b)$	$2/9h$
5	$1/9(5a-2b)$	$2/9h$
6	$1/9(a-4b)$	$4/9h$
7	$1/9(4a-b)$	$4/9h$
8	$2/9(a-b)$	$5/9h$
9	$1/9(a-b)$	$7/9h$

Figure 4 - Concrete Stress Computation Location.

axis. All rotated rigidity matrices for each point within an element are added and the average for each element is obtained. If a change in crack condition is observed within an element at a given step, the difference between the crack rigidity matrix and the uncracked rigidity matrix is used to compute the reduction in contribution of the given element to the total stiffness matrix.

The element stiffness reductions are subtracted to the original uncracked pavement total stiffness matrix.

When any of the elements change its state of cracking in a given step it is necessary to read from discs the original total uncracked stiffness, modify it with the changes in element stiffness and then condense it.

The procedure used to condense the stiffness matrix consumes a significant amount of computing time and should be further studied to optimize it. Element stiffness matrix condensation against total stiffness matrix condensation should be considered as an alternative.

3.h Soil Nonlinear Behavior

The soil structure interaction procedure is an important factor in the behavior of concrete pavements. In this research project, after analyzing the different models described in the literature search, it was decided to use the dense liquid concept because it facilitates the nonlinear behavior implementation.

The nonlinear soil behavior was included in the implementation for a one layer subbase using the modulus of subgrade reaction as well as the resilient modulus relationship given by:

$$E_t = K_1 \sigma^K \quad (18)$$

where:

- E_t = tangent modulus of subgrade reaction, psi
- K_1 = soil constant which varies from 3,000 to 3,000 psi
- K_2 = soil constant which varies from 0.5 to 0.7
- σ = sum of principal stresses or stress invariant, psi

Typical values of K_1 and K_2 for unbound base and subbase materials for different moisture conditions are shown in Table 1.

TABLE 1
TYPICAL VALUES FOR K_1 AND K_2 FOR UNBOUND
BASE AND SUBBASE MATERIALS [1]

(a) Base		
Moisture Condition	K_1^*	K_2^*
Dry	6,000 - 10,000	0.5 - 0.7
Damp	4,000 - 6,000	0.5 - 0.7
Wet	2,000 - 4,000	0.5 - 0.7
(b) Subbase		
Dry	6,000 - 8,000	0.4 - 0.6
Damp	4,000 - 6,000	0.4 - 0.6
Wet	1,500 - 4,000	0.4 - 0.6

* Ranges in K_1 and K_2 are a function of the material quality.

As shown in Figure 5, the stresses for step $n + 1$ are obtained at under each joint at the user's specified layer depth (h). The stress computations are done using the following formulas:

$$\sigma_x^{n+1} = \sum_{L=1}^K R_i C_{xi} \Delta A/A_i \quad (19)$$

$$= \sum_{i=1}^K K_i^n \delta_i^{n+1} C_{xi} \Delta A/A_i$$

$$\sigma_y^{n+1} = \sum_{L=1}^K K_i^n \delta_i^{n+1} C_{yi} \Delta A/A_i \quad (20)$$

$$\sigma_z^{n+1} = \sum_{L=1}^K K_i^n \delta_i^{n+1} C_{zi} \Delta A/A_i \quad (21)$$

where:

- K_i^n = spring constant at step n (i.e. modulus of subgrade reaction multiplied by area A_i)
- δ_i^{n+1} = vertical displacement at step $n + 1$
- A_i = contribution area for joint i (see Figure 5)
- C_{xi}, C_{yi}, C_{zi} = influence coefficient to compute stresses at elevation z using Boussinesq formula
- ΔA = differential area used in the numerical integration to compute the influence coefficient (see Figure 6)
- K = counter which is set to 4 for corner joints, 8 for edge joints, and 16 for middle joints

The contribution on the soil stresses of the equivalent forces at all adjacent points is considered. Four adjacent joints are considered for a corner joint, six for an edge joint and nine for a middle joint.

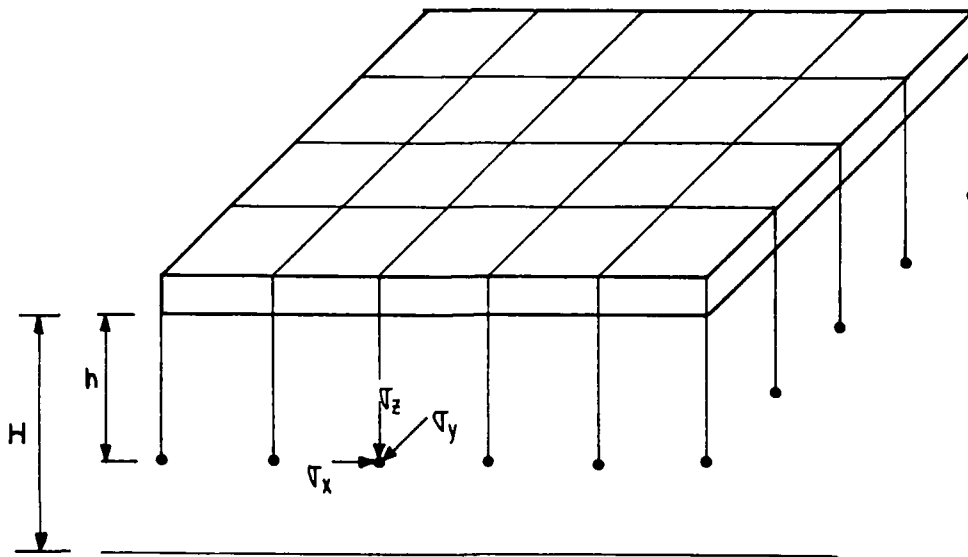


Figure 5 - Soil Element Stress Computation Location.

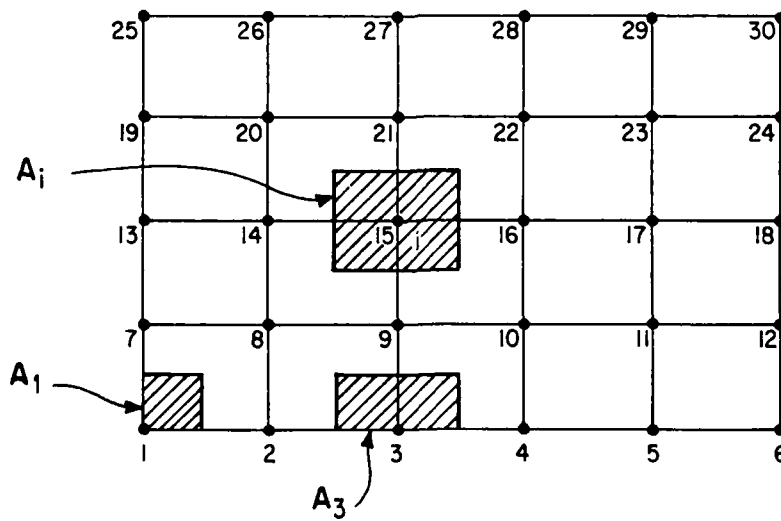


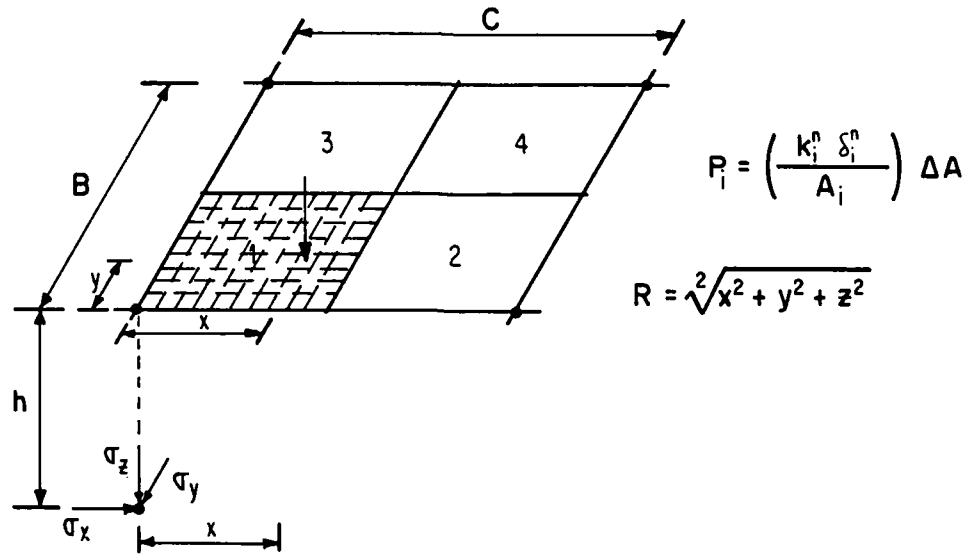
Figure 6 - Joints Contribution Area.

To determine the influence coefficient, Boussinesq equations were used to compute stresses at a given depth due to concentrated forces. To determine a uniform distributed pressure, the equivalent spring forces at each joint for each step were divided by the joint contribution area. This pressure, multiplied by the differential area used in the numerical integration, represented a small equivalent concentrated force at each differential area. (See Figure 7). If at a given step at a given joint a tension force is found, the soil stiffness is assumed to be zero for the next step.

Four independent coefficients were computed for each stress direction. Each coefficient corresponded to the influence of the pressure at four different quadrants. Each quadrant is divided as a 10 by 10 mesh. An integration is carried out to obtain each quadrant coefficient. In Figure 7, the corresponding formulas and geometry are shown.

After the influence coefficients are computed, the stresses are obtained by adding the influence of all the quadrants contributing for a given joint as defined by the formulas 19 to 21. Four quadrants are included for a corner joint, eight quadrants for an edge joint and sixteen for a middle joint.

Once the horizontal and vertical stresses are known, the principal stresses are computed applying the Mohr-Coulomb theory to determine if there had been any failure at the subbase.



$$C_{xk} = \frac{1}{2\pi} \sum_{l=1}^{100} \frac{1}{r^3} \left[(1 - 2\mu) \frac{r^2(h+r) - x^2(h+2r)}{(h+r)^2} - \frac{h(r^2 - 3x^2)}{r^2} + 2\mu h \right]$$

$$C_{yk} = \frac{1}{2\pi} \sum_{l=1}^{100} \frac{1}{r^3} \left[(1 - 2\mu) \frac{r^2(h+r) - y^2(h+2r)}{(h+r)^2} - \frac{h(r^2 - 3y^2)}{r^2} + 2\mu h \right]$$

$$C_{zk} = \frac{3}{2\pi} \sum_{l=1}^{100} \frac{h^3}{r^5}$$

Figure 7 - Influence Coefficient.

The intermediate value of the three principal stresses is identified and used to determine the limited value for minimum and maximum principal stresses using the following formulas:

$$(\sigma_1)_{\max} = \sigma_i \tan^2 (45 + \phi/2) + 2c \tan (45 + \phi/2) \quad (22)$$

$$(\sigma_3)_{\min} = \sigma_i \tan^2 (45 - \phi/2) + 2c \tan (45 - \phi/2) \quad (23)$$

where:

σ_i = principal stress intermediate values, psi

ϕ = angle of friction

c = soil cohesion, psi

Actual principal stresses are compared to minimum and maximum principal stresses and modified as described in the flow chart in Figure 8.

Once the modified principal stress is known the soil invariant, the soil modulus of subgrade reaction and the equivalent spring stiffness are computed.

3.i Pavement Roughness

The pavement roughness parameters are generated at random with a special purpose program. This program generates a file with a two column matrix, one column for each of the two tracks assumed. This random generated matrix is then smoothed out linearly by interpolating fifty intermediate points. A maximum amplitude of a half inch is assumed in the roughness generation routine but the user could modify it by giving another amplitude. The file unit is feet. A typical track roughness generated by this procedure is shown in Figure 9.

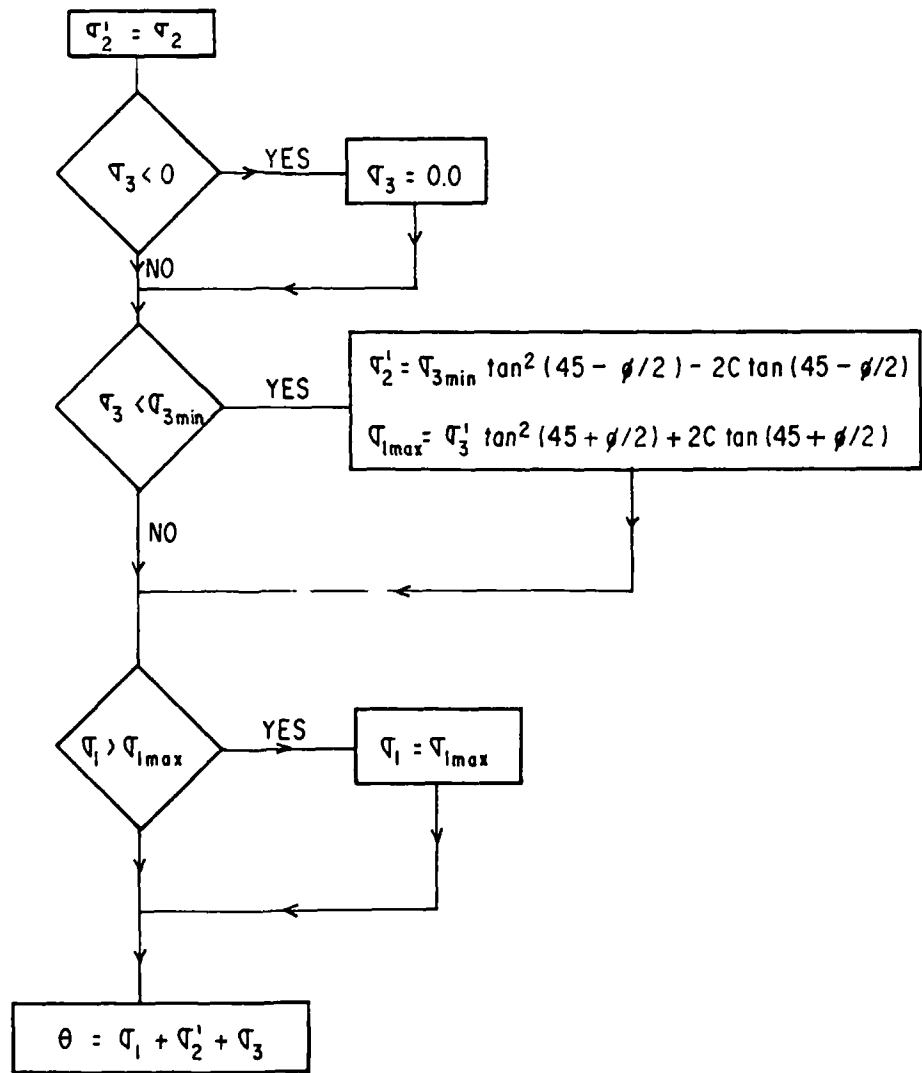
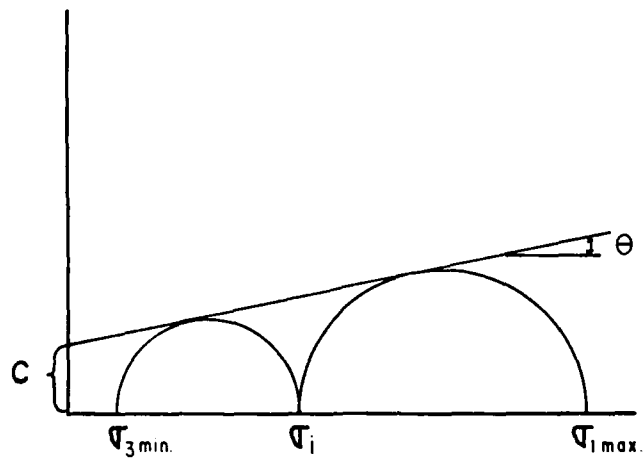


Figure 8 - Soil Failure Check Flow Chart.

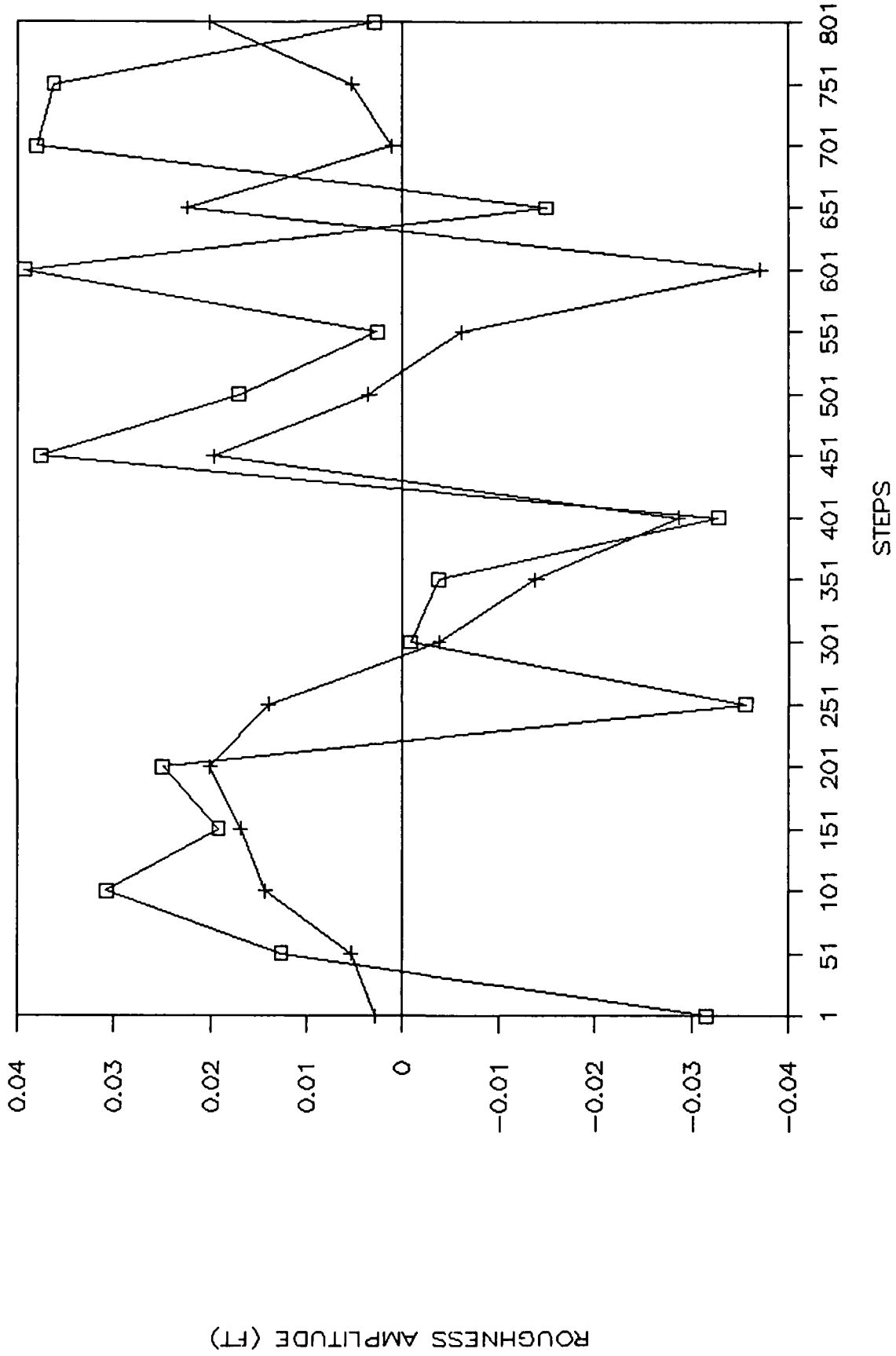


Figure 9. Roughness Amplitude

In the procedure used it is assumed that the distance between each roughness coefficient corresponds to the distance traveled by the vehicle in each step. The relative position of an axle or gear in each track is determined to read the corresponding roughness magnitude. Therefore, different axles and gears will observe the same magnitude of roughness at a given position in the pavement.

The file in which the smoothed-out roughness is stored is named RUG.DAT.

CHAPTER 4

DESCRIPTION OF PROGRAMS

4.a Dynamic Nonlinear Pavement Analysis Program (DYNOPAV)

4.a.1 Description

The main program developed as part of this project is called DYNOPAV. It is the one in which the methodology for nonlinear dynamic analysis of concrete pavements has been implemented. This program consists of seven fortran programs (name.for) linked together. The functions of these programs are described below:

- a. AF1001.FOR - This is the main program. It reads and writes data, forms linear stiffness matrix and solves for temperature and dead load.
- b. AF2001.FOR - Consists of five subroutines that perform general geometry computation.
- c. AF3001.FOR - It is composed of eight subroutines that compute the element stiffness matrix.
- d. AF4001.FOR - This part is composed of six subroutines that assemble and condense the total global stiffness, adds vehicle contribution to the stiffness matrix, assembles the force vector and obtains the static solution.
- e. AF6001.FOR - Consists of nine subroutines that perform computations for moment resultant and stress.
- f. AF7001.FOR - It is the subroutine that performs the procedure of the nonlinear dynamic analysis.
- g. AF8001.FOR - It consists of four subroutines that will perform the concrete and soil nonlinear computations and procedure.

In Figure 10, a general flow chart for the DYNOPAV program is given.

DYNOPAV FLOW CHART

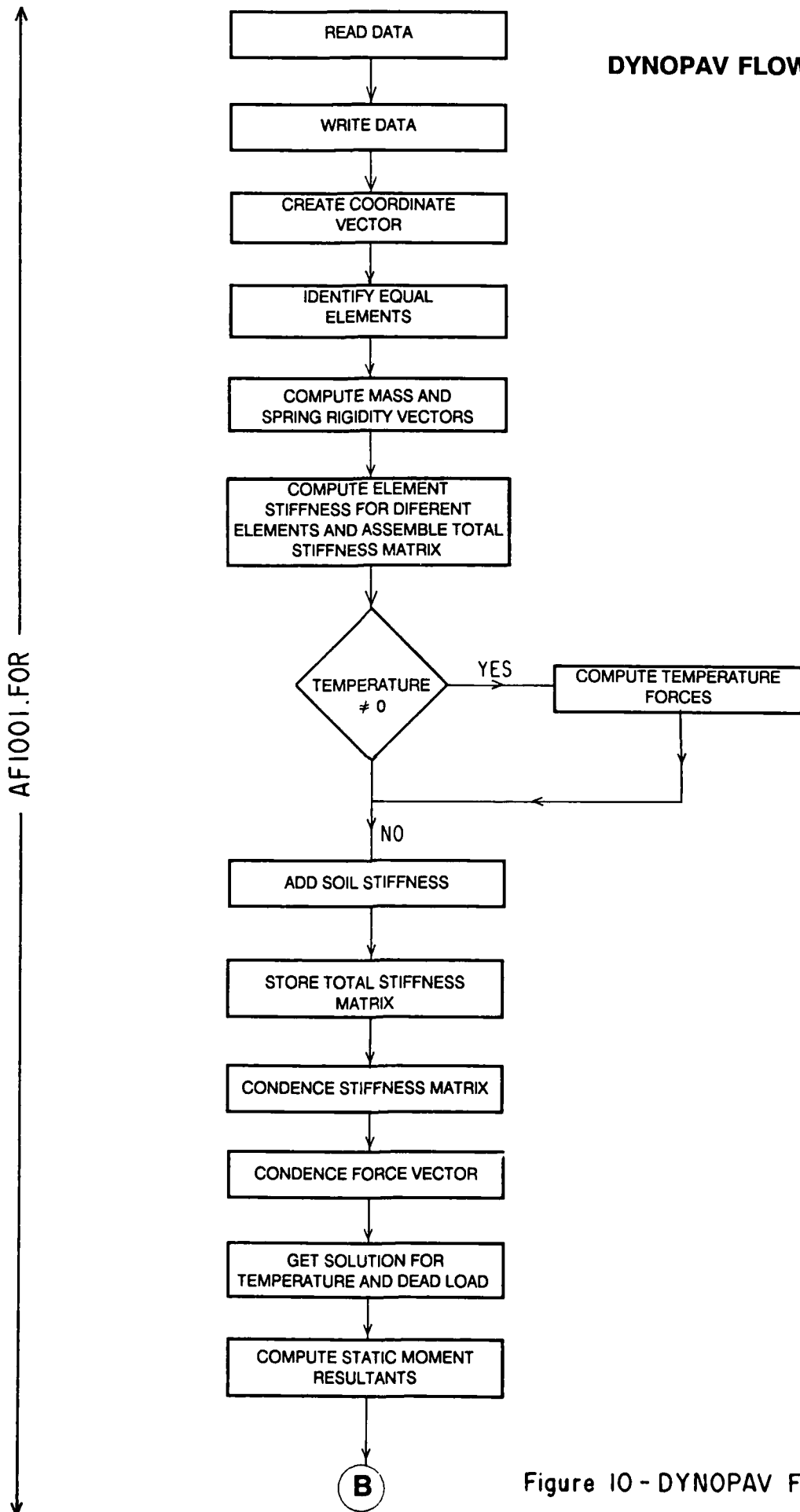
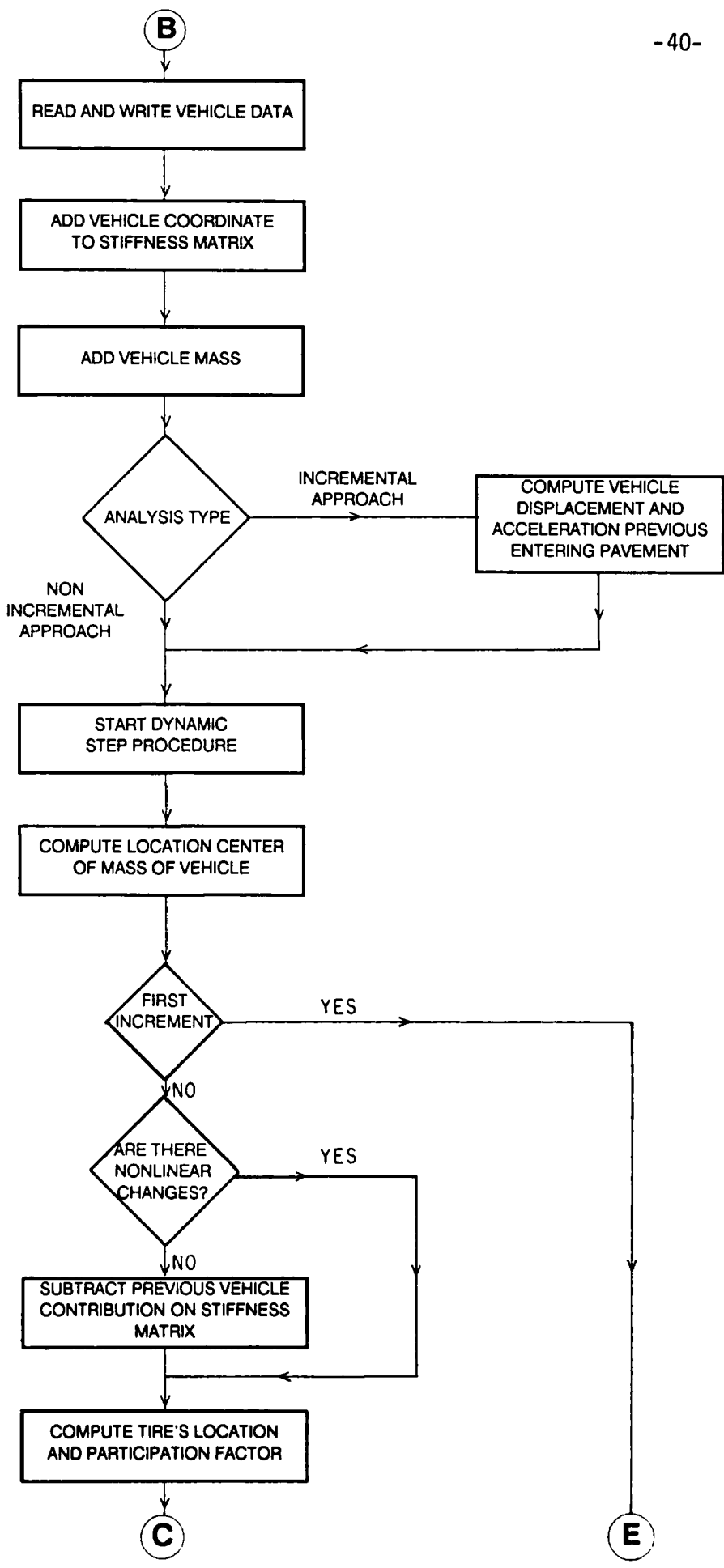
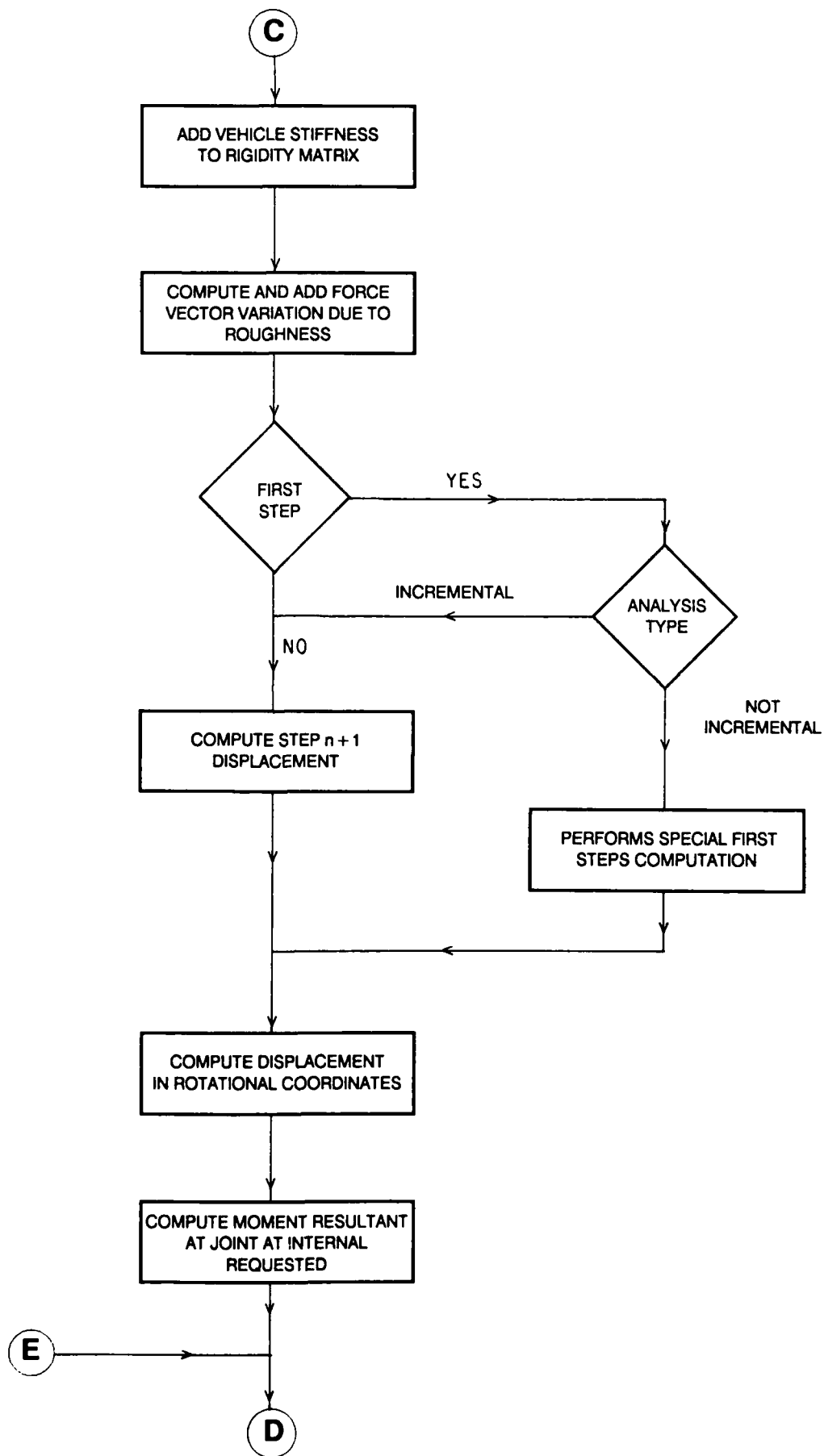
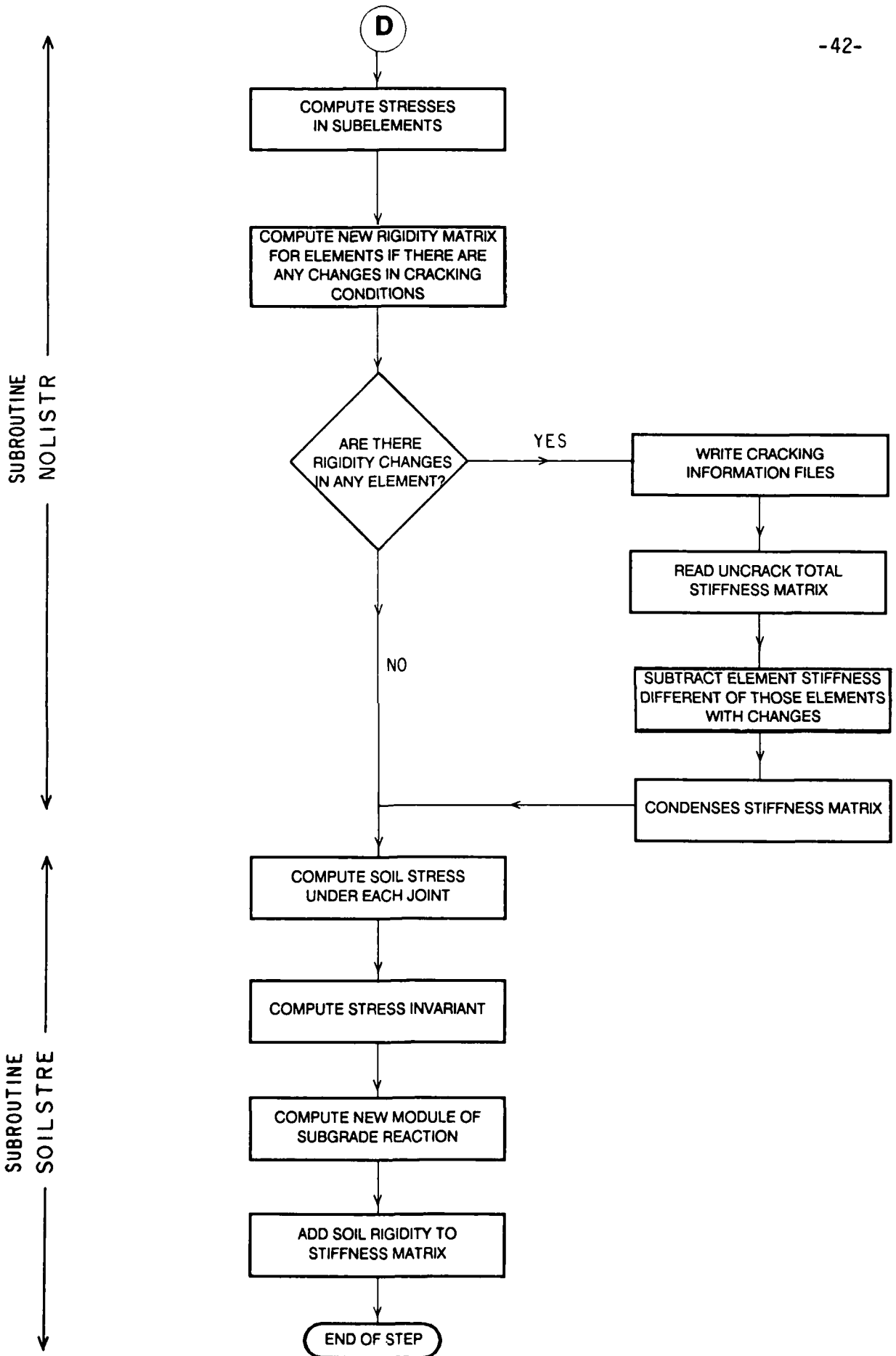


Figure 10 - DYNOPAV Flow Chart.







4.a.2 Input Data

All the necessary ASCII files to perform the nonlinear dynamic analysis can be obtained using the Graphical Input Pavement Program (GRINPAV) described later in this report. It is also possible to prepare the necessary data files using a word processor.

The DYNOPAV program requires four ASCII files. The first file is a general data file with the name of the problem to be solved; the extension .ANA contains the following information in strict order:

- a. Name of the problem - maximum of eight characters
- b. Title of the problem - general description, up to 80 characters
- c. Number of joints, number of elements, and number of axles or gears
- d. Slab thickness, (ft)
- e. Concrete modulus of elasticity (ksf)
- f. Concrete Poisson Ratio
- g. Temperature gradient ($^{\circ}\text{F}$), and concrete thermal expansion coefficient, ($^{\circ}\text{F}$)
- h. Concrete cracking stress, (ksf)
- i. Number of total intervals*, stress output interval, displacement output intervals, soil output interval, sum of soil output intervals
- j. Rotational mass in x ($\text{k} - \text{sec}^2$), rotational mass in y ($\text{k} - \text{sec}^2$), and mass factor
- k. For each axle or gear, the following information is required (see Figure 11): distance of first axle or gear to vehicle centroid (ft), distance between contact points (ft), axle or gear load ** (k), tire stiffness (k/ft), and vehicle stiffness (k/ft)
- l. Time interval for each step (secs), entrance distance in y (ft), and velocity (ft/sec)

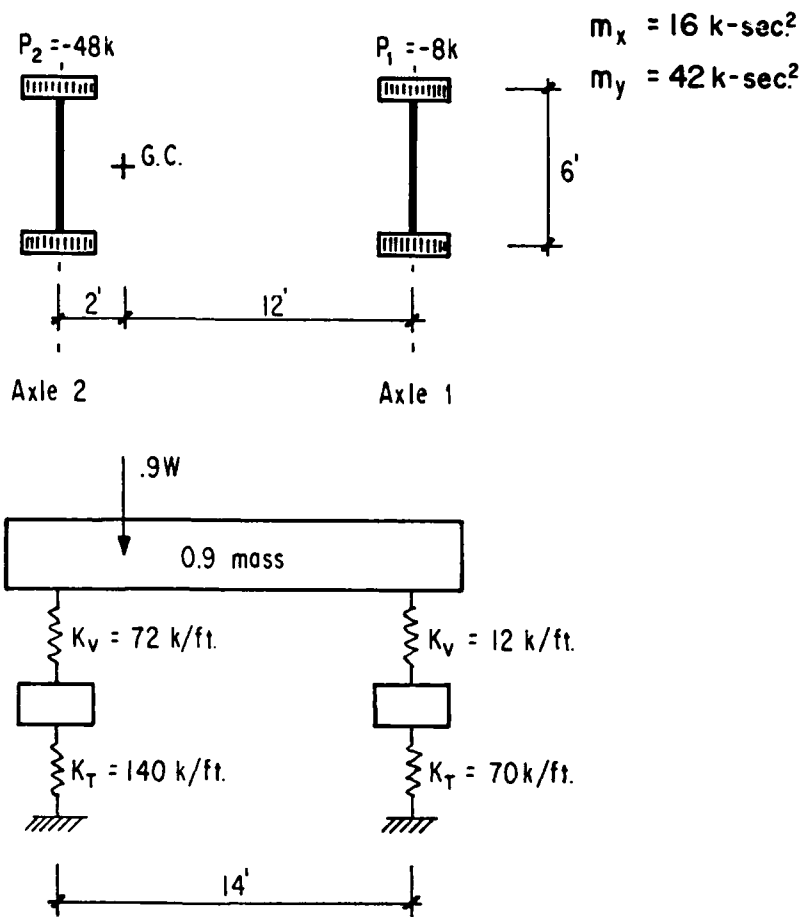


Figure II - Vehicle Parameter Used in Example Problems.

- m. Soil coefficient K_1 , soil coefficient K_2 , soil poisson, depth of subbase (ft), stress computation depth (ft), soil friction angle (degrees), and soil cohesion (ksi).
- n. Analysis type; 3 for sudden and 4 for incremental

Remarks

- * If 0 is given, the program will compute the total number of steps required for the vehicle to cross the total slab length.
- ** Should be negative.

In Table 2 a typical input file is shown. In addition to these files, four additional files are needed. A joint coordinates file that includes the coordinates, in feet, of the joints is required at the beginning and at the end of each row. The program will equally divide the distance between joints automatically. In the transverse direction, the coordinates given at the start and end of each row should also be equally spaced. This requirement was imposed to simplify and reduce the nonlinear dynamic computations. This array should be called problem name.COO. No format is required and the joint number and corresponding x and y coordinates need to be separated by blanks or a comma.

An array called problem name.INC with the triangular element incidences should also be input by the user. The program automatically generates the incidence for elements between the first and last row. No format is required, therefore, the element number as well as the, first, second and last joint numbers should be separated by blanks or comma. Joints should be given in counter-clockwise order.

EXAM1-1
EXAMPLE 1SMOOTH PAVEMENT, VEL=50,K1=4000.,K2=.6,EC=518400.KSF,FC=144KSF
49 72 2 # OF JOINT,# OF ELEM,# OF AXLE
0.100000E+01 PAVEMENT THICKNESS
0.518400E+06 CONCRETE TANGENT MODULUS
0.160000E+00 POISSON RATIO
0.00 0.500000E-04 TEMPERATURE GRADIENT AND EXPANSION COEFFICIENT
0.144000E+03 CONCRETE CRACKING STRESS (K/FT²)
0.000000E+00 ROUGHNESS AMPLITUD
200 1 100 1 100 1 100 1 20 PRINT PARAMETERS
16.0 42.0 0.9
12.0 6.0 -8.0 70.0 12.0
-2.0 6.0 -48.0 140.0 72.0
0.0002 6.0 0.0 50.0
4000.0 0.6 0.3 8.0 6.0 0.0 0.015
4 ANALYSIS TYPE = 3 SUDDEN, = 4 INCREMENTAL

TABLE 2 TYPICAL INPUT FILE

A file with the initial equivalent spring stiffness is needed. The stiffness for each joint is required, but the program will assume that stiffness of the joints omitted in the input are equal to the previous joint stiffness value. The joint and the stiffness values should be separated by blanks or commas. The file should be called Problem Name.SPR.

The file RUG.DAT that contains the roughness vector data should also be present in the disk.

To use the program, RMFORT version of the program name should be typed with the corresponding general data name.

Example: DYNOPAV < Problem Name . DAT

To use Langling FORTRAN version of the program for 386 machines in which problems with more than 75 joints and 110 elements can be solved, the program should be run in the following manner:

UP DYNOPAV < Problem Name.DAT

4.a.3 Output

The DYNOPAV program generates the following output files at the step interval specified in the data.

1. Problem Definition Data
file name = Problem Name.RES
2. Displacement and Acceleration
file name = Problem Name.DIS
3. Displacement and Acceleration due to Temperature and Dead Load
file name = Problem Name.TDI
4. Moment Resultant at Joints for Temperature and Dead Load
file name = Problem Name.TSX

5. Moment Resultant at Joints for Dynamic Analysis
file name = Problem Name.SX1
6. Principal Moment Resultants at Joints or due to
Temperature and Dead Load
file name = Problem Name.TSI
7. Principal Moment Resultant at Joints for Dynamic
Analysis
file name = Problem Name.SP1
8. Soil Reactions
file name = Problem Name.SOI
9. Sum of Soil Reactions
file Name = Problem Name.SSO

In addition, the program generates two files that are used by the graphical crack visualization program (CRACK) or the program PRICRACK that produce a listing of the crack formation sequence. These files are:

1. Problem Name . GEO
2. Problem Name . CRA

The output file could be obtained with a PRINT command, a word processor, SYMPHONY, or any other software since they are written in ASCII.

4.b Graphical Input for Pavement Program (GRINPAV)

4.b.1 Description

The GRINPAV program is a user friendly computer program that consists of graphical menus and tables designed to provide the interface information required to execute DYNOPAV program. The program was developed using the graphical tools developed by Pesquera [18]. In appendix B, information about drivers needs and configuration file requirements are given. In Figure 12, a general flowchart of the GRINPAV program is presented.

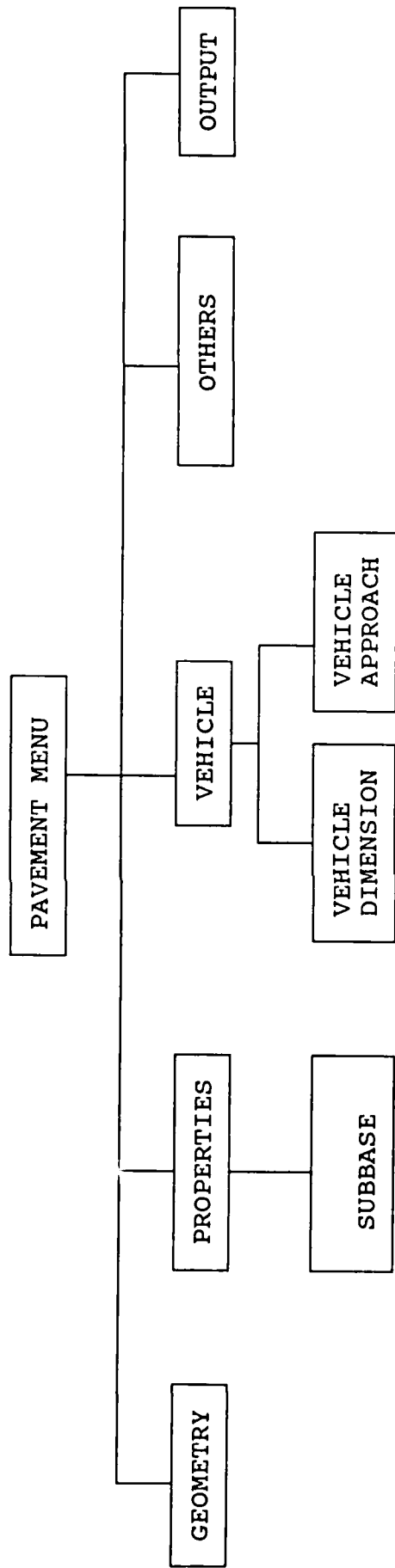


Figure 12. Flowchart Illustrating GRINPAV Screens

Essentially the program consists of the following major screens:

- a. Pavement Menu
- b. Geometry Menu
- c. Properties Menu
- d. Vehicle Menu
- e. Others Menu
- f. Output Menu

4.b.2 Input Data

The input data process is performed through the menus that are listed in Figure 12. A description of the main features of each screen is discussed below.

Pavement Menu: PAVEMENT Menu is the opening screen of GRINPAV (see Figure 13). It provides access to the other input data screens, namely, GEOMETRY, PROPERTIES, VEHICLE, OTHERS, and OUTPUT. To create a new file the option NEW is used. Existing data files can be retrieved using the READ option. The SAVE option creates a file named **Problem Name.dat** which contains all the raw data generated during the current working session.

The **ANALYSIS** option generates the following four files required for the execution of the dynamic non-linear analysis program (DYNOPAV):

- ♦ problem name.ANA
- ♦ problem name.COR
- ♦ problem name.INC
- ♦ problem name.SPR.

To finish the working session the EXIT option is selected.

Geometry Menu: The GEOMETRY menu shown in Figure 14 is used to provide the geometric characteristics of the pavement slab being considered, namely slab width, slab length, thickness, finite

Screen 1. Pavement Menu

	PAVEMENT MENU
	GEOMETRY
	PROPERTIES
	VEHICLE
	OTHERS
	OUTPUT
	NEW
	READ
	SAVE
	ANALYSIS
	EXIT

Figure 13. Pavement Menu

Screen 2. Geometry Menu

	GEOMETRY MENU
	SLAB WIDTH
	SLAB LENGTH
	SLAB THICK
	SUBDIV-LONGIT
	SUBDIV-TRANS
	RETURN

Figure 14. Geometry Menu

element mesh subdivision in the longitudinal and transverse direction. The default values for slab width and length are 12 feet and 20 feet, respectively. The default value for slab thickness is 1 ft, while the mesh subdivisions are 12 and 8 feet in the longitudinal and transverse direction, respectively.

Once this information is input, the user can return to the opening menu by selecting the RETURN option.

Properties Menu: This menu is used to input the information regarding the materials properties associated with the rigid pavement slab and granular subbase (see Figure 15). Surface roughness information is also provided in this screen.

The material properties input for rigid pavements include the compressive strength of the concrete @ 28 days (f'_c), the poisson ratio (μ) as well as the cracking stress. The default values for f'_c and poisson ratio are 4 ksi and 0.2, respectively. The cracking stress is set at 0.474 ksi.

Other options included in the properties menu are the **FRICITION ANGLE** and **SOIL COHESION**. These parameters are used to determine the principal stresses based on the Mohr-Coulomb failure theory. The default values for the angle of friction is 20° and the corresponding soil cohesion is .015 ksi.

The **ROUGHNESS** option is included in this menu and corresponds to the amplitude in inches perceived by the vehicle while crossing the slab. The default value for roughness is 0.50 inches.

Screen 3. Properties Menu

	PROPERTIES MENU
	FC
	CRACKING STR.
	POISSON RATIO
	FRICTION ANGLE
	SOIL COHESION
	ROUGHNESS
	SUBBASE
	RETURN

Figure 15. Properties Menu

When the SUBBASE option is selected, another menu is displayed on the screen (see Figure 16). The DEPTH option corresponds to the subbase thickness in feet. The STRESS DEPTH option is the depth at which the stress analysis is performed within the subbase layer. The stress depth shall always be less than the subbase thickness (i.e. depth). The corresponding default values are 5 and 3 feet. The MOD. SUBGRADE option corresponds to the modulus of subgrade reaction based on the dense liquid concept expressed in lbs./in³. The default value of k is 300 psi.

The options CONSTANT K₁ and K₂ correspond to the coefficients required to determine the subbase resilient modulus. Guidelines for K₁ and K₂ were previously presented in Table 1 and default values are 4,000 and 0.6, respectively.

The option SOIL POISSON corresponds to the subbase poisson ratio and the default value is 0.35. The RETURN option is used to return to the PROPERTIES menu.

Vehicle Menu: This screen is used to input the characteristics of the vehicle used in the analysis (see Figure 17). A vehicle can consist of either an aircraft or a truck. The option NUMBER OF AXLE, as defined herein, is the number of transverse axles with paired wheels or point of contacts which will be used to define the wheel configuration. The term axle is not necessarily associated with a truck. In Figure 18, the wheel configuration of a particular vehicle is shown as well as the computation of the number of axles. In this example, the number of axles with

Screen 6. Subbase Menu

	SUBBASE MENU
	DEPTH
	STRESS DEPTH
	MOD-SUBGRADE
	CONSTANT K1
	CONSTANT K2
	SOIL POISSON
	RETURN

Figure 16. Subbase Submenu

Screen 4. Vehicle Menu

	VEHICLE MENU
	NUMBER OF AXLE
	ROT. MASS X
	ROT. MASS Y
	VEHI-DIMENSION
	WHEEL LOAD
	WHEEL STIFFNESS
	TIRE STIFFNESS
	VEHI-APPROACH
	MASS FACTOR
	RETURN

Figure 17. Vehicle Menu

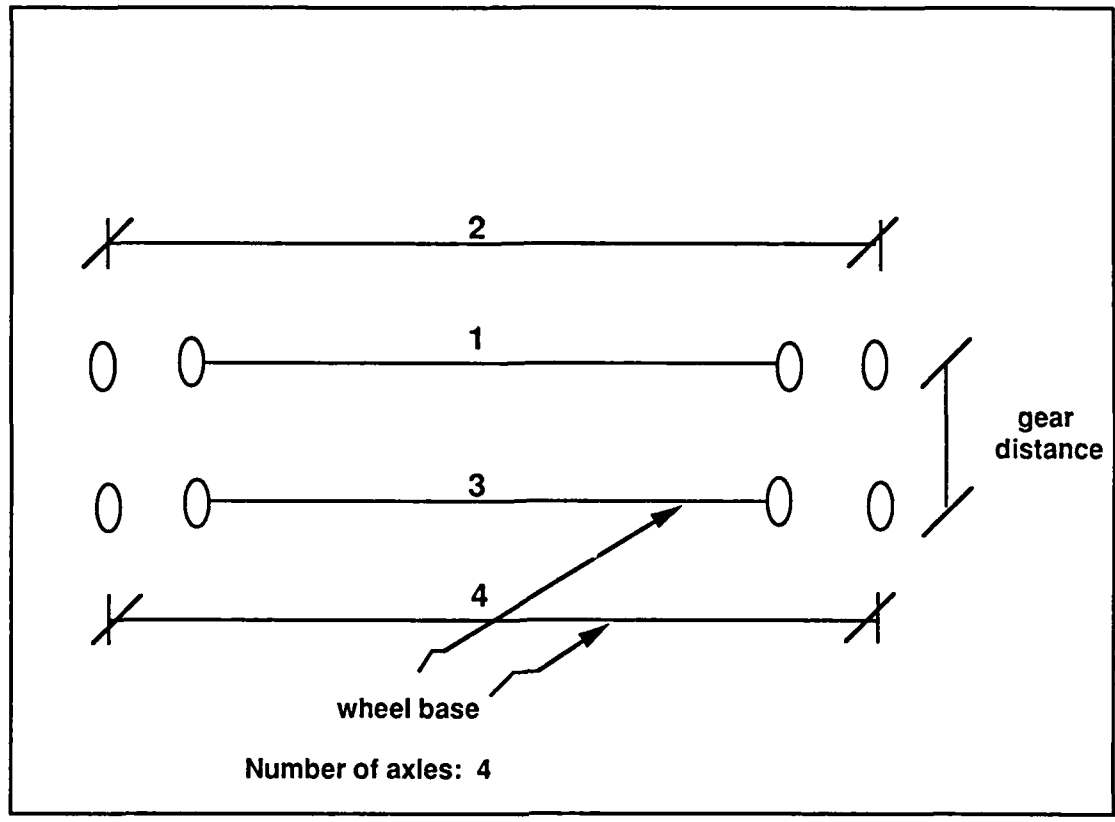


Figure 18. Vehicle Wheel Configuration Nomenclature And Sample Computation Of Number Of Axles For Paired Wheels.

two wheels is 4. It can be observed that axles 1 and 2 are on the same transverse location whereas axles 3 and 4 are located at a gear distance that must be specified. If the user wants to specify more than two contact points per axle, it can define two axles in the same relative location. The default value for number of axles is 2.

The options for **ROT. MASS X** and **ROT. MASS Y** correspond to the rotational mass in the x and y direction for the analysis vehicle. The input values shall be in terms of k-sec². The default values for rotational mass in x and y are 16 and 42 k-sec², respectively.

When the **VEHI-DIMENSION** option is selected, a new menu is displayed as shown in Figure 19. Two entries are required for each option. The **WHEEL BASE** option corresponds to the wheel spacing within an axle or gear. The default value is 6 feet. The **GEAR DISTANCE** option corresponds to the spacing between axles or the longitudinal spacing between wheels in a twin-tandem arrangement. The default value for the distance between axle one and two is 14 feet and is representative of the spacing between axles in a truck. The **RETURN** option is used to return to the **VEHICLE** menu.

The **WHEEL LOAD** option corresponds to the weight of individual wheels in an axle or gear in kips. One entry is required for each axle. The default values for two axles are 8 and 48 kips, respectively.

Screen 7. Vehi-Dimension

	VEHI-DIMENSION
	WHEEL BASE
	GEAR DISTANCE
	RETURN

Figure 19. Vehi-Dimension Submenu

The **WHEEL STIFFNESS** option corresponds to the stiffness of the wheels in a particular axle expressed in kips/feet. The default values for two axles are 12 and 72 kips/ft.

The **TIRE STIFFNESS** option is also presented in terms of kip/feet. The default values for two axles are 70 and 140 kips/ft, respectively. In Figure 11 a vehicle representation is shown in which the vehicle wheel stiffness (K_V) and the tire stiffness (K_T) are represented by springs.

If the **VEHI-APPROACH** option is selected, a submenu is displayed on the screen for the selection of one of the two options (see Figure 20). The first option, termed **INCREMENTAL**, applies when a vehicle enters the slab coming from a previous slab. In this case the vehicle is gradually approaching the slab to be analyzed. The input information required for this condition corresponds to the distance from the pavement edge at which the vehicle will enter the slab. The **SUDDEN** option corresponds to the condition when the vehicle makes a sudden contact with the pavement at a given distance from the transverse joint. The input information required for this condition are the x and y coordinates that define the location where the first axle or gear of the vehicle will make a sudden impact.

The **VELOCITY** option corresponds to the speed in ft/sec that the vehicle is moving through the slab for determining the stresses. The default value is 50 ft/sec. The **RETURN** option is used to return to the **VEHICLE** menu.

Screen 8. Vehi-Approach

	VEHI-APPROACH
	INCREMENTAL
	SUDDEN
	VELOCITY
	RETURN

Figure 20. Vehicle Approach Submenu

The last option in the VEHICLE Menu named **MASS FACTOR** corresponds to a factor that determines the percent of mass that will be assigned to the main body of the vehicle. The rest of the mass will be assigned to the tire level in proportion to the axle load. The default value is 0.9.

The **RETURN** option is used to return to the **PAVEMENT** menu.

Others Menu: The **OTHERS** menu shown in Figure 21 was developed to input information regarding temperature effect on the slab. The gradients between the top and bottom of the slab (i.e **TEMP-GRADIENT** option) as well the coefficient of thermal expansion (i.e **TEMP-COEFFICIENT** option) can be input with this option. The default values for temperature gradient is 0°F and 5×10^{-5} in/in/°F for the coefficient of thermal volume change for concrete.

The **TIME INCREMENT** option is used to specify the time increment of each step of the dynamic numerical integration. The default value is 0.2×10^{-3} . The **TOTAL # INCREMENT** option specifies the total number of increments for printing the dynamic numerical integration. If the value of zero is specified, the program computes the length of the slab and vehicle and prints the displacement and acceleration, moment resultant, soil reactions and sum of soil reactions for the entire slab. The **RETURN** option returns the user to the opening **PAVEMENT** menu.

Screen 5. Others Menu

	OTHERS
	TEMP-GRADIENT
	TEMP-COEFFICIENT
	TIME INCREMENT
	TOTAL # INCREM
	RETURN

Figure 21. Others Menu

Output Menu: The OUTPUT menu shown in Figure 22 provides the user with four types of data, namely, displacement and acceleration, moment resultant, soil reaction, and summation of soil reactions. The user can specify the interval at which the computations will be printed. The default value for displacement and acceleration computations, moment resultant and soil reactions is 100. For the summation of the soil reactions, the default value is set to 10. The RETURN option is used to return to PAVEMENT menu.

4.b.3 Output

The output of program GRINPAV are the four files generated by the ANALYSIS option and the Problem Name.dat generated by the SAVE option. These files contain input data required for the execution of DYNOPAV program and are described in detail in section 4.a.2.

Screen 9. Output Menu

	OUTPUT MENU
	DISPL.AND.ACCE
	MOMENT RESUL.
	SOIL REACTION
	SUM SOIL REAC
	RETURN

Figure 22. Output Menu

4.C Crack Visualization Program (DRACRACK)

4.C.1. Description

DRACRACK is a special purpose program that provides a graphical illustration of the concrete cracking as a vehicle moves over the pavement. The illustration on the video display terminal shows the boundaries of the pavement, the vehicle tires as they move across the pavement, and the cracks formed as a result.

4.C.2. Input

The DRACRACK program requires three files as input. Two of these are generated by the program DYNOPAV. The third one must be created by the user.

The files created by DYNOPAV are the following:

Problem Name.GEO -- file that contains information about the pavement geometry, element, and vehicle information.

Problem Name.CRA -- file that contains information about the time interval, location, and orientation of the cracks.

The additional general data file to be created by the user should contain the following information:

1) Problem Name -- eight characters or less without extension

2) TOP or BOT to identify the surface for which cracks will be drawn

3) Length of crack in millimeters

4) Drawing Spread Parameter -- an integer number from one to ten thousand; the lower the number, the lower the velocity.

To run the program the following command must be entered:

DRACRACK < General Data File

4.C.3 Output

The program will draw on the computer screen the pavement, the track of the vehicle tires across the pavement, and the cracks as they form.

4.d Program to Print Crack Formation Output (PRICRACK)

4.d.1 Description

The program that prints crack formation output is a special purpose program designed to produce an easy to understand output of the crack formation sequence.

This program uses row data from the same files used by the DRACRACK program and generated by the DYNOPAV program. It then creates an easy to interpret file with the sequence of the generated cracks.

4.d.2 Input

The PRICRACK program requires three files to operate. Two of these are generated by the program DYNOPAV. The third one is to be created by the user.

The files created by DYNOPAV are the same ones used by the program DRACRACK for the visualization of the crack formation (Problem Name .GEO, Problem Name .CRA).

The additional file needed contains only the name of the problem and can have any user selected name.

To run the program the following command must be typed:

```
PRICRACK < General Data File Name > File Name to Store Output
```

4.d.3 Output

The PRICRACK program generates a file with the number of steps that a crack change generates, the element affected, the

location of the crack and the angle of the crack axis with respect to the global coordinates.

For each subelement within an element, information for the top and bottom surface is given describing the crack formed along axis one or two or along both axes.

CHAPTER 5
PAVEMENT BEHAVIOR

A number of problems have been analyzed using the program DYNOPAV in order to study the behavior of concrete pavement under the effect of a moving vehicle.

Different parameters were modified one at a time to determine the influence in the behavior and at the same time trying to verify the correctness of the analytical procedure developed. There are currently no other analytical tools that could be used to compare results, therefore, the theory developed has been evaluated from the point of view of how logic the results look based on previous knowledge. Also, during the problem solving procedure, parameters such as the time interval had been modified to observe how consistent are the solutions and to determine the convergence of solutions.

The same slab geometry had been used for all the problems studied as well as the same vehicle characteristics. A 12 by 20 feet slab with a thickness of one foot was used. The slab was subdivided in a 6 x 6 mesh with a total of 72 triangular elements and 49 joints. The vehicle parameters used as input in the scenarios analyzed are summarized in Figure 11.

For the subbase, a depth of eight feet (8'-0") and a stress computation elevation of six feet (6'-0") were used in all examples.

A summary of the parameters of the different scenarios analyzed is presented in Table 3. As can be observed from this table, a total of thirteen analyses were performed, with

Table 3: Scenarios Analyze

PROBLEM NAME	VEHICLE VELOCITY (ft/sec)	ROUGHNESS AMPLITUDE (in)	TIME INTERVAL (sec)	SOIL COEFFICIENT K1	SOIL COEFFICIENT K2	FRACTURE ANGLE	SOIL COHESION COEFFICIENT (ksi)	CONCRETE CRACK STRESS (k/ft)
EXAMPLE 1	50.00	0.00	0.0002	4000.00	0.60	0.00	0.015	1000.00
EXAMPLE 2	100.00	0.00	0.0002	4000.00	0.60	0.00	0.015	1000.00
EXAMPLE 3	100.00	0.00	0.0001	4000.00	0.60	0.00	0.015	1000.00
EXAMPLE 4	50.00	0.00	0.0002	6000.00	0.70	0.00	0.015	1000.00
EXAMPLE 5	50.00	0.25	0.0002	4000.00	0.60	0.00	0.015	1000.00
EXAMPLE 6	50.00	0.50	0.0002	4000.00	0.60	0.00	0.015	1000.00
EXAMPLE 7	50.00	0.00	0.0002	5000.00	0.50	40.00	0.00	56.10
EXAMPLE 7B	50.00	0.00	0.0002	5000.00	0.50	30.00	0.00	45.00
EXAMPLE 7G	50.00	0.00	0.0002	5000.00	0.50	20.00	0.00	45.00
EXAMPLE 7H	50.00	0.00	0.0002	5000.00	0.50	40.00	0.00	45.00
EXAMPLE 8	50.00	0.25	0.0002	4000.00	0.60	40.00	0.00	45.00
EXAMPLE 9	100.00	0.00	0.0001	4000.00	0.60	40.00	0.00	45.00
EXAMPLE 9A	100.00	0.00	0.0001	4000.00	0.60	40.00	0.00	30.00

variation in vehicle velocity, roughness amplitude, time interval, soil coefficients and concrete crack stresses.

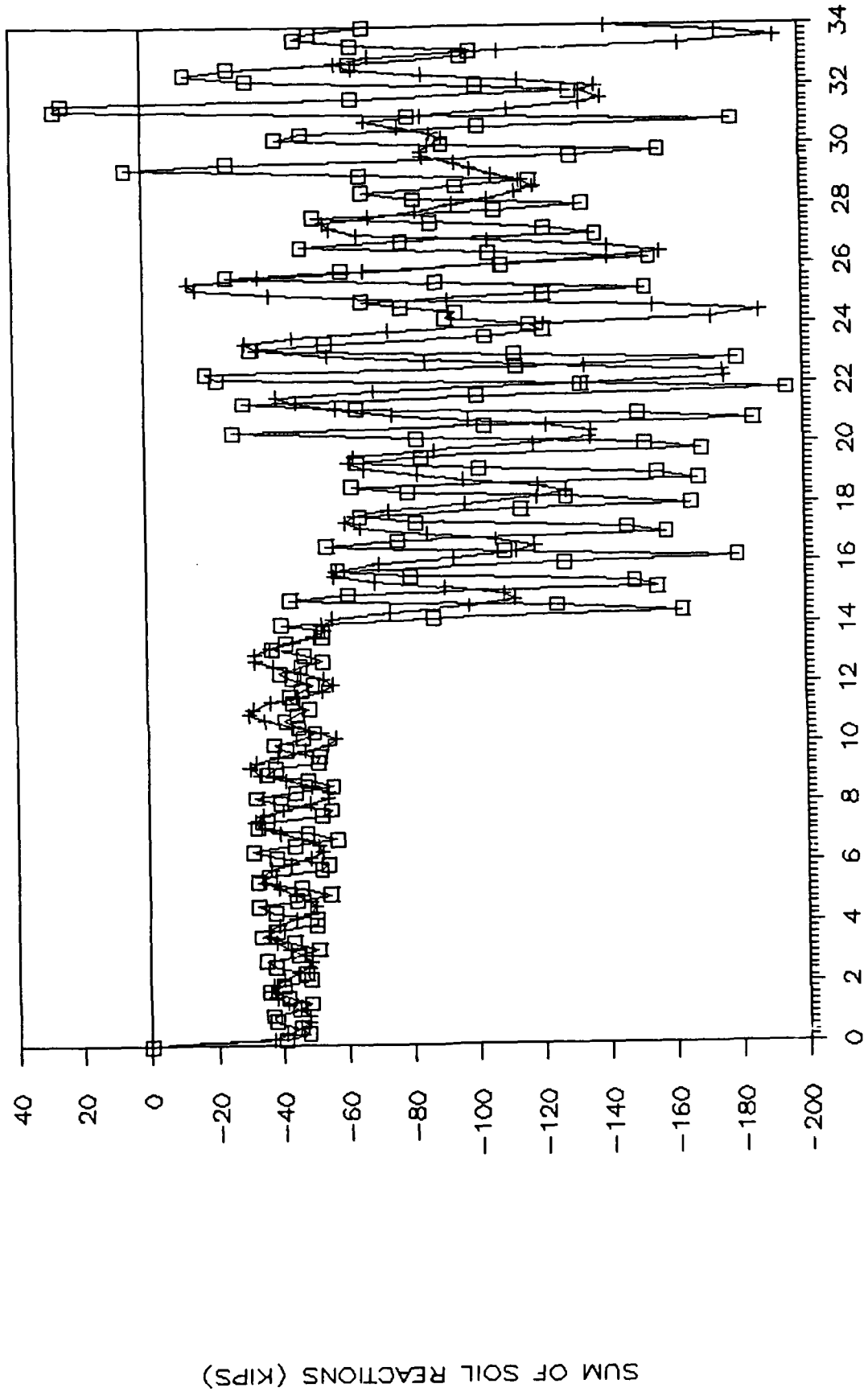
In Appendix C, a set of sample outputs is given for moment resultants, soil pressure, joint displacement and crack formation description for three sample problem analyses.

In Figures 23 to 29 a comparison between a plot of the total dynamic reaction in the soil versus travel distance for different combination of problems is shown. In Figure 23, the results of Example 1 are compared with those of Example 2. The only difference in the input is the vehicle velocity. Due to the change in velocity, a variation in the behavior could be observed. In Example 2 (100 ft/sec), the peak response occurred approximately at every two cycles of the peak response in Example 1 (50 ft/sec). This result is very logic.

From step 1 to step 1400 the peaks were very similar. This was not so after the rear axle entered the slab. After this, in most of the cases, the peaks are much smaller for the case with the higher velocity.

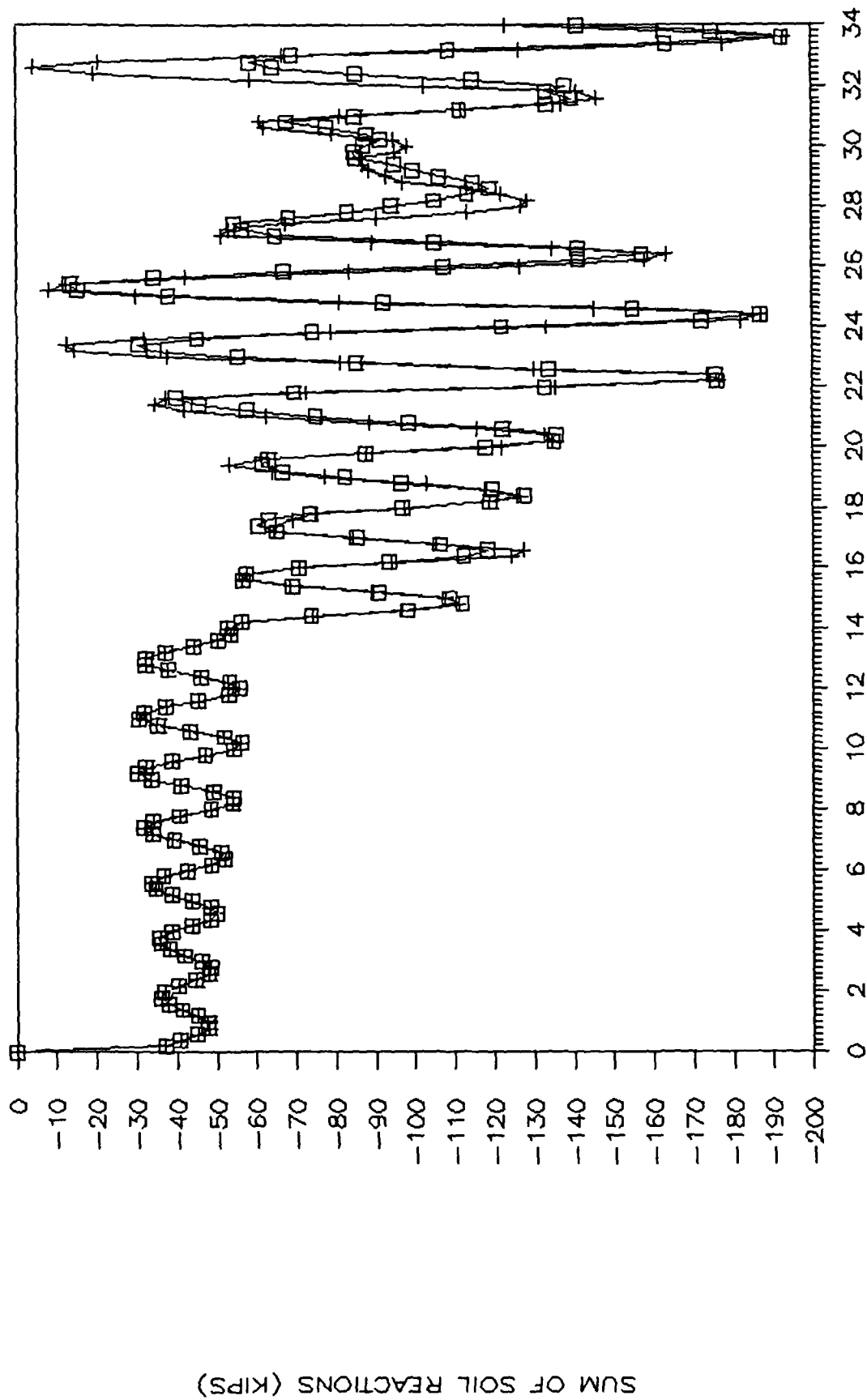
The contours for the moment resultant in x for step 1600 are shown in Figures 30 and 31 for examples 1 and 2, respectively. As can be observed, the behavior is very different. The maximum moment resultant selected from all the steps computed are larger for the cases with the lower velocity (Example 1).

The decrease in time interval by a half, from 0.0002 to 0.0001 seconds, didn't produce any significant difference in the behavior as is reflected by the plot of the sum of soil reactions. This can be observed from Figure 24. On the other



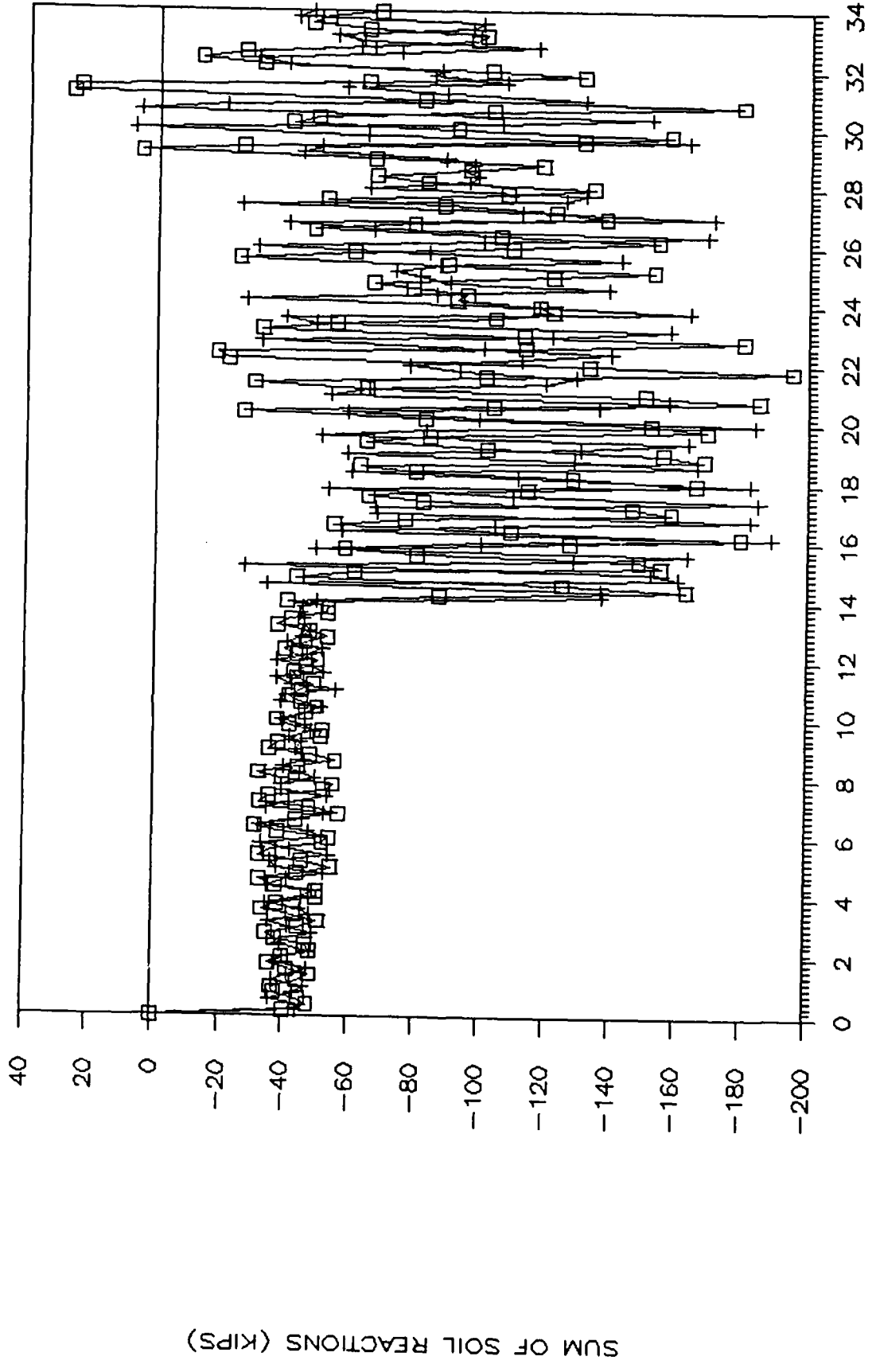
□ EXAMPLE 1
+ EXAMPLE 2

Figure 23. Sum of Soil Reaction for Example 1 vs. Example 2



□ EXAMPLE 2
+ EXAMPLE 3

Figure 24. Sum of Soil Reaction for Example 2 vs. Example 3



□ EXAMPLE 1
+ EXAMPLE 4

Figure 25. Sum of Soil Reaction for Example 1 vs. Example 4

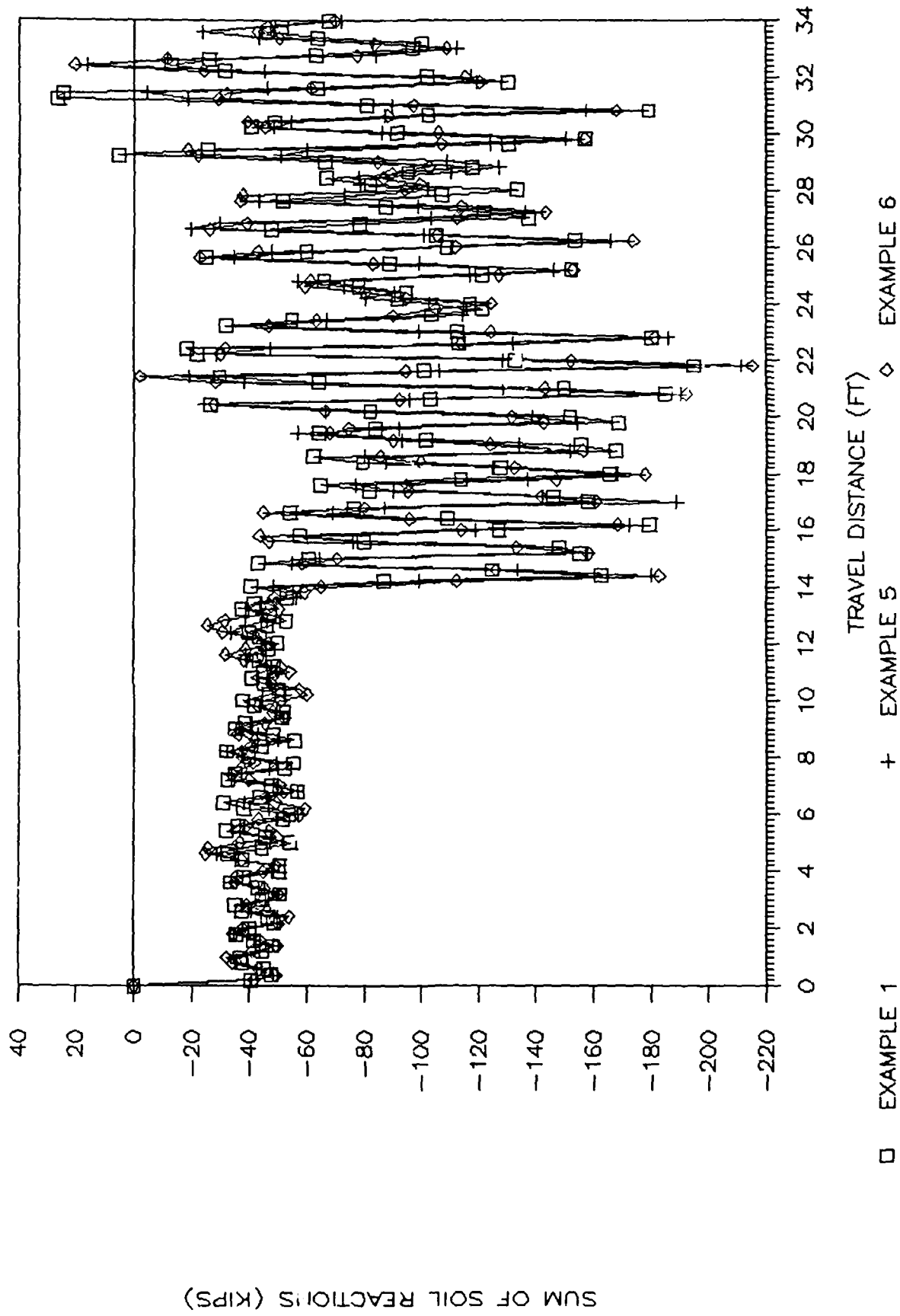


Figure 26. Sum of Soil Reaction for Example 1 vs. Example 5 vs. Example 6

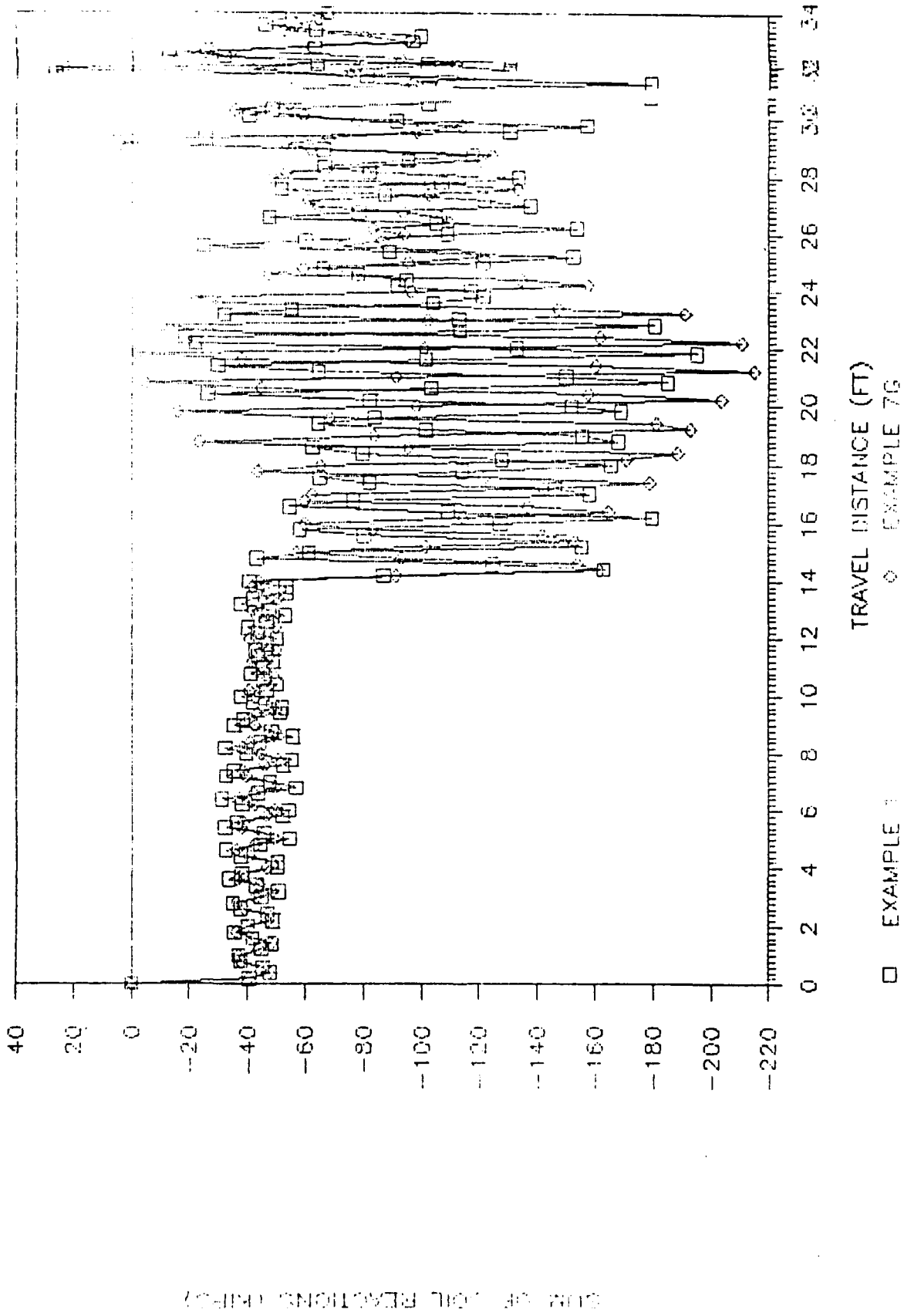


Figure 27. Sum of Soil Reaction for Example 1 vs. Example 7

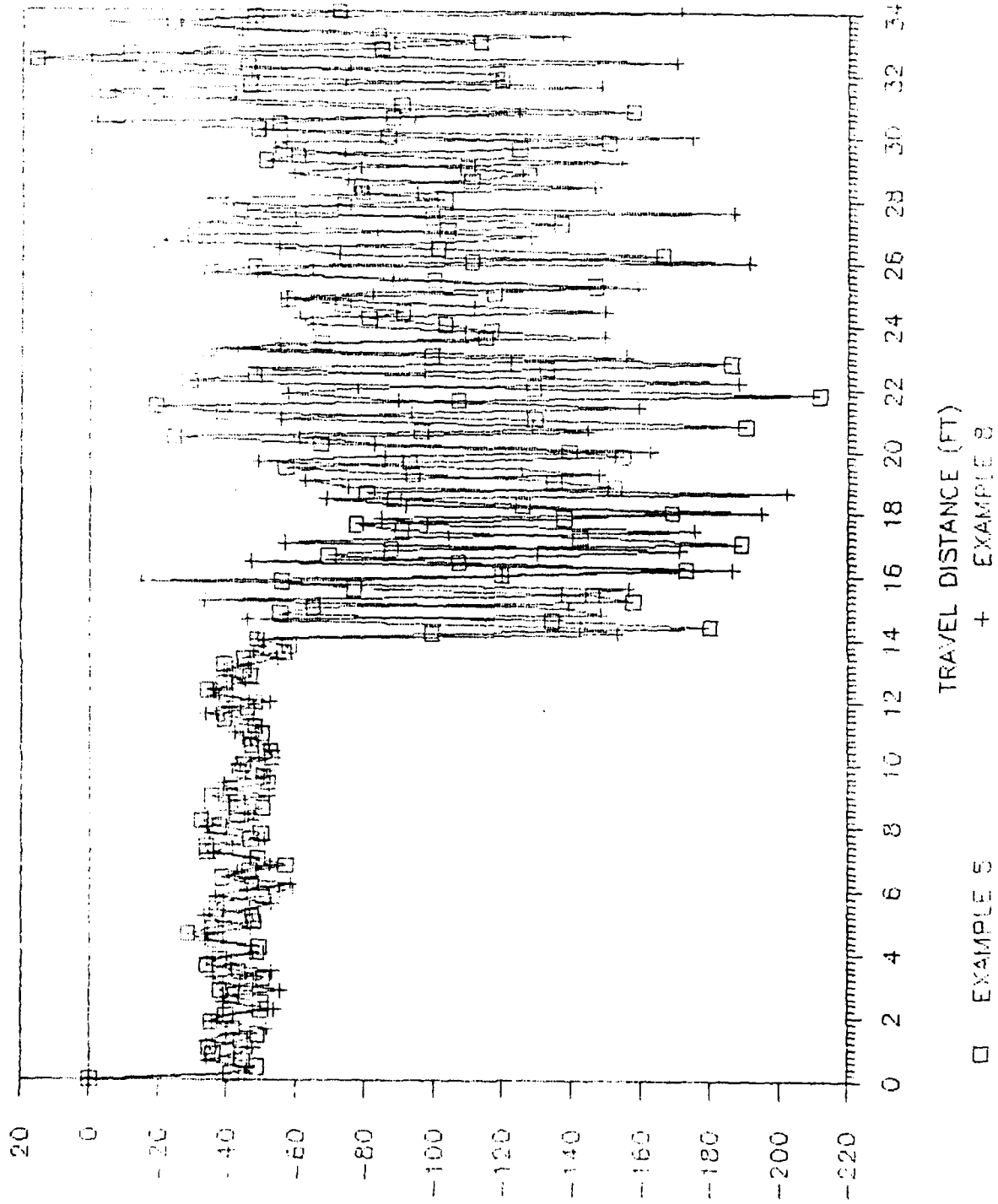


Figure 28. Sum of Soil Reaction for Example 5 vs. Example 8

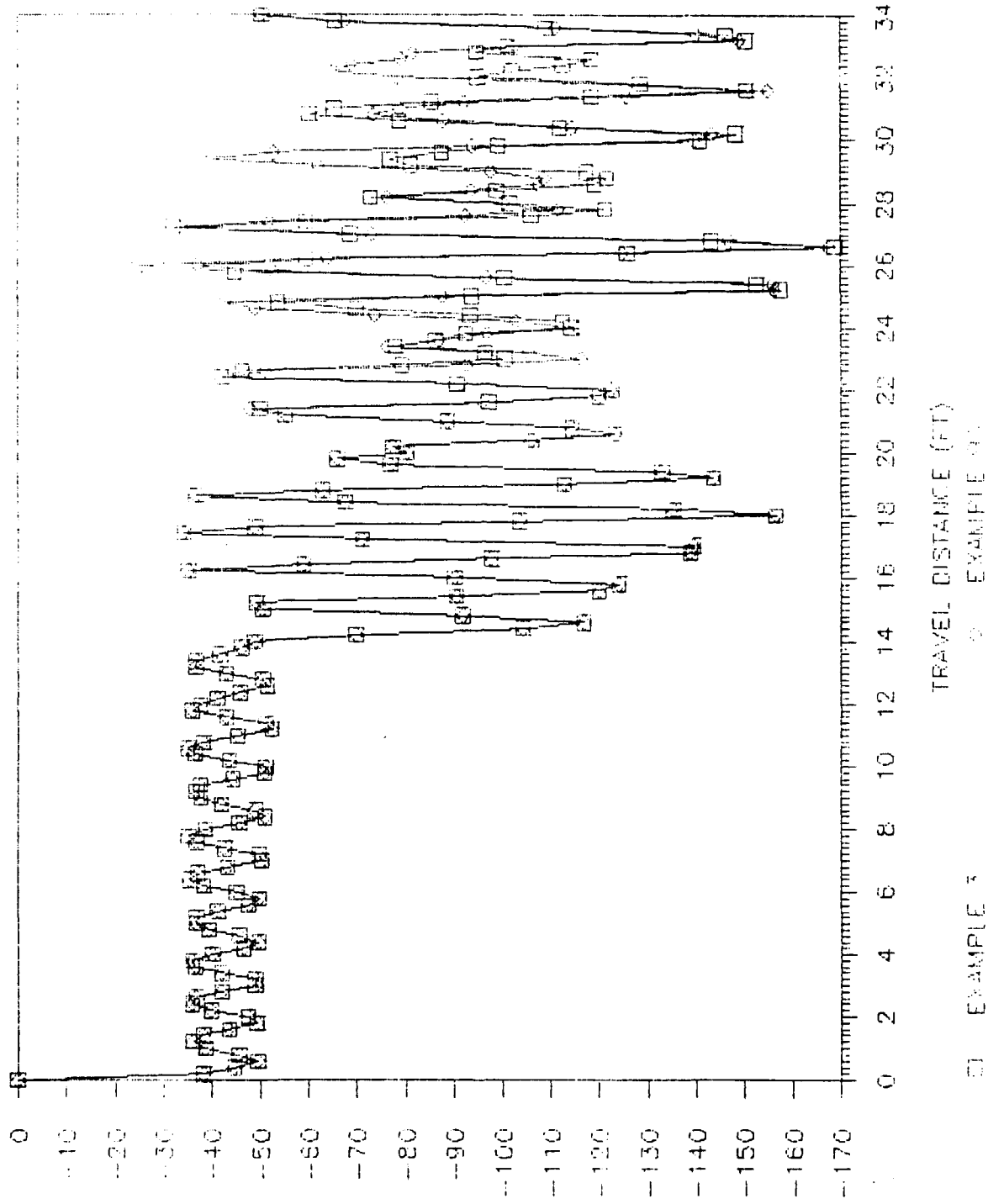
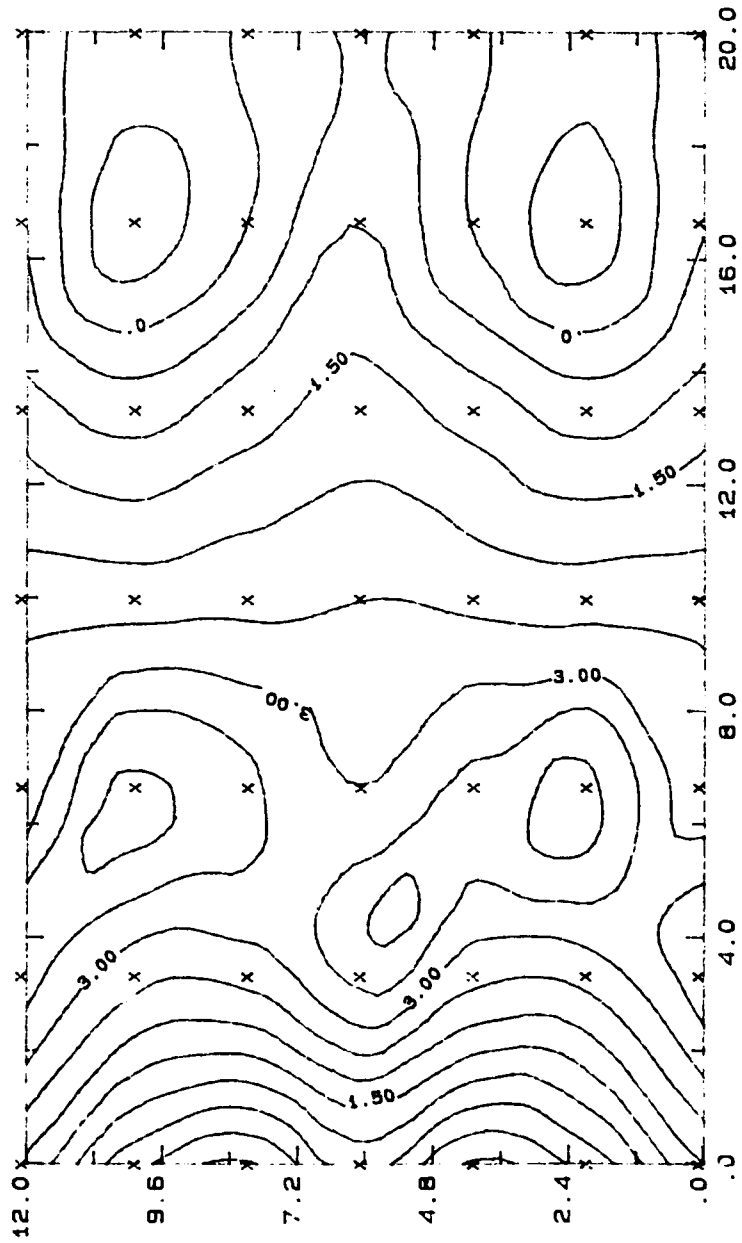
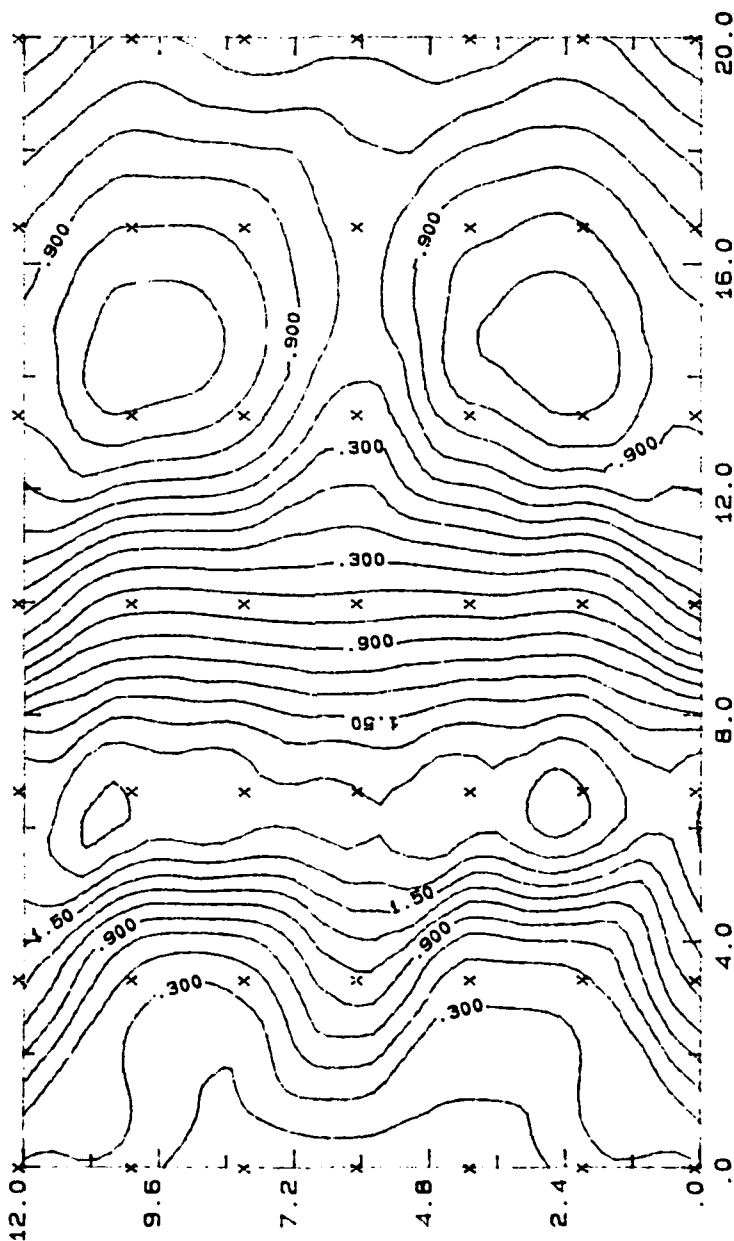


Figure 29. Sum of Soil Reaction for Example 3 vs. Example 9



CONTOUR FROM -1.00 TO 4.50 CONTOUR INTERVAL = .50

Figure 30. Contours for Moment Resultant in X for Example 1
Step 1600



CONTOUR FROM -1.50 TO 2.50 CONTOUR INTERVAL = .20

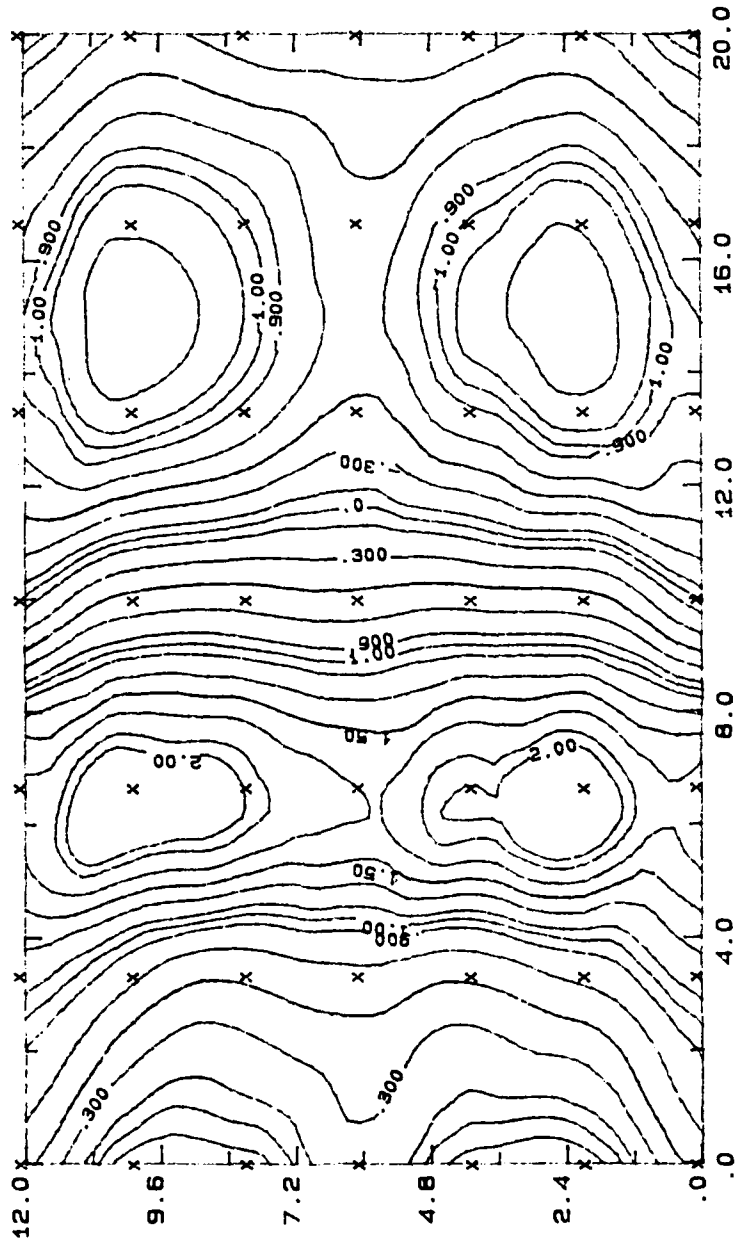
Figure 31. Contours for Moment Resultant in X for Example 2
Step 1600

hand, the results for the moment resultants show some differences in value although the behavior is similar. The moment results are very sensitive to any difference in relative displacement between joints. Figures 31 and 32 show contour plots for the moment resultants in x at similar truck locations. From these plots, it can be observed that the behavior of the moment resultant is very similar for both cases.

In Figure 26, the results of the sum of soil reactions for Examples 1, 5 and 6 are shown. These examples had pavement roughness amplitudes of zero, one fourth of an inch, and one half inch, respectively. Although the response is not exactly the same for different roughness values, it can be observed that the pattern of the variation of the sum of reactions is very similar for the three cases. Also, in general, the peaks are more or less of the same order of magnitude with few exceptions. This can be observed at the distance of four and a half and of thirteen feet.

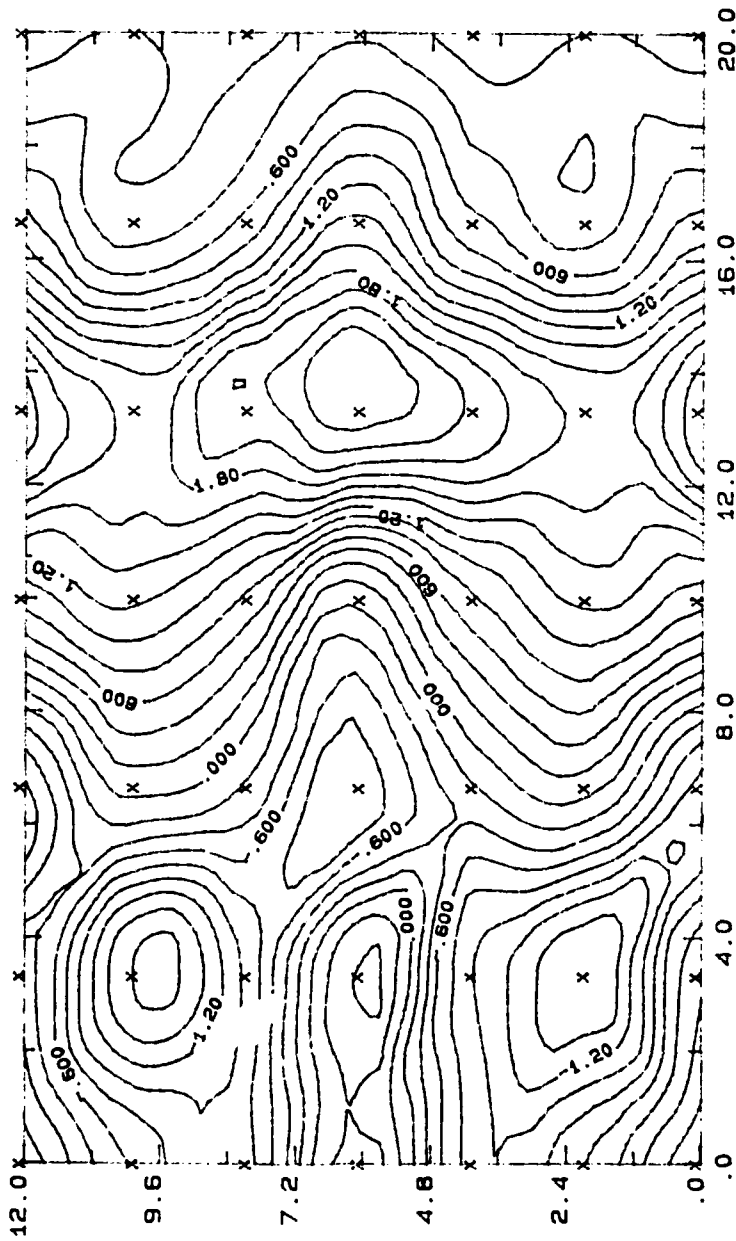
In Figures 30, 34 and 35 one can also observe that the behavior for moment resultants in x for step 1600 is also similar.

The maximum of the principal moment resultants for the interval computed are also very similar for Examples 1 and 5 and slightly smaller for Example 6. These are very significant results since they can imply that a reasonable magnitude random roughness should not increase significantly the magnitude of stresses on concrete pavements.



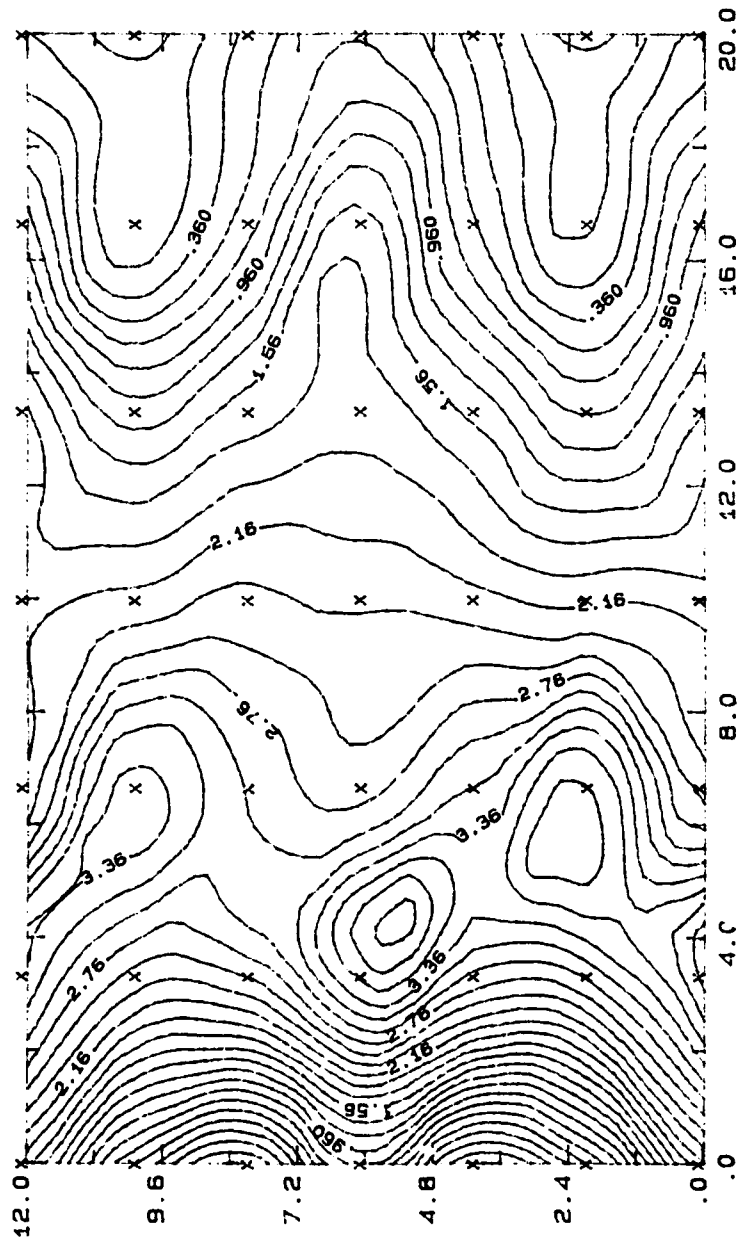
CONTOUR FROM -1.50 TO 2.50 CONTOUR INTERVAL = .50

Figure 32. Contours for Moment Resultant in X for Example 3
Step 1600



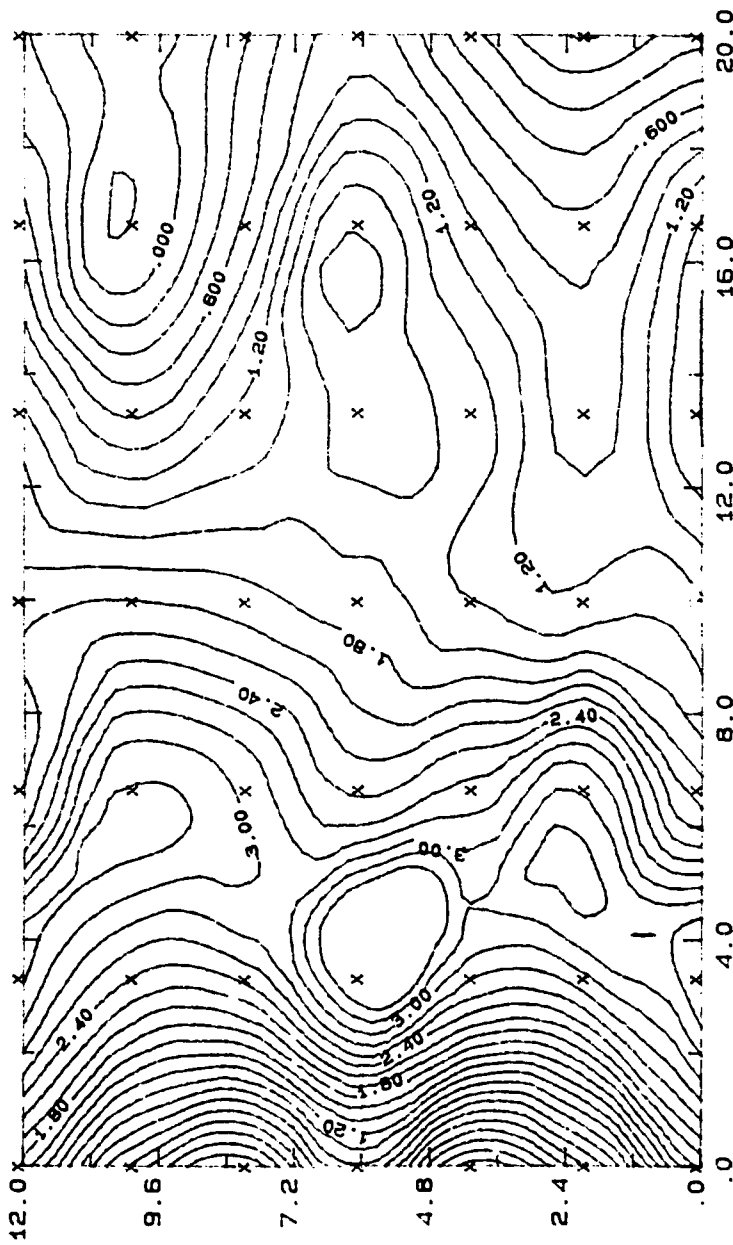
CONTOUR FROM -2.00 TO 2.40 CONTOUR INTERVAL = .20

Figure 33. Contours for Moment Resultant in X for Example 4
Step 1600



CONTOUR FROM -0.64 TO 4.36 CONTOUR INTERVAL = .20

Figure 34. Contours for Moment Resultant in X for Example 5
Step 1600



CONTOUR FROM -1.00 TO 3.40 CONTOUR INTERVAL = .20

Figure 35. Contours for Moment Resultant in X for Example 6
Step 1600

In all the cases evaluated there is a considerable increase in the dynamic response of the slab after the first axle leaves the slab.

In all the cases discussed, a very large concrete crack stress was given in order to obtain the uncracked behavior of the concrete. From example 7 to 9, the concrete crack stress values were given to allow the crack formation. In examples 7 and 9, cracking didn't occur with crack stresses of -56.1 ksf and 45 ksf, respectively. For example 7, the crack stresses were lowered to 45 ksf to allow cracking of the concrete. For the same purpose, the stresses in example 9 had to be reduced to 30 ksf.

In Figure 27, the sum of soil reactions are plotted for example 1 versus example 7G. In general, due to the difference in soil characteristics (cohesive versus granular subbase), the sum of the reactions is larger for example 1. There is an exception when cracks developed causing the situation to reverse.

In Figure 28, the sum of the reaction results are plotted for examples 5 and 8. In this case, there is no significant difference in the peaks observed between one case and another. Yet, it should be observed that in example 8 the amount of cracking developed is small.

In Figure 29, the increase in the magnitude of the sum of soil reactions due to cracking of the concrete could be observed clearly since the only difference between examples 9 and 9A is that cracks develop in the later.

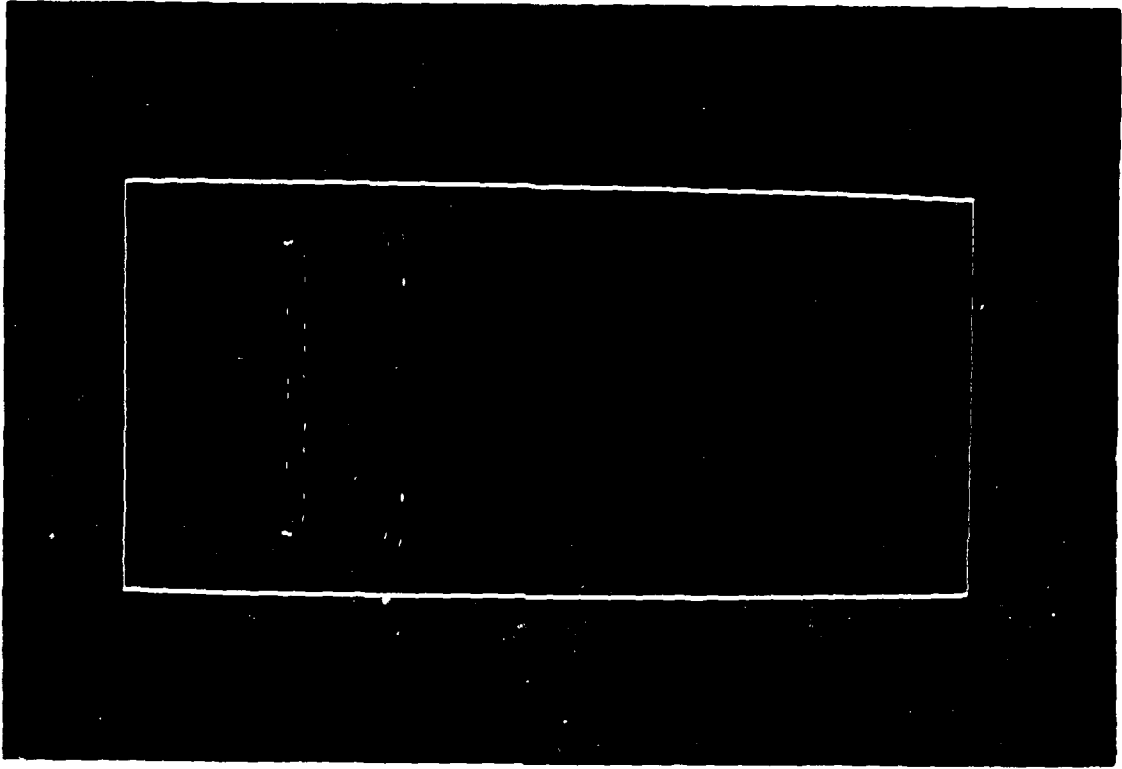
Photographies 1 to 7 show crack pictures of the different pavement examples which exhibit cracking behavior.

Example 7H starts with a transversal crack near the center of the slab when the front wheels are almost leaving the pavement. After this, other cracks develop under the wheel path and close to it. Cracks continue developing in the same manner at other locations in the pavements. The cracks closest to the tires are not transversal, but tend to take a circular pattern (see Photography 1). The top of the pavement does not crack.

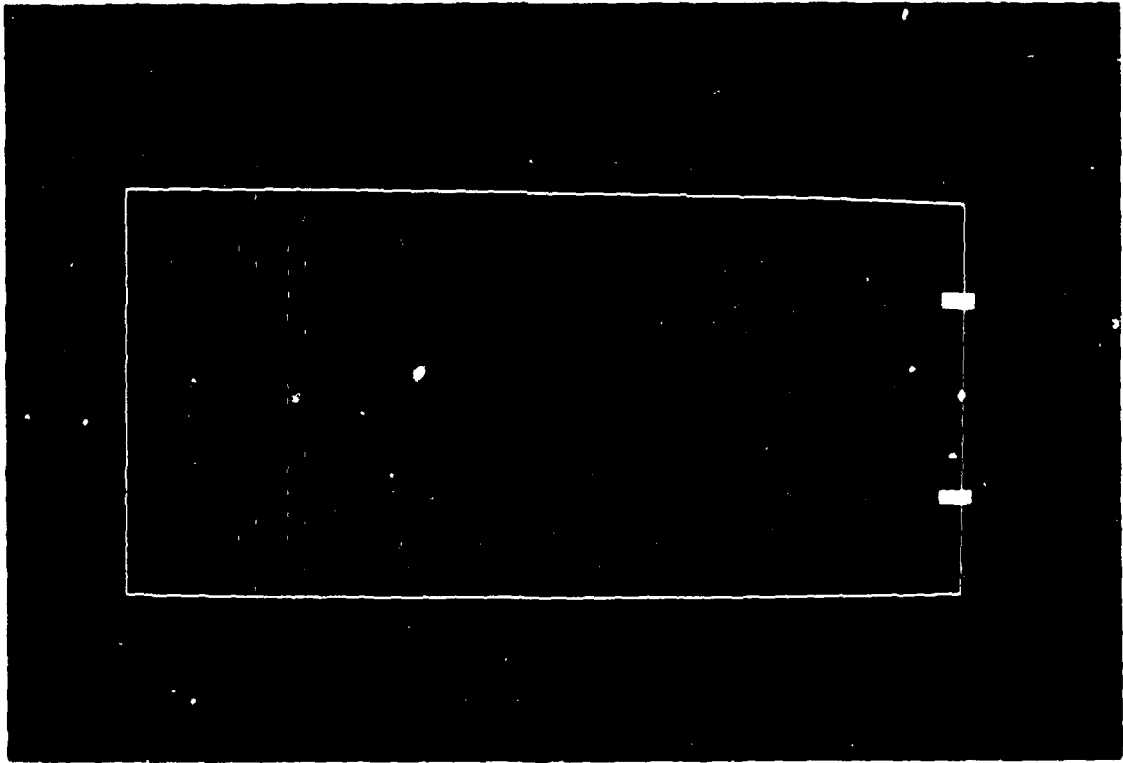
In example 7B, when the back wheels enter the pavement, some transversal cracks develop in the center of the pavement at the top surface. At the bottom, when the front wheels are near the end of the pavement, transversal cracks begin to develop at the center of the pavement. New cracks develop later near the wheels and at the edge of the pavement (see Photography 2).

In example 7G, at the bottom surface cracks start to form at the center of the pavement. This happens earlier than at example 7B. Later, other cracks appear near the wheels and close to the edge expanding towards the center along all the slab. Some cracks between the path of the wheel and the center of the slab are longitudinal. Many others form a radial pattern as can be observed from Photography 3.

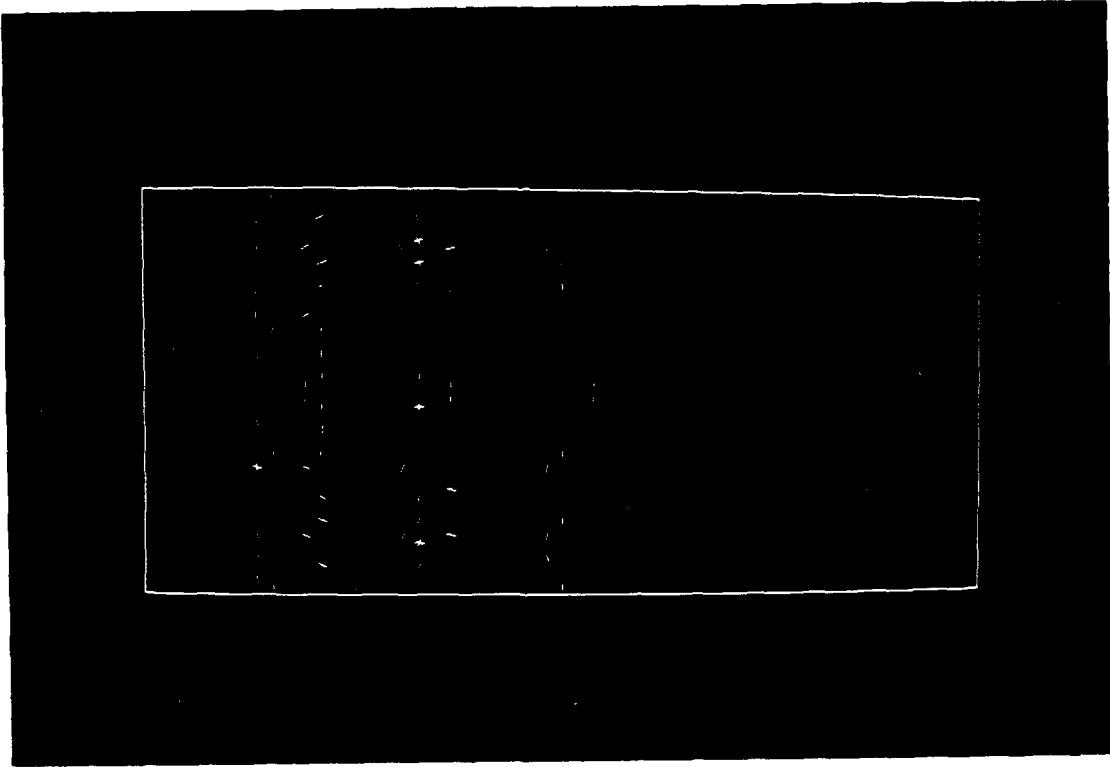
At the top surface, transversal cracks near the center of the slab start to develop when the back gear enters the slab. These cracks extend under the wheels and to the edge. As the gear advances new cracks, in a longitudinal pattern, develop between the center and the gear path (see Photography 4).



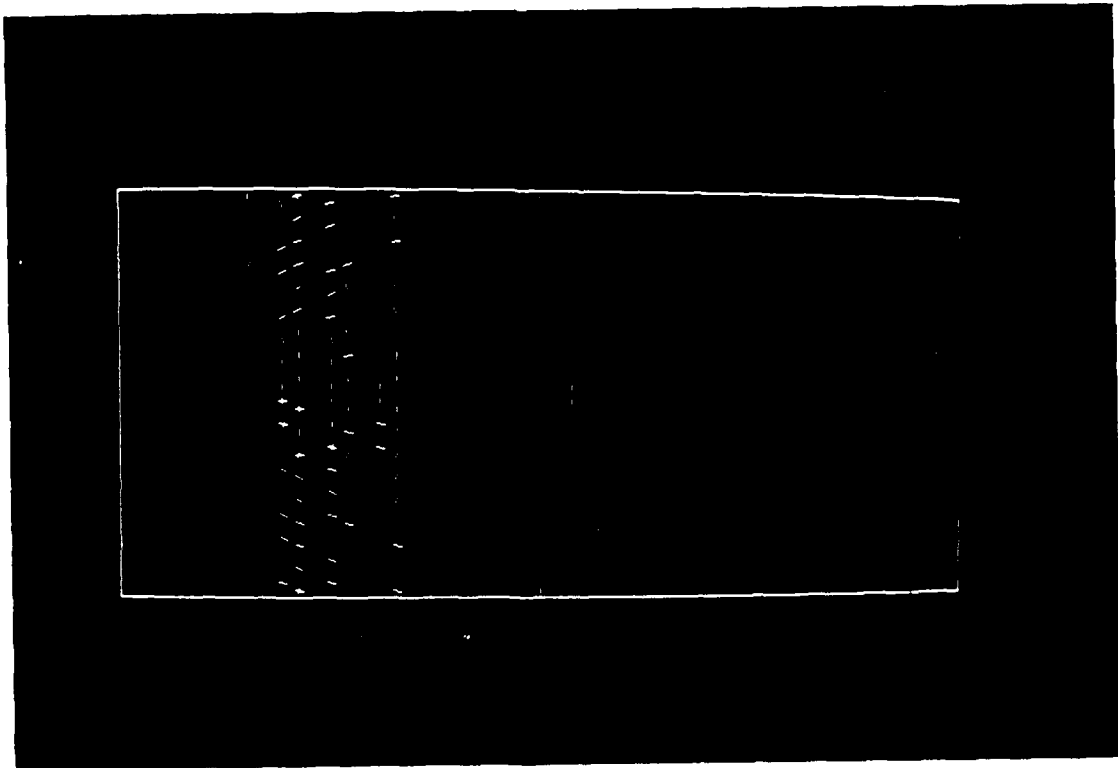
Photography 1 - Example 7H BOTTOM



Photography 2 - Example 7B BOTTOM



Photography 3 - Example 7G BOTTOM



Photography 4 - Example 7G TOP

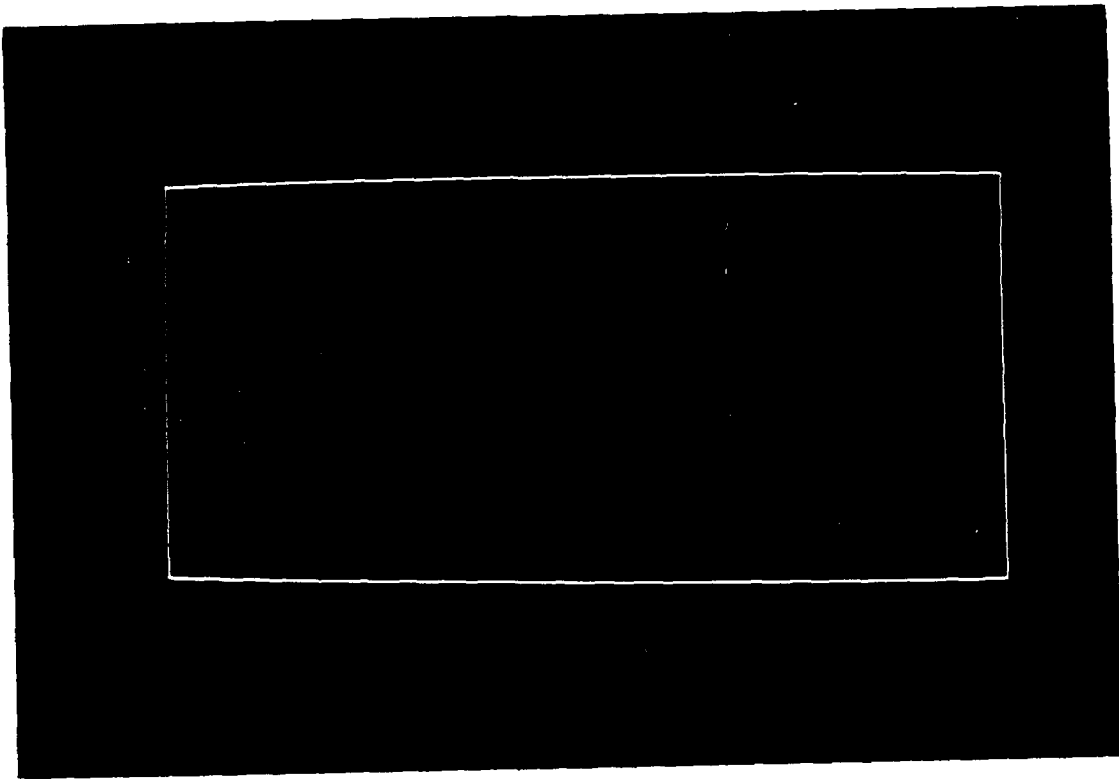
In example 8, cracks start to develop at the bottom surface when the front gear leaves the slab. These cracks form under one of the wheels and are in a transversal pattern as can be observed in Photography 5. No cracks develop at the top surface.

When the front gear in example 9A leaves the pavement, some transversal cracks develop at the bottom surface near the center. When the back gear is near the end of the slab, new cracks develop in a radial form from the tires toward the edge. Other cracks form near the center in different loops across the slab. Longitudinal cracks also develop near the edge of the slab as shown in Photography 6. At the top surface, cracks develop when the back gear is almost leaving the slab. These cracks are a few feet from the end of the pavement and in almost radial pattern (see Photography 7).

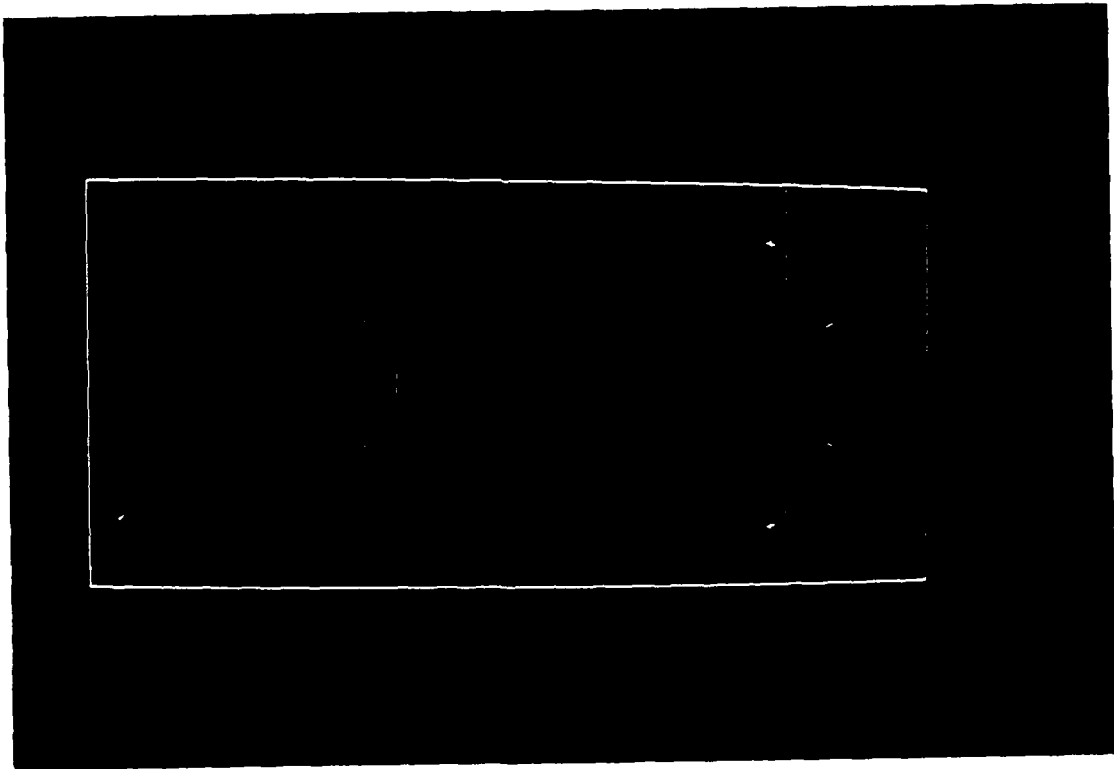
Contour plots for Examples 7 through 9 are shown respectively in Figures 37 through 39 for results of moment resultants in x at step 2000.

Figures 40 and 41 show contours for moment resultant in y at step 2000 for Examples 7 and 9, respectively. These are very similar although the moment resultants for Example 7 are larger than those for Example 9.

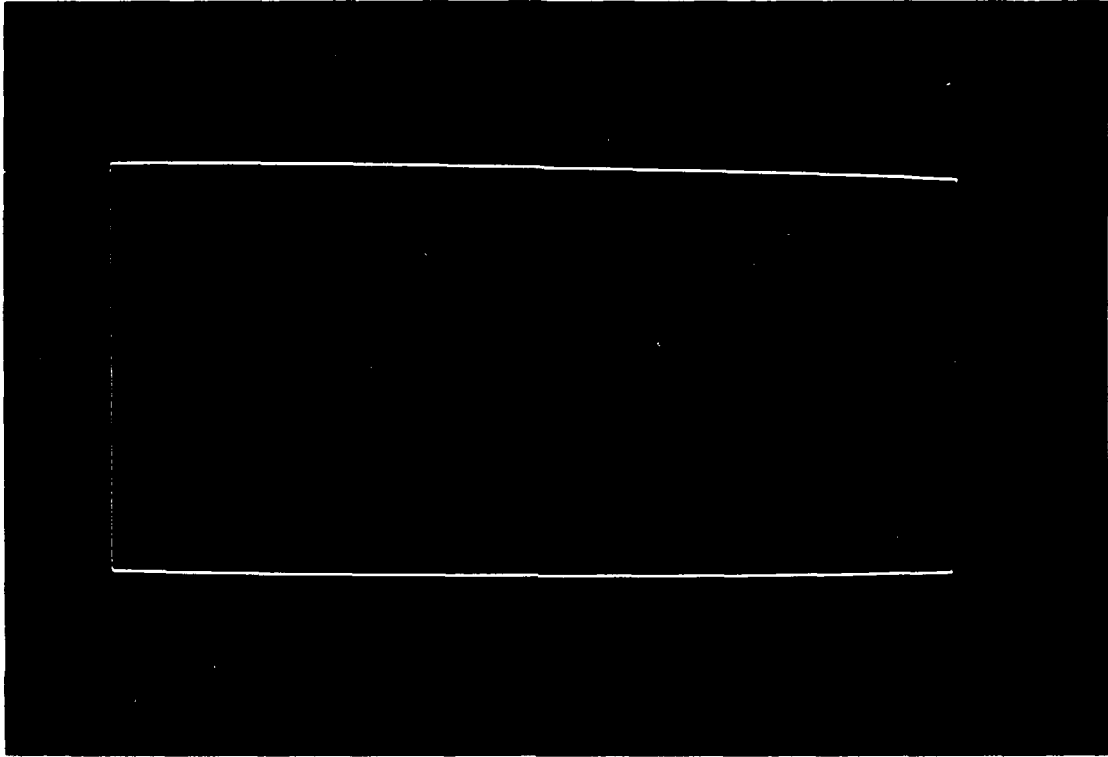
In Figures 42 and 43, contours for displacements at step 2000 for Examples 1 and 7 are shown. The effect of crack formation on the displacement for Example 7 could be observed in Figure 43. In Figures 44 and 45 soil reaction contours are shown for Examples 7 and 8 at step 1,800.



Photography 5 - Example 8 BOTTOM

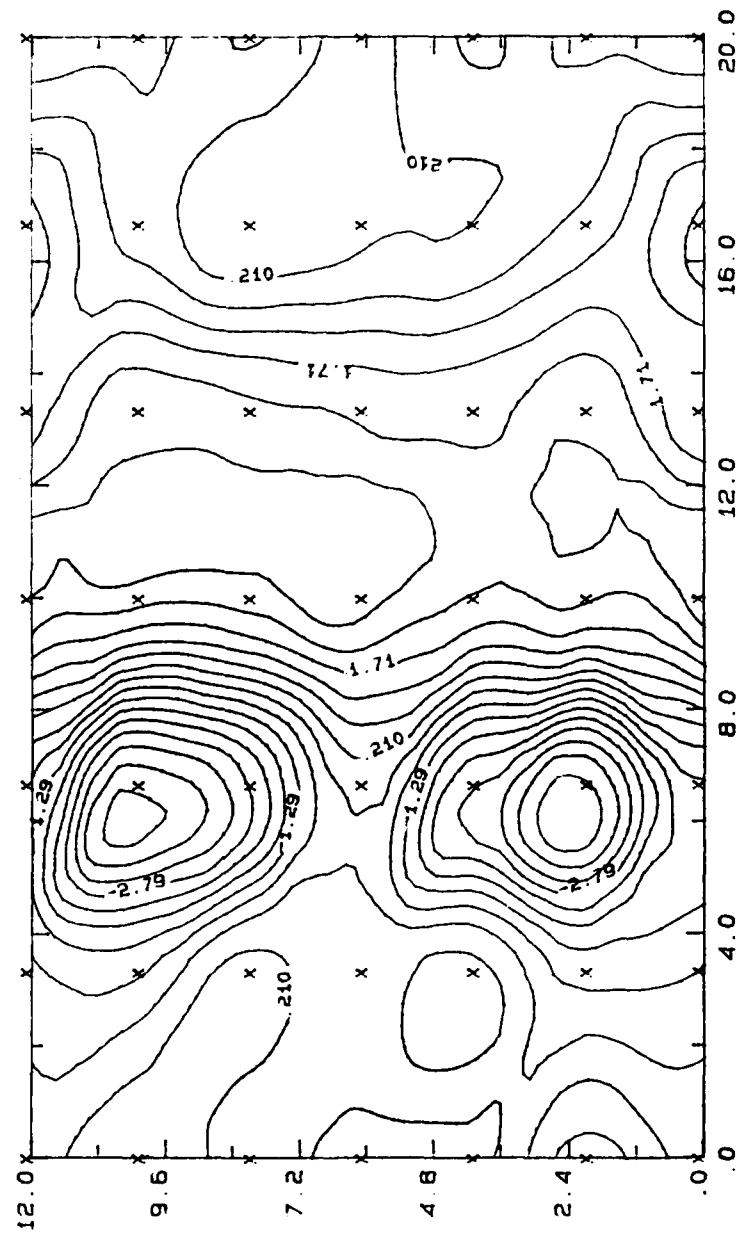


Photography 6 - Example 9A BOTTOM



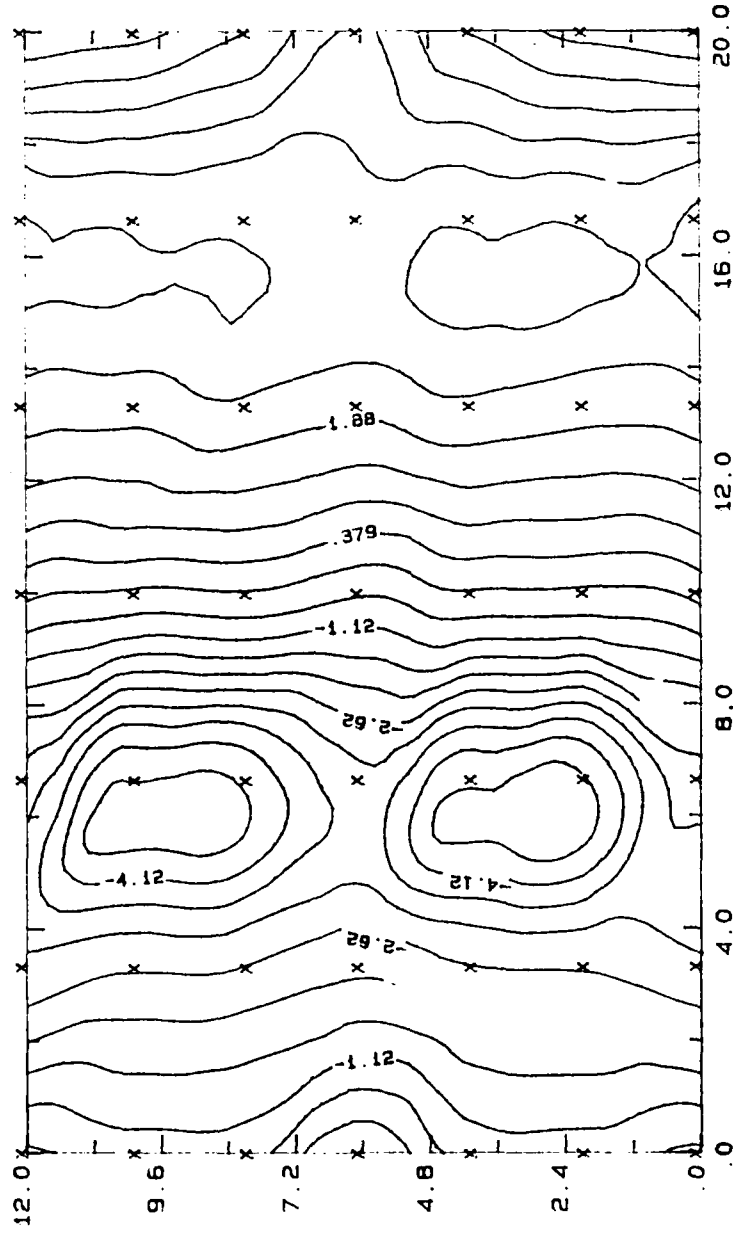
Photography 7 - Example 9A TOP

There is no doubt that soil characteristics are very important in the behavior of the pavement, particularly in the formation of cracks. Yet, there is no sufficient fundamental experimental soil data that will allow to define with precision the parameters that are needed for a precise analytical representation. Therefore, until the data is available, analytical parametric studies are needed to identify the parameter that produces an overall logic behavior. Such a parametric study is out of the scope of this project.



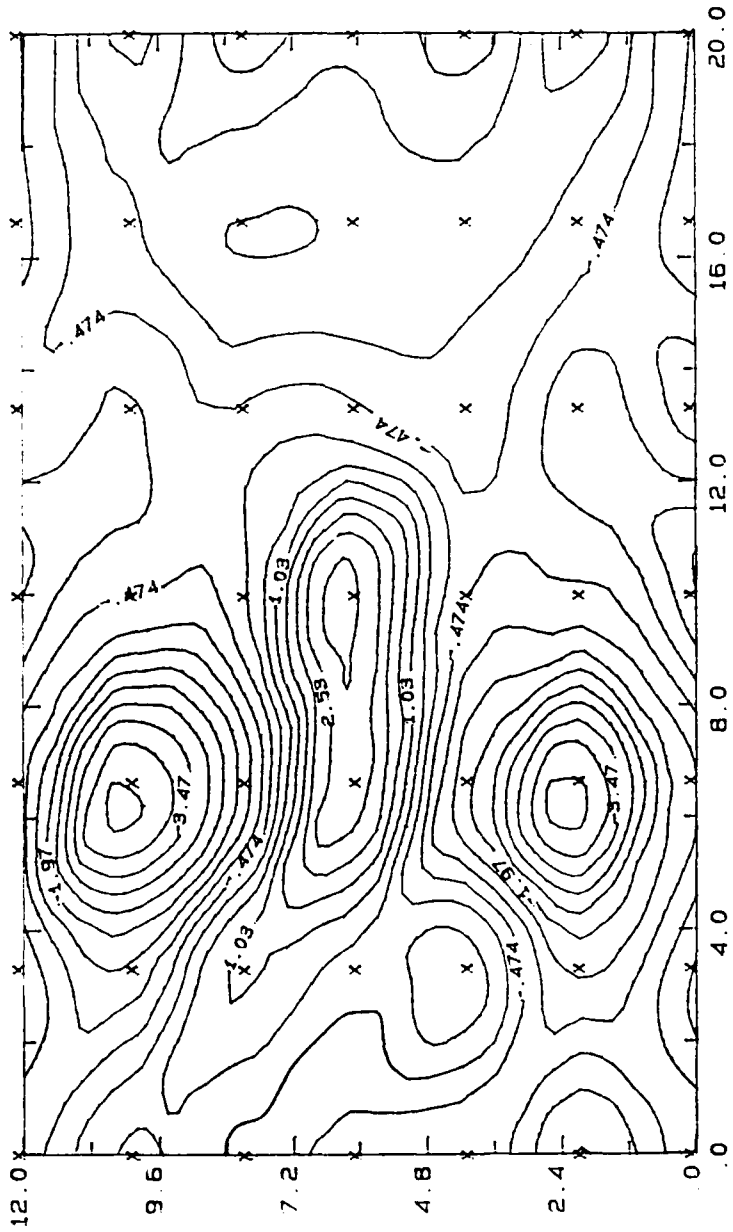
CONTOUR FROM -4.29 TO 2.71 CONTOUR INTERVAL = .50

Figure 37. Contours for Moment Resultant in X for Example 7G
Step 2000



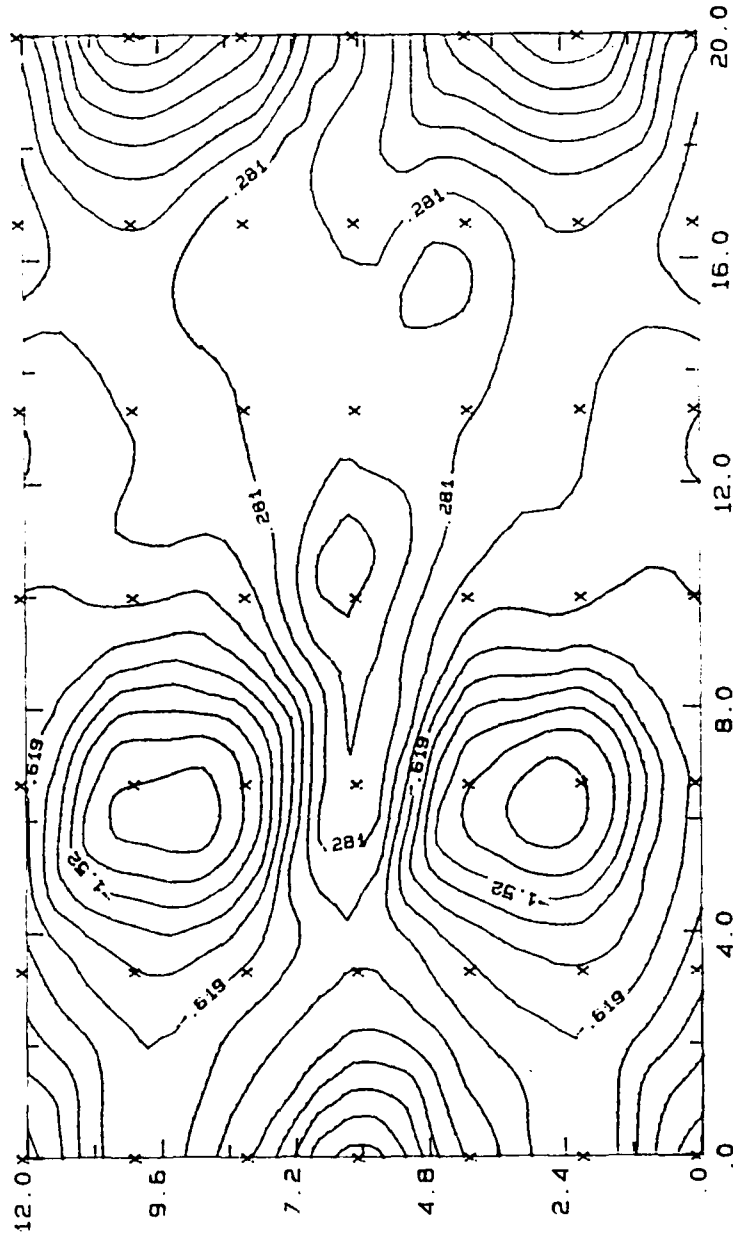
CONTOUR FROM -4.62 TO 2.88 CONTOUR INTERVAL = .50

Figure 39. Contours for Moment Resultant in X for Example 9A
Step 2000



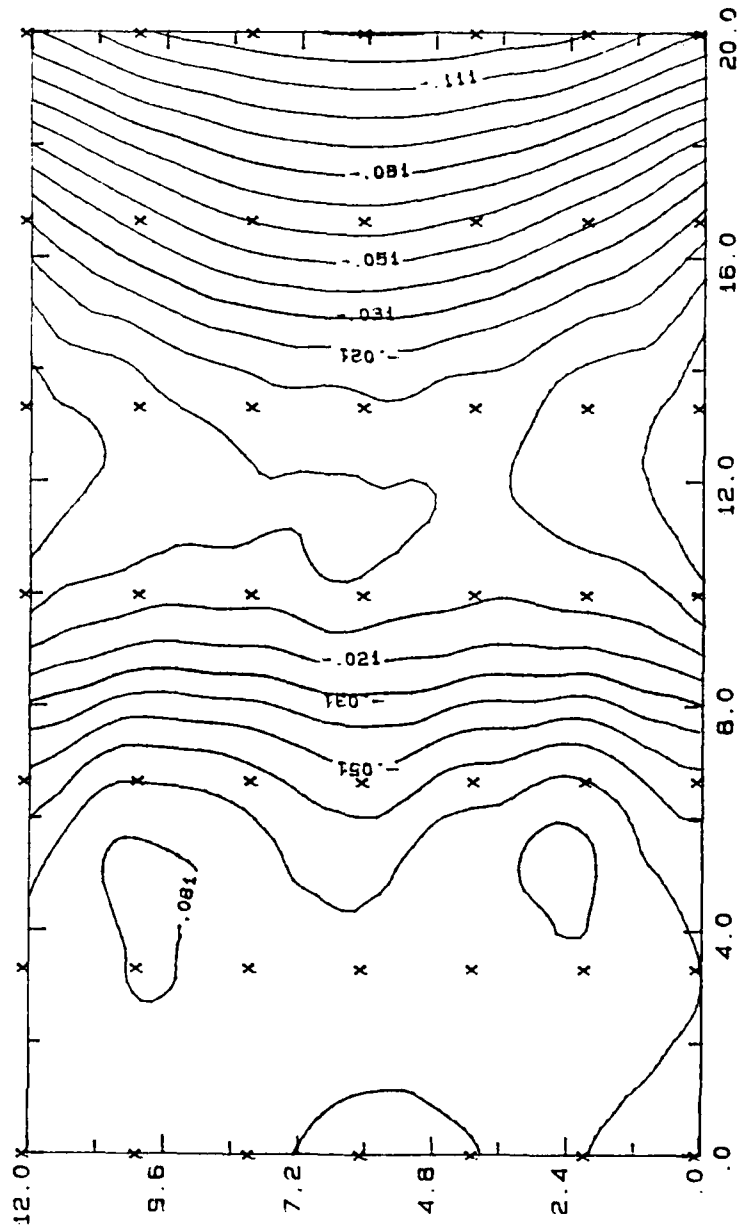
CONTOUR FROM -4.47 TO 3.03 CONTOUR INTERVAL = .50

Figure 40. Contours for Moment Resultant in Y for Example 7G
Step 2000



CONTOUR FROM -8.12 TO 1.48 CONTOUR INTERVAL = .30

Figure 41. Contours for Moment Resultant in Y for Example 9A
Step 2000



CONTOUR FROM -.131000 TO -.089000 CONTOUR INTERVAL = .050000

Figure 43. Displacement Contours for Example 7G
Step 2000 (x1000)

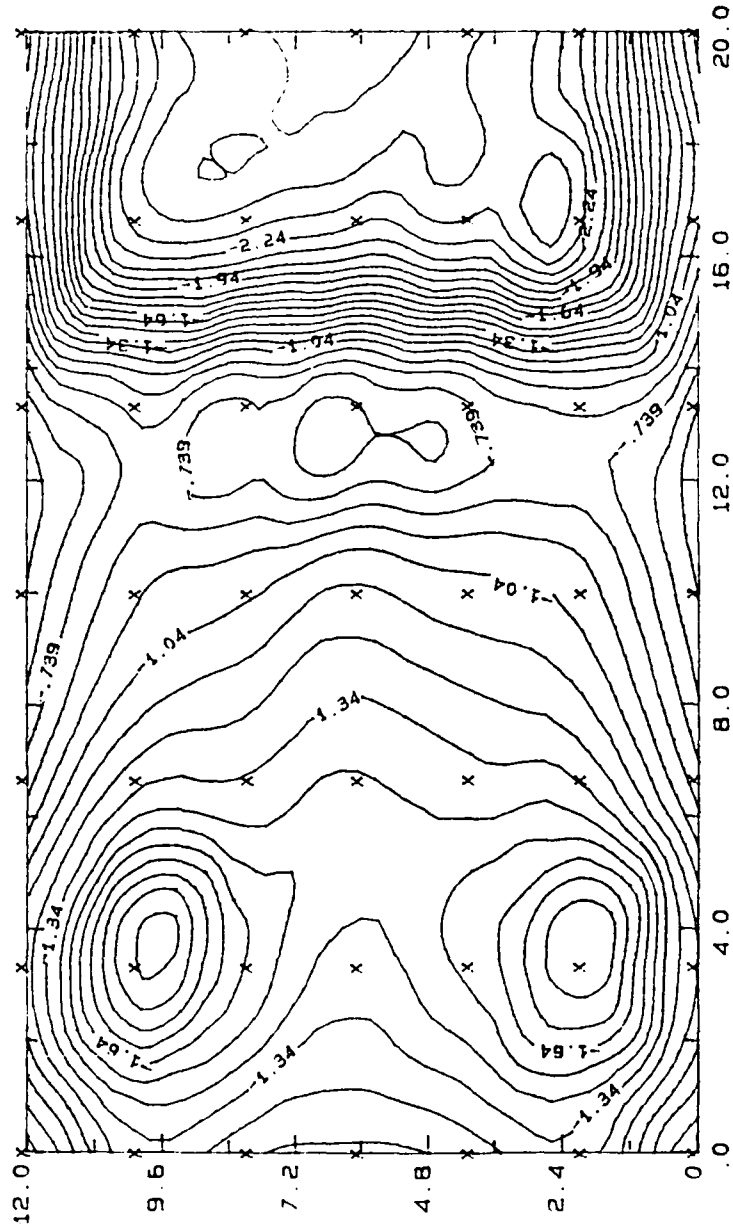
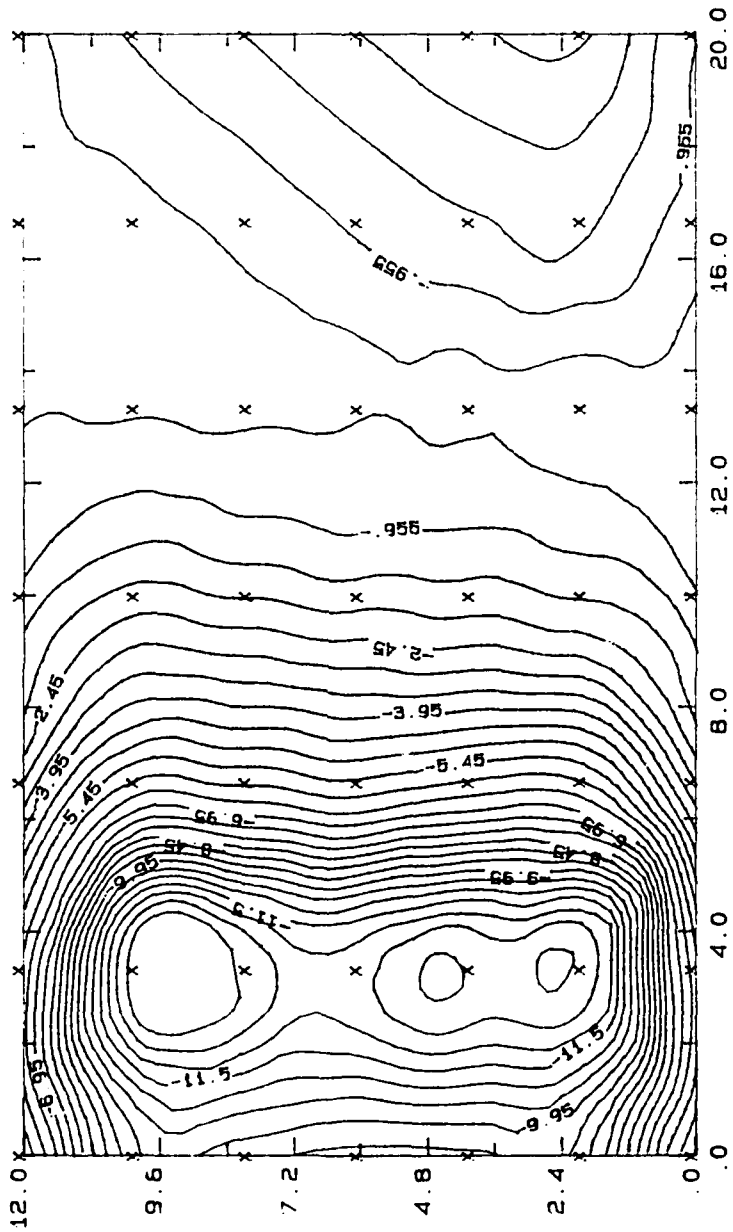


Figure 44. Soil Reaction Contours for Example 7G
Step 1800



CONTOUR FROM -12.95 TO -1.45 CONTOUR INTERVAL = .50

Figure 45. Soil Reaction Contours for Example 8
Step 1800

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.a Conclusions

An analytical methodology has been developed to analyze concrete pavements considering vehicle dynamic translation along the slab, soil and concrete linear behavior and roughness. The developed methodology produced very logic results representing the behavior of concrete pavements.

From the examples studied it was observed that an increase in the velocity of the vehicle does not increase the magnitude of the maximum moment resultant. On the contrary, for the cases studied, an increase in velocity decreased the maximum moment resultant. It was also observed that the introduction of a random generated roughness doesn't change significantly the behavior of the pavement.

With a time increment of 0.0002 it was possible to achieve convergence of results.

Crack formation is dependent on the subbase characteristics. Whenever soil parameters that produce a soft subbase were given, the pavement cracked transversally under the effect of the rear gear. On the contrary, when a hard subbase was defined the crack formation (if cracks occurred) was around each wheel of the rear gear and didn't propagate across the pavement.

The crack visualization program (DRACRACK) is a very usefull tool to understand the overall behavior of the pavement.

6.b Recommendations

One of the limitations of the developed methodology is the time consumed each time a variation in element stiffness occurred, due to a new crack formation. To improve this condition, it is recommended to modify the procedure by condensing the element stiffness matrix for each element that changes instead of condensing the total stiffness matrix. This should reduce considerable the amount of time required to obtain a solution.

Due to time limitations it was not possible to conduct a sensitivity analysis of all the parameters that affect concrete pavement behavior. It is recommended to perform additional computer runs in order to be able to define the overall pavement behavior.

Although the present study considers the level of soil stress and the soil failure effect in the computation of the modulus of subgrade reactions, it does not consider the permanent soil deformation due to soil failure. In future research studies this factor should be considered.

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APPENDICES

APPENDIX A
Matrices to Compute Element Stiffness

[C] =

+1	-b			b^2			$-m'b^3$	$-n'b^3$
		+1			-b			
	-1			$2b$			$-3m'b^2$	$-3n'b^2$
+1	a		a^2				ma^3	na^3
		+1			+a			
	-1		$-2a$				$-3ma^2$	$-3na^2$
1		h				h^2		h^3
		+1				+2h		+3h ²
	-1				-h		$-h^2$	

[Ba] =

0	0	0	-2				$-6mx$	$-6nx$
						-2	$-2x$	$-6y$
					-2		$-4y$	0

[Bb] =

0	0	0	0	-2	0	0	$-6m'x$	$-6n'x$
0	0	0	0	0	0	-2	$-2x$	$-6y$
0	0	0	0	0	-2	0	$-4y$	0

where:

$$m = [2 - (h/a)^2]/3 \qquad n = -h/a$$

$$m' = [2 - (h/b)^2]/3 \qquad n' = h/b$$

APPENDIX B

Drivers Needs and Configuration File Requirements

To run the program GRINPAV it is necessary to use graphic drivers in the machine configuration file.

The required configuration file (CONFIG.SYS) is a follow:

```
files = 20
buffers = 20
device=\cgi\ibmpro.sys /g:printer
device=\cgi\msmouse.sys /g:input
device=\cgi\ibmega.sys /g:crt
device=\cgi\gsscgi.sys
```

Where the drivers are in subdirectory CGI.

Software license for the graphic drivers is included for a workstation.

Additional license can be purchased directly from:

```
Graphic Software System, Inc.
P.O. Box 4900
Benverton, Oregon 97005
```

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1200 00072

APPENDIX C
TYPICAL OUTPUT LISTING

DDDDDD	YY	YY	NN	NN	OOOOO	PPPPPP	AAA	VV	VV
DD DD	YY	YY	NNN	NN	O O	PP PP	A A	VV	VV
DD DD	YY	YY	NNNN	NN	OO OO	PP PP	AA AA	VV	VV
DD DD	YY		NN NN	NN	OO OO	PP PP	AA AA	VV	VV
DD DD	YY		NN NN	NN	OO OO	PPPPPP	AAAAAA	VV	VV
DD DD	YY		NN NNN	NN	O O	PP	AA AA	VV	VV
DDDDDD	YY		NN	NN	OOOOO	PP	AA AA	VV	VV

=====

UNIVERSITY OF PUERTO RICO
MAYAGUEZ CAMPUS
PAVEMENT BEHAVIOR PROGRAM
DYNAMIC NON-LINEAL PAVEMENT ANALYSIS
CONSIDERING CONCRETE CRACK FORMATION
AND NONLINEAR SOIL BEHAVIOR
SPONSORED BY:
AIRFORCE OFFICE OF SCIENTIFIC RESEARCH
VERSION 1.0, NOV. 1989

=====

DATE : 12-11-1989

HOUR :10: 4:41:91

NAME OF PROBLEM :

EXAM1-1 PAV.LISO. 20X12X1. VEL=50ft/sec I=.0002 K1=4000 K2=0.6 Ft=10000 KSF

NUMBER OF ELEMENTS = 72

NUMBER OF JOINTS = 49

NUMBER OF AXLES = 2

JOINT INFORMATION

JOINT	X (FT)	Y (FT)	BORDER CONDITION	SPRING CONSTANT (K/FT)	MASS (K-SEC**2/FT)
1	0.000	0.000	0	250.00	0.01
2	3.333	0.000	0	500.00	0.02
3	6.667	0.000	0	500.00	0.02
4	10.000	0.000	0	500.00	0.02
5	13.333	0.000	0	500.00	0.02
6	16.667	0.000	0	500.00	0.02
7	20.000	0.000	0	250.00	0.01
8	0.000	2.000	0	500.00	0.02
9	3.333	2.000	0	1000.00	0.03
10	6.667	2.000	0	1000.00	0.03
11	10.000	2.000	0	1000.00	0.03
12	13.333	2.000	0	1000.00	0.03
13	16.667	2.000	0	1000.00	0.03
14	20.000	2.000	0	500.00	0.02
15	0.000	4.000	0	500.00	0.02
16	3.333	4.000	0	1000.00	0.03
17	6.667	4.000	0	1000.00	0.03
18	10.000	4.000	0	1000.00	0.03
19	13.333	4.000	0	1000.00	0.03
20	16.667	4.000	0	1000.00	0.03
21	20.000	4.000	0	500.00	0.02
22	0.000	6.000	0	500.00	0.02
23	3.333	6.000	0	1000.00	0.03
24	6.667	6.000	0	1000.00	0.03
25	10.000	6.000	0	1000.00	0.03
26	13.333	6.000	0	1000.00	0.03
27	16.667	6.000	0	1000.00	0.03
28	20.000	6.000	0	500.00	0.02
29	0.000	8.000	0	500.00	0.02
30	3.333	8.000	0	1000.00	0.03
31	6.667	8.000	0	1000.00	0.03
32	10.000	8.000	0	1000.00	0.03
33	13.333	8.000	0	1000.00	0.03
34	16.667	8.000	0	1000.00	0.03
35	20.000	8.000	0	500.00	0.02
36	0.000	10.000	0	500.00	0.02
37	3.333	10.000	0	1000.00	0.03
38	6.667	10.000	0	1000.00	0.03
39	10.000	10.000	0	1000.00	0.03
40	13.333	10.000	0	1000.00	0.03
41	16.667	10.000	0	1000.00	0.03
42	20.000	10.000	0	500.00	0.02
43	0.000	12.000	0	250.00	0.01
44	3.333	12.000	0	500.00	0.02
45	6.667	12.000	0	500.00	0.02
46	10.000	12.000	0	500.00	0.02
47	13.333	12.000	0	500.00	0.02
48	16.667	12.000	0	500.00	0.02
49	20.000	12.000	0	250.00	0.01

ELEMENT INFORMATION

ELEMENTS	JOINT DEFINITION			THICKNESS (FT)	YOUNG MODULE (KSF)	POISSON
	FROM	TO	TO			
1	9	1	2	1.000	0.5184E+06	0.160
2	10	2	3	1.000	0.5184E+06	0.160
3	11	3	4	1.000	0.5184E+06	0.160
4	12	4	5	1.000	0.5184E+06	0.160
5	13	5	6	1.000	0.5184E+06	0.160
6	14	6	7	1.000	0.5184E+06	0.160
7	1	9	8	1.000	0.5184E+06	0.160
8	2	10	9	1.000	0.5184E+06	0.160
9	3	11	10	1.000	0.5184E+06	0.160
10	4	12	11	1.000	0.5184E+06	0.160
11	5	13	12	1.000	0.5184E+06	0.160
12	6	14	13	1.000	0.5184E+06	0.160
13	16	8	9	1.000	0.5184E+06	0.160
14	17	9	10	1.000	0.5184E+06	0.160
15	18	10	11	1.000	0.5184E+06	0.160
16	19	11	12	1.000	0.5184E+06	0.160
17	20	12	13	1.000	0.5184E+06	0.160
18	21	13	14	1.000	0.5184E+06	0.160
19	8	16	15	1.000	0.5184E+06	0.160
20	9	17	16	1.000	0.5184E+06	0.160
21	10	18	17	1.000	0.5184E+06	0.160
22	11	19	18	1.000	0.5184E+06	0.160
23	12	20	19	1.000	0.5184E+06	0.160
24	13	21	20	1.000	0.5184E+06	0.160
25	23	15	16	1.000	0.5184E+06	0.160
26	24	16	17	1.000	0.5184E+06	0.160
27	25	17	18	1.000	0.5184E+06	0.160
28	26	18	19	1.000	0.5184E+06	0.160
29	27	19	20	1.000	0.5184E+06	0.160
30	28	20	21	1.000	0.5184E+06	0.160
31	15	23	22	1.000	0.5184E+06	0.160
32	16	24	23	1.000	0.5184E+06	0.160
33	17	25	24	1.000	0.5184E+06	0.160
34	18	26	25	1.000	0.5184E+06	0.160
35	19	27	26	1.000	0.5184E+06	0.160
36	20	28	27	1.000	0.5184E+06	0.160
37	23	29	22	1.000	0.5184E+06	0.160
38	24	30	23	1.000	0.5184E+06	0.160
39	25	31	24	1.000	0.5184E+06	0.160
40	26	32	25	1.000	0.5184E+06	0.160
41	27	33	26	1.000	0.5184E+06	0.160
42	28	34	27	1.000	0.5184E+06	0.160
43	29	23	30	1.000	0.5184E+06	0.160
44	30	24	31	1.000	0.5184E+06	0.160
45	31	25	32	1.000	0.5184E+06	0.160
46	32	26	33	1.000	0.5184E+06	0.160
47	33	27	34	1.000	0.5184E+06	0.160
48	34	28	35	1.000	0.5184E+06	0.160
49	30	36	29	1.000	0.5184E+06	0.160
50	31	37	30	1.000	0.5184E+06	0.160
51	32	38	31	1.000	0.5184E+06	0.160
52	33	39	32	1.000	0.5184E+06	0.160
53	34	40	33	1.000	0.5184E+06	0.160
54	35	41	34	1.000	0.5184E+06	0.160
55	36	30	37	1.000	0.5184E+06	0.160
56	37	31	38	1.000	0.5184E+06	0.160
57	38	32	39	1.000	0.5184E+06	0.160
58	39	33	40	1.000	0.5184E+06	0.160

ELEMENT INFORMATION

ELEMENTS	JOINT DEFINITION			THICKNESS (FT)	YOUNG MODULE (KSF)	POISSON
	FROM	TO	TO			
59	40	34	41	1.000	0.5184E+06	0.160
60	41	35	42	1.000	0.5184E+06	0.160
61	37	43	36	1.000	0.5184E+06	0.160
62	38	44	37	1.000	0.5184E+06	0.160
63	39	45	38	1.000	0.5184E+06	0.160
64	40	46	39	1.000	0.5184E+06	0.160
65	41	47	40	1.000	0.5184E+06	0.160
66	42	48	41	1.000	0.5184E+06	0.160
67	43	37	44	1.000	0.5184E+06	0.160
68	44	38	45	1.000	0.5184E+06	0.160
69	45	39	46	1.000	0.5184E+06	0.160
70	46	40	47	1.000	0.5184E+06	0.160
71	47	41	48	1.000	0.5184E+06	0.160
72	48	42	49	1.000	0.5184E+06	0.160

ANALYSIS CHARACTERISTICS

INCREMENTAL PROCEDURE

TIME INCREMENT = 1.99999995E-04 SEG

VEHICLE CHARACTERISTICS

NUMBER OF AXLES = 2
 VEHICLE MASS = 1.565
 ROTATIONAL MASSX = 16.000
 ROTATIONAL MASSY = 42.000
 FRACTION OF MASS AT BODY LEVEL = 0.900
 DISTANCE BETWEEN "X" AXIS AND
 VEHICLE CENTER OF GRAVITY = 6.000 (FT)
 VEHICLE VELOCITY = 50.000 (FT/SEG)

AXLE NUM	DISTANCE TO CENTROID (FT)	WHEEL SEPARATION (FT)	AXLE FORCE (KIPS)	TIRE STIFFNESS (K/FT)	VEHICLE STIFFNESS (K/FT)	TIRE MASS (K-SEC ² /FT)
1	12.00	6.00	-8.00	70.00	12.00	0.01
2	-2.00	6.00	-48.00	140.00	72.00	0.07

SOIL PROPERTIES

SOIL COEFFICIENT ONE = 4000.000
 SOIL COEFFICIENT TWO = 0.600
 SOIL POSSION RATIO = 0.300
 SOIL DEPTH = 8.000 (FT)
 SOIL ELEVATION FACTOR = 6.000
 SOIL FRICTION ANGLE = 0.000 (DEGREE)
 SOIL COHESION = 0.015 (PSI)

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-1 .SX PAGE 1

INTERVAL = 200 TIME = 0.040 DISTANCE = 2.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	0.246	-0.136	-0.077
2	3.333	0.000	0.554	0.090	-0.104
3	6.667	0.000	0.364	0.022	-0.064
4	10.000	0.000	0.201	-0.001	-0.025
5	13.333	0.000	0.103	-0.001	-0.021
6	16.667	0.000	0.058	0.009	-0.015
7	20.000	0.000	0.019	0.034	-0.007
8	0.000	2.000	0.069	-0.358	-0.030
9	3.333	2.000	0.424	-0.069	-0.064
10	6.667	2.000	0.486	0.067	-0.057
11	10.000	2.000	0.213	-0.033	-0.032
12	13.333	2.000	0.047	-0.115	-0.026
13	16.667	2.000	-0.013	-0.135	-0.013
14	20.000	2.000	-0.021	-0.126	-0.003
15	0.000	4.000	-0.030	-0.376	0.039
16	3.333	4.000	0.382	-0.133	-0.006
17	6.667	4.000	0.450	-0.013	-0.024
18	10.000	4.000	0.225	-0.006	-0.029
19	13.333	4.000	0.105	0.010	-0.027
20	16.667	4.000	0.059	0.015	-0.012
21	20.000	4.000	0.031	-0.032	-0.006
22	0.000	6.000	0.074	0.253	0.000
23	3.333	6.000	0.446	0.099	0.000
24	6.667	6.000	0.409	-0.090	0.000
25	10.000	6.000	0.236	-0.067	0.000
26	13.333	6.000	0.153	0.058	0.000
27	16.667	6.000	0.134	0.143	0.000
28	20.000	6.000	0.088	0.132	0.000
29	0.000	8.000	-0.030	-0.376	-0.039
30	3.333	8.000	0.382	-0.133	0.006
31	6.667	8.000	0.450	-0.013	0.024
32	10.000	8.000	0.225	-0.006	0.029
33	13.333	8.000	0.105	0.010	0.027
34	16.667	8.000	0.059	0.015	0.012
35	20.000	8.000	0.031	-0.032	0.006
36	0.000	10.000	0.069	-0.358	0.030
37	3.333	10.000	0.424	-0.069	0.064
38	6.667	10.000	0.486	0.067	0.057
39	10.000	10.000	0.213	-0.033	0.032
40	13.333	10.000	0.047	-0.115	0.026
41	16.667	10.000	-0.013	-0.135	0.013
42	20.000	10.000	-0.021	-0.126	0.003
43	0.000	12.000	0.246	-0.136	0.077
44	3.333	12.000	0.554	0.090	0.104
45	6.667	12.000	0.364	0.022	0.064
46	10.000	12.000	0.201	-0.001	0.025
47	13.333	12.000	0.103	-0.001	0.021
48	16.667	12.000	0.058	0.009	0.015
49	20.000	12.000	0.019	0.034	0.007

INTERVAL = 400 TIME = 0.080 DISTANCE = 4.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	-0.198	0.090	0.082
2	3.333	0.000	-0.367	-0.181	0.091
3	6.667	0.000	0.193	-0.009	0.013
4	10.000	0.000	0.326	0.070	-0.039
5	13.333	0.000	0.139	0.039	-0.039
6	16.667	0.000	-0.028	-0.031	-0.016
7	20.000	0.000	0.000	0.012	-0.009
8	0.000	2.000	-0.060	0.182	0.036
9	3.333	2.000	-0.386	-0.122	0.055
10	6.667	2.000	0.013	-0.091	0.009
11	10.000	2.000	0.269	-0.006	-0.019
12	13.333	2.000	0.205	0.064	-0.025
13	16.667	2.000	0.031	0.034	-0.022
14	20.000	2.000	-0.027	-0.035	-0.020
15	0.000	4.000	-0.081	0.080	-0.005
16	3.333	4.000	-0.434	-0.165	0.019
17	6.667	4.000	0.053	0.013	-0.004
18	10.000	4.000	0.289	0.033	0.002
19	13.333	4.000	0.159	0.014	-0.002
20	16.667	4.000	0.010	0.030	-0.020
21	20.000	4.000	0.031	0.077	-0.034
22	0.000	6.000	0.002	0.051	0.000
23	3.333	6.000	-0.367	-0.048	0.000
24	6.667	6.000	0.069	0.198	0.000
25	10.000	6.000	0.337	0.141	0.000
26	13.333	6.000	0.151	-0.025	0.000
27	16.667	6.000	-0.008	-0.030	0.000
28	20.000	6.000	0.027	0.086	0.000
29	0.000	8.000	-0.081	0.080	0.005
30	3.333	8.000	-0.434	-0.165	-0.019
31	6.667	8.000	0.053	0.013	0.004
32	10.000	8.000	0.289	0.033	-0.002
33	13.333	8.000	0.159	0.014	0.002
34	16.667	8.000	0.010	0.030	0.020
35	20.000	8.000	0.031	0.077	0.034
36	0.000	10.000	-0.060	0.182	-0.036
37	3.333	10.000	-0.386	-0.122	-0.055
38	6.667	10.000	0.013	-0.091	-0.009
39	10.000	10.000	0.269	-0.006	0.019
40	13.333	10.000	0.205	0.064	0.025
41	16.667	10.000	0.031	0.034	0.022
42	20.000	10.000	-0.027	-0.035	0.020
43	0.000	12.000	-0.198	0.090	-0.081
44	3.333	12.000	-0.367	-0.181	-0.091
45	6.667	12.000	0.193	-0.009	-0.013
46	10.000	12.000	0.326	0.070	0.039
47	13.333	12.000	0.139	0.039	0.039
48	16.667	12.000	-0.028	-0.031	0.016
49	20.000	12.000	0.000	0.012	0.009

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-2 .SX PAGE 1

INTERVAL = 100 TIME = 0.020 DISTANCE = 2.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	0.019	-0.047	-0.016
2	3.333	0.000	0.127	-0.001	-0.046
3	6.667	0.000	0.186	0.054	-0.065
4	10.000	0.000	-0.013	0.001	-0.024
5	13.333	0.000	-0.092	-0.012	-0.006
6	16.667	0.000	-0.052	-0.016	-0.002
7	20.000	0.000	0.010	0.030	0.004
8	0.000	2.000	0.019	-0.087	-0.018
9	3.333	2.000	0.012	-0.099	-0.031
10	6.667	2.000	0.219	0.055	-0.052
11	10.000	2.000	0.068	0.026	-0.030
12	13.333	2.000	-0.146	-0.087	-0.010
13	16.667	2.000	-0.075	-0.050	-0.003
14	20.000	2.000	-0.038	-0.057	0.002
15	0.000	4.000	-0.029	-0.153	-0.006
16	3.333	4.000	-0.016	-0.153	-0.008
17	6.667	4.000	0.196	0.012	-0.023
18	10.000	4.000	0.064	0.022	-0.025
19	13.333	4.000	-0.100	-0.015	-0.014
20	16.667	4.000	-0.057	0.012	-0.003
21	20.000	4.000	0.009	0.032	-0.004
22	0.000	6.000	-0.002	-0.004	0.000
23	3.333	6.000	0.071	-0.001	0.000
24	6.667	6.000	0.157	-0.028	0.000
25	10.000	6.000	0.043	-0.066	0.000
26	13.333	6.000	-0.020	0.068	0.000
27	16.667	6.000	-0.025	0.104	0.000
28	20.000	6.000	0.009	0.094	0.000
29	0.000	8.000	-0.029	-0.153	0.006
30	3.333	8.000	-0.016	-0.153	0.008
31	6.667	8.000	0.196	0.012	0.023
32	10.000	8.000	0.064	0.022	0.025
33	13.333	8.000	-0.100	-0.015	0.014
34	16.667	8.000	-0.057	0.012	0.003
35	20.000	8.000	0.009	0.032	0.004
36	0.000	10.000	0.019	-0.087	0.018
37	3.333	10.000	0.012	-0.099	0.031
38	6.667	10.000	0.219	0.055	0.052
39	10.000	10.000	0.068	0.026	0.031
40	13.333	10.000	-0.146	-0.087	0.010
41	16.667	10.000	-0.075	-0.050	0.003
42	20.000	10.000	-0.038	-0.057	-0.002
43	0.000	12.000	0.019	-0.047	0.016
44	3.333	12.000	0.127	-0.001	0.046
45	6.667	12.000	0.186	0.054	0.065
46	10.000	12.000	-0.013	0.001	0.024
47	13.333	12.000	-0.092	-0.012	0.006
48	16.667	12.000	-0.052	-0.016	0.002
49	20.000	12.000	0.010	0.030	-0.004

INTERVAL = 200 TIME = 0.040 DISTANCE = 4.000

JOINT	X (FT)	Y (FT)	Mx (K. FT/FT)	My (K. FT/FT)	Mxy (K. FT/FT)
1	0.000	0.000	0.098	-0.081	-0.050
2	3.333	0.000	0.256	0.067	-0.081
3	6.667	0.000	0.132	-0.006	-0.059
4	10.000	0.000	0.121	-0.013	-0.020
5	13.333	0.000	0.104	-0.008	-0.009
6	16.667	0.000	0.090	0.017	-0.007
7	20.000	0.000	0.016	0.028	0.002
8	0.000	2.000	0.022	-0.226	-0.029
9	3.333	2.000	0.106	-0.125	-0.052
10	6.667	2.000	0.208	0.015	-0.053
11	10.000	2.000	0.130	-0.019	-0.030
12	13.333	2.000	0.044	-0.102	-0.017
13	16.667	2.000	0.015	-0.124	-0.005
14	20.000	2.000	-0.014	-0.130	0.004
15	0.000	4.000	-0.034	-0.237	0.004
16	3.333	4.000	0.079	-0.177	-0.012
17	6.667	4.000	0.168	-0.060	-0.021
18	10.000	4.000	0.142	0.009	-0.027
19	13.333	4.000	0.108	0.028	-0.023
20	16.667	4.000	0.086	0.028	-0.008
21	20.000	4.000	0.038	-0.036	-0.001
22	0.000	6.000	0.014	0.069	0.000
23	3.333	6.000	0.200	0.053	0.000
24	6.667	6.000	0.148	-0.065	0.000
25	10.000	6.000	0.129	-0.028	0.000
26	13.333	6.000	0.150	0.087	0.000
27	16.667	6.000	0.161	0.161	0.000
28	20.000	6.000	0.098	0.129	0.000
29	0.000	8.000	-0.034	-0.237	-0.004
30	3.333	8.000	0.079	-0.177	0.012
31	6.667	8.000	0.168	-0.060	0.021
32	10.000	8.000	0.142	0.009	0.027
33	13.333	8.000	0.108	0.028	0.023
34	16.667	8.000	0.086	0.028	0.008
35	20.000	8.000	0.038	-0.036	0.001
36	0.000	10.000	0.022	-0.226	0.029
37	3.333	10.000	0.106	-0.125	0.052
38	6.667	10.000	0.208	0.015	0.053
39	10.000	10.000	0.130	-0.019	0.030
40	13.333	10.000	0.044	-0.102	0.017
41	16.667	10.000	0.015	-0.124	0.005
42	20.000	10.000	-0.014	-0.130	-0.004
43	0.000	12.000	0.098	-0.081	0.050
44	3.333	12.000	0.256	0.067	0.081
45	6.667	12.000	0.132	-0.006	0.059
46	10.000	12.000	0.121	-0.013	0.020
47	13.333	12.000	0.104	-0.008	0.009
48	16.667	12.000	0.090	0.017	0.007
49	20.000	12.000	0.016	0.028	-0.002

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-3 .SX PAGE 1

INTERVAL = 200 TIME = 0.020 DISTANCE = 2.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	0.067	0.006	-0.056
2	3.333	0.000	0.096	-0.012	-0.054
3	6.667	0.000	0.189	0.046	-0.057
4	10.000	0.000	0.006	0.007	-0.025
5	13.333	0.000	-0.092	-0.019	-0.004
6	16.667	0.000	-0.039	-0.010	-0.002
7	20.000	0.000	0.011	0.030	-0.001
8	0.000	2.000	-0.043	-0.195	-0.021
9	3.333	2.000	0.032	-0.085	-0.032
10	6.667	2.000	0.219	0.063	-0.047
11	10.000	2.000	0.061	0.010	-0.031
12	13.333	2.000	-0.132	-0.090	-0.011
13	16.667	2.000	-0.090	-0.076	-0.002
14	20.000	2.000	-0.033	-0.059	0.000
15	0.000	4.000	-0.034	-0.132	0.010
16	3.333	4.000	0.002	-0.132	-0.001
17	6.667	4.000	0.189	0.012	-0.024
18	10.000	4.000	0.071	0.023	-0.027
19	13.333	4.000	-0.079	0.001	-0.015
20	16.667	4.000	-0.051	0.019	-0.004
21	20.000	4.000	0.004	0.016	-0.004
22	0.000	6.000	0.024	0.039	0.000
23	3.333	6.000	0.019	-0.054	0.000
24	6.667	6.000	0.144	-0.041	0.000
25	10.000	6.000	0.062	-0.054	0.000
26	13.333	6.000	-0.031	0.043	0.000
27	16.667	6.000	-0.018	0.108	0.000
28	20.000	6.000	0.019	0.111	0.000
29	0.000	8.000	-0.034	-0.132	-0.010
30	3.333	8.000	0.002	-0.132	0.001
31	6.667	8.000	0.189	0.012	0.024
32	10.000	8.000	0.071	0.023	0.027
33	13.333	8.000	-0.079	0.001	0.015
34	16.667	8.000	-0.051	0.019	0.004
35	20.000	8.000	0.004	0.016	0.004
36	0.000	10.000	-0.043	-0.194	0.021
37	3.333	10.000	0.032	-0.085	0.032
38	6.667	10.000	0.219	0.063	0.047
39	10.000	10.000	0.061	0.010	0.031
40	13.333	10.000	-0.132	-0.090	0.011
41	16.667	10.000	-0.090	-0.076	0.002
42	20.000	10.000	-0.033	-0.059	0.000
43	0.000	12.000	0.067	0.006	0.056
44	3.333	12.000	0.096	-0.012	0.054
45	6.667	12.000	0.189	0.046	0.057
46	10.000	12.000	0.006	0.007	0.025
47	13.333	12.000	-0.092	-0.019	0.004
48	16.667	12.000	-0.039	-0.010	0.002
49	20.000	12.000	0.011	0.030	0.001

INTERVAL = 400 TIME = 0.040 DISTANCE = 4.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	0.129	-0.052	-0.066
2	3.333	0.000	0.234	0.038	-0.072
3	6.667	0.000	0.160	-0.002	-0.052
4	10.000	0.000	0.148	0.019	-0.035
5	13.333	0.000	0.072	-0.027	-0.010
6	16.667	0.000	0.100	0.014	0.003
7	20.000	0.000	0.014	0.036	0.010
8	0.000	2.000	-0.013	-0.272	-0.028
9	3.333	2.000	0.137	-0.108	-0.048
10	6.667	2.000	0.182	-0.035	-0.048
11	10.000	2.000	0.099	-0.067	-0.034
12	13.333	2.000	0.082	-0.061	-0.018
13	16.667	2.000	0.010	-0.127	-0.002
14	20.000	2.000	-0.025	-0.163	0.007
15	0.000	4.000	-0.013	-0.190	0.007
16	3.333	4.000	0.115	-0.126	-0.014
17	6.667	4.000	0.185	-0.034	-0.028
18	10.000	4.000	0.133	-0.010	-0.024
19	13.333	4.000	0.108	0.022	-0.018
20	16.667	4.000	0.083	0.031	-0.012
21	20.000	4.000	0.048	-0.031	-0.008
22	0.000	6.000	0.016	0.000	0.000
23	3.333	6.000	0.138	-0.032	0.000
24	6.667	6.000	0.162	-0.053	0.000
25	10.000	6.000	0.176	0.030	0.000
26	13.333	6.000	0.118	0.059	0.000
27	16.667	6.000	0.161	0.162	0.000
28	20.000	6.000	0.109	0.145	0.000
29	0.000	8.000	-0.013	-0.190	-0.007
30	3.333	8.000	0.115	-0.126	0.014
31	6.667	8.000	0.185	-0.034	0.028
32	10.000	8.000	0.133	-0.010	0.024
33	13.333	8.000	0.108	0.022	0.018
34	16.667	8.000	0.083	0.031	0.012
35	20.000	8.000	0.048	-0.031	0.008
36	0.000	10.000	-0.013	-0.272	0.028
37	3.333	10.000	0.137	-0.108	0.048
38	6.667	10.000	0.182	-0.035	0.048
39	10.000	10.000	0.099	-0.067	0.034
40	13.333	10.000	0.082	-0.061	0.018
41	16.667	10.000	0.010	-0.127	0.002
42	20.000	10.000	-0.025	-0.163	-0.007
43	0.000	12.000	0.129	-0.052	0.066
44	3.333	12.000	0.234	0.038	0.072
45	6.667	12.000	0.160	-0.002	0.052
46	10.000	12.000	0.148	0.019	0.035
47	13.333	12.000	0.072	-0.027	0.010
48	16.667	12.000	0.100	0.014	-0.003
49	20.000	12.000	0.014	0.036	-0.010

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-4 .SX PAGE 1

INTERVAL = 200 TIME = 0.040 DISTANCE = 2.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	-0.056	0.052	-0.032
2	3.333	0.000	-0.165	0.020	-0.032
3	6.667	0.000	-0.073	-0.048	-0.018
4	10.000	0.000	0.157	-0.028	0.021
5	13.333	0.000	0.200	0.042	0.028
6	16.667	0.000	0.034	0.004	0.035
7	20.000	0.000	0.009	0.008	0.040
8	0.000	2.000	-0.103	-0.131	-0.006
9	3.333	2.000	-0.312	-0.193	-0.007
10	6.667	2.000	-0.030	0.026	-0.012
11	10.000	2.000	0.219	0.089	0.005
12	13.333	2.000	0.153	-0.033	0.021
13	16.667	2.000	0.032	-0.074	0.038
14	20.000	2.000	0.005	-0.026	0.047
15	0.000	4.000	-0.116	-0.051	0.015
16	3.333	4.000	-0.282	-0.166	0.023
17	6.667	4.000	-0.077	-0.046	0.010
18	10.000	4.000	0.204	0.065	-0.008
19	13.333	4.000	0.212	0.028	0.003
20	16.667	4.000	0.055	-0.070	0.031
21	20.000	4.000	-0.035	-0.127	0.043
22	0.000	6.000	0.046	0.271	0.000
23	3.333	6.000	-0.151	0.054	0.000
24	6.667	6.000	-0.162	-0.049	0.000
25	10.000	6.000	0.117	-0.013	0.000
26	13.333	6.000	0.270	0.064	0.000
27	16.667	6.000	0.095	-0.031	0.000
28	20.000	6.000	-0.005	-0.099	0.000
29	0.000	8.000	-0.116	-0.051	-0.015
30	3.333	8.000	-0.282	-0.166	-0.023
31	6.667	8.000	-0.077	-0.046	-0.010
32	10.000	8.000	0.204	0.065	0.009
33	13.333	8.000	0.212	0.028	-0.003
34	16.667	8.000	0.055	-0.070	-0.030
35	20.000	8.000	-0.035	-0.127	-0.043
36	0.000	10.000	-0.103	-0.131	0.006
37	3.333	10.000	-0.312	-0.193	0.007
38	6.667	10.000	-0.030	0.026	0.012
39	10.000	10.000	0.219	0.089	-0.005
40	13.333	10.000	0.153	-0.033	-0.021
41	16.667	10.000	0.032	-0.074	-0.038
42	20.000	10.000	0.005	-0.026	-0.047
43	0.000	12.000	-0.057	0.052	0.032
44	3.333	12.000	-0.165	0.020	0.032
45	6.667	12.000	-0.073	-0.048	0.018
46	10.000	12.000	0.157	-0.028	-0.021
47	13.333	12.000	0.200	0.042	-0.028
48	16.667	12.000	0.034	0.004	-0.035
49	20.000	12.000	0.009	0.008	-0.040

INTERVAL = 400 TIME = 0.080 DISTANCE = 4.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	-0.037	0.012	0.007
2	3.333	0.000	-0.139	0.020	0.007
3	6.667	0.000	-0.084	-0.056	0.001
4	10.000	0.000	0.216	-0.016	0.004
5	13.333	0.000	0.304	0.040	0.014
6	16.667	0.000	0.155	0.025	0.021
7	20.000	0.000	-0.003	-0.013	0.028
8	0.000	2.000	-0.084	-0.171	0.019
9	3.333	2.000	-0.318	-0.270	0.023
10	6.667	2.000	-0.144	-0.119	0.011
11	10.000	2.000	0.188	-0.001	0.002
12	13.333	2.000	0.309	0.016	0.015
13	16.667	2.000	0.174	-0.009	0.024
14	20.000	2.000	0.028	-0.055	0.025
15	0.000	4.000	-0.101	-0.018	0.018
16	3.333	4.000	-0.267	-0.181	0.031
17	6.667	4.000	-0.187	-0.153	0.031
18	10.000	4.000	0.180	-0.012	0.005
19	13.333	4.000	0.339	0.014	0.009
20	16.667	4.000	0.131	-0.098	0.023
21	20.000	4.000	0.020	-0.104	0.020
22	0.000	6.000	0.034	0.362	0.000
23	3.333	6.000	-0.007	0.253	0.000
24	6.667	6.000	-0.171	0.039	0.000
25	10.000	6.000	0.127	0.036	0.000
26	13.333	6.000	0.367	0.045	0.000
27	16.667	6.000	0.164	-0.099	0.000
28	20.000	6.000	0.014	-0.167	0.000
29	0.000	8.000	-0.101	-0.018	-0.018
30	3.333	8.000	-0.267	-0.184	-0.031
31	6.667	8.000	-0.187	-0.153	-0.031
32	10.000	8.000	0.180	-0.012	-0.005
33	13.333	8.000	0.339	0.014	-0.009
34	16.667	8.000	0.131	-0.098	-0.023
35	20.000	8.000	0.020	-0.104	-0.020
36	0.000	10.000	-0.084	-0.171	-0.019
37	3.333	10.000	-0.318	-0.270	-0.023
38	6.667	10.000	-0.144	-0.119	-0.011
39	10.000	10.000	0.188	-0.001	-0.002
40	13.333	10.000	0.309	0.016	-0.015
41	16.667	10.000	0.174	-0.009	-0.024
42	20.000	10.000	0.028	-0.055	-0.025
43	0.000	12.000	-0.037	0.012	-0.007
44	3.333	12.000	-0.139	0.020	-0.007
45	6.667	12.000	-0.084	-0.056	-0.001
46	10.000	12.000	0.216	-0.016	-0.004
47	13.333	12.000	0.304	0.040	-0.014
48	16.667	12.000	0.155	0.025	-0.021
49	20.000	12.000	-0.003	-0.013	-0.028

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-5 .SX PAGE 1

INTERVAL = 200 TIME = 0.040 DISTANCE = 2.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	0.290	-0.147	-0.046
2	3.333	0.000	0.621	0.083	-0.070
3	6.667	0.000	0.450	0.022	-0.047
4	10.000	0.000	0.261	0.022	-0.038
5	13.333	0.000	0.068	-0.002	-0.030
6	16.667	0.000	0.016	-0.004	-0.002
7	20.000	0.000	0.027	0.053	0.015
8	0.000	2.000	0.075	-0.410	0.010
9	3.333	2.000	0.501	-0.067	-0.028
10	6.667	2.000	0.549	0.061	-0.037
11	10.000	2.000	0.252	-0.042	-0.041
12	13.333	2.000	0.020	-0.142	-0.036
13	16.667	2.000	-0.055	-0.169	-0.002
14	20.000	2.000	-0.045	-0.152	0.018
15	0.000	4.000	-0.033	-0.419	0.088
16	3.333	4.000	0.451	-0.138	0.030
17	6.667	4.000	0.480	-0.047	-0.006
18	10.000	4.000	0.243	-0.022	-0.031
19	13.333	4.000	0.101	0.014	-0.034
20	16.667	4.000	0.045	0.022	-0.005
21	20.000	4.000	0.022	-0.047	0.009
22	0.000	6.000	0.083	0.269	0.045
23	3.333	6.000	0.491	0.096	0.035
24	6.667	6.000	0.444	-0.113	0.020
25	10.000	6.000	0.252	-0.078	0.011
26	13.333	6.000	0.152	0.072	0.004
27	16.667	6.000	0.138	0.185	0.009
28	20.000	6.000	0.099	0.186	0.012
29	0.000	8.000	-0.030	-0.423	0.001
30	3.333	8.000	0.402	-0.162	0.044
31	6.667	8.000	0.504	0.009	0.053
32	10.000	8.000	0.239	0.020	0.046
33	13.333	8.000	0.098	0.031	0.039
34	16.667	8.000	0.064	0.059	0.032
35	20.000	8.000	0.054	0.037	0.033
36	0.000	10.000	0.075	-0.395	0.076
37	3.333	10.000	0.450	-0.081	0.114
38	6.667	10.000	0.527	0.091	0.098
39	10.000	10.000	0.209	-0.021	0.049
40	13.333	10.000	0.041	-0.105	0.040
41	16.667	10.000	-0.007	-0.116	0.040
42	20.000	10.000	-0.010	-0.111	0.037
43	0.000	12.000	0.263	-0.153	0.127
44	3.333	12.000	0.612	0.115	0.163
45	6.667	12.000	0.365	0.030	0.107
46	10.000	12.000	0.172	-0.014	0.040
47	13.333	12.000	0.111	-0.001	0.037
48	16.667	12.000	0.069	0.015	0.045
49	20.000	12.000	0.015	0.025	0.042

INTERVAL = 400 TIME = 0.080 DISTANCE = 4.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	-0.167	0.080	0.119
2	3.333	0.000	-0.301	-0.183	0.112
3	6.667	0.000	0.243	0.003	-0.005
4	10.000	0.000	0.328	0.071	-0.087
5	13.333	0.000	0.141	0.019	-0.088
6	16.667	0.000	0.018	-0.034	-0.067
7	20.000	0.000	-0.005	0.020	-0.060
8	0.000	2.000	-0.059	0.167	0.088
9	3.333	2.000	-0.288	-0.056	0.083
10	6.667	2.000	0.039	-0.067	-0.005
11	10.000	2.000	0.272	0.016	-0.064
12	13.333	2.000	0.241	0.100	-0.079
13	16.667	2.000	0.068	0.036	-0.083
14	20.000	2.000	-0.044	-0.100	-0.083
15	0.000	4.000	-0.106	0.040	0.068
16	3.333	4.000	-0.389	-0.135	0.057
17	6.667	4.000	0.052	0.033	-0.020
18	10.000	4.000	0.280	0.059	-0.039
19	13.333	4.000	0.195	0.070	-0.062
20	16.667	4.000	0.038	0.054	-0.101
21	20.000	4.000	0.036	0.047	-0.125
22	0.000	6.000	0.002	0.016	0.082
23	3.333	6.000	-0.408	-0.098	0.050
24	6.667	6.000	0.045	0.188	-0.008
25	10.000	6.000	0.310	0.138	-0.037
26	13.333	6.000	0.132	-0.032	-0.059
27	16.667	6.000	-0.002	-0.021	-0.085
28	20.000	6.000	0.038	0.109	-0.101
29	0.000	8.000	-0.066	0.096	0.084
30	3.333	8.000	-0.510	-0.193	0.025
31	6.667	8.000	-0.008	-0.017	-0.005
32	10.000	8.000	0.237	-0.012	-0.042
33	13.333	8.000	0.108	-0.036	-0.052
34	16.667	8.000	0.012	0.053	-0.045
35	20.000	8.000	0.052	0.163	-0.038
36	0.000	10.000	-0.052	0.254	0.027
37	3.333	10.000	-0.495	-0.146	-0.025
38	6.667	10.000	-0.093	-0.140	-0.024
39	10.000	10.000	0.205	-0.045	-0.020
40	13.333	10.000	0.174	0.057	-0.012
41	16.667	10.000	0.030	0.075	-0.016
42	20.000	10.000	0.001	0.042	-0.019
43	0.000	12.000	-0.249	0.123	-0.038
44	3.333	12.000	-0.505	-0.199	-0.077
45	6.667	12.000	0.093	-0.023	-0.034
46	10.000	12.000	0.289	0.071	0.003
47	13.333	12.000	0.132	0.054	0.010
48	16.667	12.000	-0.054	-0.022	-0.014
49	20.000	12.000	0.000	-0.009	-0.021

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-6 .SX PAGE 1

INTERVAL = 200 TIME = 0.040 DISTANCE = 2.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	0.336	-0.148	-0.028
2	3.333	0.000	0.668	0.067	-0.041
3	6.667	0.000	0.543	0.025	-0.036
4	10.000	0.000	0.314	0.047	-0.067
5	13.333	0.000	0.009	-0.009	-0.066
6	16.667	0.000	-0.030	-0.021	-0.021
7	20.000	0.000	0.037	0.078	0.004
8	0.000	2.000	0.078	-0.473	0.040
9	3.333	2.000	0.558	-0.082	0.004
10	6.667	2.000	0.611	0.055	-0.020
11	10.000	2.000	0.279	-0.049	-0.065
12	13.333	2.000	-0.038	-0.180	-0.075
13	16.667	2.000	-0.104	-0.207	-0.026
14	20.000	2.000	-0.077	-0.196	0.006
15	0.000	4.000	-0.047	-0.471	0.136
16	3.333	4.000	0.515	-0.140	0.066
17	6.667	4.000	0.505	-0.077	0.010
18	10.000	4.000	0.234	-0.046	-0.050
19	13.333	4.000	0.056	0.006	-0.071
20	16.667	4.000	0.021	0.029	-0.033
21	20.000	4.000	0.016	-0.060	-0.013
22	0.000	6.000	0.089	0.295	0.092
23	3.333	6.000	0.536	0.106	0.072
24	6.667	6.000	0.473	-0.123	0.035
25	10.000	6.000	0.229	-0.095	0.002
26	13.333	6.000	0.104	0.073	-0.022
27	16.667	6.000	0.128	0.233	-0.012
28	20.000	6.000	0.114	0.259	-0.007
29	0.000	8.000	-0.025	-0.446	0.043
30	3.333	8.000	0.420	-0.176	0.082
31	6.667	8.000	0.535	0.034	0.074
32	10.000	8.000	0.200	0.032	0.040
33	13.333	8.000	0.052	0.051	0.023
34	16.667	8.000	0.061	0.121	0.029
35	20.000	8.000	0.082	0.137	0.038
36	0.000	10.000	0.077	-0.425	0.122
37	3.333	10.000	0.468	-0.088	0.162
38	6.667	10.000	0.533	0.108	0.127
39	10.000	10.000	0.145	-0.022	0.045
40	13.333	10.000	0.006	-0.087	0.031
41	16.667	10.000	-0.008	-0.081	0.048
42	20.000	10.000	0.008	-0.075	0.056
43	0.000	12.000	0.276	-0.166	0.176
44	3.333	12.000	0.653	0.143	0.217
45	6.667	12.000	0.325	0.045	0.137
46	10.000	12.000	0.084	-0.031	0.033
47	13.333	12.000	0.090	-0.004	0.031
48	16.667	12.000	0.074	0.023	0.057
49	20.000	12.000	0.009	0.008	0.062

INTERVAL = 400 TIME = 0.080 DISTANCE = 4.000

JOINT	X (FT)	Y (FT)	Mx (K.FT/FT)	My (K.FT/FT)	Mxy (K.FT/FT)
1	0.000	0.000	-0.123	0.074	0.155
2	3.333	0.000	-0.234	-0.182	0.141
3	6.667	0.000	0.293	0.005	0.001
4	10.000	0.000	0.380	0.062	-0.110
5	13.333	0.000	0.230	0.022	-0.121
6	16.667	0.000	0.067	-0.040	-0.099
7	20.000	0.000	-0.007	0.031	-0.087
8	0.000	2.000	-0.057	0.121	0.142
9	3.333	2.000	-0.190	-0.007	0.118
10	6.667	2.000	0.066	-0.060	0.003
11	10.000	2.000	0.309	0.026	-0.083
12	13.333	2.000	0.363	0.152	-0.114
13	16.667	2.000	0.123	0.029	-0.124
14	20.000	2.000	-0.061	-0.168	-0.122
15	0.000	4.000	-0.133	-0.042	0.150
16	3.333	4.000	-0.336	-0.134	0.107
17	6.667	4.000	0.059	0.030	-0.011
18	10.000	4.000	0.309	0.076	-0.052
19	13.333	4.000	0.305	0.132	-0.101
20	16.667	4.000	0.087	0.058	-0.166
21	20.000	4.000	0.030	-0.017	-0.195
22	0.000	6.000	-0.001	-0.051	0.176
23	3.333	6.000	-0.434	-0.168	0.116
24	6.667	6.000	0.028	0.149	0.007
25	10.000	6.000	0.318	0.120	-0.043
26	13.333	6.000	0.172	-0.045	-0.093
27	16.667	6.000	0.032	-0.034	-0.161
28	20.000	6.000	0.044	0.092	-0.194
29	0.000	8.000	-0.040	0.101	0.175
30	3.333	8.000	-0.564	-0.228	0.083
31	6.667	8.000	-0.052	-0.070	0.008
32	10.000	8.000	0.226	-0.076	-0.048
33	13.333	8.000	0.097	-0.097	-0.078
34	16.667	8.000	0.034	0.063	-0.105
35	20.000	8.000	0.064	0.225	-0.112
36	0.000	10.000	-0.033	0.327	0.097
37	3.333	10.000	-0.575	-0.166	0.014
38	6.667	10.000	-0.166	-0.195	-0.019
39	10.000	10.000	0.200	-0.081	-0.023
40	13.333	10.000	0.163	0.037	-0.021
41	16.667	10.000	0.037	0.111	-0.048
42	20.000	10.000	0.028	0.124	-0.060
43	0.000	12.000	-0.294	0.145	0.009
44	3.333	12.000	-0.614	-0.220	-0.054
45	6.667	12.000	0.037	-0.047	-0.036
46	10.000	12.000	0.322	0.089	0.003
47	13.333	12.000	0.132	0.073	0.009
48	16.667	12.000	-0.086	-0.013	-0.036
49	20.000	12.000	0.004	-0.029	-0.050

INTERVAL = 200 TIME = 0.040 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.43431
2	3.333	0.000	-0.59936
3	6.667	0.000	-0.41796
4	10.000	0.000	-0.39837
5	13.333	0.000	-0.44160
6	16.667	0.000	-0.52687
7	20.000	0.000	-0.29580
8	0.000	2.000	-1.12887
9	3.333	2.000	-1.36013
10	6.667	2.000	-0.84142
11	10.000	2.000	-0.74440
12	13.333	2.000	-0.86806
13	16.667	2.000	-1.08439
14	20.000	2.000	-0.64454
15	0.000	4.000	-1.17185
16	3.333	4.000	-1.44136
17	6.667	4.000	-0.89440
18	10.000	4.000	-0.76835
19	13.333	4.000	-0.86607
20	16.667	4.000	-1.06654
21	20.000	4.000	-0.63581
22	0.000	6.000	-1.16904
23	3.333	6.000	-1.45658
24	6.667	6.000	-0.91559
25	10.000	6.000	-0.77741
26	13.333	6.000	-0.85899
27	16.667	6.000	-1.04886
28	20.000	6.000	-0.62627
29	0.000	8.000	-1.17186
30	3.333	8.000	-1.44137
31	6.667	8.000	-0.89441
32	10.000	8.000	-0.76836
33	13.333	8.000	-0.86607
34	16.667	8.000	-1.06654
35	20.000	8.000	-0.63581
36	0.000	10.000	-1.12887
37	3.333	10.000	-1.36014
38	6.667	10.000	-0.84143
39	10.000	10.000	-0.74440
40	13.333	10.000	-0.86807
41	16.667	10.000	-1.08439
42	20.000	10.000	-0.64454
43	0.000	12.000	-0.43431
44	3.333	12.000	-0.59936
45	6.667	12.000	-0.41796
46	10.000	12.000	-0.39838
47	13.333	12.000	-0.44160
48	16.667	12.000	-0.52687
49	20.000	12.000	-0.29580

TOTAL = -40.1138

INTERVAL = 400 TIME = 0.080 DISTANCE 4.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.45855
2	3.333	0.000	-0.96643
3	6.667	0.000	-0.74067
4	10.000	0.000	-0.56046
5	13.333	0.000	-0.52772
6	16.667	0.000	-0.56343
7	20.000	0.000	-0.28419
8	0.000	2.000	-1.01872
9	3.333	2.000	-1.93333
10	6.667	2.000	-1.53211
11	10.000	2.000	-1.16946
12	13.333	2.000	-1.06477
13	16.667	2.000	-1.12819
14	20.000	2.000	-0.59050
15	0.000	4.000	-1.00770
16	3.333	4.000	-1.92884
17	6.667	4.000	-1.53298
18	10.000	4.000	-1.17165
19	13.333	4.000	-1.06703
20	16.667	4.000	-1.11536
21	20.000	4.000	-0.57455
22	0.000	6.000	-1.00423
23	3.333	6.000	-1.92020
24	6.667	6.000	-1.52318
25	10.000	6.000	-1.16420
26	13.333	6.000	-1.06907
27	16.667	6.000	-1.11402
28	20.000	6.000	-0.56768
29	0.000	8.000	-1.00770
30	3.333	8.000	-1.92883
31	6.667	8.000	-1.53298
32	10.000	8.000	-1.17165
33	13.333	8.000	-1.06704
34	16.667	8.000	-1.11537
35	20.000	8.000	-0.57455
36	0.000	10.000	-1.01872
37	3.333	10.000	-1.93333
38	6.667	10.000	-1.53211
39	10.000	10.000	-1.16946
40	13.333	10.000	-1.06479
41	16.667	10.000	-1.12821
42	20.000	10.000	-0.59051
43	0.000	12.000	-0.45855
44	3.333	12.000	-0.96643
45	6.667	12.000	-0.74067
46	10.000	12.000	-0.56046
47	13.333	12.000	-0.52773
48	16.667	12.000	-0.56345
49	20.000	12.000	-0.28420

TOTAL = -50.2359

INTERVAL = 100 TIME = 0.020 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.26722
2	3.333	0.000	-0.48669
3	6.667	0.000	-0.45877
4	10.000	0.000	-0.48768
5	13.333	0.000	-0.52557
6	16.667	0.000	-0.52874
7	20.000	0.000	-0.25194
8	0.000	2.000	-0.58859
9	3.333	2.000	-1.04187
10	6.667	2.000	-0.92057
11	10.000	2.000	-0.96542
12	13.333	2.000	-1.05722
13	16.667	2.000	-1.05917
14	20.000	2.000	-0.50172
15	0.000	4.000	-0.61455
16	3.333	4.000	-1.08802
17	6.667	4.000	-0.94715
18	10.000	4.000	-0.96677
19	13.333	4.000	-1.03912
20	16.667	4.000	-1.03680
21	20.000	4.000	-0.49217
22	0.000	6.000	-0.61953
23	3.333	6.000	-1.09557
24	6.667	6.000	-0.95817
25	10.000	6.000	-0.97011
26	13.333	6.000	-1.02639
27	16.667	6.000	-1.02237
28	20.000	6.000	-0.48672
29	0.000	8.000	-0.61455
30	3.333	8.000	-1.08802
31	6.667	8.000	-0.94715
32	10.000	8.000	-0.96677
33	13.333	8.000	-1.03912
34	16.667	8.000	-1.03680
35	20.000	8.000	-0.49217
36	0.000	10.000	-0.58859
37	3.333	10.000	-1.04187
38	6.667	10.000	-0.92057
39	10.000	10.000	-0.96542
40	13.333	10.000	-1.05722
41	16.667	10.000	-1.05917
42	20.000	10.000	-0.50172
43	0.000	12.000	-0.26722
44	3.333	12.000	-0.48669
45	6.667	12.000	-0.45877
46	10.000	12.000	-0.48768
47	13.333	12.000	-0.52557
48	16.667	12.000	-0.52874
49	20.000	12.000	-0.25194

TOTAL = -36.8304

INTERVAL = 200 TIME = 0.040 DISTANCE 4.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.31269
2	3.333	0.000	-0.53538
3	6.667	0.000	-0.46385
4	10.000	0.000	-0.44764
5	13.333	0.000	-0.46990
6	16.667	0.000	-0.52704
7	20.000	0.000	-0.28761
8	0.000	2.000	-0.76178
9	3.333	2.000	-1.19964
10	6.667	2.000	-0.95550
11	10.000	2.000	-0.88248
12	13.333	2.000	-0.93814
13	16.667	2.000	-1.08098
14	20.000	2.000	-0.61967
15	0.000	4.000	-0.80793
16	3.333	4.000	-1.26375
17	6.667	4.000	-0.99550
18	10.000	4.000	-0.89518
19	13.333	4.000	-0.92779
20	16.667	4.000	-1.05995
21	20.000	4.000	-0.61111
22	0.000	6.000	-0.81400
23	3.333	6.000	-1.27199
24	6.667	6.000	-1.00893
25	10.000	6.000	-0.89986
26	13.333	6.000	-0.91744
27	16.667	6.000	-1.04081
28	20.000	6.000	-0.60188
29	0.000	8.000	-0.80793
30	3.333	8.000	-1.26375
31	6.667	8.000	-0.99551
32	10.000	8.000	-0.89518
33	13.333	8.000	-0.92779
34	16.667	8.000	-1.05994
35	20.000	8.000	-0.61111
36	0.000	10.000	-0.76179
37	3.333	10.000	-1.19964
38	6.667	10.000	-0.95550
39	10.000	10.000	-0.88248
40	13.333	10.000	-0.93814
41	16.667	10.000	-1.08098
42	20.000	10.000	-0.61967
43	0.000	12.000	-0.31270
44	3.333	12.000	-0.53538
45	6.667	12.000	-0.46386
46	10.000	12.000	-0.44764
47	13.333	12.000	-0.46990
48	16.667	12.000	-0.52704
49	20.000	12.000	-0.28761

TOTAL = -38.6419

INTERVAL = 200 TIME = 0.020 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.26787
2	3.333	0.000	-0.49224
3	6.667	0.000	-0.45989
4	10.000	0.000	-0.48475
5	13.333	0.000	-0.52223
6	16.667	0.000	-0.52703
7	20.000	0.000	-0.25269
8	0.000	2.000	-0.59841
9	3.333	2.000	-1.05153
10	6.667	2.000	-0.92420
11	10.000	2.000	-0.96181
12	13.333	2.000	-1.05061
13	16.667	2.000	-1.05965
14	20.000	2.000	-0.50474
15	0.000	4.000	-0.62119
16	3.333	4.000	-1.09780
17	6.667	4.000	-0.95277
18	10.000	4.000	-0.96339
19	13.333	4.000	-1.03252
20	16.667	4.000	-1.03639
21	20.000	4.000	-0.49538
22	0.000	6.000	-0.62413
23	3.333	6.000	-1.11013
24	6.667	6.000	-0.96575
25	10.000	6.000	-0.96613
26	13.333	6.000	-1.02177
27	16.667	6.000	-1.02142
28	20.000	6.000	-0.48915
29	0.000	8.000	-0.62119
30	3.333	8.000	-1.09780
31	6.667	8.000	-0.95277
32	10.000	8.000	-0.96339
33	13.333	8.000	-1.03252
34	16.667	8.000	-1.03639
35	20.000	8.000	-0.49538
36	0.000	10.000	-0.59841
37	3.333	10.000	-1.05153
38	6.667	10.000	-0.92421
39	10.000	10.000	-0.96182
40	13.333	10.000	-1.05061
41	16.667	10.000	-1.05965
42	20.000	10.000	-0.50474
43	0.000	12.000	-0.26787
44	3.333	12.000	-0.49224
45	6.667	12.000	-0.45989
46	10.000	12.000	-0.48475
47	13.333	12.000	-0.52223
48	16.667	12.000	-0.52703
49	20.000	12.000	-0.25269

TOTAL = -36.9127

INTERVAL = 400 TIME = 0.040 DISTANCE 4.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.31677
2	3.333	0.000	-0.54099
3	6.667	0.000	-0.46228
4	10.000	0.000	-0.44609
5	13.333	0.000	-0.47192
6	16.667	0.000	-0.52680
7	20.000	0.000	-0.28709
8	0.000	2.000	-0.77778
9	3.333	2.000	-1.20617
10	6.667	2.000	-0.95936
11	10.000	2.000	-0.88619
12	13.333	2.000	-0.93698
13	16.667	2.000	-1.08150
14	20.000	2.000	-0.62072
15	0.000	4.000	-0.82337
16	3.333	4.000	-1.26967
17	6.667	4.000	-0.99544
18	10.000	4.000	-0.89598
19	13.333	4.000	-0.92896
20	16.667	4.000	-1.06105
21	20.000	4.000	-0.61116
22	0.000	6.000	-0.83232
23	3.333	6.000	-1.28547
24	6.667	6.000	-1.00727
25	10.000	6.000	-0.89473
26	13.333	6.000	-0.92114
27	16.667	6.000	-1.04228
28	20.000	6.000	-0.60084
29	0.000	8.000	-0.82338
30	3.333	8.000	-1.26968
31	6.667	8.000	-0.99544
32	10.000	8.000	-0.89598
33	13.333	8.000	-0.92895
34	16.667	8.000	-1.06105
35	20.000	8.000	-0.61116
36	0.000	10.000	-0.77779
37	3.333	10.000	-1.20618
38	6.667	10.000	-0.95937
39	10.000	10.000	-0.88619
40	13.333	10.000	-0.93698
41	16.667	10.000	-1.08150
42	20.000	10.000	-0.62071
43	0.000	12.000	-0.31677
44	3.333	12.000	-0.54099
45	6.667	12.000	-0.46228
46	10.000	12.000	-0.44609
47	13.333	12.000	-0.47192
48	16.667	12.000	-0.52680
49	20.000	12.000	-0.28709

TOTAL = -38.7966

INTERVAL = 200 TIME = 0.040 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.31527
2	3.333	0.000	-0.75875
3	6.667	0.000	-0.61459
4	10.000	0.000	-0.43135
5	13.333	0.000	-0.37883
6	16.667	0.000	-0.42944
7	20.000	0.000	-0.25825
8	0.000	2.000	-0.76560
9	3.333	2.000	-1.62649
10	6.667	2.000	-1.27675
11	10.000	2.000	-0.80457
12	13.333	2.000	-0.66905
13	16.667	2.000	-0.88858
14	20.000	2.000	-0.58549
15	0.000	4.000	-0.77051
16	3.333	4.000	-1.63979
17	6.667	4.000	-1.30511
18	10.000	4.000	-0.82392
19	13.333	4.000	-0.68294
20	16.667	4.000	-0.94315
21	20.000	4.000	-0.63965
22	0.000	6.000	-0.74638
23	3.333	6.000	-1.61594
24	6.667	6.000	-1.32223
25	10.000	6.000	-0.84295
26	13.333	6.000	-0.67971
27	16.667	6.000	-0.95583
28	20.000	6.000	-0.65941
29	0.000	8.000	-0.77051
30	3.333	8.000	-1.63979
31	6.667	8.000	-1.30511
32	10.000	8.000	-0.82392
33	13.333	8.000	-0.68294
34	16.667	8.000	-0.94315
35	20.000	8.000	-0.63965
36	0.000	10.000	-0.76560
37	3.333	10.000	-1.62649
38	6.667	10.000	-1.27675
39	10.000	10.000	-0.80457
40	13.333	10.000	-0.66905
41	16.667	10.000	-0.88858
42	20.000	10.000	-0.58548
43	0.000	12.000	-0.31527
44	3.333	12.000	-0.75875
45	6.667	12.000	-0.61459
46	10.000	12.000	-0.43135
47	13.333	12.000	-0.37883
48	16.667	12.000	-0.42944
49	20.000	12.000	-0.25824

TOTAL = -40.0386

INTERVAL = 400 TIME = 0.080 DISTANCE 4.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.43703
2	3.333	0.000	-0.97042
3	6.667	0.000	-0.73483
4	10.000	0.000	-0.42550
5	13.333	0.000	-0.33507
6	16.667	0.000	-0.38621
7	20.000	0.000	-0.27346
8	0.000	2.000	-1.06484
9	3.333	2.000	-2.05139
10	6.667	2.000	-1.57711
11	10.000	2.000	-0.87966
12	13.333	2.000	-0.56287
13	16.667	2.000	-0.77985
14	20.000	2.000	-0.64344
15	0.000	4.000	-1.04208
16	3.333	4.000	-2.04185
17	6.667	4.000	-1.61897
18	10.000	4.000	-0.93585
19	13.333	4.000	-0.61415
20	16.667	4.000	-0.88436
21	20.000	4.000	-0.70726
22	0.000	6.000	-1.00561
23	3.333	6.000	-1.97777
24	6.667	6.000	-1.61213
25	10.000	6.000	-0.95329
26	13.333	6.000	-0.62386
27	16.667	6.000	-0.92020
28	20.000	6.000	-0.73664
29	0.000	8.000	-1.04207
30	3.333	8.000	-2.04185
31	6.667	8.000	-1.61897
32	10.000	8.000	-0.93584
33	13.333	8.000	-0.61415
34	16.667	8.000	-0.88436
35	20.000	8.000	-0.70726
36	0.000	10.000	-1.06483
37	3.333	10.000	-2.05139
38	6.667	10.000	-1.57710
39	10.000	10.000	-0.87966
40	13.333	10.000	-0.56287
41	16.667	10.000	-0.77985
42	20.000	10.000	-0.64343
43	0.000	12.000	-0.43703
44	3.333	12.000	-0.97042
45	6.667	12.000	-0.73483
46	10.000	12.000	-0.42550
47	13.333	12.000	-0.33507
48	16.667	12.000	-0.38621
49	20.000	12.000	-0.27346

TOTAL = -45.7619

INTERVAL = 200 TIME = 0.040 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.46261
2	3.333	0.000	-0.59682
3	6.667	0.000	-0.38783
4	10.000	0.000	-0.37006
5	13.333	0.000	-0.42503
6	16.667	0.000	-0.51463
7	20.000	0.000	-0.28791
8	0.000	2.000	-1.19038
9	3.333	2.000	-1.35626
10	6.667	2.000	-0.77156
11	10.000	2.000	-0.67707
12	13.333	2.000	-0.83211
13	16.667	2.000	-1.06802
14	20.000	2.000	-0.63262
15	0.000	4.000	-1.21732
16	3.333	4.000	-1.43330
17	6.667	4.000	-0.84188
18	10.000	4.000	-0.71806
19	13.333	4.000	-0.84046
20	16.667	4.000	-1.05870
21	20.000	4.000	-0.63348
22	0.000	6.000	-1.19329
23	3.333	6.000	-1.43717
24	6.667	6.000	-0.86810
25	10.000	6.000	-0.74029
26	13.333	6.000	-0.84584
27	16.667	6.000	-1.05318
28	20.000	6.000	-0.63287
29	0.000	8.000	-1.17399
30	3.333	8.000	-1.40319
31	6.667	8.000	-0.84436
32	10.000	8.000	-0.74318
33	13.333	8.000	-0.87246
34	16.667	8.000	-1.09691
35	20.000	8.000	-0.66071
36	0.000	10.000	-1.10261
37	3.333	10.000	-1.29297
38	6.667	10.000	-0.79160
39	10.000	10.000	-0.73811
40	13.333	10.000	-0.90123
41	16.667	10.000	-1.15406
42	20.000	10.000	-0.69941
43	0.000	12.000	-0.40889
44	3.333	12.000	-0.55149
45	6.667	12.000	-0.40385
46	10.000	12.000	-0.40453
47	13.333	12.000	-0.46353
48	16.667	12.000	-0.57576
49	20.000	12.000	-0.32417

TOTAL = -39.6938

INTERVAL = 400 TIME = 0.080 DISTANCE 4.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.38285
2	3.333	0.000	-0.79176
3	6.667	0.000	-0.58279
4	10.000	0.000	-0.47827
5	13.333	0.000	-0.49586
6	16.667	0.000	-0.58714
7	20.000	0.000	-0.31811
8	0.000	2.000	-0.87768
9	3.333	2.000	-1.64715
10	6.667	2.000	-1.30108
11	10.000	2.000	-1.02023
12	13.333	2.000	-0.99818
13	16.667	2.000	-1.16253
14	20.000	2.000	-0.66774
15	0.000	4.000	-0.88714
16	3.333	4.000	-1.71941
17	6.667	4.000	-1.38308
18	10.000	4.000	-1.08123
19	13.333	4.000	-1.02368
20	16.667	4.000	-1.13009
21	20.000	4.000	-0.61670
22	0.000	6.000	-0.89921
23	3.333	6.000	-1.79255
24	6.667	6.000	-1.46076
25	10.000	6.000	-1.14212
26	13.333	6.000	-1.06278
27	16.667	6.000	-1.11295
28	20.000	6.000	-0.57194
29	0.000	8.000	-0.91374
30	3.333	8.000	-1.87353
31	6.667	8.000	-1.55643
32	10.000	8.000	-1.21803
33	13.333	8.000	-1.09692
34	16.667	8.000	-1.10185
35	20.000	8.000	-0.54733
36	0.000	10.000	-0.93748
37	3.333	10.000	-1.94612
38	6.667	10.000	-1.63355
39	10.000	10.000	-1.27292
40	13.333	10.000	-1.11987
41	16.667	10.000	-1.10918
42	20.000	10.000	-0.54496
43	0.000	12.000	-0.43246
44	3.333	12.000	-1.00745
45	6.667	12.000	-0.83077
46	10.000	12.000	-0.63080
47	13.333	12.000	-0.56062
48	16.667	12.000	-0.55713
49	20.000	12.000	-0.26680

TOTAL = -48.3529

INTERVAL = 200 TIME = 0.040 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.42253
2	3.333	0.000	-0.49485
3	6.667	0.000	-0.32217
4	10.000	0.000	-0.32468
5	13.333	0.000	-0.40447
6	16.667	0.000	-0.51587
7	20.000	0.000	-0.29093
8	0.000	2.000	-1.12018
9	3.333	2.000	-1.16034
10	6.667	2.000	-0.59469
11	10.000	2.000	-0.58242
12	13.333	2.000	-0.79249
13	16.667	2.000	-1.07458
14	20.000	2.000	-0.64024
15	0.000	4.000	-1.14812
16	3.333	4.000	-1.26344
17	6.667	4.000	-0.69803
18	10.000	4.000	-0.65741
19	13.333	4.000	-0.82161
20	16.667	4.000	-1.06206
21	20.000	4.000	-0.63381
22	0.000	6.000	-1.11835
23	3.333	6.000	-1.28831
24	6.667	6.000	-0.76191
25	10.000	6.000	-0.70528
26	13.333	6.000	-0.84859
27	16.667	6.000	-1.05622
28	20.000	6.000	-0.62521
29	0.000	8.000	-1.09400
30	3.333	8.000	-1.27292
31	6.667	8.000	-0.77230
32	10.000	8.000	-0.74154
33	13.333	8.000	-0.90221
34	16.667	8.000	-1.11538
35	20.000	8.000	-0.65713
36	0.000	10.000	-1.01472
37	3.333	10.000	-1.17599
38	6.667	10.000	-0.75851
39	10.000	10.000	-0.78193
40	13.333	10.000	-0.96673
41	16.667	10.000	-1.20618
42	20.000	10.000	-0.71734
43	0.000	12.000	-0.36866
44	3.333	12.000	-0.50428
45	6.667	12.000	-0.40835
46	10.000	12.000	-0.43496
47	13.333	12.000	-0.50346
48	16.667	12.000	-0.61939
49	20.000	12.000	-0.33941

TOTAL = -37.7842

INTERVAL = 400 TIME = 0.080 DISTANCE 4.000

JOINT	X (FT)	Y (FT)	SOIL REACTION (KIPS)
1	0.000	0.000	-0.32796
2	3.333	0.000	-0.60134
3	6.667	0.000	-0.43058
4	10.000	0.000	-0.36768
5	13.333	0.000	-0.40694
6	16.667	0.000	-0.55214
7	20.000	0.000	-0.34161
8	0.000	2.000	-0.75647
9	3.333	2.000	-1.35572
10	6.667	2.000	-1.00389
11	10.000	2.000	-0.75034
12	13.333	2.000	-0.79503
13	16.667	2.000	-1.11481
14	20.000	2.000	-0.74475
15	0.000	4.000	-0.78891
16	3.333	4.000	-1.49550
17	6.667	4.000	-1.16898
18	10.000	4.000	-0.88948
19	13.333	4.000	-0.88129
20	16.667	4.000	-1.11125
21	20.000	4.000	-0.68783
22	0.000	6.000	-0.80338
23	3.333	6.000	-1.63182
24	6.667	6.000	-1.32880
25	10.000	6.000	-1.03223
26	13.333	6.000	-0.99085
27	16.667	6.000	-1.12121
28	20.000	6.000	-0.62603
29	0.000	8.000	-0.81102
30	3.333	8.000	-1.75803
31	6.667	8.000	-1.49575
32	10.000	8.000	-1.18180
33	13.333	8.000	-1.08879
34	16.667	8.000	-1.13424
35	20.000	8.000	-0.58505
36	0.000	10.000	-0.82828
37	3.333	10.000	-1.86668
38	6.667	10.000	-1.62842
39	10.000	10.000	-1.29006
40	13.333	10.000	-1.15878
41	16.667	10.000	-1.16815
42	20.000	10.000	-0.57756
43	0.000	12.000	-0.38601
44	3.333	12.000	-0.98625
45	6.667	12.000	-0.84989
46	10.000	12.000	-0.65810
47	13.333	12.000	-0.59570
48	16.667	12.000	-0.59878
49	20.000	12.000	-0.27959

TOTAL = -45.0338

UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-8 .DIS PAGE 1

INTERVAL = 200 TIME = 0.040 DISTANCE 2.000

JOINT	X (FT)	Y (FT)	DISPLACEMENT (FT)	ACCELERATION (FT/SEG ²)
1	0.000	0.000	0.000019119	-49.209
2	3.333	0.000	-0.000047506	-0.072
3	6.667	0.000	-0.000042782	28.773
4	10.000	0.000	0.000015624	-9.755
5	13.333	0.000	0.000037431	-25.192
6	16.667	0.000	0.000002654	13.305
7	20.000	0.000	-0.000042429	14.736
8	0.000	2.000	0.000006704	-41.049
9	3.333	2.000	-0.000052251	5.971
10	6.667	2.000	-0.000042952	7.859
11	10.000	2.000	0.000011546	-19.569
12	13.333	2.000	0.000034088	-3.406
13	16.667	2.000	0.000008073	4.375
14	20.000	2.000	-0.000035407	5.435
15	0.000	4.000	0.000005586	-45.913
16	3.333	4.000	-0.000049132	-7.572
17	6.667	4.000	-0.000045015	18.258
18	10.000	4.000	0.000005380	-5.200
19	13.333	4.000	0.000033455	-11.354
20	16.667	4.000	0.000012840	-8.997
21	20.000	4.000	-0.000031937	7.448
22	0.000	6.000	0.000005185	-56.499
23	3.333	6.000	-0.000044098	-10.378
24	6.667	6.000	-0.000044280	27.500
25	10.000	6.000	0.000001433	10.711
26	13.333	6.000	0.000032108	-21.190
27	16.667	6.000	0.000011819	-8.198
28	20.000	6.000	-0.000034601	5.001
29	0.000	8.000	-0.000016589	-30.071
30	3.333	8.000	-0.000051171	-6.444
31	6.667	8.000	-0.000040778	8.816
32	10.000	8.000	0.000003551	-7.543
33	13.333	8.000	0.000028761	-10.487
34	16.667	8.000	0.000005973	5.093
35	20.000	8.000	-0.000041555	16.589
36	0.000	10.000	-0.000034472	-13.679
37	3.333	10.000	-0.000057119	4.888
38	6.667	10.000	-0.000039489	-0.841
39	10.000	10.000	0.000004247	-13.180
40	13.333	10.000	0.000026969	-1.916
41	16.667	10.000	0.000003373	8.539
42	20.000	10.000	-0.000044710	12.641
43	0.000	12.000	-0.000035917	-21.455
44	3.333	12.000	-0.000056070	-10.667
45	6.667	12.000	-0.000044411	30.816
46	10.000	12.000	0.000000972	12.937
47	13.333	12.000	0.000030773	-26.445
48	16.667	12.000	0.000007397	-10.295
49	20.000	12.000	-0.000043322	11.446

INTERVAL = 200 TIME = 0.040 DISTANCE 2.000

VEHICLE COORDINATES DISPLACEMENTS

COORDINATE	DISPLACEMENT (FT)	ACCELERATION (FT/SEG^2)
50	-0.2823899	-12.5383463
51	-0.0011917	-0.2184160
52	0.0000028	-0.0185978
53	-0.0616840	46.6565666
54	-0.0535258	8.7769899
55	-0.1061397	-5.3862419
56	-0.1061412	-5.3980532

INTERVAL = 400

TIME = 0.080

DISTANCE 4.000

JOINT	X (FT)	Y (FT)	DISPLACEMENT (FT)	ACCELERATION (FT/SEG^2)
1	0.000	0.000	-0.000096314	-25.459
2	3.333	0.000	-0.000113784	9.546
3	6.667	0.000	-0.000071108	19.140
4	10.000	0.000	0.000023007	-10.292
5	13.333	0.000	0.000073335	-26.686
6	16.667	0.000	0.000027395	2.369
7	20.000	0.000	-0.000066418	25.895
8	0.000	2.000	-0.000109303	31.936
9	3.333	2.000	-0.000118621	34.317
10	6.667	2.000	-0.000075547	28.594
11	10.000	2.000	0.000013850	-7.859
12	13.333	2.000	0.000063541	-25.237
13	16.667	2.000	0.000021301	-8.875
14	20.000	2.000	-0.000069636	21.630
15	0.000	4.000	-0.000111946	22.219
16	3.333	4.000	-0.000111815	5.912
17	6.667	4.000	-0.000074551	27.957
18	10.000	4.000	0.000006686	-0.854
19	13.333	4.000	0.000055557	-22.208
20	16.667	4.000	0.000015010	5.601
21	20.000	4.000	-0.000072431	7.672
22	0.000	6.000	-0.000121474	-20.426
23	3.333	6.000	-0.000109551	-23.150
24	6.667	6.000	-0.000073062	10.829
25	10.000	6.000	0.000001353	-0.935
26	13.333	6.000	0.000049390	-26.082
27	16.667	6.000	0.000011872	-0.070
28	20.000	6.000	-0.000076390	32.329
29	0.000	8.000	-0.000156352	59.837
30	3.333	8.000	-0.000132205	13.000
31	6.667	8.000	-0.000083067	19.953
32	10.000	8.000	-0.000005589	-1.259
33	13.333	8.000	0.000043027	-15.445
34	16.667	8.000	0.000011897	-0.384
35	20.000	8.000	-0.000073159	23.756
36	0.000	10.000	-0.000184004	50.087
37	3.333	10.000	-0.000151294	16.902
38	6.667	10.000	-0.000094102	21.685
39	10.000	10.000	-0.000013305	3.773
40	13.333	10.000	0.000038572	-16.157
41	16.667	10.000	0.000015181	-13.808
42	20.000	10.000	-0.000063977	25.534
43	0.000	12.000	-0.000196495	22.687
44	3.333	12.000	-0.000158542	7.113
45	6.667	12.000	-0.000102329	26.345
46	10.000	12.000	-0.000019790	6.310
47	13.333	12.000	0.000035861	-9.923
48	16.667	12.000	0.000018560	1.482
49	20.000	12.000	-0.000050383	1.192

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UNIVERSITY OF PUERTO RICO FILE NAME = EXAM1-8 .DIS PAGE 4

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INTERVAL = 400 TIME = 0.080 DISTANCE 4.000

	VEHICLE COORDINATES DISPLACEMENTS	
COORDINATE	DISPLACEMENT (FT)	ACCELERATION (FT/SEG^2)
50	-0.3125502	-9.8846874
51	-0.0018504	-0.4244176
52	0.0000009	0.0462096
53	-0.0191168	-106.2856600
54	-0.0396572	9.7815361
55	-0.1171834	-4.3871613
56	-0.1171893	-4.3756075

UNIVERSITY OF PUERTO RICO

FILE NAME = exam1-7h.CRA

STEP NUMBER 1887

ELEMENT	SUB-ELEMENT								
	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
32	TOP	none	none	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
38	TOP	none	none	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	179.9

STEP NUMBER 1888

ELEMENT	SUB-ELEMENT								
	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
20	TOP	none	none	none	ONE	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.5
50	TOP	none	none	none	none	ONE	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	0.0	178.1	0.0	0.0	179.5

STEP NUMBER 1889

ELEMENT	SUB-ELEMENT								
	# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
2	TOP	ONE	none	none	none	none	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	-186.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	TOP	none	none	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.6
14	TOP	none	none	ONE	none	none	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	-182.2	0.0	0.0	0.0	0.0	0.0
26	TOP	none	none	ONE	none	none	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	-179.9	0.0	0.0	0.0	0.0	0.0
44	TOP	ONE	none	none	none	none	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56	TOP	ONE	none	none	none	none	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	TOP	none	none	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	180.6
68	TOP	none	none	ONE	none	none	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	6.5	0.0	0.0	0.0	0.0	0.0

		STEP NUMBER 1890								
ELEMENT		SUB-ELEMENT								
		# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
32	TOP	none	none	none	ONE	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	1.6	0.0	0.0	0.0	0.0	0.2

38	TOP	none	none	none	none	ONE	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	0.0	0.0	178.4	0.0	0.0	0.0	179.8

		STEP NUMBER 2037								
ELEMENT		SUB-ELEMENT								
		# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
8	TOP	none	none	ONE	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	-10.4	0.0	0.0	0.0	0.0	0.0	75.9

62	TOP	ONE	none	none	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	190.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	104.2

		STEP NUMBER 2038								
ELEMENT		SUB-ELEMENT								
		# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
14	TOP	none	none	ONE	none	none	ONE	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	-188.5	0.0	0.0	-180.5	0.0	0.0	0.0

56	TOP	ONE	none	none	none	none	none	ONE	none	none
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	8.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0

		STEP NUMBER 2039								
ELEMENT		SUB-ELEMENT								
		# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
26	TOP	none	none	ONE	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	-180.1	0.0	0.0	0.0	0.0	0.0	-180.1

44	TOP	ONE	none	none	none	none	none	none	none	ONE
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

		STEP NUMBER 2105								
ELEMENT		SUB-ELEMENT								
		# 1	# 2	# 3	# 4	# 5	# 6	# 7	# 8	# 9
2	TOP	ONE	none	none	none	none	ONE	none	none	none
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	-189.3	0.0	0.0	0.0	0.0	-188.4	0.0	0.0	0.0

68	TOP	none	none	ONE	none	none	none	ONE	none	none
	BOTTOM	none	none	none	none	none	none	none	none	none
	ANGLE	0.0	0.0	9.3	0.0	0.0	0.0	8.5	0.0	0.0