NBS BUILDING SCIENCE SERIES 132

A Study of Reaction Forces on Mobile Home Foundations Caused by Wind and Flood Loads

U.S. DEPARTMENT OF COMMERCE • NATIONAL BUREAU OF STANDARDS

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ABSTRACT

Forces acting on the foundations of mobile homes subjected to wind and flood loads were calculated and are presented in a series of computer-generated charts. The loading conditions considered are the two levels of wind loads presently stipulated in the Federal Mobile Home Construction and Safety Standard, a hurricane windload recommended by the National Bureau of Standards (NBSIR 77-1289), buoyancy forces, and drag forces resulting from flood water flow. The calculated forces are compared with present anchoring requirements in ANSI Standard 119.3 (NFPA No. 501 A). It is concluded that diagonal ties are instrumental in resisting wind forces, and that vertical ties are more effective than diagonal ties in resisting flood forces.

Key words: Buoyancy forces; flood forces; foundations; hurricane forces; mobile home; soil anchors; standards; tiedown; wind forces.

COVER: *An example of wind and flood damage sustained by a mobile home park during Hurricane Frederic.*

PREFACE

This report is part of a study which was sponsored by the Department of Housing and Urban Development. The objectives of this study are: to determine wind and flood forces acting on mobile homes; to study the performance characteristics of soil anchors; and to develop performance criteria and tests for mobile home foundations with particular emphasis on the tiedown system. In the initial stages of this work measurements were made of wind forces acting on mobile homes, and the state-of-the-art in anchoring technology was studied. This work was published in References [3][1] and [4], respectively. This report deals specifically with the forces acting on the foundations of mobile homes subjected to wind and flood loads. Tests to determine the characteristics of soil anchors are presently in progress and initial results were published in Reference [6].

This work was performed by the Geotechnical Engineering Group of the Center for Building Technology.

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1 Numbers in brackets refer to literature references in section 6.

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LIST OF SYMBOLS

A = projected vertical submerged area normal to flow directions, ft^2.

B = width of mobile home, ft.

C_D = hydrodynamic drag coefficient.

e = eccentricity of weight of mobile home with respect to longitudinal axis, ft.

F_D = hydrodynamic drag force, lb.

H = height from ground surface to top of mobile home, ft.

H' = height from bottom of floor to top of roof, ft.

h_s = submerged depth from bottom of chassis beam, ft.

h_s' = submerged depth from bottom of floor, ft.

Δh = differential head between water levels outside and inside the mobile home, ft.

P_W = windward pier reaction, lb

P_L = leeward pier reaction, lb.

T_1 = vertical-tie force, lb.

T_2 = diagonal-tie force, lb.

v = average flow velocity, ft/sec.

W = average weight of mobile home per linear ft, lb/ft.

X_t = horizontal distance from intersection of anchor straps to the point where the extension of the diagonal strap intersects the underside of the floor, ft.

Y_t = vertical distance from intersection of anchor straps to underside of floor, ft.

α = load transfer coefficient for over-the-roof ties

β = angle of diagonal ties with horizontal degrees

ρ = mass density of water, lb sec^2/ft^4

SI CONVERSION UNITS

In view of present accepted practice in the U.S. mobile home industry, common U.S. units of measurement were used throughout this report. The table below is presented to facilitate conversion to S.I. Units.

TO CONVERT FROM	TO	MULTIPLY BY
ft	m	0.305
in	mm	25.4
lb (force)	N	4.45
lb/ft	N/m	14.6

Facing page: *The trees surrounding this mobile home community provide a natural barrier to wind pressures, thus mitigating some of the potential damage caused by high winds.*

1. INTRODUCTION

Mobile homes are lighter than conventional houses and thus are more vulnerable to the effects of horizontal and uplift forces caused by windstorms and floods. These horizontal and uplift forces must be resisted by suitable foundations.

The most common foundation type presently used to support mobile homes consists of pairs of piers (ungrouted concrete masonry resting on a small footing slab on top of the ground, pre-fabricated metal stands, or others), about 8 to 10 ft on center, which support the two chassis beams of the mobile home; and soil anchors located under the outer walls of the mobile home, to which the mobile home is tied by transverse over-the-roof straps, transverse diagonal straps tied to the chassis beams, or both. While in actual practice often only over-the-roof ties are used, the model standard which presently provides guidance for the installation of mobile home foundations (NFPA Standard 501A [5]) calls for diagonal ties, and requires that the minimum number of diagonal ties exceed the minimum number of over-the-roof ties.

In order to insure the adequacy of the previously described mobile home foundations, it is necessary to determine the forces that would be induced in the soil anchors and piers by extreme winds and floods, and then to install anchors and piers that can resist these forces.

This report contains information on forces acting on soil anchors and piers as a result of extreme winds, floods, and a combination of floods and wind.

It is not the intent of this report to make specific recommendations with respect to preferable anchoring methods, required safety margins against sliding, overturning and buoyancy, or desirable limitations on the construction of mobile homes in flood plains, but rather to convey information which can be used to calculate actual anchor-strap and pier reaction forces for a wide variety of anchoring systems and loading conditions. Thus the inclusion of any specific type of anchor-strap connection should not be construed as an endorsement of the use of these connections, and the inclusion of results of calculations which show actual forces, rather than forces multiplied by a factor of 1.5, as required in the present Federal standard for the design of mobile home foundations, should not be construed as a recommendation to drop this added safety margin.

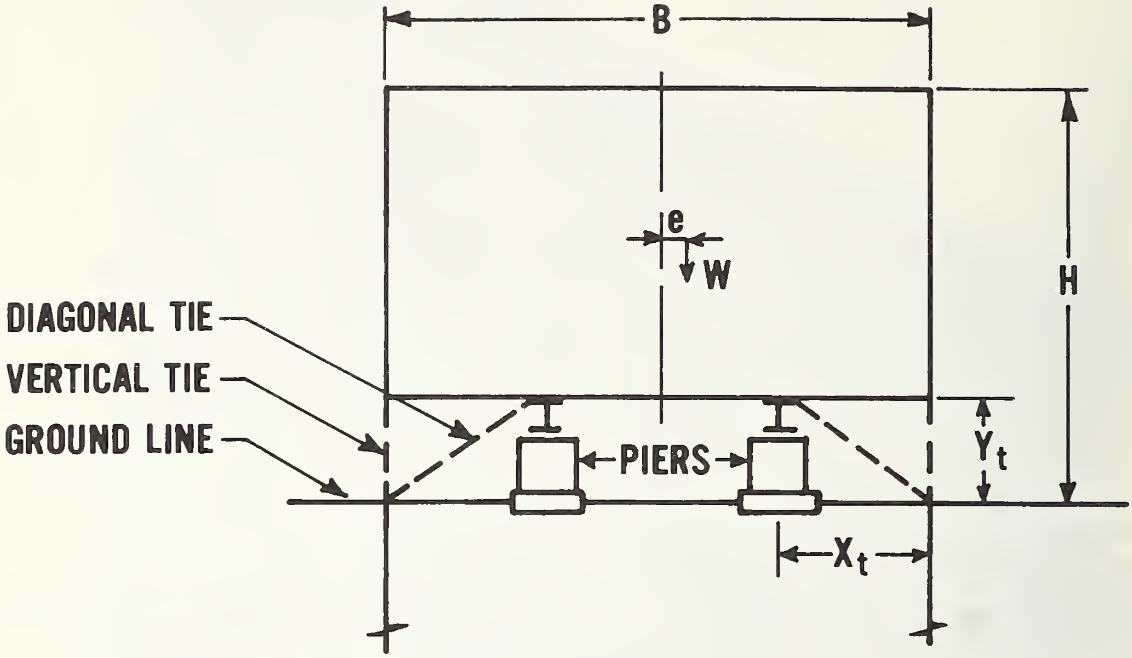
Facing page: *An example of field measurement of mobile home response to simulated wind loading.*

2. ANALYSIS OF FORCES INDUCED IN MOBILE HOME FOUNDATIONS

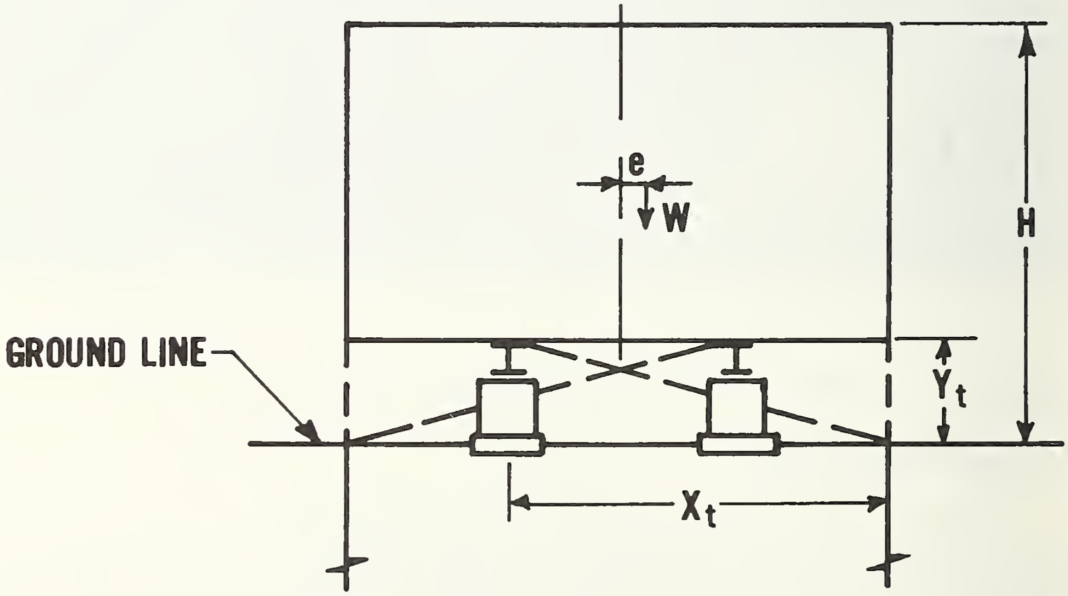
2.1 VARIABLES CONSIDERED

2.1.1 Geometry of the Mobile Home and Its Foundation

Figure 2.1 shows typical anchor arrangements for mobile homes. The two chassis beams rest on piers. The mobile home is tied to the soil anchors by vertical (over-the-roof) and diagonal ties. Two typical methods of presently used diagonal-tie attachments are shown. In figure 2.1(A) the diagonal tie



2.1A - Near Tie Connection



2.1B - Far Tie Connection

Figure 2.1 Typical Mobile Home Anchoring System is attached to the chassis beam nearest to the anchor (near-tie connection) and in figure 2.1(B) to the far chassis beam (far-tie connection). Realizing that there is a wide range of features of mobile homes, as they are positioned on their supports, that would affect the forces transmitted to the foundation systems, it was necessary to identify the most important features and set limits on their magnitudes. The dimensions considered as variables in the analysis are as follows:

1) Width and height of the mobile home: either a 12-ft or a 14-ft width was used. The double-wide unit was not specifically considered in the analysis. The height ($H - y_t$ in figure 2.1) was assumed to be 8 ft in all cases.

2) Center to center spacing of chassis beams: this spacing can vary from about 6 ft to 7.5 ft. Measurements were made on several 1960- and 1970-vintage mobile homes located on the NBS Gaithersburg, Md., grounds and 6.46 ft was found to be a typical spacing. This spacing was used for the calculations.

3) Dimensions x_t and y_t (Figure 2.1): dimension x_t is determined in accordance with the chassis beam spacing. It was assumed that the anchor straps are wrapped around the chassis beam, resulting in the tiedown configurations shown in figure 2.1. Accordingly, the following x_t values were used in the calculation (in ft).

	dimension X_t, ft	
width of mobile home, ft	far tie	near tie
12	9.08	2.62
14	10.08	3.62

The y_t dimension depends on the height of the piers or other load-bearing support systems and could vary considerably. A typical value y_t = 2.5 ft can be calculated assuming a 10-in high chassis beam, a 2-in high base plate below the chassis beam, two 8-in high concrete blocks with a 4-in high footing, and an intersection point of the axes of the two tie straps 2 inches above ground. Since the height of the piers can vary, anchor forces were calculated for a range of y_t values from 1 ft to 8 ft.

2.1.2 Weight of Mobile Home

Weights of mobile homes vary for various makes. There seems to be a tendency for the weights to increase as the industry develops new models. Thus, older mobile homes tend to weigh less than those produced today, and it is conceivable that this trend could continue. Longitudinally, the weight is not evenly distributed over the floor area. However, the load calculations presented in this report are for a 1-ft transverse slice of a mobile home and it is assumed that mobile homes have the strength and stiffness required to minimize the effect of longitudinal load variations. This assumption is based on the fact that mobile homes can withstand the loads associated with their transportation.

Laterally, the resultant gravity force from the weight of the mobile home does not normally act through its geometric centerline. A study was therefore made of the furnishing and major appliance layout to determine the range of lateral eccentricities for the weight of a mobile home. The weight of 1 linear ft of a mobile home can vary from 180 to 300 lb for a 12-ft wide mobile home, and from 240 to 560 lb for a 14-ft wide mobile home. Typical weights were determined on the basis of information obtained from several producers and industry sources on new mobile homes presently produced. The assumptions on weight, weight eccentricities, and dimensions that were made in the calculations are summarized in table 2.1.

Table 2.1. Mobile Home Characteristics Assumed in the Load Calculations

B, ft	W, lb	e, ft	x_t(near tie), ft	x_t(far tie), ft	y_t, ft
12	230	0.55	2.62	9.08	1-8
14	250	0.75	3.62	10.08	1-8

B = nominal width of mobile home.
W = weight of mobile home per linear ft.
e = lateral weight eccentricity with respect to the vertical center line of a cross-section.
x_t = horizontal distance from intersection of anchor straps (vertically below exterior wall) to the point where the diagonal strap intersects with the underside of the floor of the mobile home.
y_t = vertical distance from the point of intersection of the anchor straps to the underside of the floor of the mobile home.

2.1.3 Lateral Load Resistance by Piers

NFPA Standard 501A [5] has no explicit requirement to build piers which can resist lateral loads. Presently, concrete block piers without mortar, constructed in accordance with the NFPA standard, are most frequently used; however, several pre-fabricated systems are commercially available. Since there is no explicit requirement that piers must provide lateral load resistance, anchor loads were conservatively calculated on the basis of the assumption that the entire horizontal load is resisted by the soil anchors. However, the effect of the lateral load resistance of the piers, which would probably equal at least 20 percent of the resultant vertical downward thrust was also studied.

2.1.4 Load Transfer by Over-The-Roof Ties

If there were no friction between the over-the-roof ties and the mobile home, any tension force acting on an over-the-roof tie on one side of a mobile home would also have to act on the other side. However, this situation could only arise if the tie force would be transmitted to the mobile home by pulleys. In actual practice, most over-the-roof ties are securely attached to the mobile home, thereby preventing slip. However, it is conceivable that in instances where over-the-roof ties were not incorporated into the mobile home construction there would be some load transfer. In this report, loads were calculated for two extreme conditions: load transfer coefficient $\alpha=0$ (no load transferred) and $\alpha=1$ (all the load is transferred). Intermediate cases were also studied and the results are presented in section 3.3.4.4.

2.2 WIND AND FLOOD LOADS

2.2.1 Wind Loads

Three different levels of wind loads were investigated: wind pressures specified in the HUD Mobile Home Construction and Safety Standards [1] for (1) the "Standard Wind Zone (Zone I), and (2) the "Hurricane Zone" (Zone II), and (3) hurricane wind pressures recommended by the National Bureau of Standards (NBS) [3]. Both of the hurricane cases assume 90 mph wind speeds. The assumed windloads are shown in figure 2.2(A), (B), and (C), and are described hereafter:

(1) HUD Standard Wind: (Zone I)

A 15 psf uniformly distributed horizontal pressure acting on the vertical projected area of the sidewalls, and a 9 psf uniformly distributed uplift pressure (suction) acting on the horizontal projection of the roof area.

(2) HUD Hurricane: (Zone II)

A 25 psf uniformly distributed horizontal pressure acting on the vertical projected area (walls) and a 15 psf uniformly distributed uplift pressure (suction) acting on the horizontal projected area (roof).

(3) NBS Hurricane [3]:[2]

A 26.5 psf average horizontal pressure acting on the vertical projected area (walls and skirt) in such a manner that the line of action of the resultant force will be 0.6H above the ground, where H is the height from the ground to the top of the mobile home (the pressure was assumed to vary linearly with the maximum pressure occurring at the top of the mobile home and the minimum near the ground). Only the portion of this pressure acting on the sidewall was considered in the calculations, assuming that the skirt would not transmit force to the mobile home (skirts would be either free standing masonry

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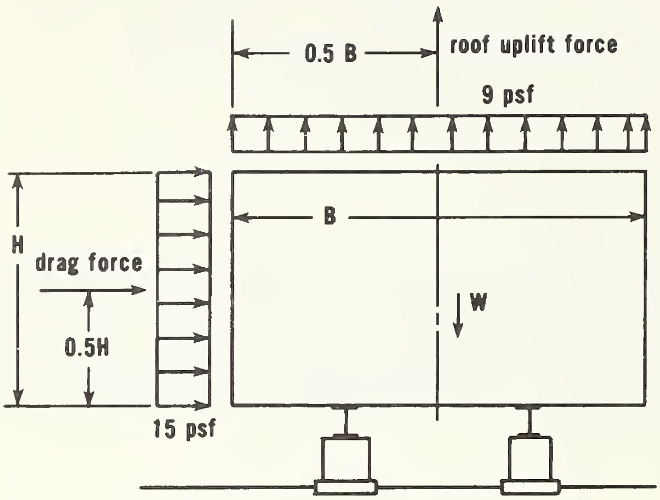
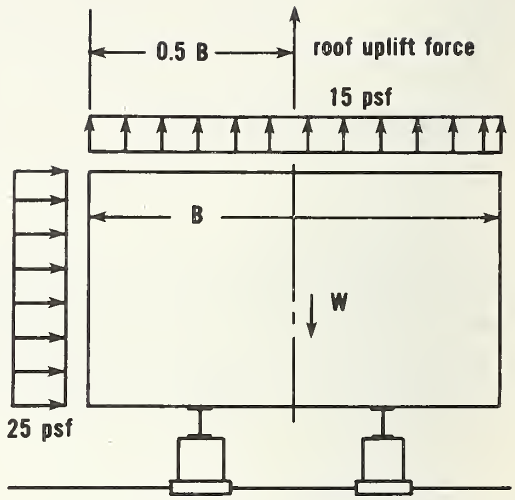
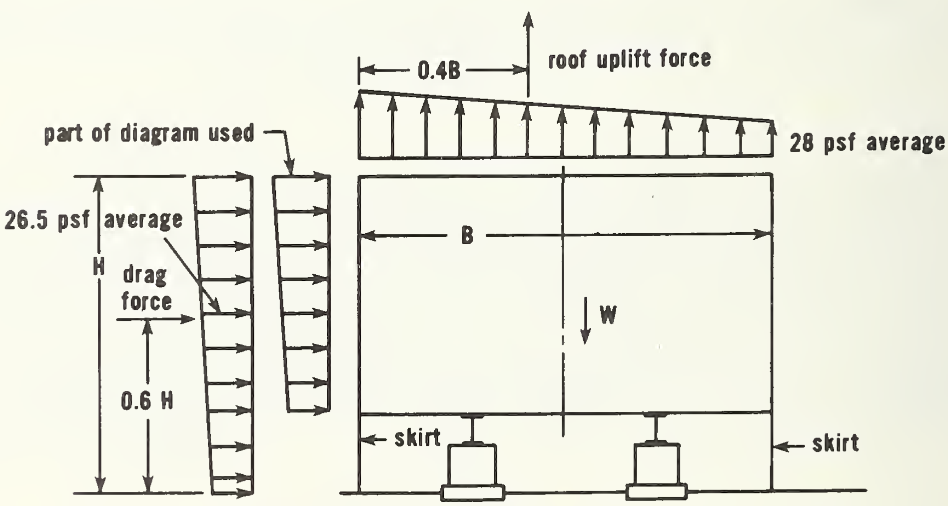
[2] Wind pressure calculations for the NBS hurricane are based on a reference height (height of the top of the roof of the mobile home above ground) of 9.5 ft. With an increase in this height there is a slight increase in the wind pressures. The increase is approximately 1.8 percent for the typical reference height of 10.5 ft and 9.8 percent for the maximum reference height considered in this report of 16 ft.



2.2A HUD Standard Wind (Zone I)



2.2B HUD Hurricane (Zone II)



2.2C NBS Hurricane

Figure 2.2 Assumed Wind Loading Conditions walls which transmit the lateral forces directly to the foundation soil, or very thin construction which could not transmit large forces to the mobile home). A 28 psf average uplift pressure acting on the horizontal projection of the roof area and distributed in a manner which produces a resultant vertical upward force acting at a distance of 0.4B from the windward wall, where B = width of the mobile home.

The horizontal wind pressure recommended by Marshall [3] varies over the length of the mobile home, with 29 psf acting on the 1/4 lengths near the ends and 24 psf acting in the center 1/2 length. This was averaged in the report as 26.5 psf acting on any 1-ft wide slice of mobile home.

2.2.2 Flood Loads

Mobile homes located in flood plains may be subjected to the effects of buoyancy and flow velocity, depending upon the nature of the flooding and the relative water tightness of the home. Thus, two types of flood forces were considered: buoyancy forces and drag forces. The flood forces are shown in figures 2.3 (A) and (B) and are discussed below.

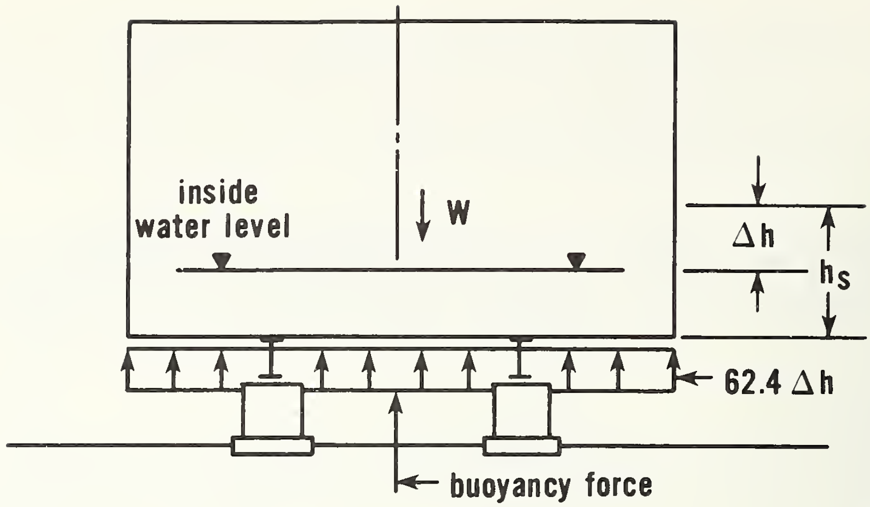
(1) Buoyancy Forces result when the flood water level outside the mobile home is higher than that inside the mobile home. The extent to which buoyancy can develop depends on the rate at which flood waters can flow into a closed mobile home. Field observations indicate that water rapidly penetrates into mobile homes with air conditioning ducts, and in at least one case observed by NBS in the New Orleans area, there was no evidence that buoyancy forces developed. However in other instances where there were no air conditioning ducts, there was evidence that buoyancy forces did build up, particularly in situations where the flood water was rising rapidly. Buoyancy forces were calculated as uplift forces evenly distributed over the floor area of the mobile home. Thus, effects of tilting of the mobile home were disregarded. This assumption is conservative, since effects of tilting would tend to decrease the overturning moment on the mobile home. Differential water levels of from 0.5 to 2.0 ft, in 6-in increments, were used in the calculations.

(2) Drag Forces

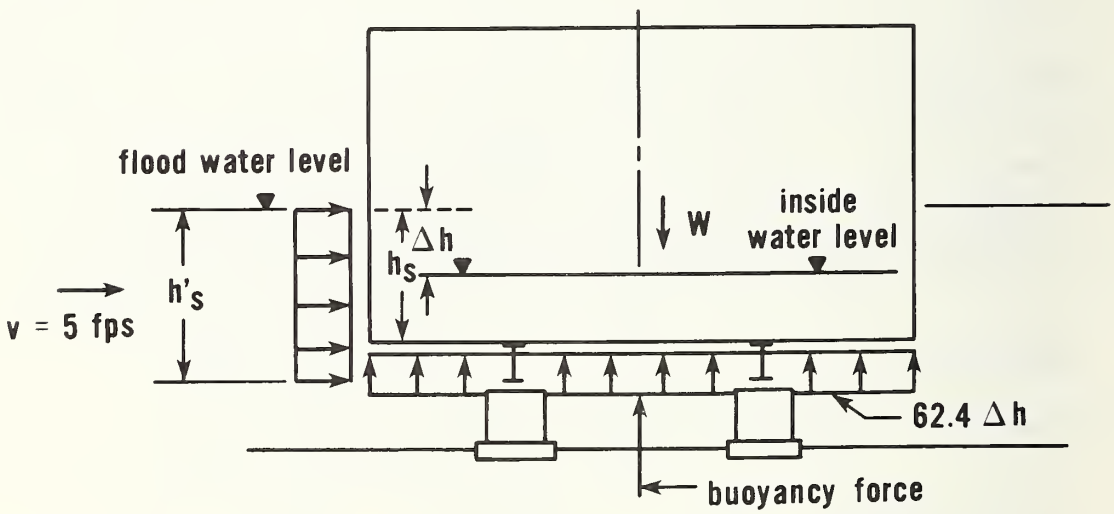
Drag forces were calculated by the equation:

$$F_D = C_D \frac{A \rho v^2}{2} \qquad (1)$$

where: F_D = Drag force
ρ = mass density of water
C_D = a drag coefficient
v = average flow velocity of water
A = projected vertical submerged area



2.3A Buoyancy Force Without Flow Velocity



2.3B Buoyancy Force Plus Flow Velocity

Figure 2.3 Assumed Flood Loading Conditions

The drag coefficient was assumed to be similar to that of a typical barge, which was determined to be approximately 1.0 [2]. Thus for a 1-ft wide strip of the mobile home:

$$F_D = 0.97\ h_s'\ v^2 \tag{2}$$

where h_s' = submerged depth in ft

and F_D is the drag force in lb

For the velocity v = 5 ft/sec for which these forces were calculated:

$$F_D = 24.25\ h_s'\ \text{lb} \tag{3}$$

As in the case of wind forces, it was assumed that the skirt would not transmit forces to the mobile home. The depth h_s' was taken from the bottom of the chassis beam, and the force F_D was assumed to act at a distance 0.5 h_s' above the bottom of the chassis beam.

The calculation assumes that the flow would be sub-critical (Froude Number <1). This assumption is justified for the velocity v = 5 ft/sec. It may not be justified for larger flow velocities.

The 5 ft/sec velocity was used because it is considered undesirable to locate any mobile home in a zone where larger flow velocities are anticipated. Equation (2) could be used to calculate the horizontal force for other flood velocities. The calculations are presented for the depth $h_s = h_s' - 0.83$ ft in which h_s is the depth from the bottom of the mobile home floor to the upstream water surface.

In addition to buoyancy and drag forces, a combination of buoyancy and HUD Standard Wind was also considered.

Facing page: *Although this mobile home sustained roofing damage during Hurricane Frederic, it was sufficiently anchored to resist overturning.*

3. RESULTS OF CALCULATIONS OF REACTION FORCES

3.1 PRESENTATION OF RESULTS

The results of the calculations are presented in the appendix in a series of computer-generated graphs. The data-location matrix which preceeds the graphs shows where the data for any particular loading condition can be found. Data are presented for the following loading conditions: (1) HUD Standard Wind; (2) HUD Hurricane Wind; (3) NBS Hurricane Wind; (4) buoyancy acting alone; (5) 5 ft/sec velocity flow acting alone; (6) 5 ft/sec flow velocity combined with buoyancy; and (7) buoyancy combined with HUD Standard Wind. The symbols used and the loading conditions are shown in the two figures following the data location matrix.

The data show tie forces and pier reactions as a function of the ratio y_t/x_t for a range of y_t dimensions from 1 to 8 ft. A separate set of graphs shows the magnitude and direction (angle with the horizontal) of total resulting anchor forces. These graphs can be used when each anchor is connected to a vertical and diagonal tie.

The forces shown are for a unit length of mobile home. In each particular instance a total force to be resisted by an anchor or tie can be calculated by multiplying the force shown in the graph by the anchor or tie spacing.

3.2 ASSUMPTIONS MADE IN THE CALCULATIONS

Several conservative assumptions were made when the data in the appendix were generated. These assumptions are listed hereafter:

(1) It was assumed that the diagonal ties alone resist horizontal forces, disregarding the potential resistance provided by the piers.

(2) It was assumed that the weight of the mobile home acts with an eccentricity on the downwind side, thus using the lower resisting moment.

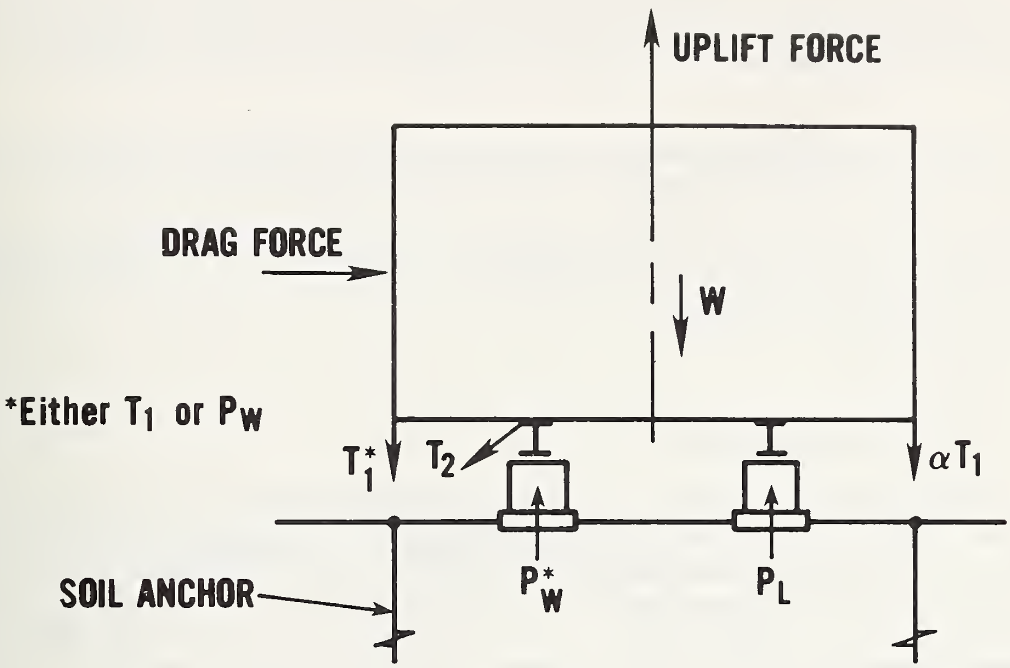
(3) The unit weight of the mobile home was assumed to be at the lower end of the range, thus reducing resistance to overturning and uplift forces.

(4) The load transfer coefficient for the over-the-roof ties was only calculated for the two extreme values, $\alpha=0$ (no load is transfered) and $\alpha=1$ (all the load is transfered).

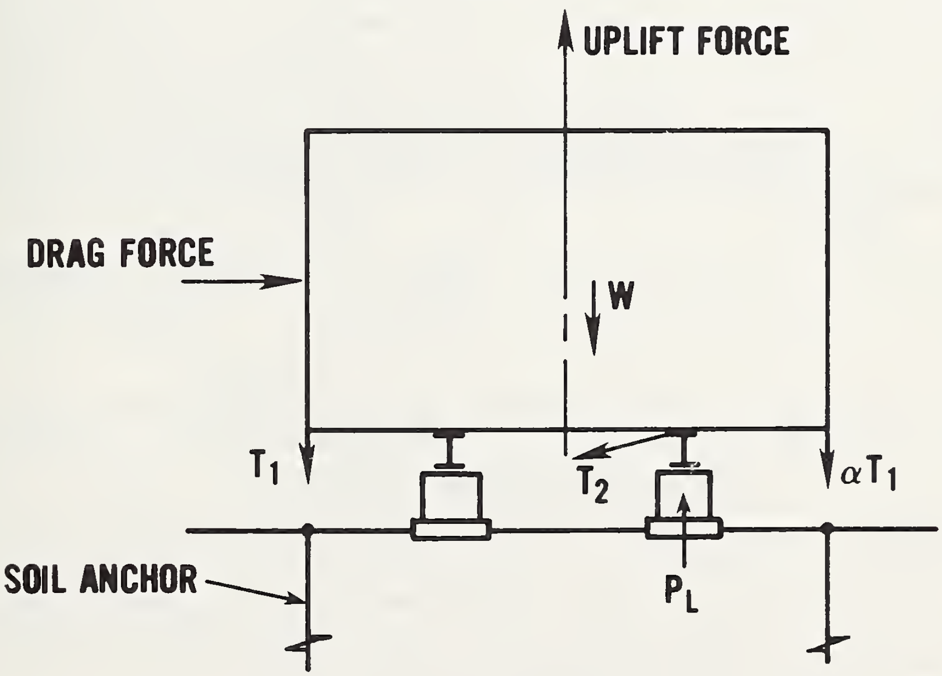
3.3 INTERPRETATION OF RESULTS

3.3.1 General

Figure 3.1 shows free-body diagrams of a mobile home for the near-tie and far-tie connections for the case of wind force. In the near-tie connection, given the loading cases considered, the windward diagonal tie force (T_2) and the leeward pier reaction (P_L) will always be engaged. The windward vertical tie force (T_1) is only engaged when overturning impends, a case that only occurs when piers are very low (the center of rotation in overturning would be the bottom of the leeward chassis beam). For the particular case where force T_2 balances the horizontal drag force and the overturning moment simultaneously neither T_1 nor P_W is engaged.



3.1A - Near Tie Connection



3.1B - Far Tie Connection

Figure 3.1 Free Body Diagrams of A Mobile Home Subjected to External Wind Loads

In all other cases P_W is engaged and there is no vertical-tie force (T_1=0). If the friction between the over-the-roof-tie and the mobile home is very low, the leeward vertical tie (αT_1) is engaged whenever the windward tie is engaged.

For the far-tie connection and the loading cases considered, the reactions T_1, T_2 and P_L are always engaged. αT_1 is only engaged when $\alpha \neq 0$.

For the case where buoyancy forces exceed the weight of the mobile home, all four ties are engaged for both the near-tie and the far-tie connection. No diagram is shown for this case.

3.3.2 Wind Forces

3.3.2.1 Near-Tie Connection

Figure 3.2 is taken from Chart 5 in the appendix and shows tie and pier forces (per linear foot of mobile home) induced in a 14-ft wide mobile home with near-tie connections by the HUD Hurricane Wind. To obtain actual tie and pier forces, the forces shown in the figure must be multiplied by the tie and pier spacing, respectively. To the left of the vertical broken line overturning is impending and the windward vertical tie is loaded (T_1 in figure 3.1). To the right of the broken line the windward pier is loaded (P_W) and the vertical ties are not engaged. Note that the vertical ties are only engaged when y_t/x_t is smaller than 0.63 which corresponds to a clearance above the ground of less than 27 inches, and that even then the vertical tie force is very small. When the transfer coefficient α=1, the windward and the leeward vertical ties are equally stressed and the vertical tie forces increase. It can be concluded from this and all the other plots in this report that a load transfer from one side to the other of the over-the roof ties tends to increase anchor and pier forces and is therefore undesirable.

For the typical case of 2.5 ft clearance above the ground (y_t/x_t = 0.69), the vertical ties are not engaged, there is a very small windward pier reaction, the leeward pier reaction is approximately 160 lb/ft, and the windward diagonal-tie force is approximately 240 lb/ft.

It is interesting to follow the trend of the reaction forces as the pier height increases (move from left to right on figure 3.2). Initially there is a vertical-tie force which disappears when y_t/x_t > 0.63. As y_t/x_t increases the windward pier is loaded. The pier load increases with pier height as the diagonal-tie inclination becomes steeper, until a point is reached where the windward pier reaction is greater than that of the leeward pier. The leeward pier reaction decreases with y_t/x_t when α=1 and slightly increases when α=0 until y_t/x_t = 0.63. For larger values of y_t/x_t the leeward pier reaction remains constant. The windward diagonal-tie reaction increases steadily with increasing values of y_t/x_t.

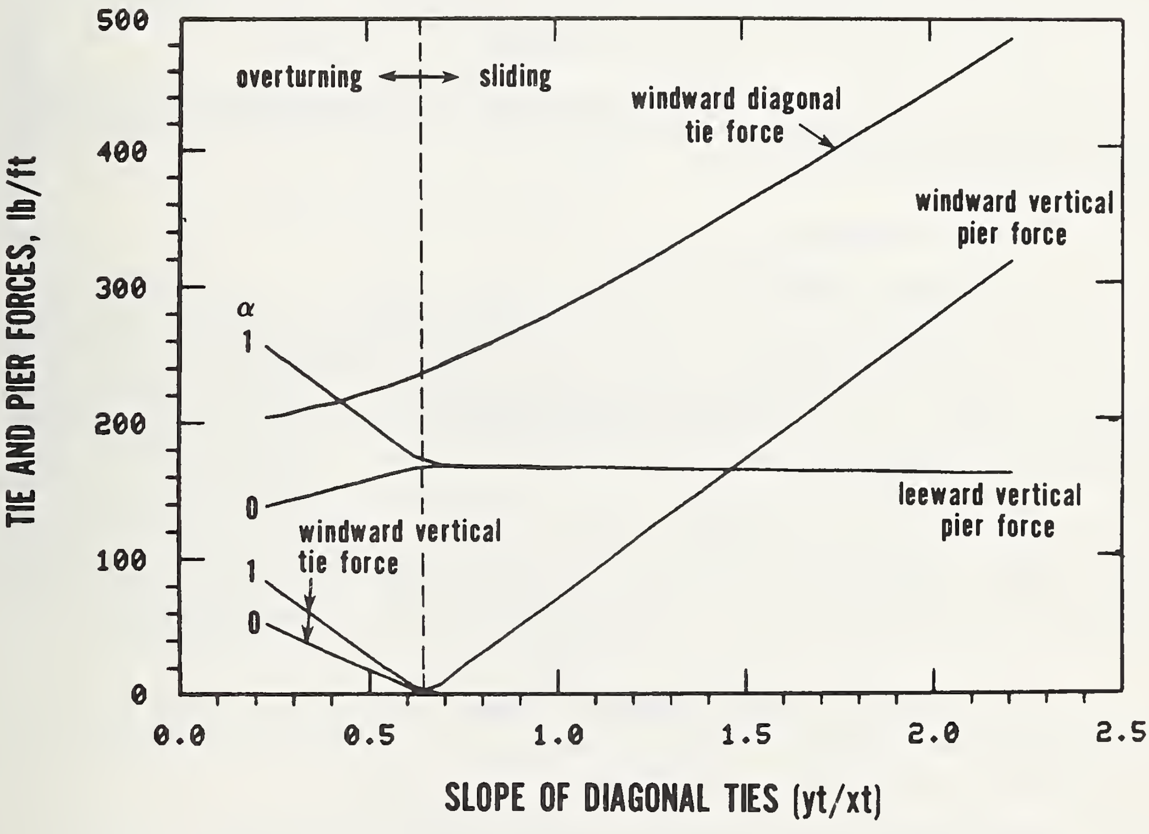


Figure 3.2 Tie and Pier Forces in a 14-ft Wide Mobile Home with Near-Tie Connections Subjected to the HUD Hurricane Wind Load

The previously discussed trends can be explained as follows: The windward diagonal tie force (T_2) is the only reaction force which balances the horizontal drag force. Thus its magnitude must be

$$F_h \cdot (\sqrt{y_t^2 + x_t^2})/x_t$$

where F_h is the horizontal drag force. Thus, the diagonal tie force increases as the slope y_t/x_t increases. The vertical downward component of the diagonal-tie force contributes toward balancing the overturning moment. When y_t/x_t is small, this vertical force component is too small to balance the overturning moment and the windward vertical tie is engaged. When y_t/x_t is larger, the vertical downward component of the windward diagonal tie is larger than the force necessary to balance the moments and is therefore partially resisted by the windward pier reaction. The leeward pier reaction for values of y_t/x_t greater than 0.63 is then equal to the weight minus the uplift force plus that part of the downward component of the windward diagonal tie force which is required to balance the moments.

It is important to note that the vertical ties for the near-tie connections could be eliminated entirely. The diagonal-tie force would then increase for the cases where $y_t/x_t < 0.63$.

3.3.2.2 Far-Tie Connection

Figure 3.3 is taken from Chart 6 in the appendix and shows the tie and pier forces induced by the HUD Hurricane Wind in the case of a 14-ft wide mobile home with a far-tie connection. Note that in this instance the windward diagonal tie force does not contribute significantly toward balancing the overturning moment. The windward vertical tie is therefore always engaged and there is no windward pier reaction. The windward diagonal-tie force increases only slightly with increasing value of y_t/x_t since the tie inclination is less sensitive to changes in pier height. Vertical-tie forces are constant and leeward vertical-pier forces increase as the vertical component of the windward diagonal-pier force increases. Note the large increase in the leeward pier reaction as α is changed from 0 to 1, giving further indication of the adverse effect of load transfer by over-the-roof ties.

For the typical values $y_t/x_t = 0.25$ and $\alpha=0$, the vertical-tie force is approximately 100 lb/ft, the diagonal-tie force is slightly over 200 lb/ft, and the leeward pier force is approximately 180 lb/ft.

3.3.2.3 Comparison of HUD and NBS Hurricane Loads

Tie and pier forces induced by the HUD and NBS Hurricane Wind are compared in figures 3.4 and 3.5 for the near-tie and the far-tie connection, respectively. Note that for the typical value $y_t/x_t = 0.69$, the NBS hurricane induces a windward vertical tie force of about 100 lb/ft while the windward vertical tie is not loaded as a result of the HUD hurricane pressures. Similarly, at the typical y_t/x_t value of 0.25 for the far-tie connection, the

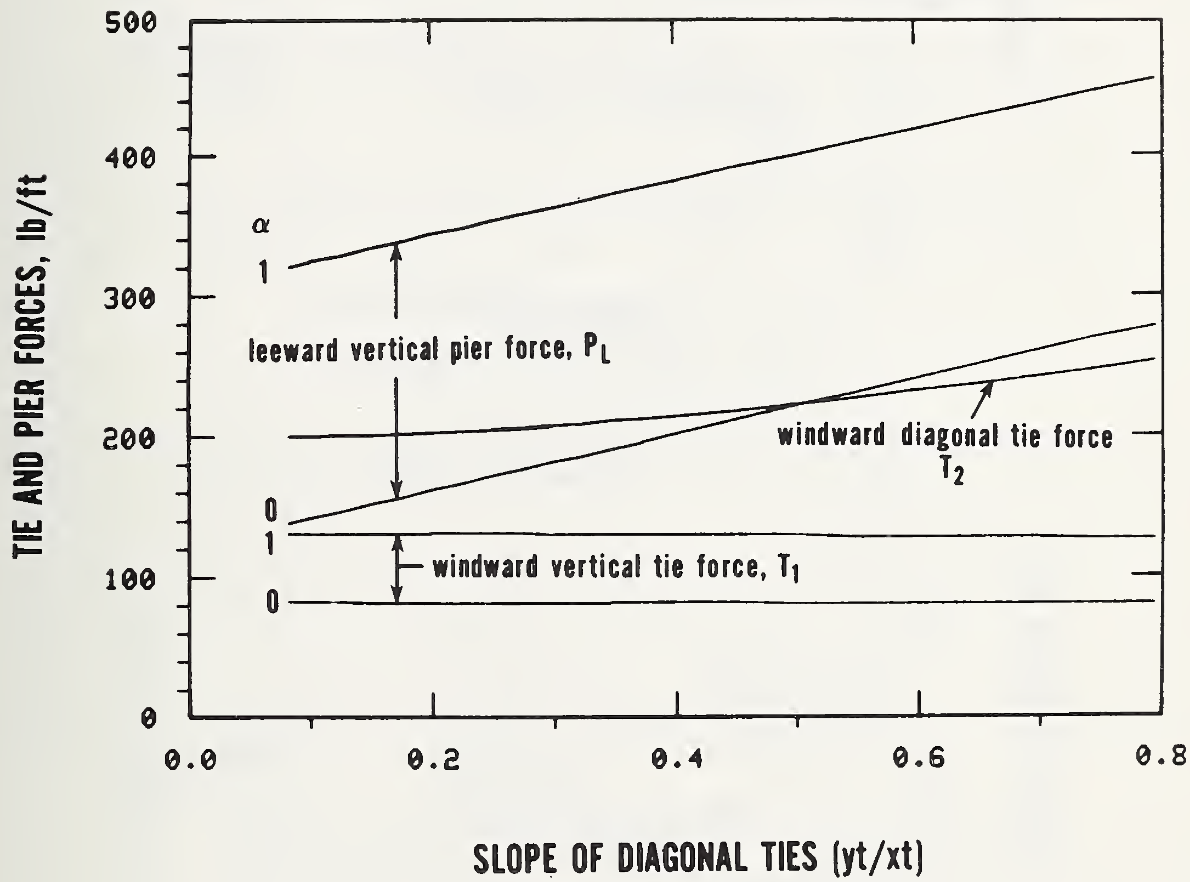
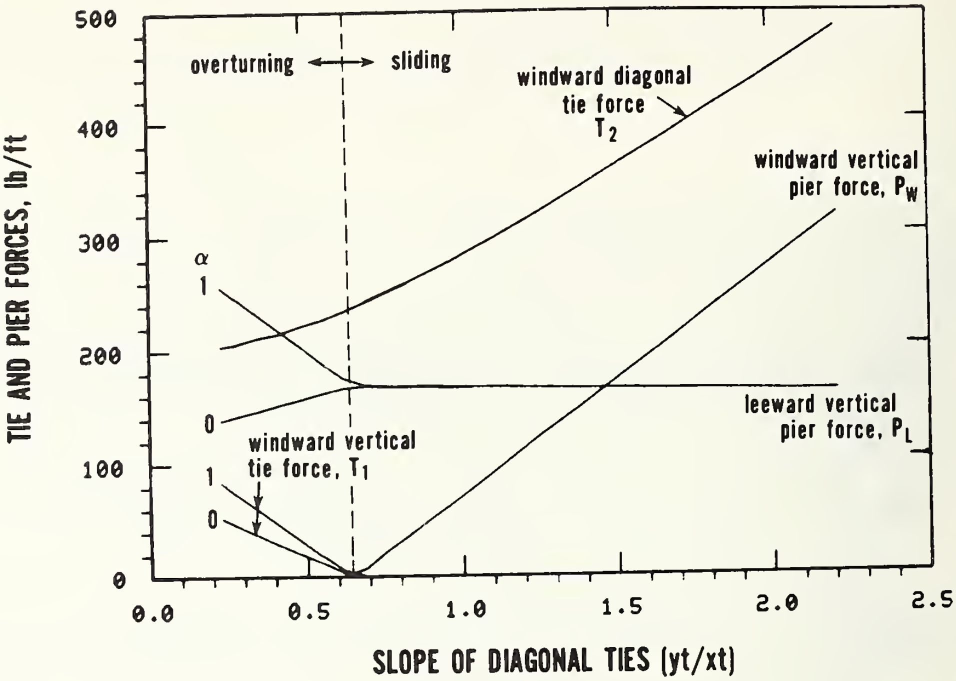
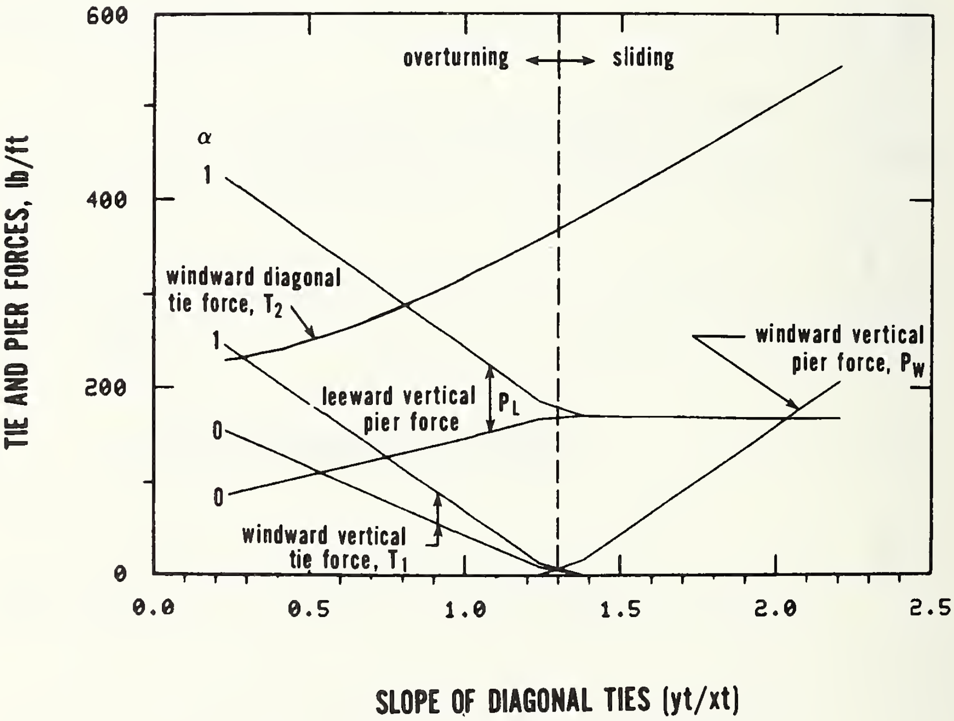


Figure 3.3 Tie and Pier Forces in a 14 ft Wide Mobile Home with Far-Tie Connections Subjected to the HUD Hurricane Wind Load

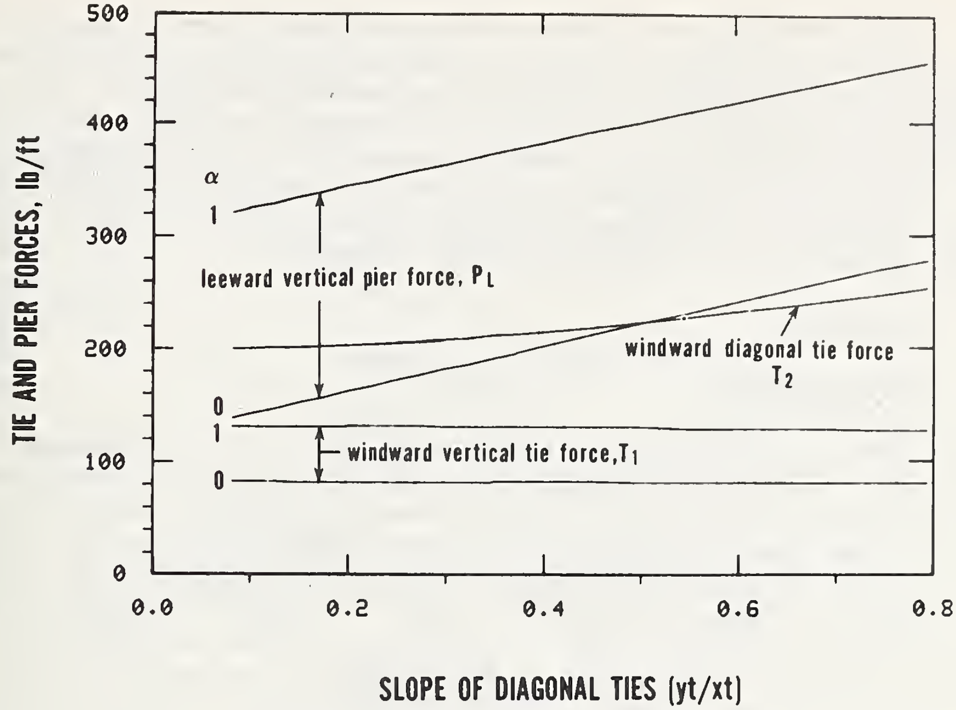


3.4A - HUD Hurricane Pressures

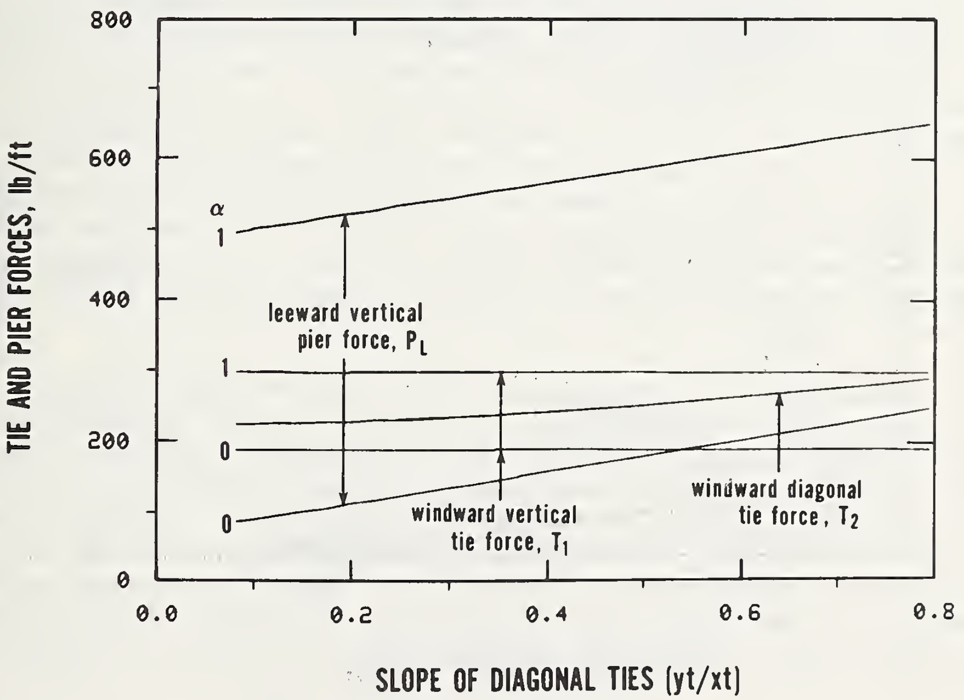


3.4B - NBS Hurricane Pressures

Figure 3.4 Comparison of the Effects of the HUD and NBS Hurricane Loads on a 14-ft Wide Mobile Home with Near-Tie Connections



3.5A - HUD Hurricane Pressures



3.5B - NBS Hurricane Pressures

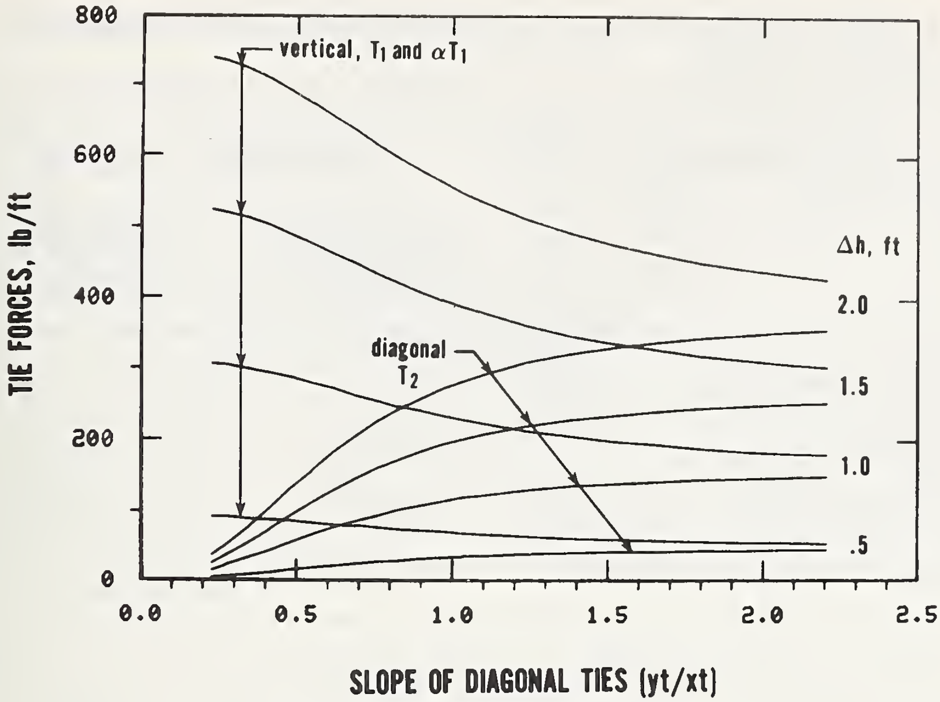
Figures 3.5 Comparison of the Effects of the HUD and NBS Hurricane Loads on a 14-ft Wide Mobile Home with Far-Tie Connections windward vertical-tie forces induced by the NBS Hurricane wind exceed those induced by the HUD hurricane wind by approximately 100 lb/ft. This significant difference between the two loading conditions is caused by the increased overturning moments and uplift forces associated with the NBS hurricane loading. The windward diagonal-tie forces are similar for both loading conditions, and the pier forces corresponding to $\alpha=0$ are smaller for the NBS hurricane because of increased uplift forces.

3.3.3 Flood Forces

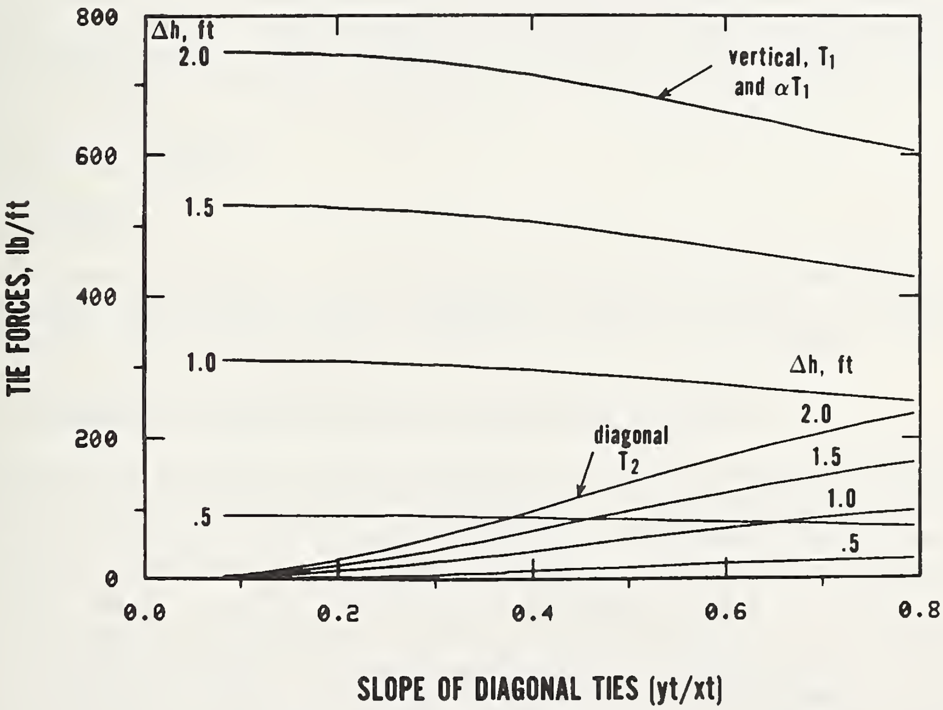
3.3.3.1 Buoyancy Forces

Tie forces, for near-tie and far-tie connections induced by buoyancy are shown in figure 3.6, which is taken from Charts 13 and 14 of the appendix. Differential heads (Δh) of 0.5, 1.0, 1.5 and 2.0 ft were used in the calculations. Note that for the typical cases, namely y_t/x_t = 0.69 and 0.25 for the near-tie and far-tie connections, respectively, the diagonal ties resist relatively little load and most of the load is carried by the vertical ties. To derive the diagonal and vertical tie forces, it was assumed that their magnitudes would be proportional to the relative strains in the ties. Thus, the ratio of the forces induced in the diagonal ties to those in the vertical ties is $\sin^2\beta$, where β is the angle of the diagonal tie with the horizontal. It should be noted that unless the ties are very ductile (which is normally not the case) the vertical ties could fail before the diagonal ties are fully stressed by buoyancy forces. However in the absence of vertical ties, or after the vertical ties fail, the diagonal ties could be engaged to their full load capacity. Since the same ties have to resist wind as well as flood loads, it is of interest to determine what bouyancy forces could be resisted by ties originally selected for resisting the HUD and NBS hurricane loads. A rough comparison is made in table 3.1 based on the assumption that all ties are loaded to the working load of 3150 lb and that the number of ties used does not exceed that necessary to resist the wind forces (actually the number of vertical ties used in near-tie connection is likely to exceed the minimum necessary).

Table 3.1 was derived for the typical cases y_t/x_t = 0.69 (near-tie) and 0.25 (far-tie) and on the assumption that the safety margins against failure are the same for wind and flood. It can be seen from the table that the ties provided to resist windloads could resist differential heads ranging from 0.5 to 0.7 ft. If, however, a vertical tie would be provided for every diagonal tie, the system could resist buoyancy forces resulting from a differential head of approximately 0.8 to 1 ft. It is important to note that selecting ties to meet wind load requirements generally results in the use of more diagonal than vertical ties (see table 4.2.2.1(a) of ANSI/NFPA 501A [5]).



3.6A - Near-Tie Connection



3.6B - Far-Tie Connection

Figure 3.6 Effects of Buoyancy Forces on a 14-ft Wide Mobile Home

Table 3.1 Buoyancy Condition That Can Be Resisted by Ties Designed for Hurricane Loads

Wind Load \ Buoyancy Condition	Differential head, Δh, ft	
	Vertical Ties Stressed to Capacity	Diagonal Ties[3] Stressed to Capacity Vertical Ties Failed
HUD Hurricane, Near Tie	---	0.65
HUD Hurricane, Far Tie	0.5	0.5
NBS Hurricane, Near Tie	0.5	0.7
NBS Hurricane, Far Tie	0.7	0.5

[3] The vertical ties are assumed to have failed before the diagonal-tie resistance shown in the second column in table 3.1 is developed.

3.3.3.2 Buoyancy Forces Combined with Hydrodynamic Drag or Wind

The effect of buoyancy forces combined with hydrodynamic forces caused by a velocity flow of 5 ft/sec normal to the long axis of the mobile home is shown in Charts 17 through 28 in the appendix. Many charts must be presented since differential head Δh, as well as depth of submergence h_s must be considered simultaneously. For the sake of comparing these loading conditions with buoyancy effects caused by a differential head $\Delta h = 1$ ft acting alone, reference is made to Charts 13 and 25, for near-tie and Charts 14 and 26 far-tie connections, respectively. It can be seen that the drag force does not cause large diagonal tie forces. The vertical tie forces are slightly greater than those caused by buoyancy alone. For instance, in the case of the typical y_t/x_t value for far-tie connections, 0.25, the vertical tie force increases from approximately 305 lb/ft for buoyancy acting alone (see Chart 14) to 325 lb/ft for the load combination (see Chart 26). Even though the effects of the assumed velocity flow conditions seem moderate, it is important to keep in mind that drag effects could be significantly increased by floating debris which can be entangled in the straps and jammed against the mobile home.

The effects on a 14-ft wide mobile home of combining the HUD Standard Wind load with buoyancy force resulting from differential heads, Δh, of 0.5 and 1.0 ft are shown in Charts 29 and 30 of the appendix. Comparison of these charts with those for buoyancy acting alone indicates that this loading condition causes a significant increase in the tie forces, which may be critical for the vertical ties. This increase is caused by the effects of uplift and overturning moment, combined with those of the horizontal load.

3.3.4 Parametric Study

3.3.4.1 General

In this section the effects of the assumptions listed in paragraph 3.2 are quantified for the typical y_t/x_t values of 0.69 for near-tie connections and 0.25 for far-tie connections for 14-ft wide mobile homes.

3.3.4.2 Effects of Horizontal-Load Resistance of Piers

The effects of horizontal load resistance of piers is shown in figure 3.7. The horizontal load resistance is viewed as a "friction factor," μ, which is given as a fraction of the pier reaction. Thus, μ=0.2 would mean that if a reaction force P is exerted by a pier, the pier will also resist a horizontal force equal to 0.2P. A range of μ values from 0 to 0.4 is considered. Note that it may be misleading to view pier resistance as a "friction factor," since the limiting factor may not be friction but the ability of the pier to resist horizontal load. As long as there is no requirement to provide a positive connection between the pier and the mobile home, any horizontal-load resistance of the pier would be limited by the friction coefficient or the

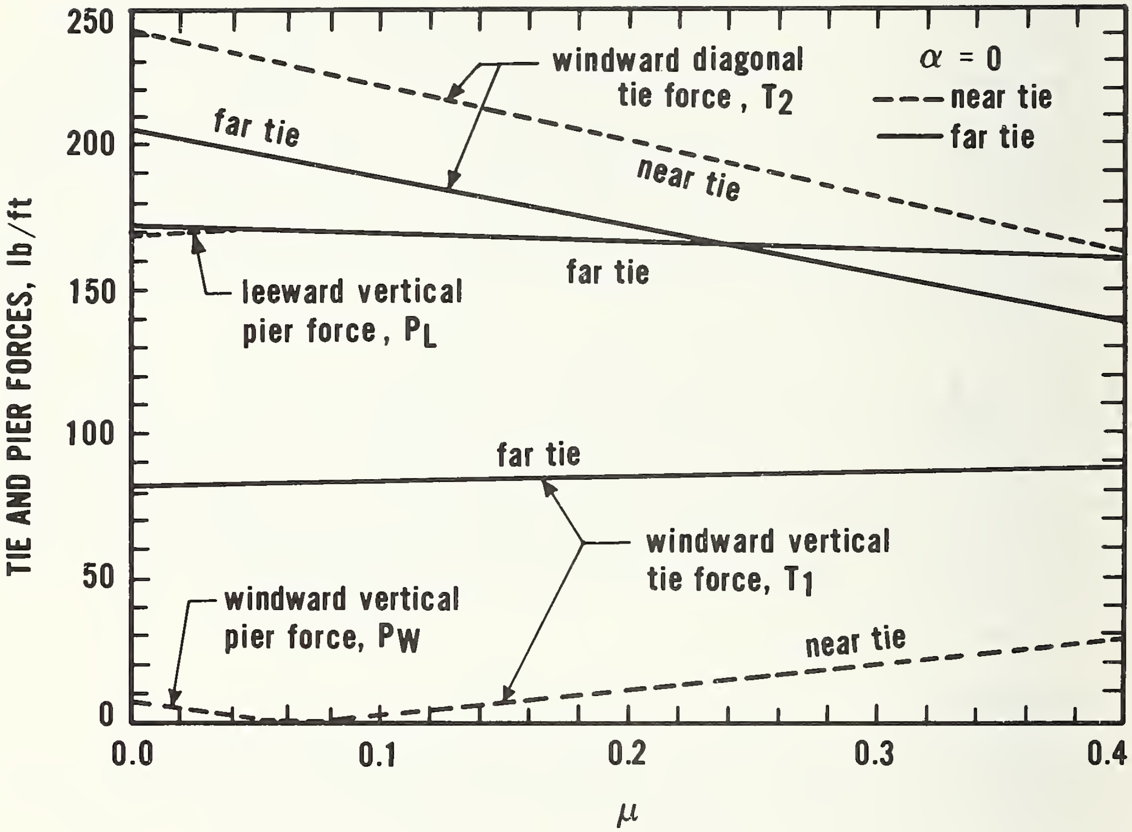


Figure 3.7 Effects of Horizontal-Load Resistance of Piers on 14-ft Wide Mobile Homes

horizontal-load capacity of the pier. Note that an increase in pier resistance would cause a decrease in the diagonal tie forces for the near-tie and the the far-tie connection. Between μ=0 and μ=0.4 this decrease would be about 50 lb/ft. For the near-tie connection, small forces would develop in the windward vertical tie as the load in the diagonal tie is reduced.

3.3.4.3 Effects of Eccentricity

The effect of varying the weight eccentricity with respect to the longitudinal axis (transverse eccentricity) is shown in figure 3.8. It was assumed in the calculations that the over-the-roof ties do not transfer loads from one side of the mobile home to the other (α=0), since this is the case in most instances. Negative eccentricity is eccentricity on the windward side and positive eccentricity is on the leeward side. Note that the effect on near-tie connections of increasing the eccentricity on the leeward side is an increase in the leeward pier reaction and a corresponding decrease in the windward pier reaction. For far-tie connections there is an increase in the leeward pier reaction and the windward vertical tie force with increasing leeward eccentricity. The effect of moving the center of gravity 0.75 ft from the centerline in the leeward direction is about a 20 lb/ft increase in the windward vertical tie force.

3.3.4.4 Effects of the Weight of the Mobile Home

Weight effects are shown in figure 3.9. Note that an increase in the weight of the mobile home would not affect diagonal-tie forces. However, this conclusion is predicated on the assumption that the piers resist no lateral load. Increased weight would substantially decrease diagonal-tie forces if horizontal reactions are also provided by frictional resistance at the top of piers. As should be expected, increased weight will increase pier reactions and reduce windward vertical-tie forces.

3.3.4.5 Effects of Load Transfer Coefficient α

Effects of changing coefficient α are shown in figure 3.10. The extremes of these effects are also shown in the appendix. Note that there is a moderate effect on the vertical-tie forces which is caused by the increase in overturning moment about the leeward pier, and a strong effect on the leeward pier reaction which is caused by the added downward pull.

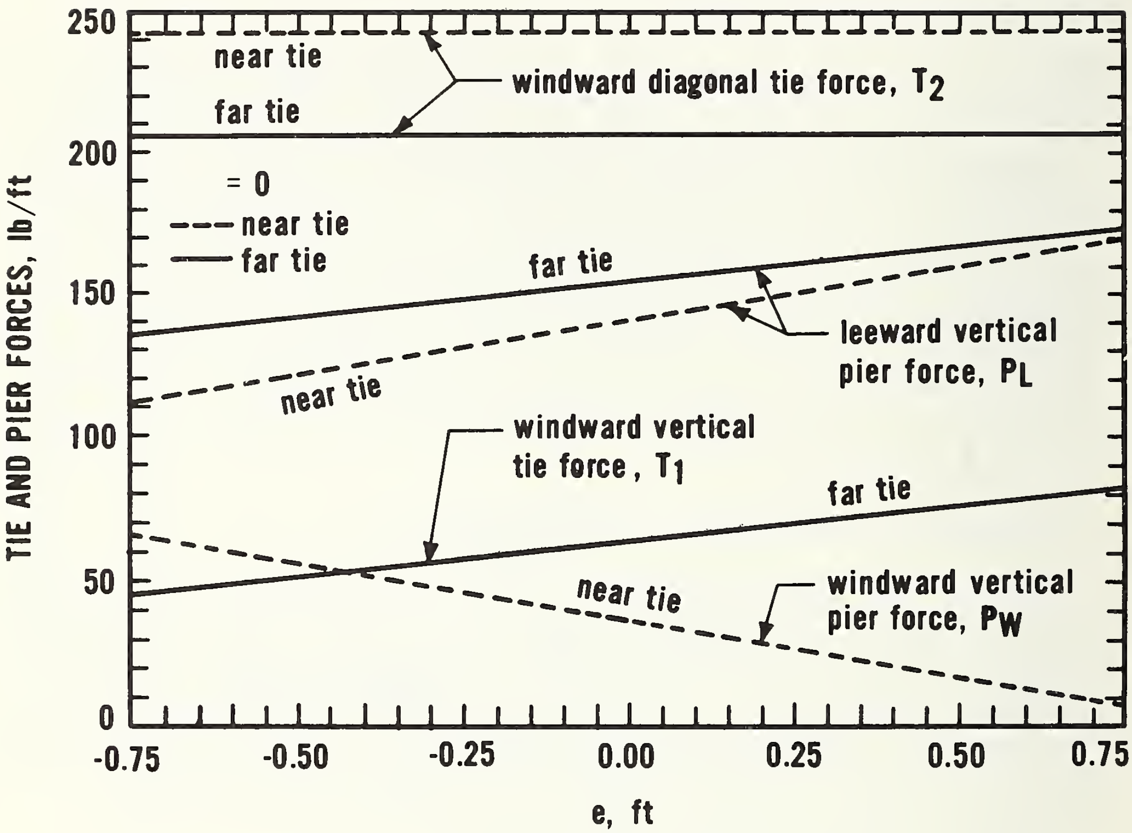


Figure 3.8 Effects of Weight Eccentricity on 14-ft Wide Mobile Homes

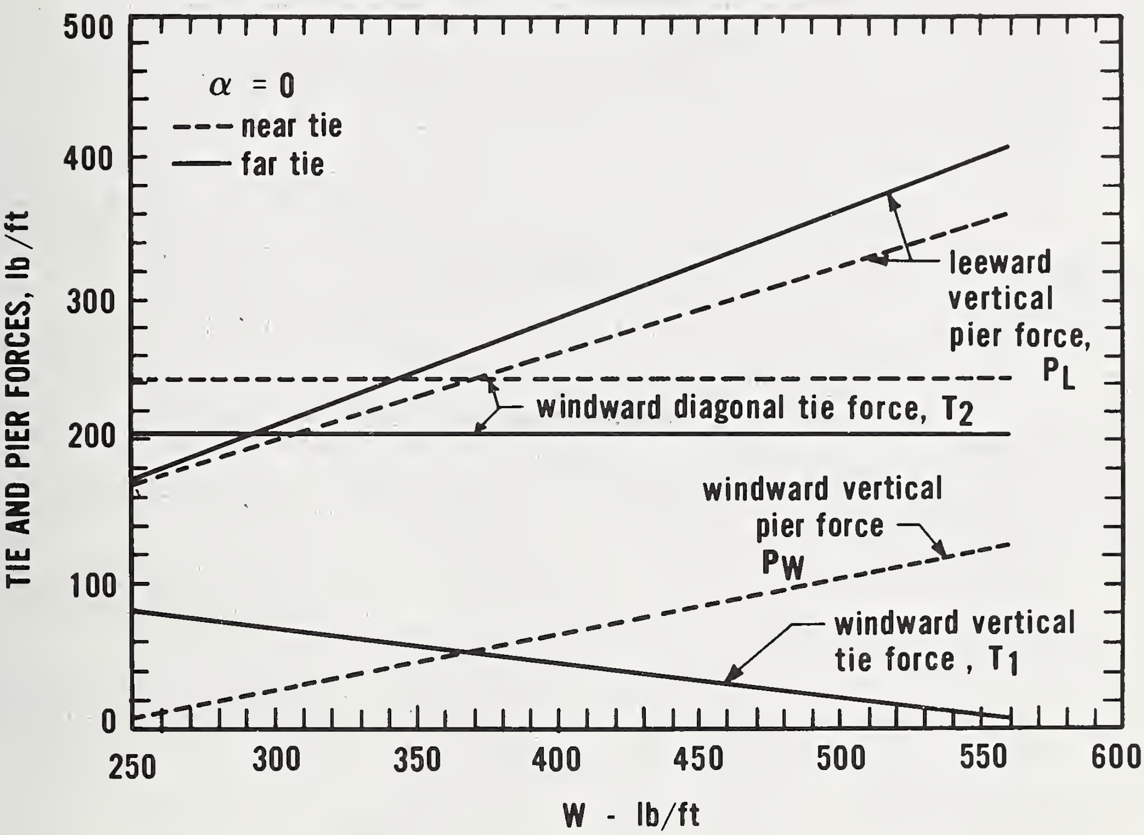


Figure 3.9 Effects of the Weight of a 14-ft Wide Mobile Home on Expected Reaction Forces

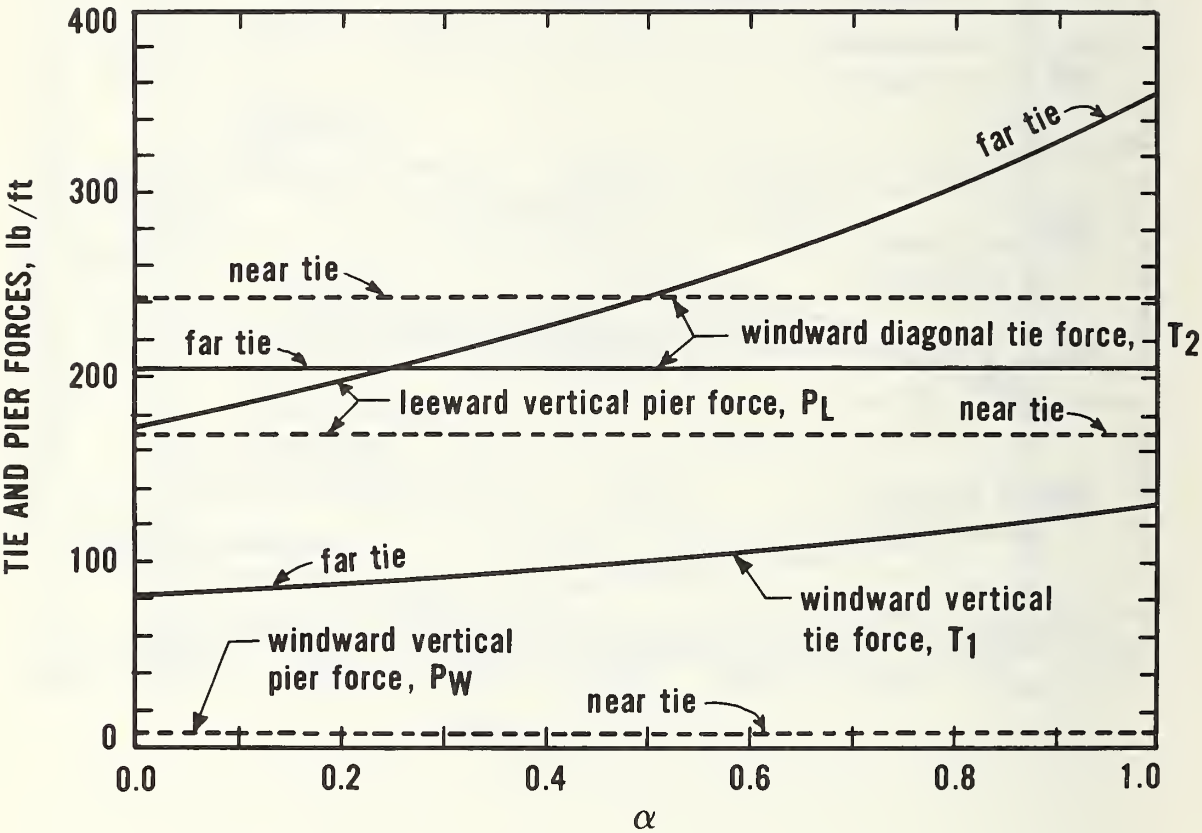


Figure 3.10 Effects of the Load Transfer Coefficient of Over-the-Roof Ties on the Reaction Forces in a 14-ft Wide Mobile Home

Facing page: *The forces transmitted to this soil anchor exceeded its pullout capacity with the result that the mobile home was blown off its support.*

4. COMPARISON OF CALCULATED REACTIONS WITH PRESENT STANDARD PROVISIONS

The present Federal Standard [1] calls for a 50 percent increase of the horizontal and vertical wind pressures mentioned in paragraphs 2.2.1 (1) and 2.2.1 (2) when calculating forces acting on the tiedown system. This specified overload factor results in tie and pier design forces which can be derived by increasing the reaction forces in the appendix (charts 1 through 8) by 50 percent. However the Federal Standard does not stipulate specific tiedown methods, whose resistance can be quantified and compared with calculated design forces. A more prescriptive approach is taken in the NFPA-ANSI Standard [5], which in the past has provided guidance to mobile home manufacturers and anchor installers in providing ties and selecting the number of anchors required. Thus, calculated tie forces such as those in the appendix can be compared with requirements in Table 4.2.2.2(a) of the NFPA Standard. The table is based on a working load of 3150 lb per tie. This working load can be directly compared with calculated forces, since the calculated forces are also working load values. The comparison will be made for the "typical" near-tie and far-tie connections for a 14-ft wide mobile home, namely y_t/x_t = 0.69 for the near-tie and y_t/x_t = 0.25 for the far-tie. A 73 ft long mobile home is assumed in order to compare the calculated number of ties with those for the 70-73 ft length in the NFPA table. It is further assumed that the anchor can provide the required load resistance since this assumption is implicit in the NFPA Standard. The same method of calculating the number of ties is extrapolated to the NBS hurricane and flood conditions in order to afford comparisons. It is emphasized that the calculated number of ties would not comply with the federal overload provision, since it is assumed that no such provisions were contemplated when the NFPA Standard was written.

The comparison of the number of ties calculated in accordance with the appendix and the number of ties required in the NFPA Standard is given in table 4.1.

Considering the fact that the NFPA table was prepared for the HUD Standard (Zone I) and Hurricane (Zone II) winds, there appears to be reasonable agreement between the calculated tie forces and the required number of ties in the NFPA table.

A comparison of wind induced pier reactions with minimum foundation loads stipulated in the NFPA Standard is difficult to make because other line loads may contribute to foundation pressures. In section 4.3.3 of the Standard, maximum "combined live and dead loads" of 55 psf and 65 psf are recommended for the "Middle Zone" and the "North and Hurricane Zone," respectively. Obviously the intent was to provide for either extreme wind or extreme snow load, but not for both loads simultaneously, and the added allowance for the weight of occupants is not stipulated. Nevertheless some insight can be gained by comparing calculated pier reactions with the stipulated NFPA design pressures. This comparison is made in table 4.2. Note that the calculated pressures are for a light mobile home and a 2.5 ft high pier.

The pressures could increase by as much as 10 psf for a heavy mobile home, and for far-tie connections they could further increase by another 10 psf when the height of the pier increases to 8 ft. However, even for the case of extreme pier heights and mobile home weight, the footing pressures caused by combined dead and wind loads could not exceed those stipulated in the NFPA Standard. Table 4.1 is for the case of α=0. Footing pressures could substantially increase if there is a load transfer across the vertical ties, a condition which should be avoided.

Table 4.1 Comparison of NFPA Standard Provisions with Calculated Tied Forces

REQUIRED TIES	NFPA		CALCULATED			
			NEAR TIE		FAR TIE	
LOADING	V	D	V[b]	D	V[b]	D
HUD STANDARD WIND	2	4	-	4	1	3
HUD HURRICANE	3	7	-	6	2	5
NBS HURRICANE			2	7	5	6
BUOYANCY[a], Δh=1 ft.			6	6	7	7
BUOYANCY, Δh=1 ft. + VELOCITY, v=5 ft./sec.			7	7	8	8
h_s = 1.5 ft.						
BUOYANCY, Δh=1 ft. + HUD STANDARD WIND			8	8	10	10

V = Vertical tie direction

D = Diagonal tie direction

a/ For all buoyancy forces it was assumed that there is a vertical tie for each diagonal tie.

b/ The number of ties shown is that calculated from the forces. However, it would be unreasonable to have less than 2 vertical ties, and probably the minimum should be three.

Table 4.2 Comparison of NFPA Standard Provisions for Footings with Calculated Pier Loads

LOADING	MINIMUM FOOTING PRESSURE PER FT^2 OF TRIBUTARY AREA IN PSF		
	CALCULATED		NFPA STANDARD
	NEAR TIE	FAR TIE	
HUD STANDARD	24	18	55
HUD HURRICANE	24	26	65
NBS HURRICANE	26	25	

Facing page: *Unanchored mobile homes are susceptible to overturning during a windstorm.*

5. CONCLUSIONS

The conclusions drawn herein relate to the calculated working loads. They do not relate to safety margins in design which should be based on the variability of the loads and the reliability of the anchors and tiedown systems, and which should be consistent with safety margins required in other parts of the mobile home.

The following conclusions can be drawn from the previously discussed results of the calculations.

(1) The diagonal ties are instrumental in resisting the windloads. Wind-loads can be resisted by diagonal ties alone if a near-tie connection is used. Vertical ties alone can not provide adequate wind resistance unless the piers are designed to resist the horizontal load component.

(2) Hurricane windloads recommended by NBS result in larger uplift forces and overturning moments and therefore require an increased number of vertical ties.

(3) Vertical ties are more effective than diagonal ties in resisting the buoyancy forces resulting from flooding. If the number of vertical ties is not adequate to resist the uplift forces, the vertical ties would probably fail (unless they are very ductile) before the diagonal ties are fully loaded. Buoyancy forces could be resisted by diagonal ties alone if there are near-tie connections, but the ties will not be very efficient. If flooding is anticipated, it is desirable to have an equal number of diagonal and vertical ties.

(4) Tiedown systems designed for hurricane winds (HUD or NBS) can resist buoyancy forces resulting from differential heads of 6 to 8 inches. If vertical ties are added so that there is an equal number of vertical and diagonal ties, resistance would be increased to 10-12 inches of differential head.

(5) The drag force resulting from a flow velocity of 5 ft/sec when combined with the buoyancy force resulting from a 1-ft differential head will not substantially overload a system designed for the buoyancy alone (provided that the forces are not increased by floating debris). However, if HUD Standard Wind is combined with buoyancy, there is a significant increase in the tie forces which should be considered in the design of anchor systems.

(6) The prescriptive provisions in the NFPA Standard provide adequate resistance to the wind loads stipulated in the Standard, provided the anchors can provide the resistance required of the straps. To also provide moderate resistance against flooding, the number of vertical ties should be increased to equal the number of diagonal ties.

(7) The maximum pressures on pier footings caused by combined dead and wind loads are not likely to exceed the design pressures stipulated in the NFPA Standard.

6. REFERENCES

[1] Department of Housing and Urban Development, Mobile Home Construction and Safety Standard, Federal Register, Vol. 70, No. 244, Title 24, Chapter II, Part 280, Subpart D, Amended Version dated November, 1979.

[2] Hoerner, S., Fluid Dynamic Drag; Practical Information on Aerodynamic Drag and Hydrodynamic Resistance, Midland Park, N.J., 1958.

[3] Marshall, R.D., The Measurement of Wind Loads on a Full Scale Mobile Home, NBSIR 77-1289, National Bureau of Standards, Washington, D.C. September, 1977.

[4] Kovacs, W.D., and Yokel, F.Y., Soil and Rock Anchors for Mobile Homes - A-State-of-the-Art Report, NBS Building Science Series 107, National Bureau of Standards, October, 1979.

[5] National Fire Protection Association (NFPA) No. 501 A (ANSI 119.3), Standards for the Installation of Mobile Homes, Manufactured Housing Institute and National Fire Protection Association, Boston, MA, 1975.

[6] Yokel, F.Y., Chung, R.M., Performance of Soil Anchors for Mobile Home, Third Moble Home/Manufactured Housing Engineering Conference, University of Texas, Austin TX, Jan. 1980.

APPENDIX

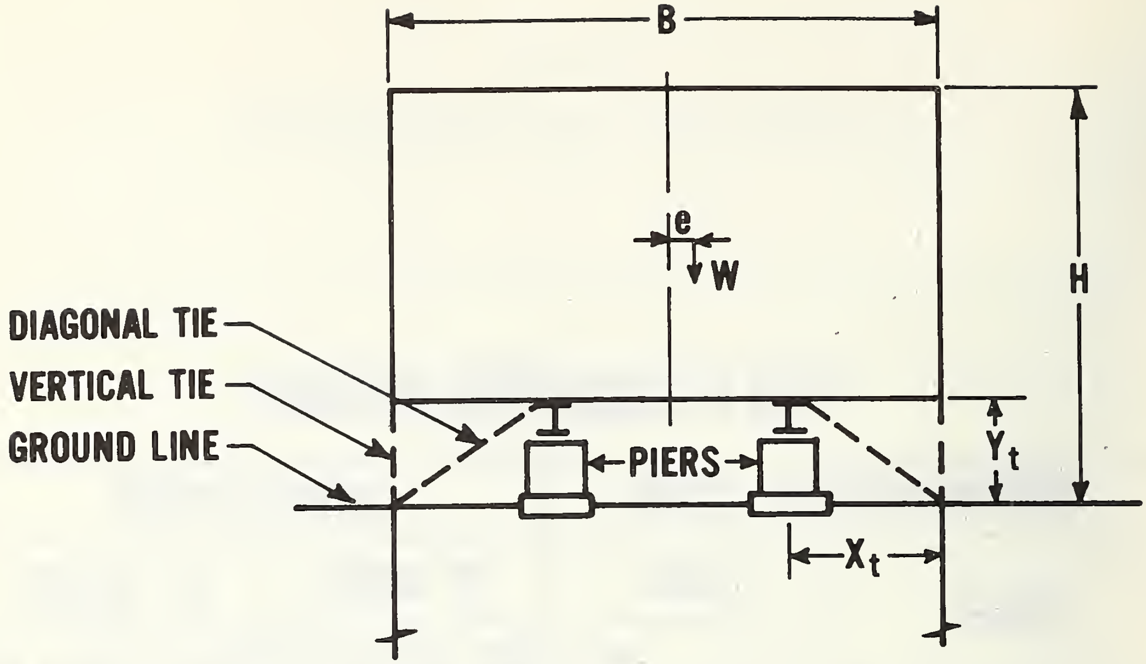
Calculated Strap, Anchor, and Pier Loads

DATA LOCATION MATRIX

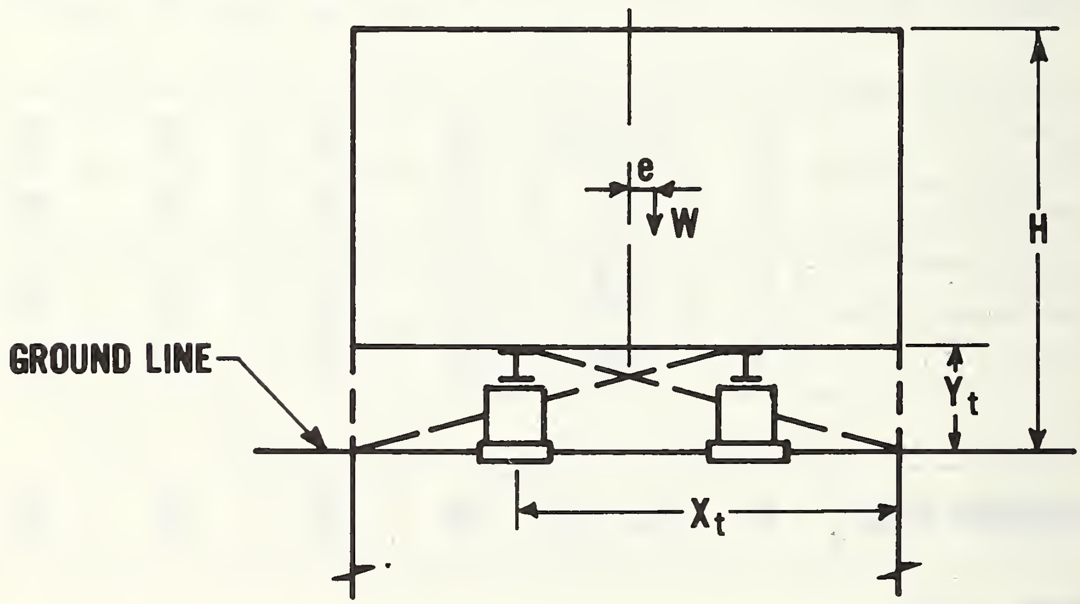
ENVIRONMENTAL LOADS			MOBILE HOME			
WIND	FLOOD		14' WIDTH		12' WIDTH	
	v 1/	Δh 2/	NEAR TIE	FAR TIE	NEAR TIE	FAR TIE
STANDARD HUD			1	2	3	4
HURRICANE HUD			5	6	7	8
HURRICANE NBS			9	10	11	12
	0	0.5-2.0	13	14	15	16
	5	0	17	18	19	20
	5	0.5	21	22	23	24
	5	1.0	25	26	27	28
STANDARD HUD	0	0.5, 1.0	29	30	31	32

1/ velocity, ft/sec

2/ differential head, ft

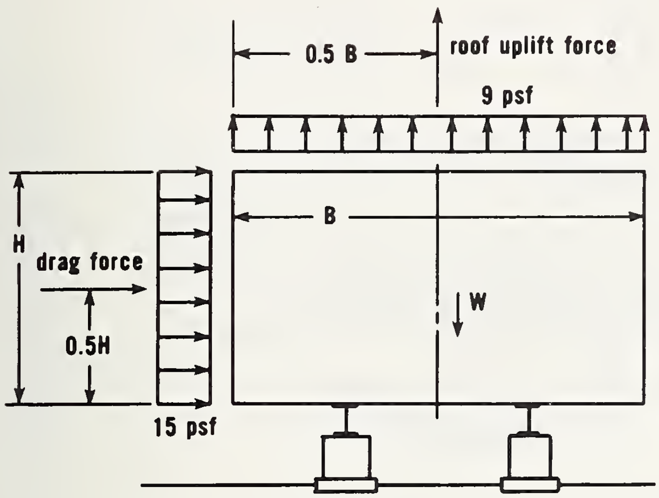


A.1A Near Tie Connection

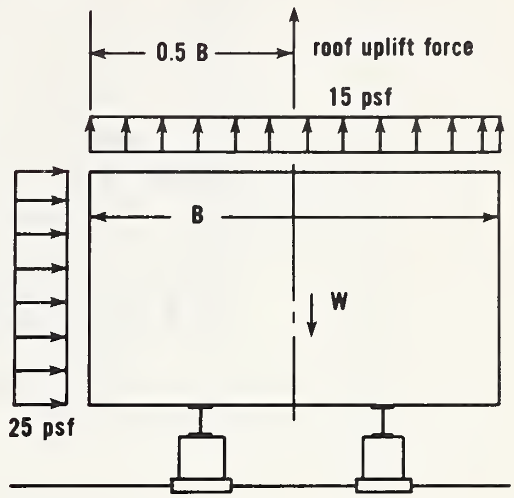


A.1B Far Tie Connection

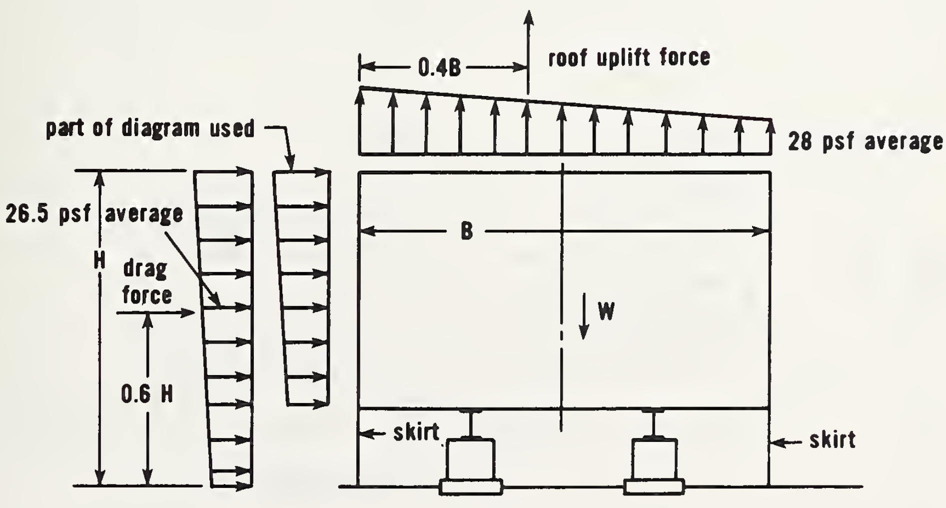
Figure A.1 Typical Mobile Home Anchoring System



A.2A HUD Standard wind (Zone I)

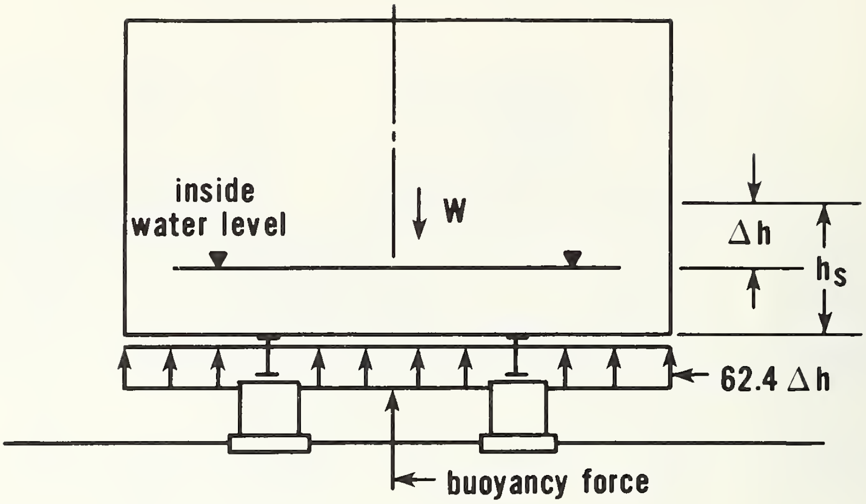


A.2B HUD Hurricane (Zone II)

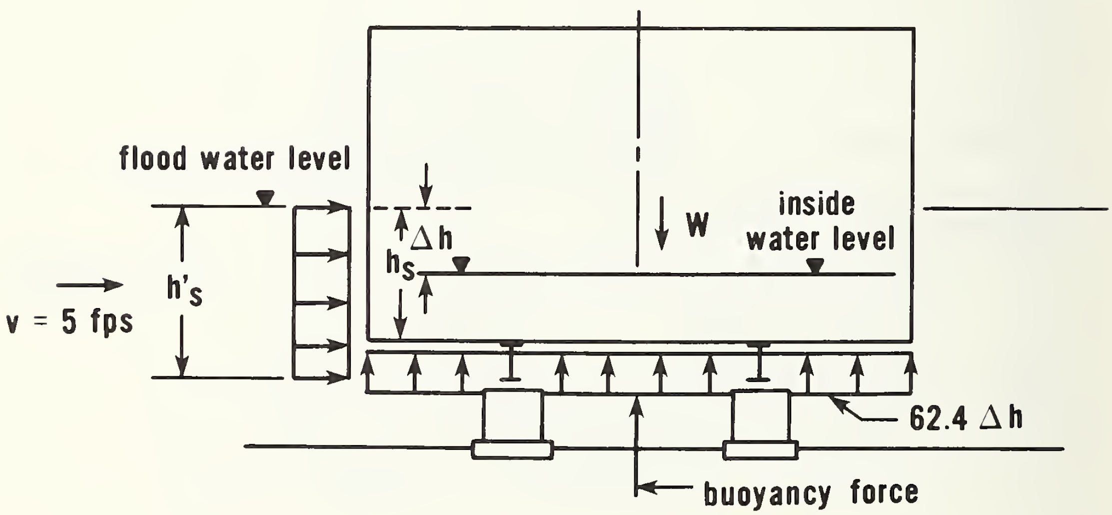


A.2C NBS Hurricane

Figure A.2 Assumed Wind Loading Conditions



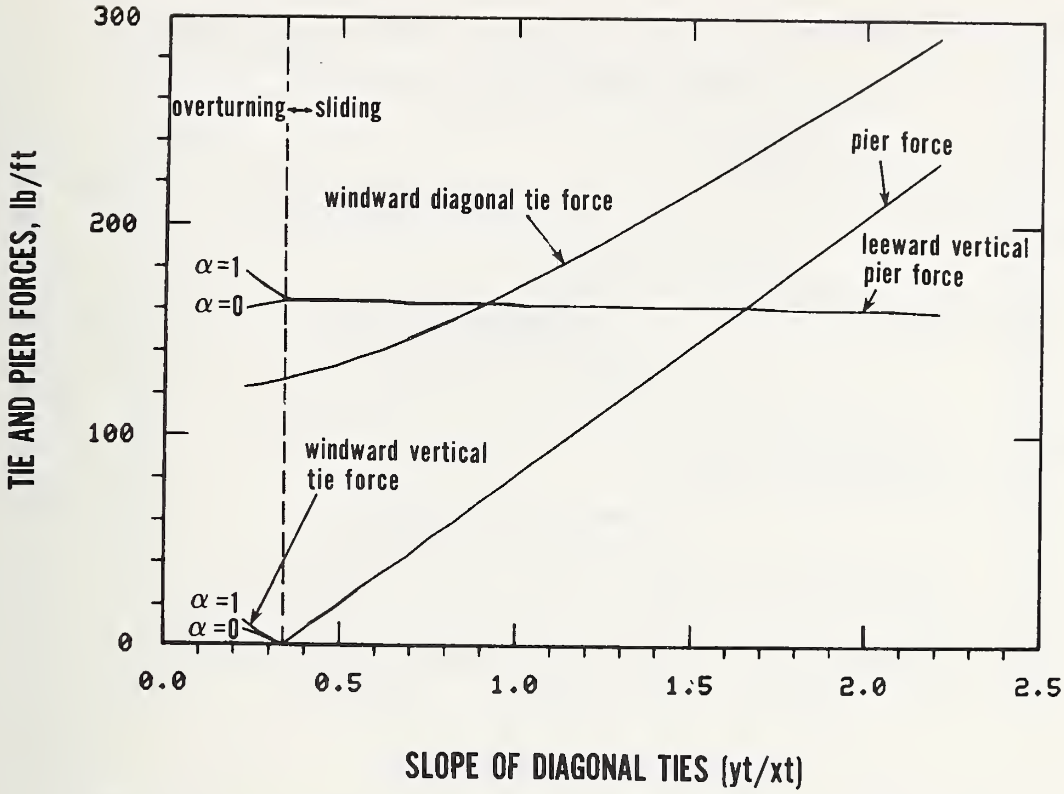
A.3A Buoyancy Force Without Flow Velocity

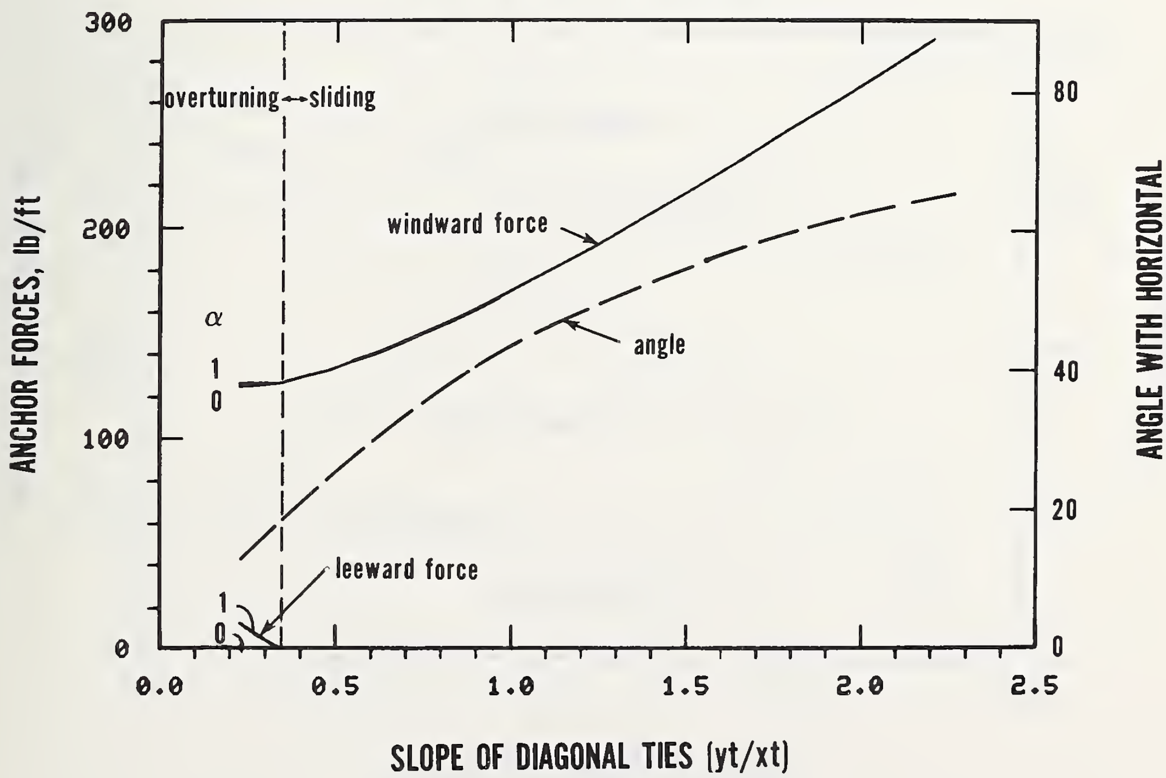


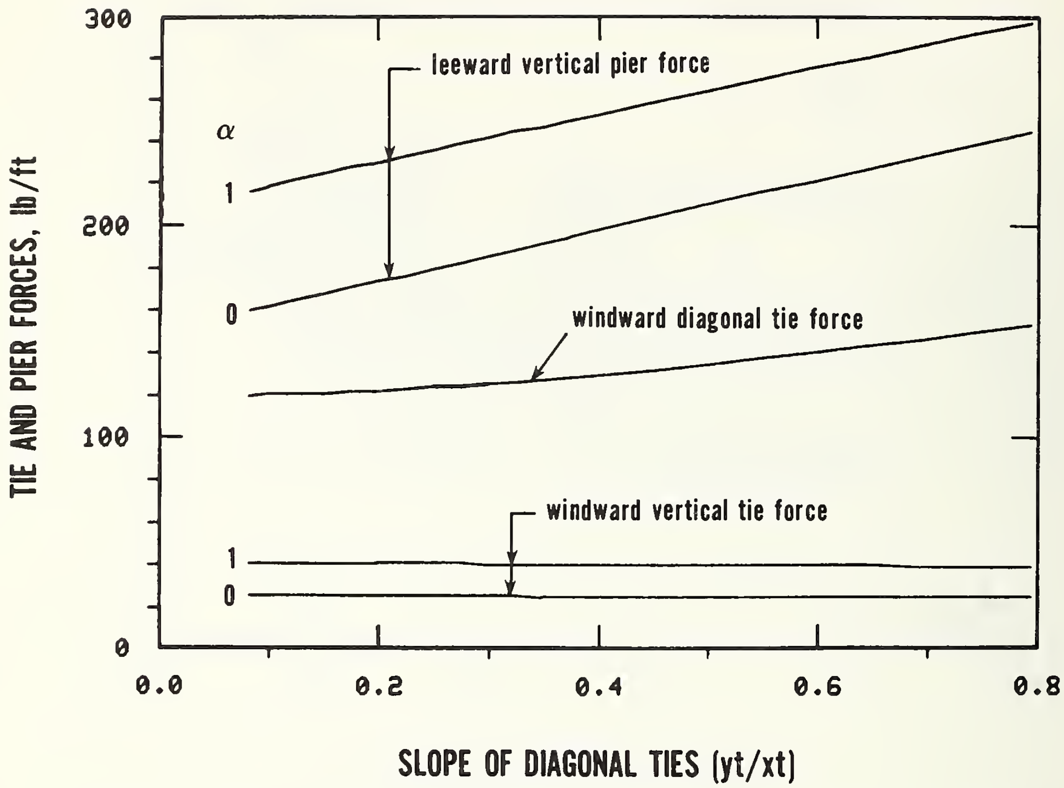
A.3B Buoyancy Force Plus Flow Velocity

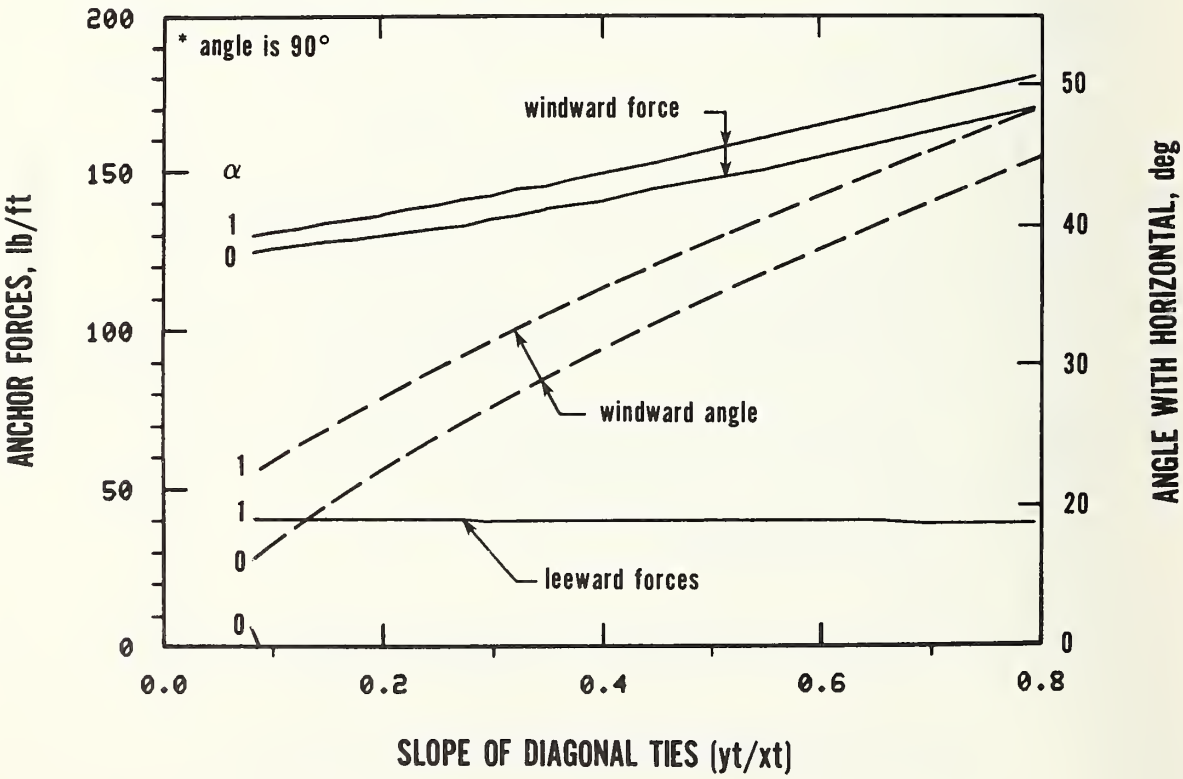
Figure A.3 Assumed Flood Loading Conditions

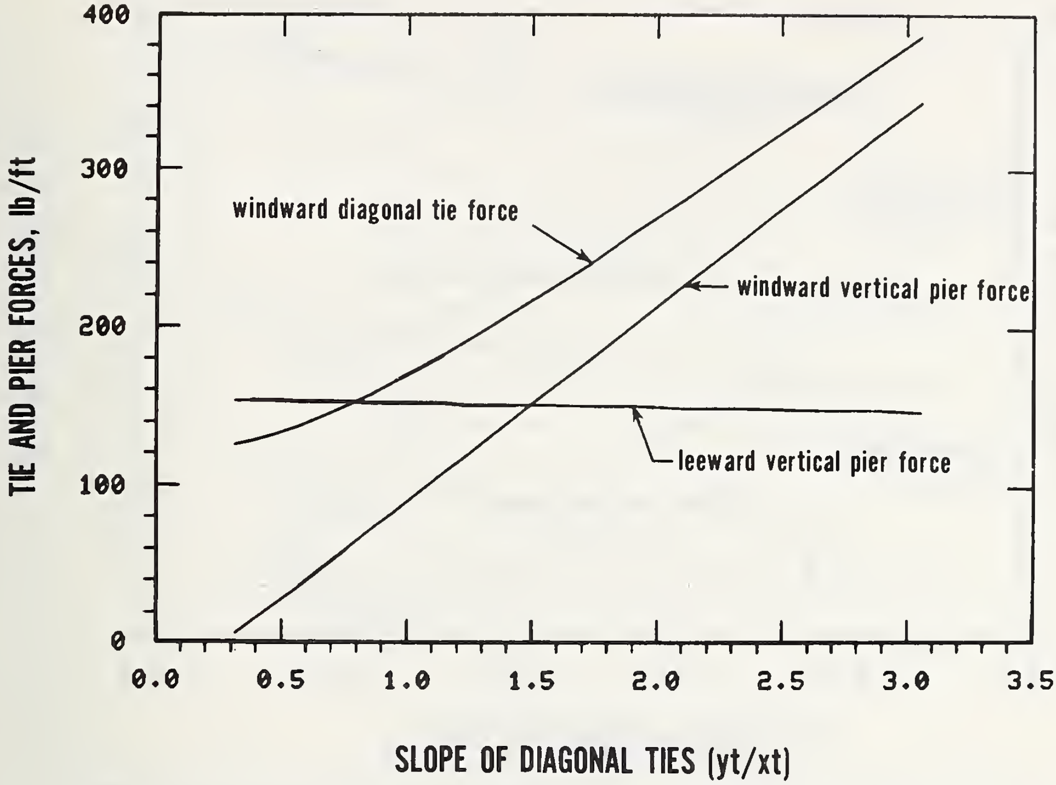
1

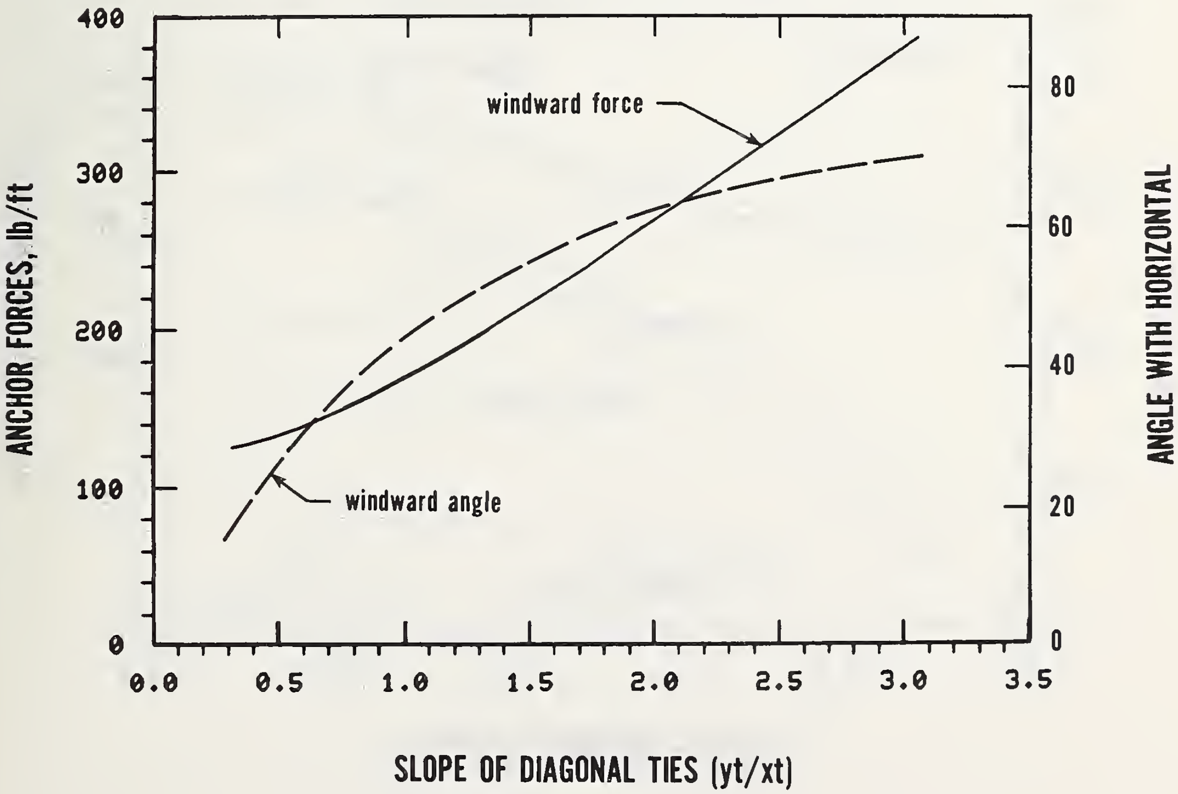

300
200
100
0
TIE AND PIER FORCES, lb/ft
overturning↔sliding
windward diagonal tie force
pier force
leeward vertical
pier force
α=1
α=0
windward vertical
tie force
α=1
α=0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

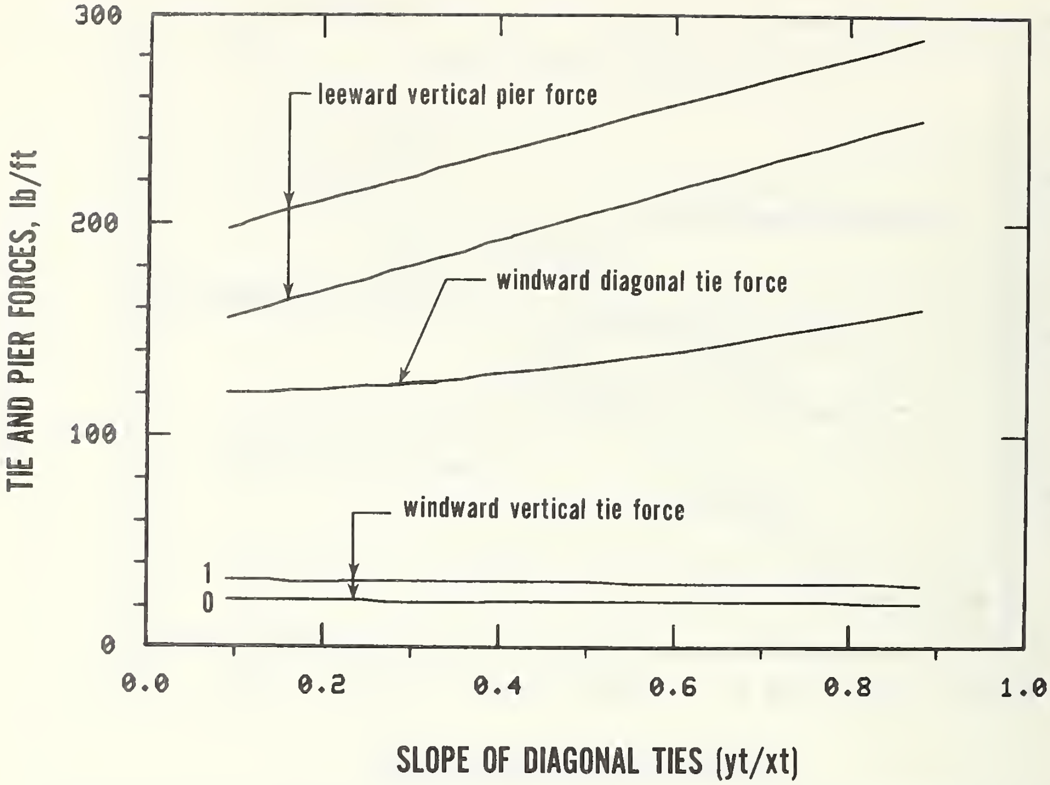

300
200
100
0
ANCHOR FORCES, lb/ft
overturning↔sliding
windward force
angle
α
1
0
leeward force
1
0
80
40
20
0
ANGLE WITH HORIZONTAL
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)


300
200
100
0
0.0
0.2
0.4
0.6
0.8
TIE AND PIER FORCES, lb/ft
leeward vertical pier force
α
1
0
windward diagonal tie force
windward vertical tie force
1
0
SLOPE OF DIAGONAL TIES (yt/xt)

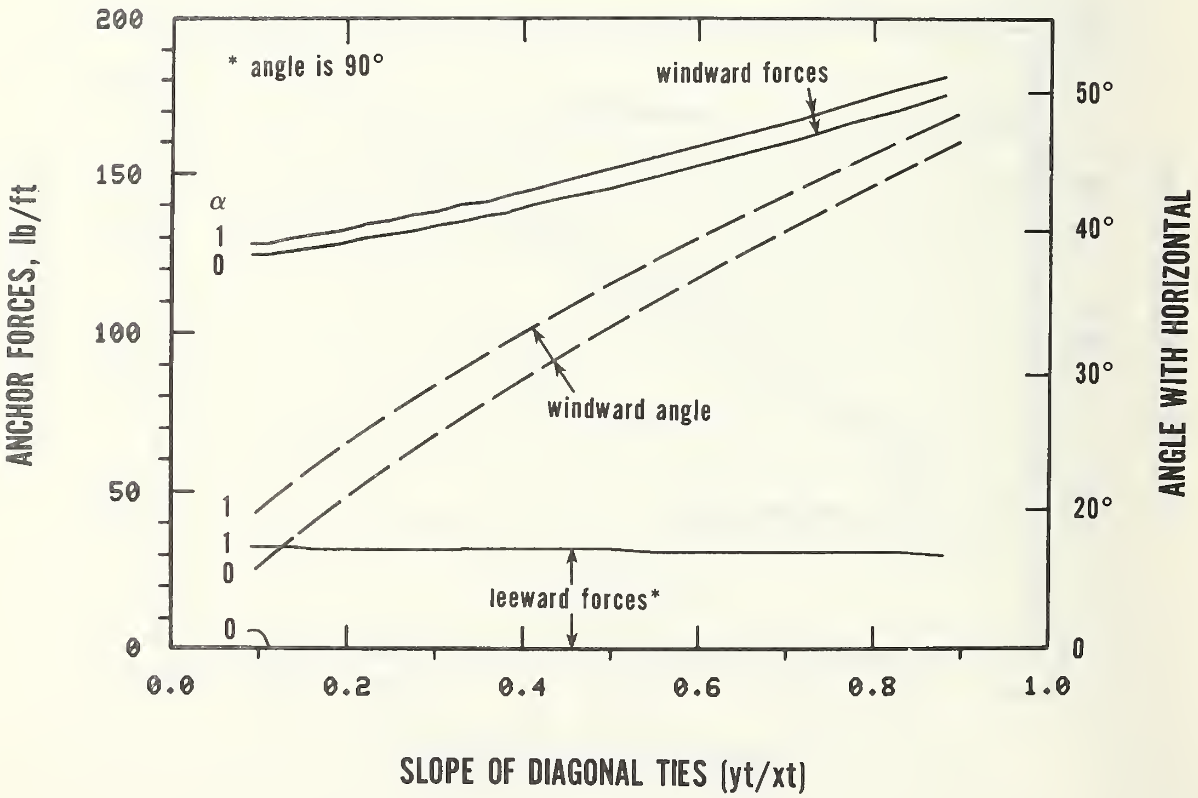

200
150
100
50
0
0.0
0.2
0.4
0.6
0.8
ANCHOR FORCES, lb/ft
* angle is 90°
windward force
α
1
0
windward angle
1
1
0
leeward forces
0
50
40
30
20
0
ANGLE WITH HORIZONTAL, deg
SLOPE OF DIAGONAL TIES (yt/xt)


TIE AND PIER FORCES, lb/ft
400
300
200
100
0
windward diagonal tie force
windward vertical pier force
leeward vertical pier force
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

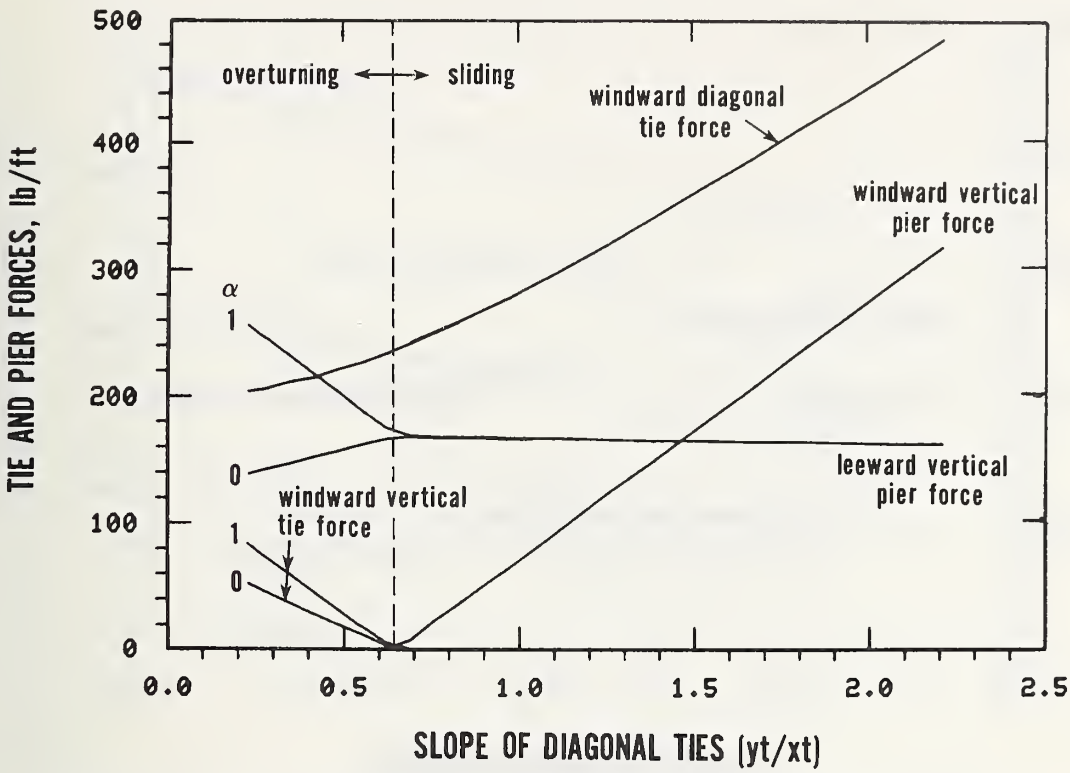

ANCHOR FORCES, lb/ft
400
300
200
100
0
windward force
windward angle
ANGLE WITH HORIZONTAL
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

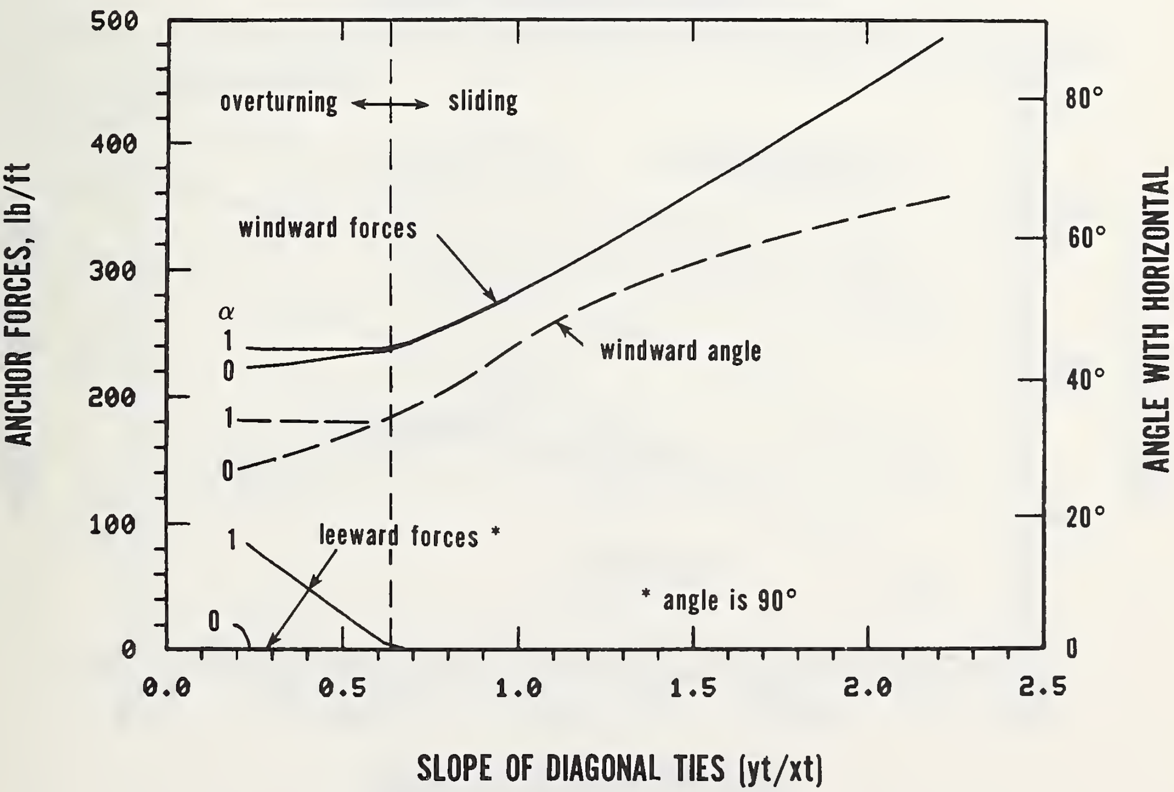


300
200
100
0
leeward vertical pier force
windward diagonal tie force
windward vertical tie force
1
0
0.0
0.2
0.4
0.6
0.8
1.0
TIE AND PIER FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)

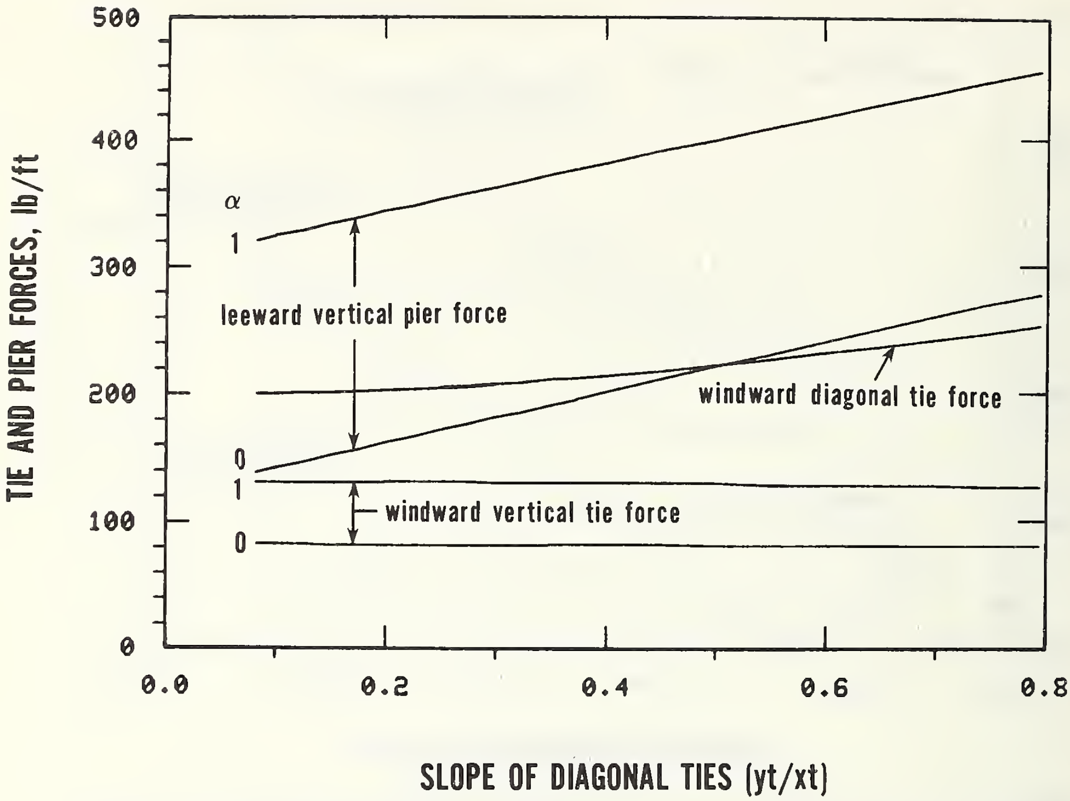


200
150
100
50
0
* angle is 90°
windward forces
α
1
0
windward angle
1
1
0
leeward forces*
0
50°
40°
30°
20°
0
0.0
0.2
0.4
0.6
0.8
1.0
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)

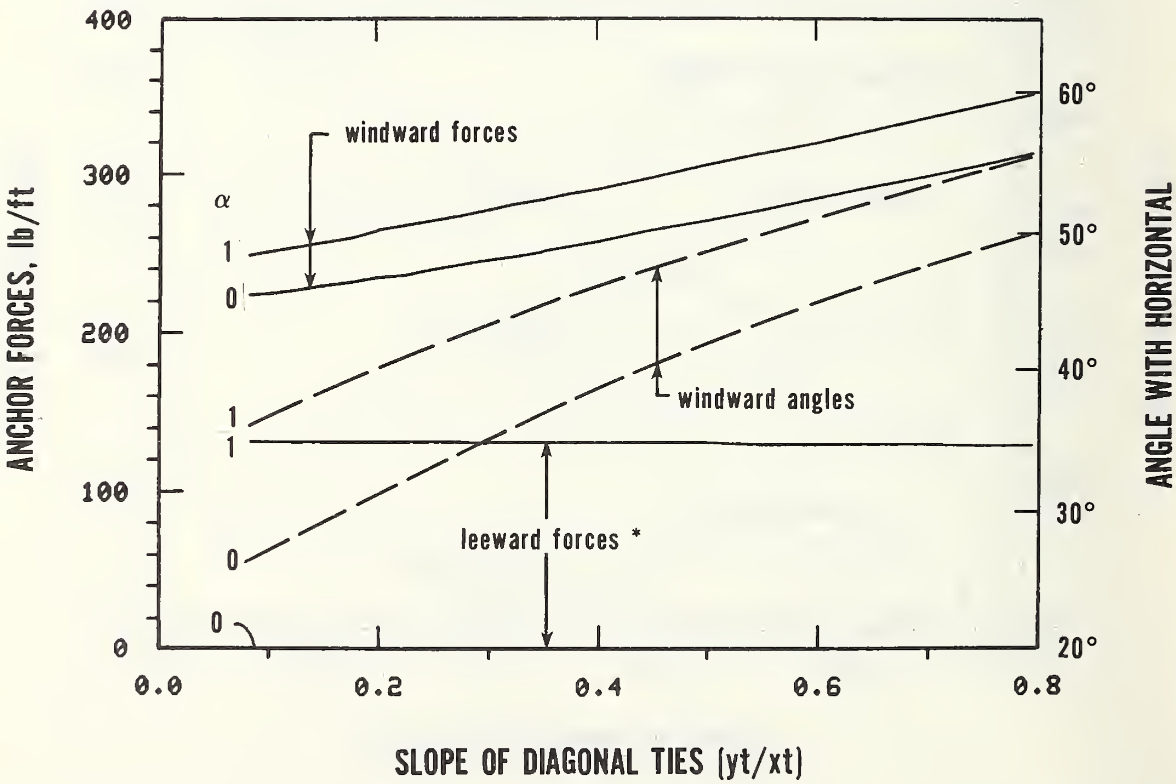

TIE AND PIER FORCES, lb/ft
overturning sliding
windward diagonal tie force
windward vertical pier force
leeward vertical pier force
windward vertical tie force
α
1
0
1
0
500
400
300
200
100
0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)


ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
overturning sliding
windward forces
windward angle
leeward forces *
* angle is 90°
α
1
0
1
0
1
0
500
400
300
200
100
0
80°
60°
40°
20°
0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

6

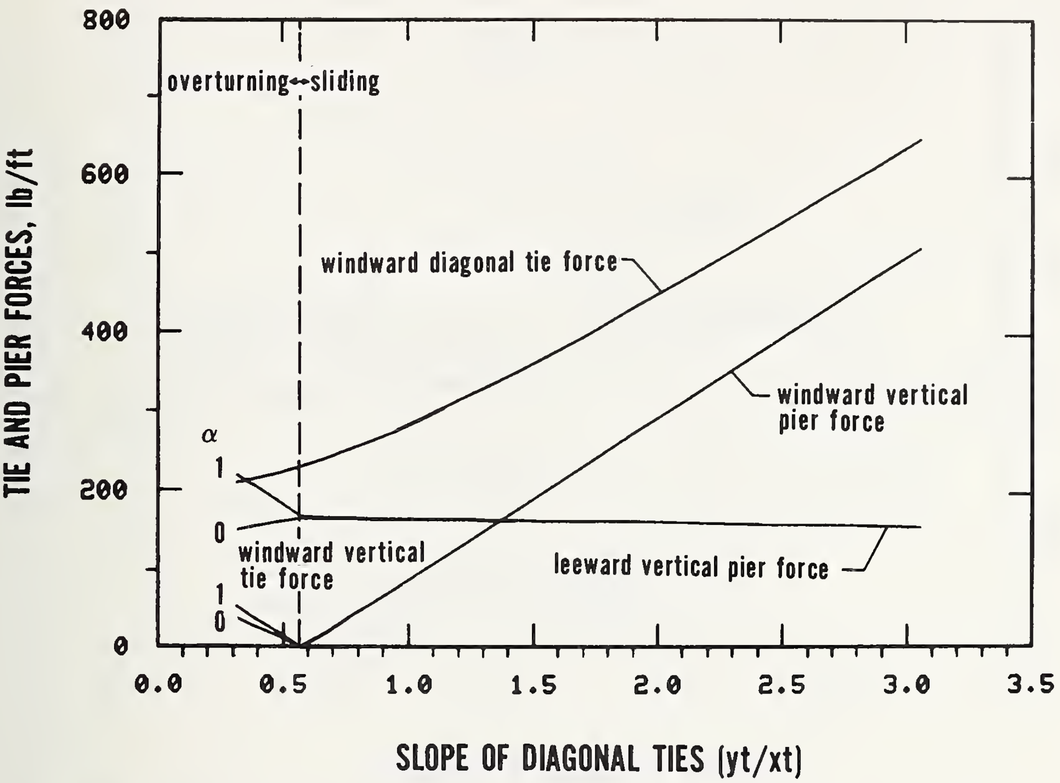


500
400
300
200
100
0
α
1
0
1
0
leeward vertical pier force
windward diagonal tie force
windward vertical tie force
0.0
0.2
0.4
0.6
0.8
TIE AND PIER FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)

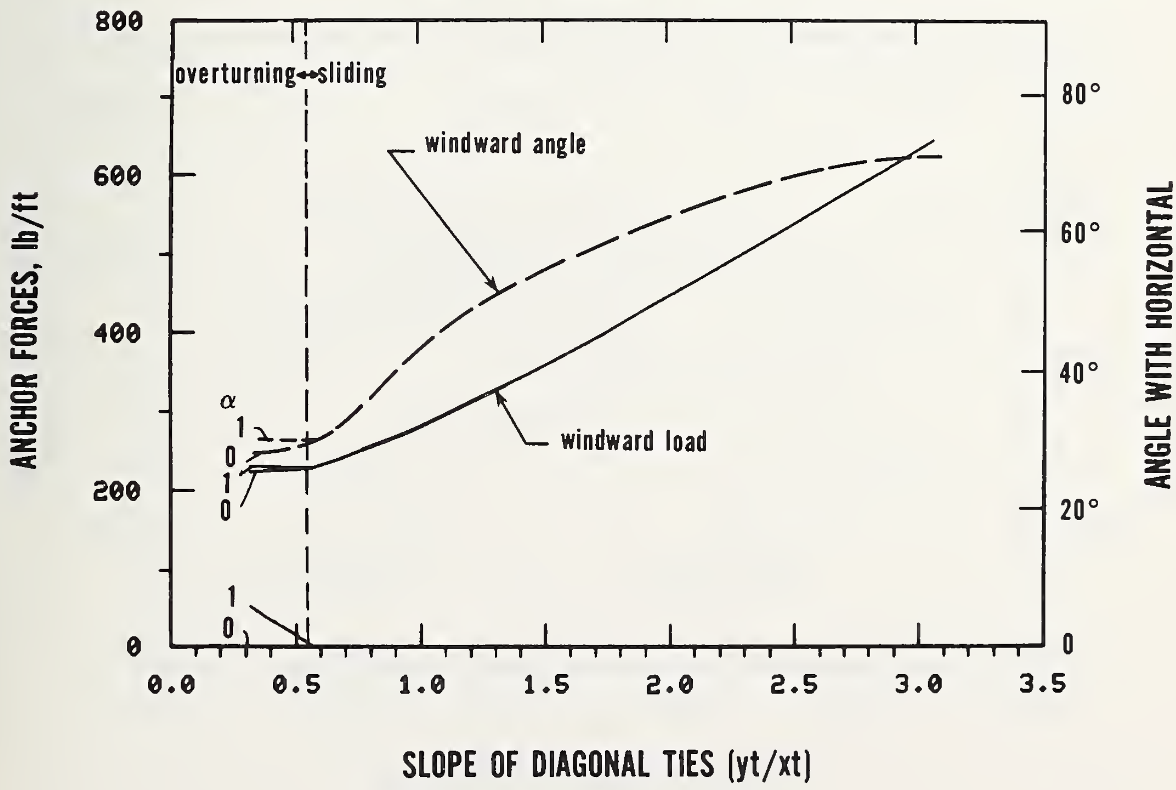


400
300
200
100
0
α
1
0
1
1
0
0
windward forces
windward angles
leeward forces *
60°
50°
40°
30°
20°
0.0
0.2
0.4
0.6
0.8
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)

7

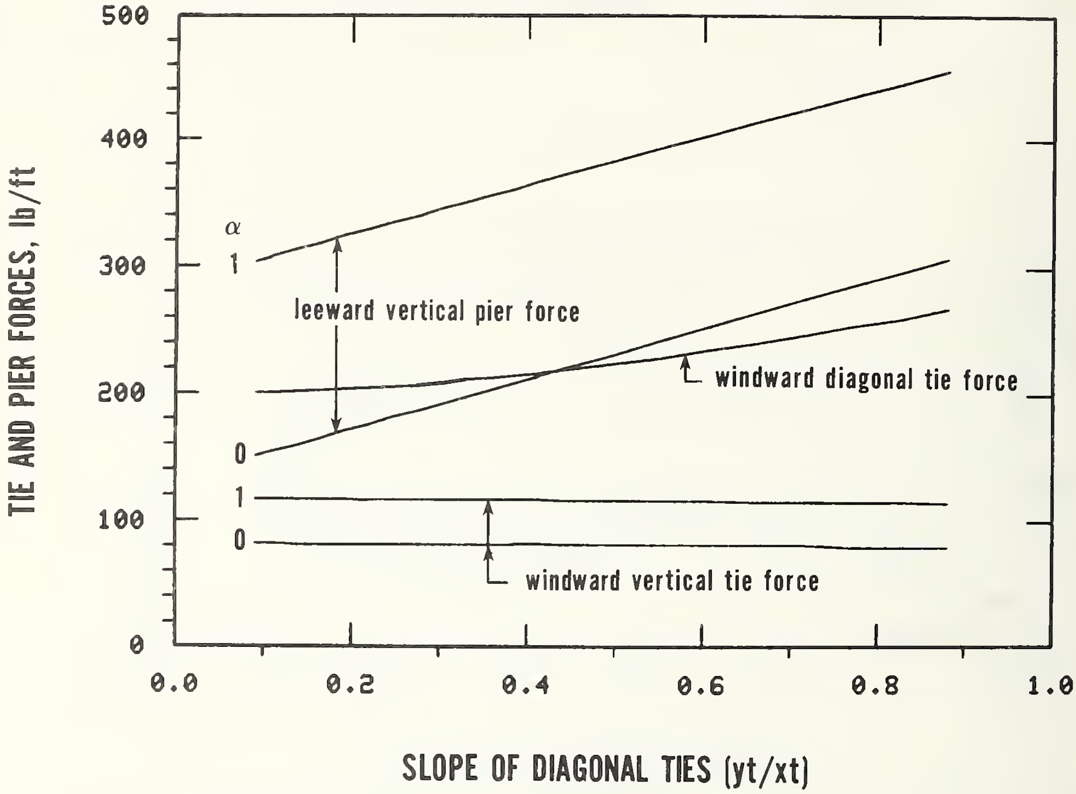


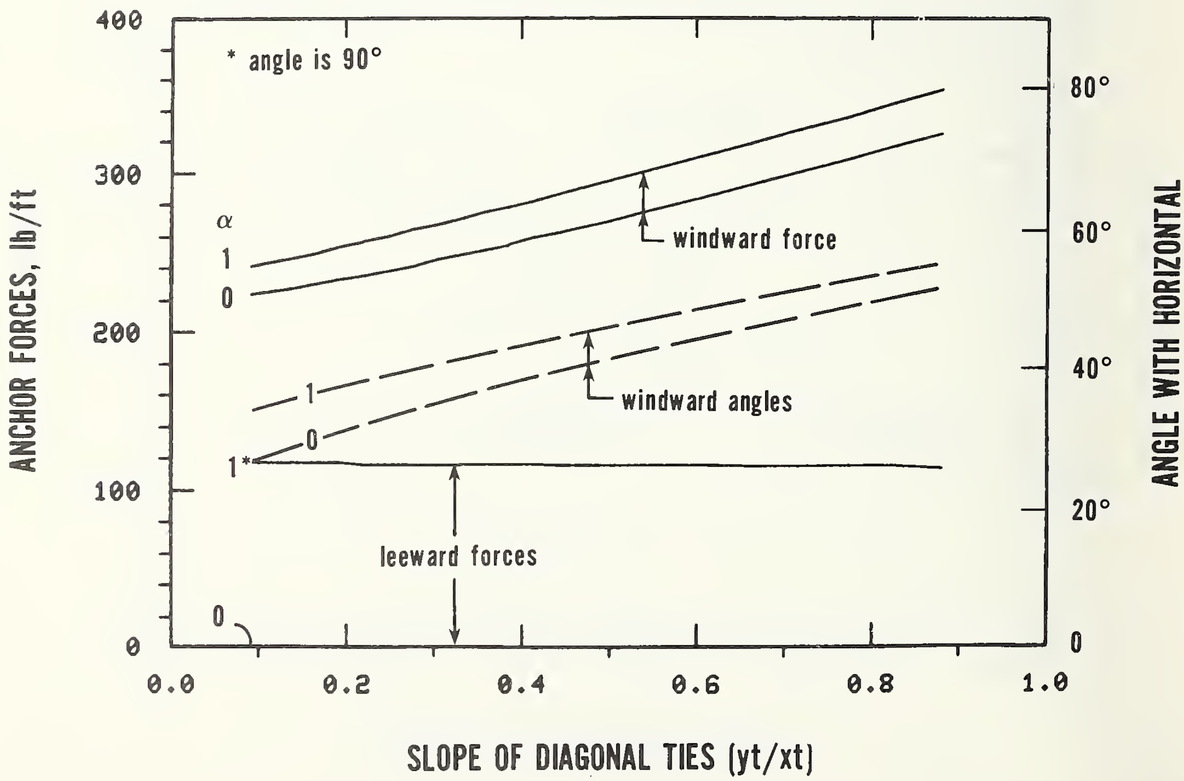
overturning↔sliding
windward diagonal tie force
windward vertical pier force
leeward vertical pier force
windward vertical tie force
α
1
0
1
0
TIE AND PIER FORCES, lb/ft
800
600
400
200
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

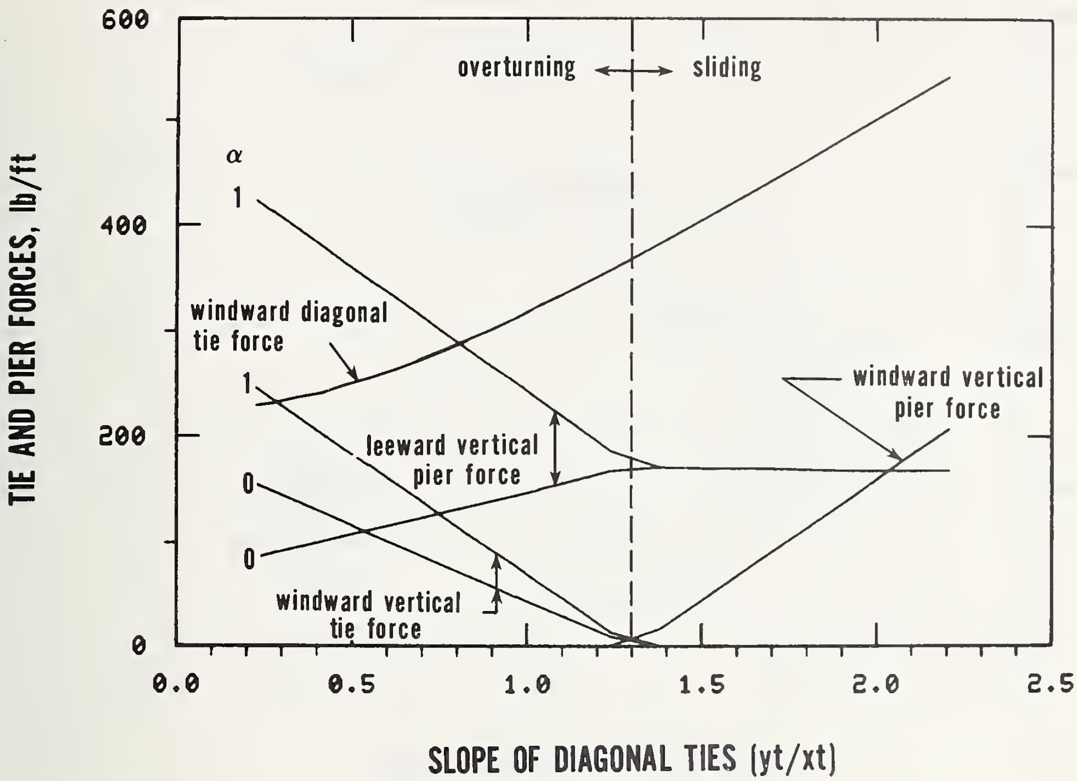


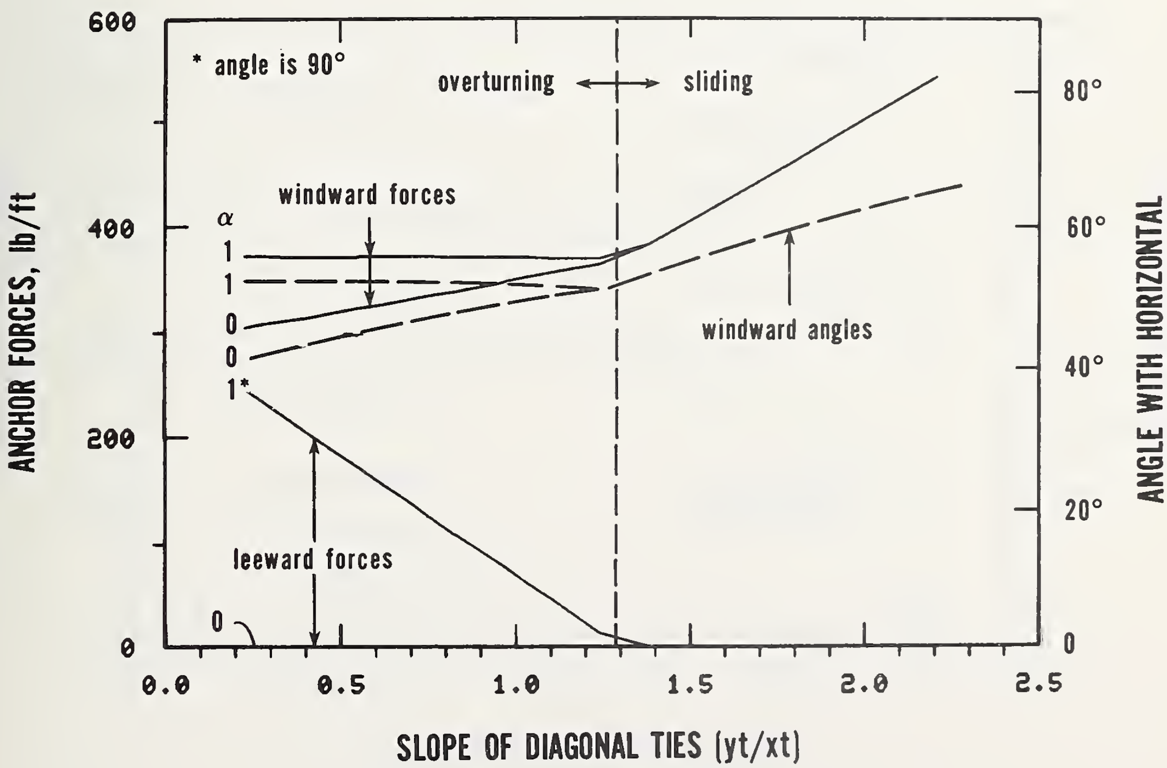
overturning↔sliding
windward angle
windward load
α
1
0
1
0
1
0
ANCHOR FORCES, lb/ft
800
600
400
200
0
ANGLE WITH HORIZONTAL
80°
60°
40°
20°
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

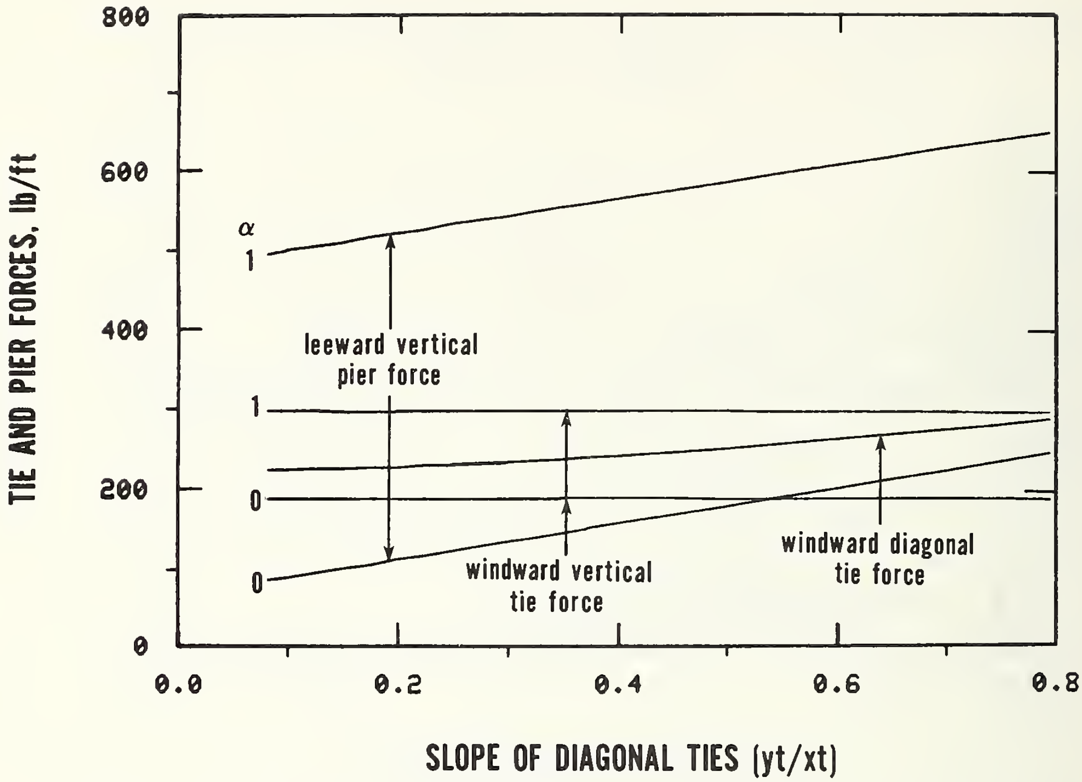
8

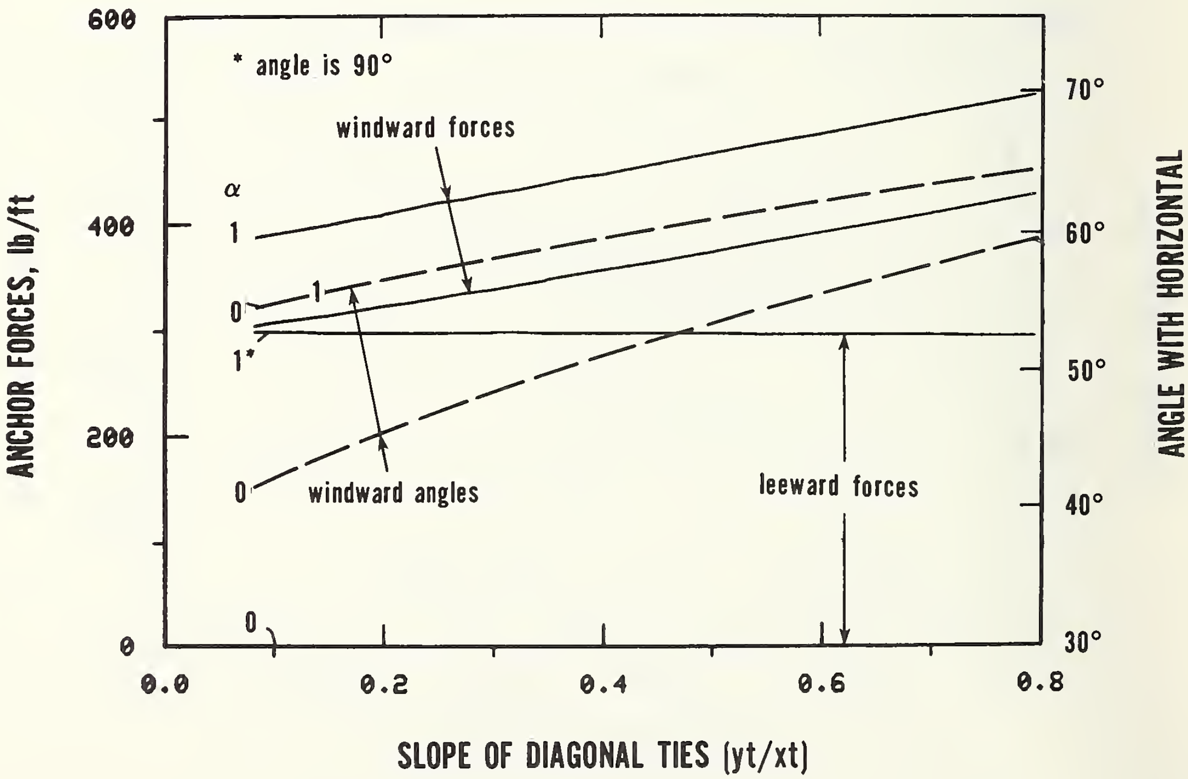

TIE AND PIER FORCES, lb/ft
α
1
0
1
0
leeward vertical pier force
windward diagonal tie force
windward vertical tie force
0
100
200
300
400
500
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)


ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
* angle is 90°
α
1
0
windward force
1
0
windward angles
1*
leeward forces
0
0
100
200
300
400
0
20°
40°
60°
80°
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

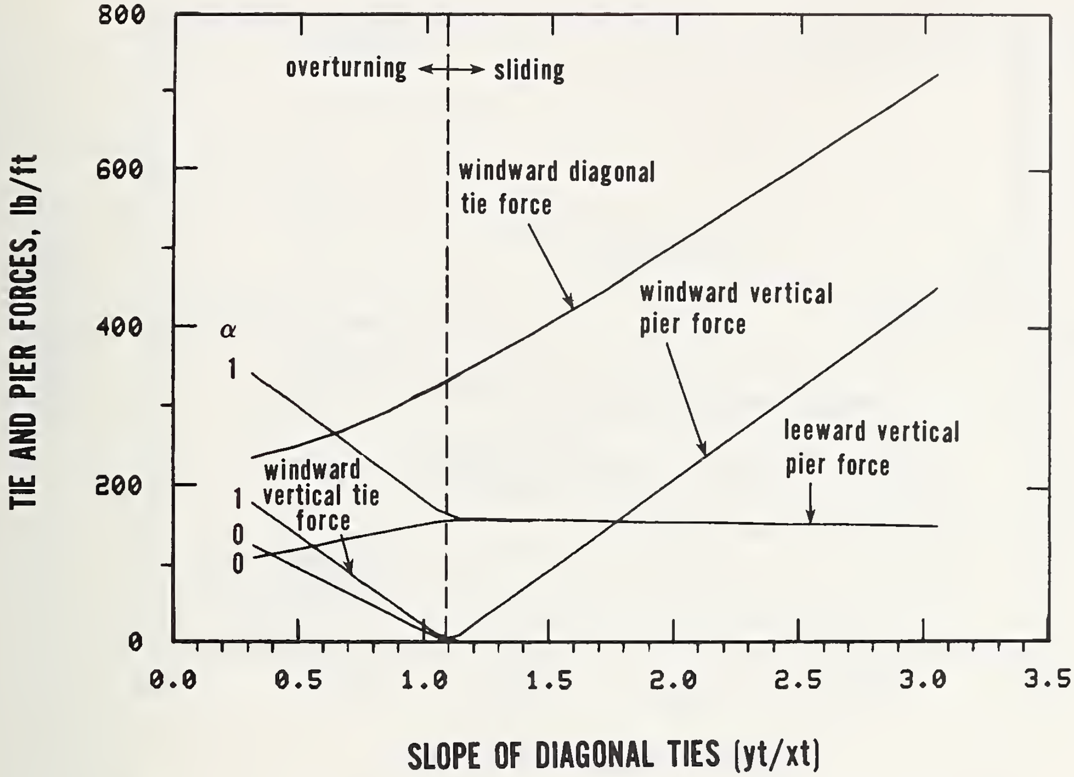

overturning
sliding
α
1
1
0
0
windward diagonal tie force
leeward vertical pier force
windward vertical pier force
windward vertical tie force
TIE AND PIER FORCES, lb/ft
600
400
200
0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)


* angle is 90°
overturning
sliding
windward forces
α
1
1
0
0
1*
windward angles
leeward forces
0
ANCHOR FORCES, lb/ft
600
400
200
0
80°
60°
40°
20°
0
ANGLE WITH HORIZONTAL
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

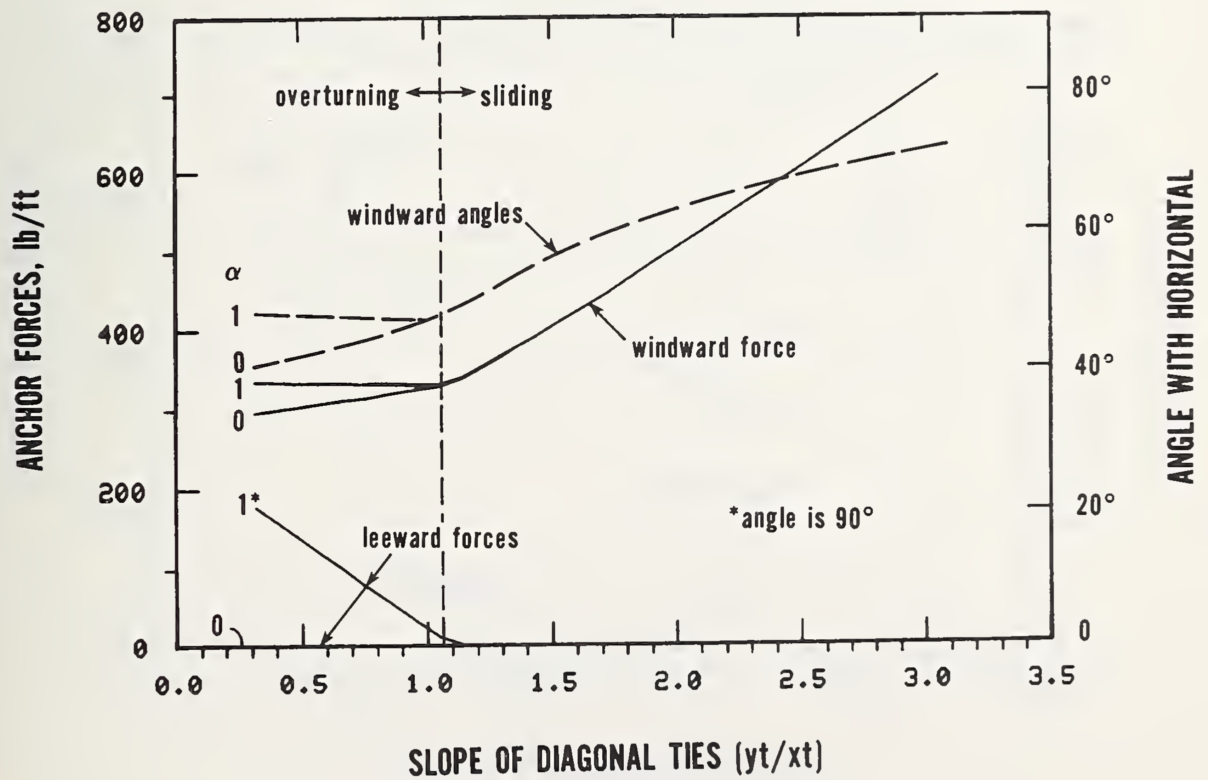

800
600
400
200
0
TIE AND PIER FORCES, lb/ft
α
1
leeward vertical
pier force
1
0
0
windward vertical
tie force
windward diagonal
tie force
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)


600
400
200
0
ANCHOR FORCES, lb/ft
* angle is 90°
windward forces
α
1
0
1
1*
0
windward angles
leeward forces
0
70°
60°
50°
40°
30°
ANGLE WITH HORIZONTAL
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)

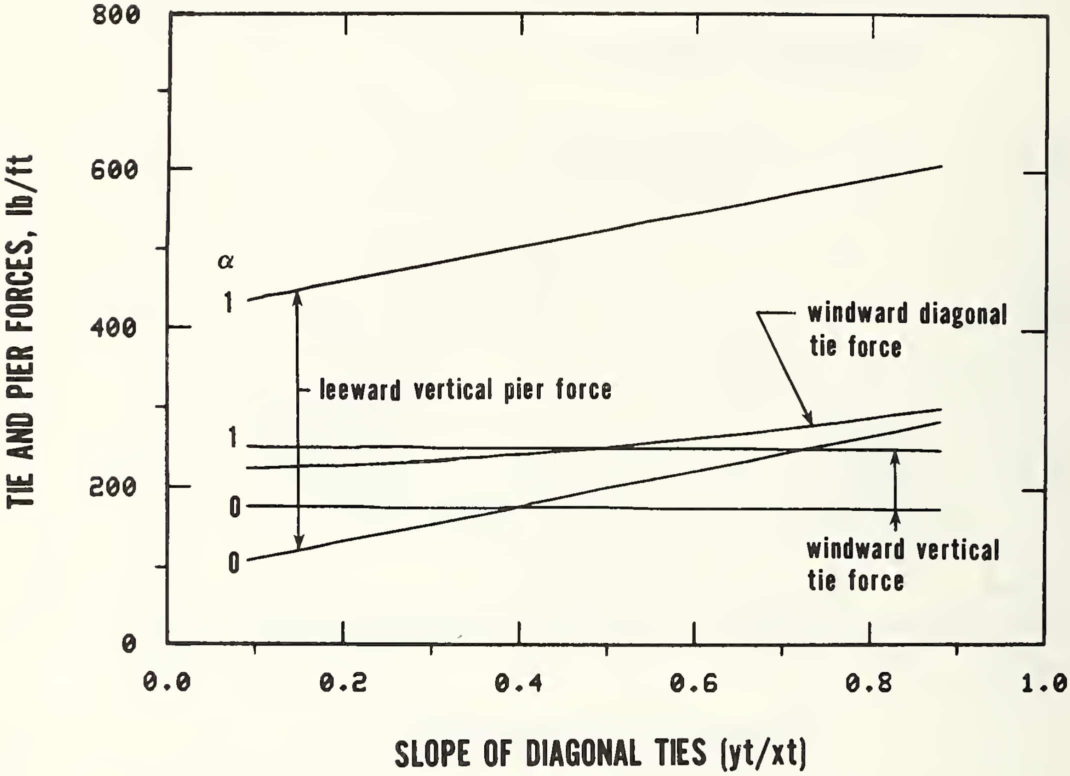
11

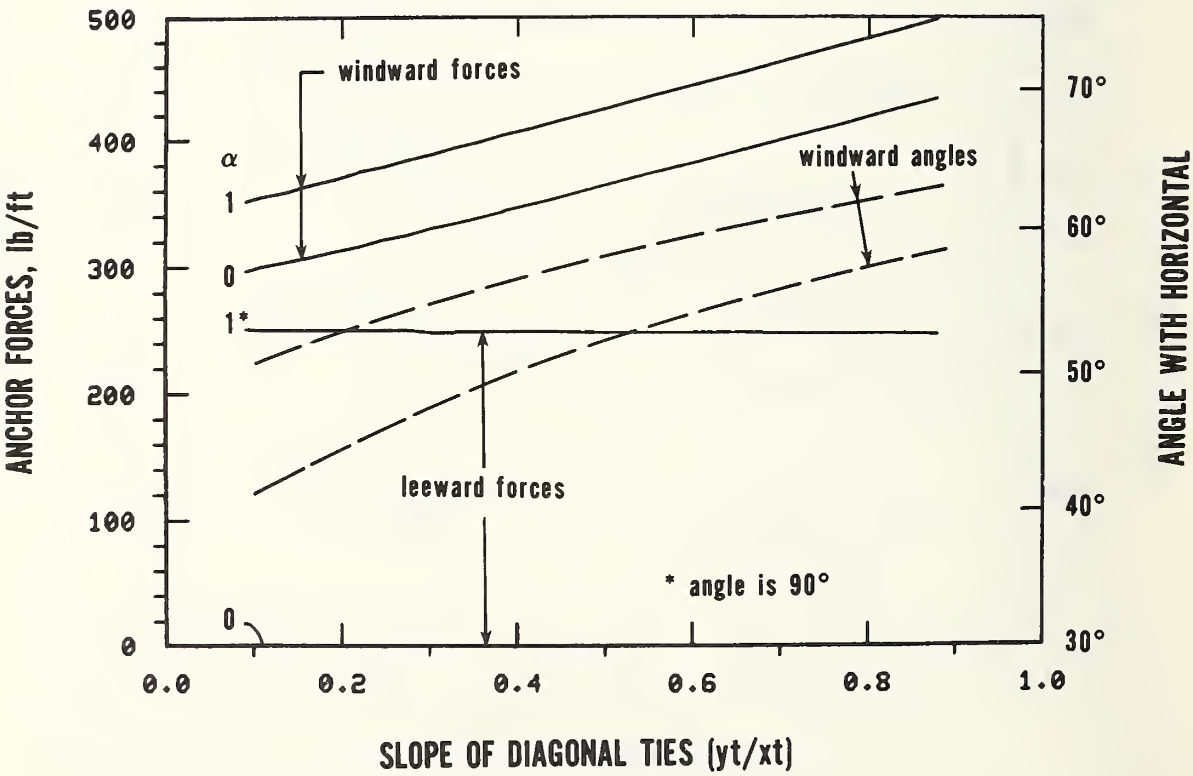


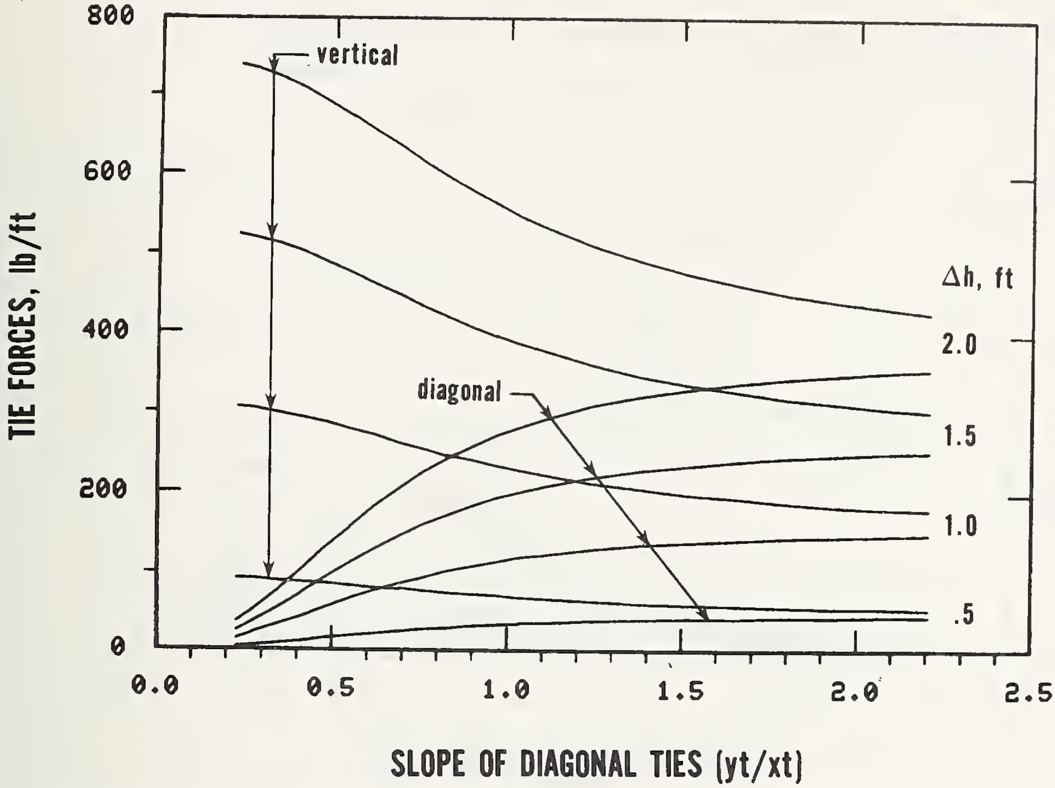
800
600
400
200
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
TIE AND PIER FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
overturning
sliding
windward diagonal tie force
windward vertical pier force
leeward vertical pier force
windward vertical tie force
α
1
1
0
0



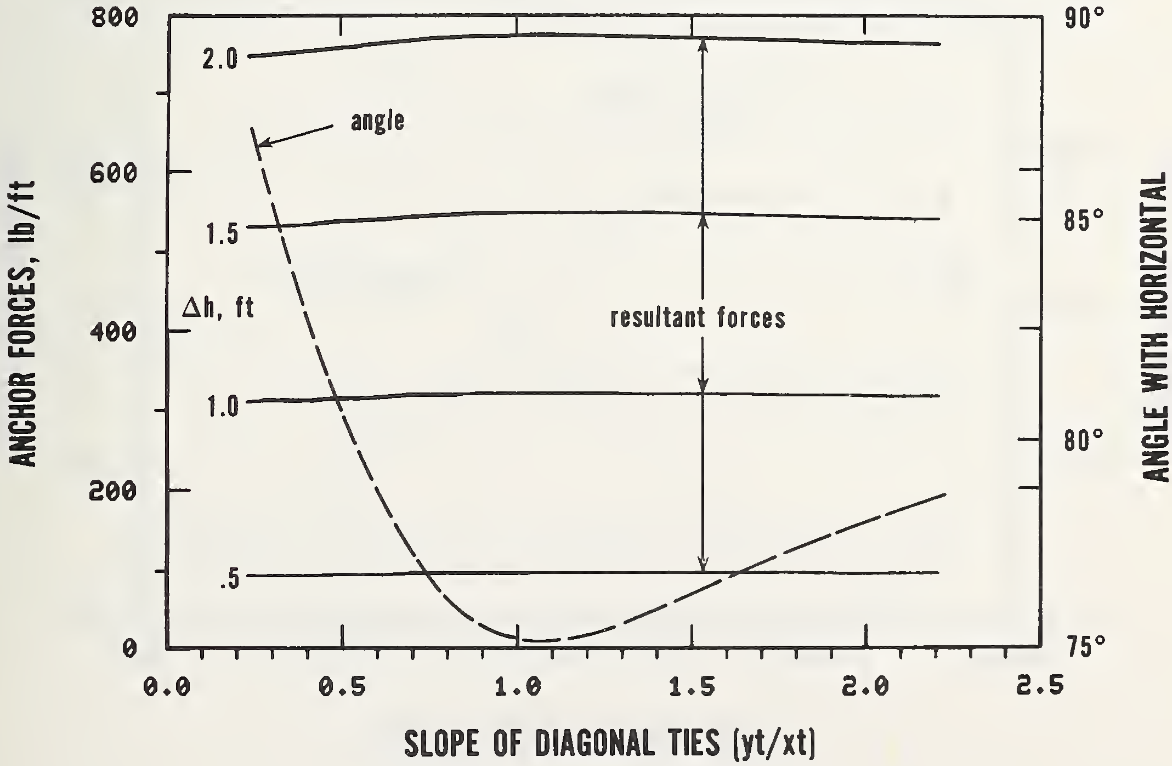
800
600
400
200
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
80°
60°
40°
20°
0
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)
overturning
sliding
windward angles
windward force
leeward forces
*angle is 90°
α
1
0
1
0
1*
0


TIE AND PIER FORCES, lb/ft
800
600
400
200
0
α
1
1
0
0
leeward vertical pier force
windward diagonal
tie force
windward vertical
tie force
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)


ANCHOR FORCES, lb/ft
500
400
300
200
100
0
α
1
0
1*
0
windward forces
windward angles
leeward forces
* angle is 90°
70°
60°
50°
40°
30°
ANGLE WITH HORIZONTAL
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

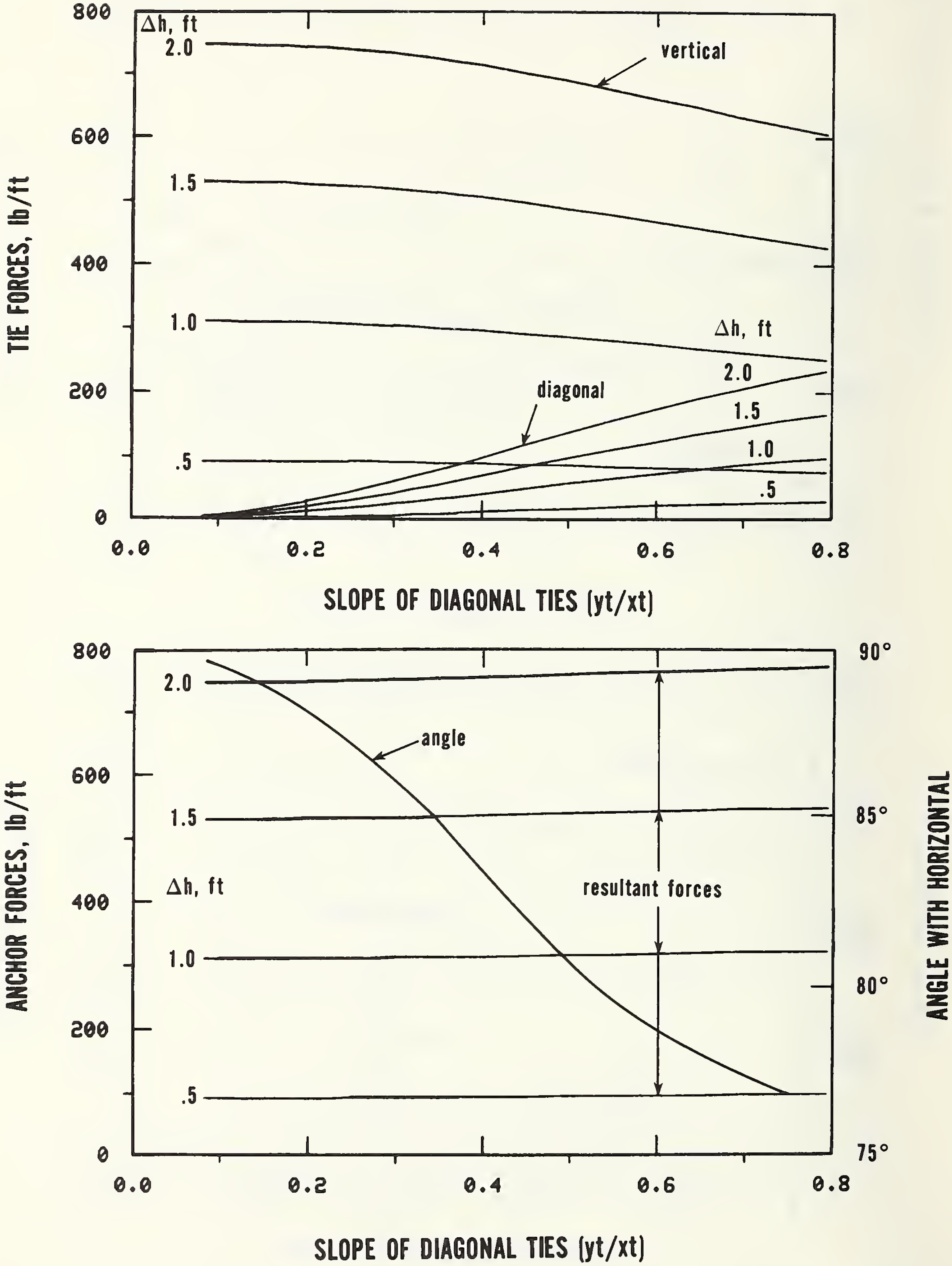


800
600
400
200
0
vertical
diagonal
Δh, ft
2.0
1.5
1.0
.5
0.0
0.5
1.0
1.5
2.0
2.5
TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)



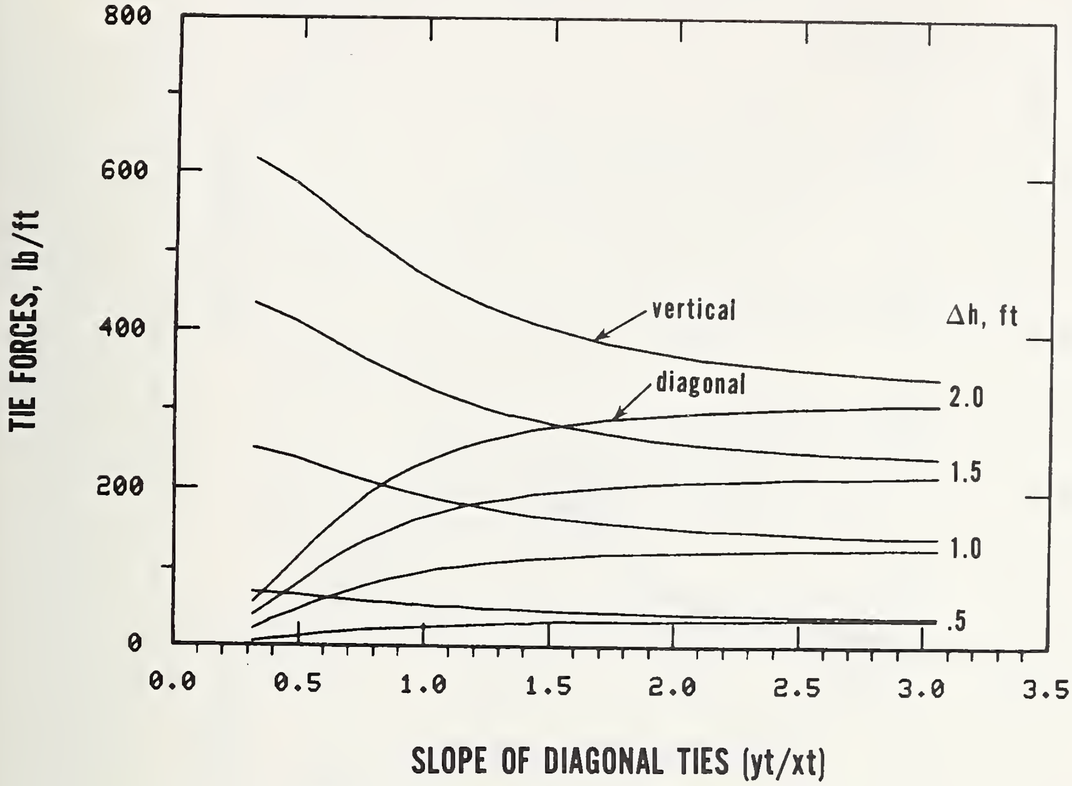
800
600
400
200
0
2.0
1.5
1.0
.5
angle
Δh, ft
resultant forces
90°
85°
80°
75°
0.0
0.5
1.0
1.5
2.0
2.5
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)

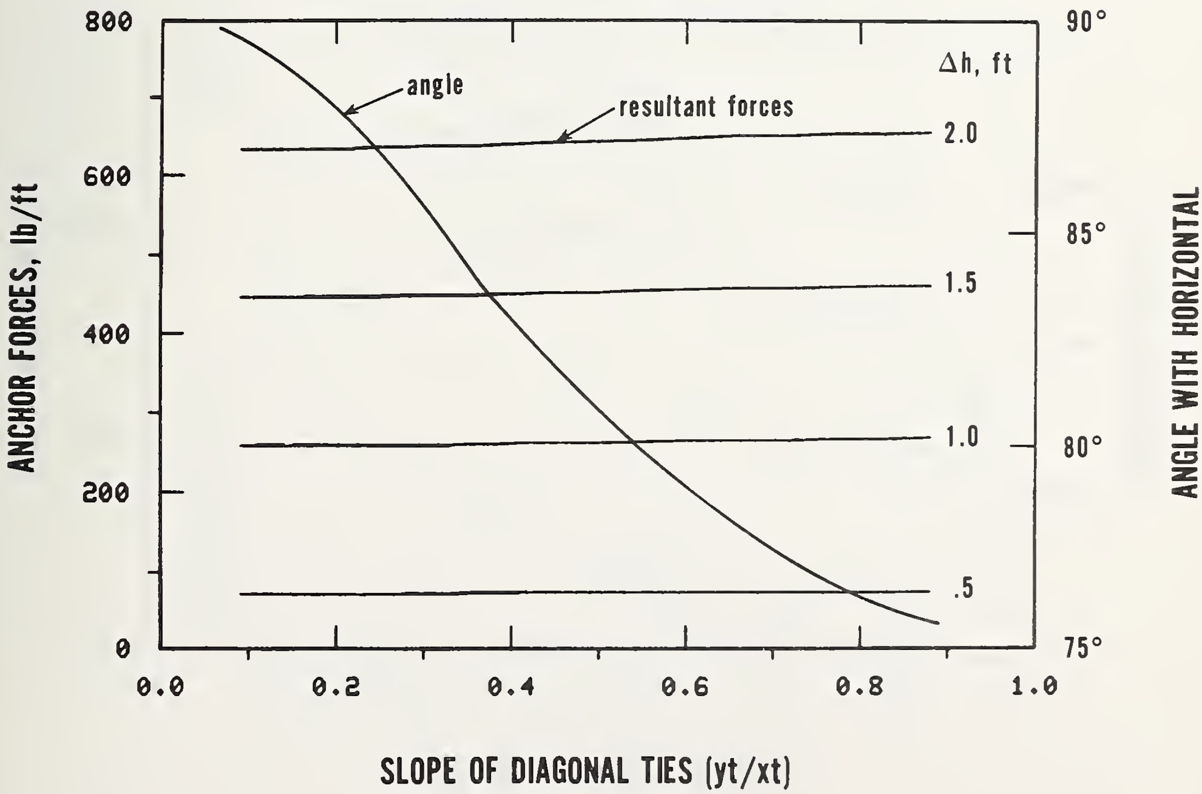
14

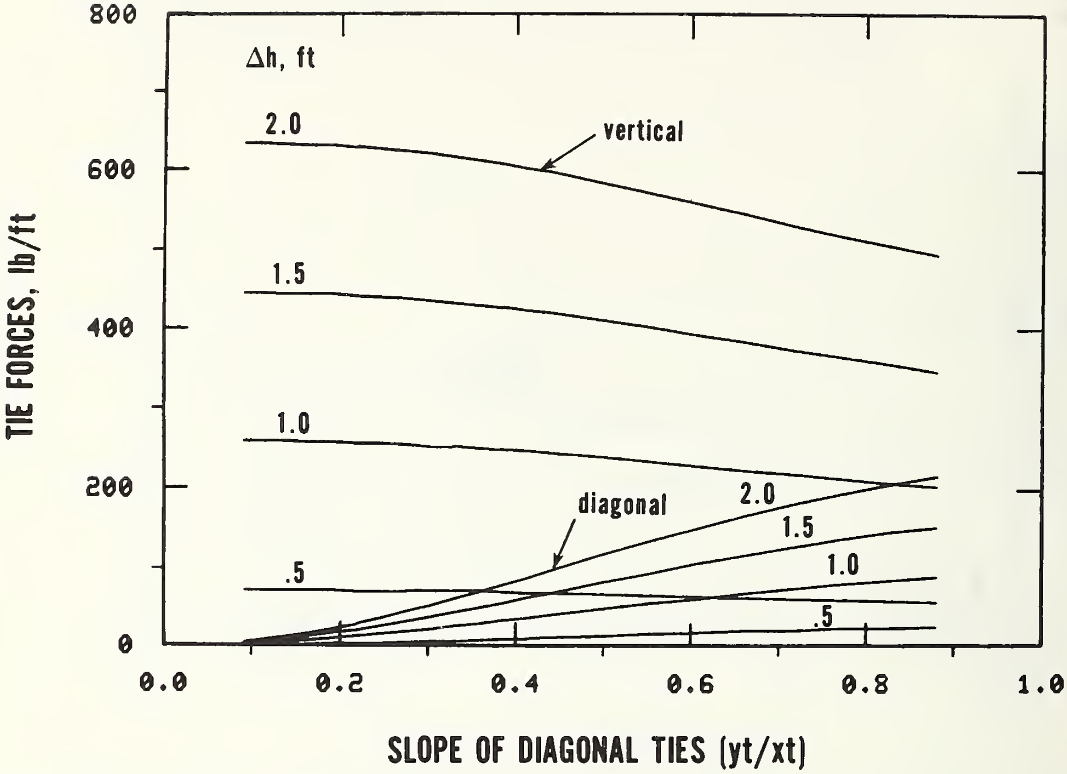


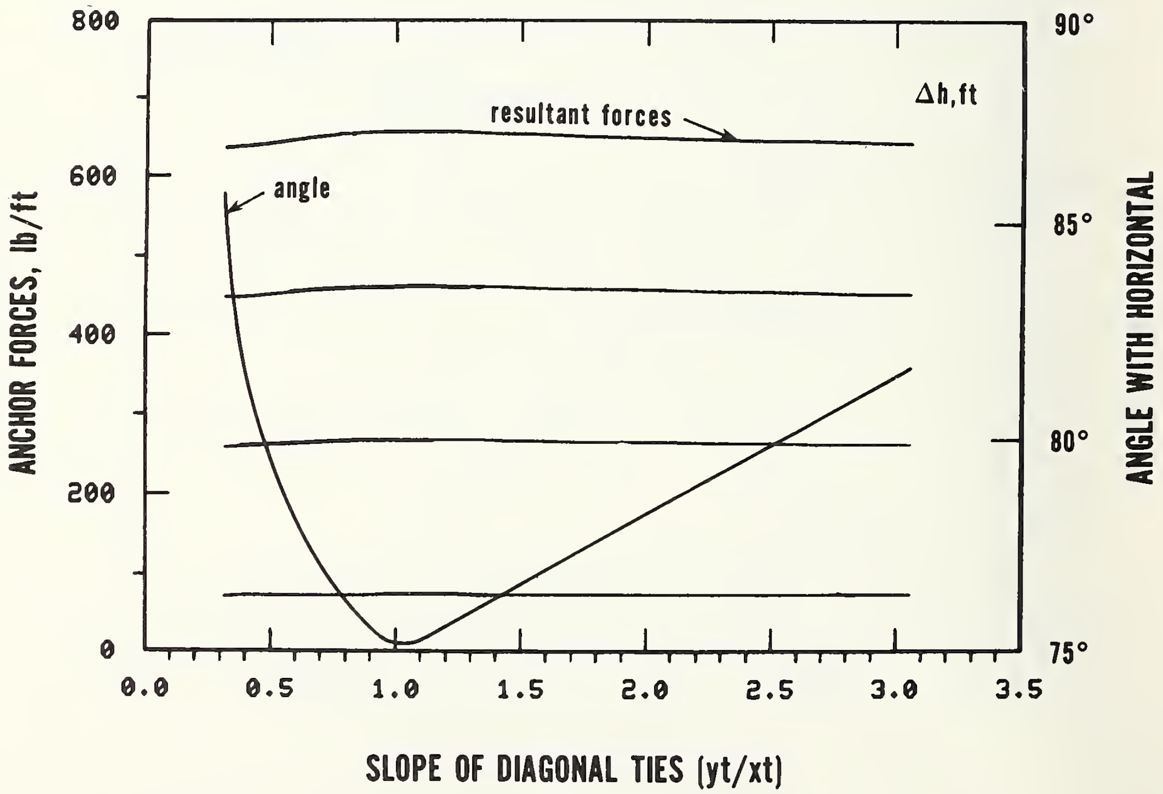
800
600
400
200
0
TIE FORCES, lb/ft
Δh, ft
2.0
1.5
1.0
.5
vertical
Δh, ft
2.0
1.5
1.0
.5
diagonal
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)
800
600
400
200
0
ANCHOR FORCES, lb/ft
2.0
1.5
Δh, ft
1.0
.5
angle
resultant forces
90°
85°
80°
75°
ANGLE WITH HORIZONTAL
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)

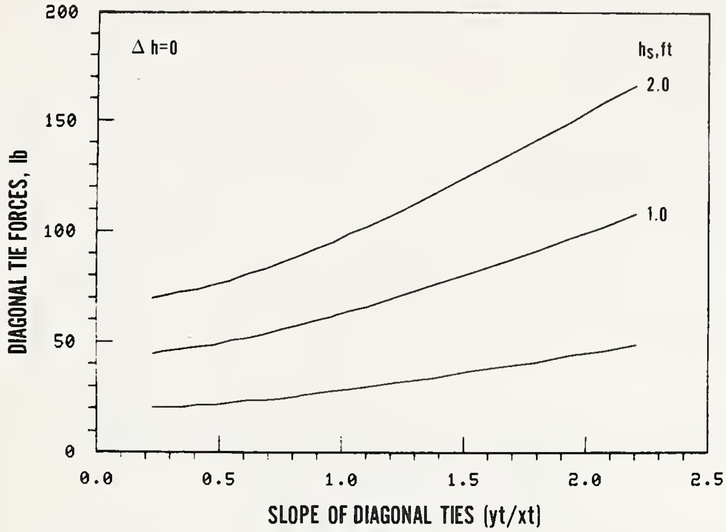
15

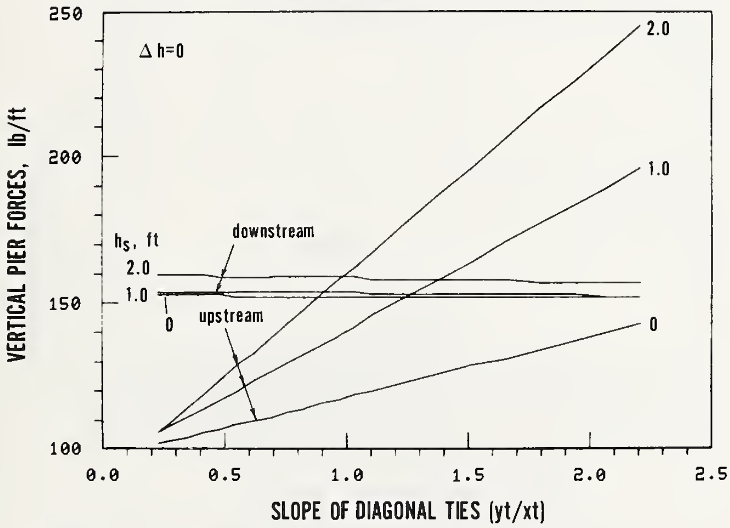

800
600
400
200
0
TIE FORCES, lb/ft
vertical
diagonal
Δh, ft
2.0
1.5
1.0
.5
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

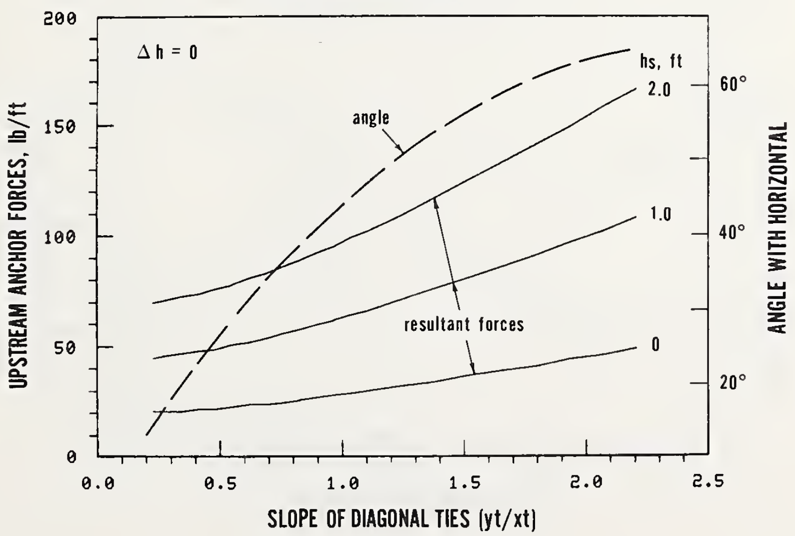

800
600
400
200
0
ANCHOR FORCES, lb/ft
angle
resultant forces
Δh, ft
2.0
1.5
1.0
.5
90°
85°
80°
75°
ANGLE WITH HORIZONTAL
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

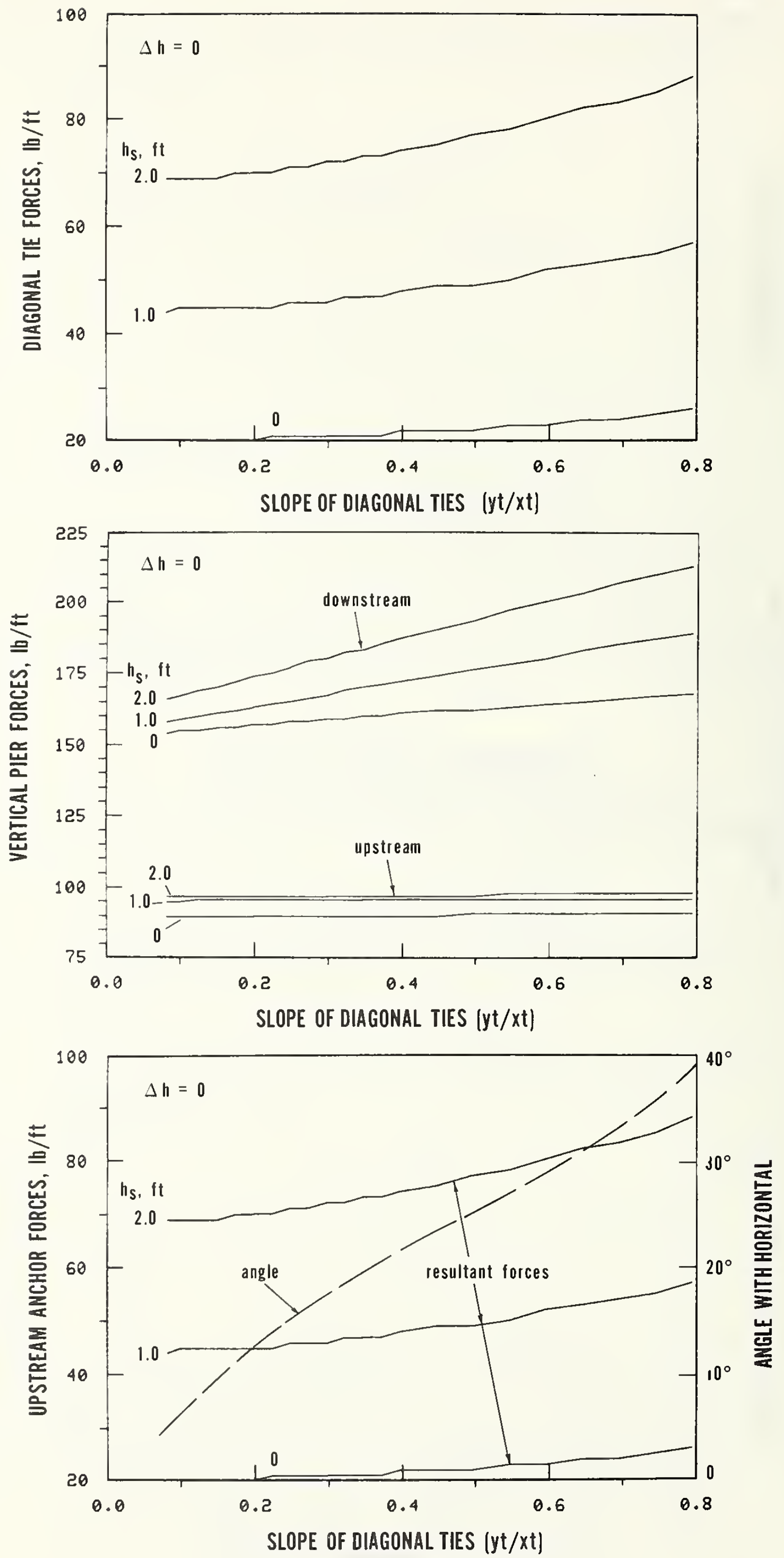

800
600
400
200
0
Δh, ft
2.0
vertical
1.5
1.0
diagonal
2.0
1.5
1.0
.5
.5
0.0
0.2
0.4
0.6
0.8
1.0
TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)

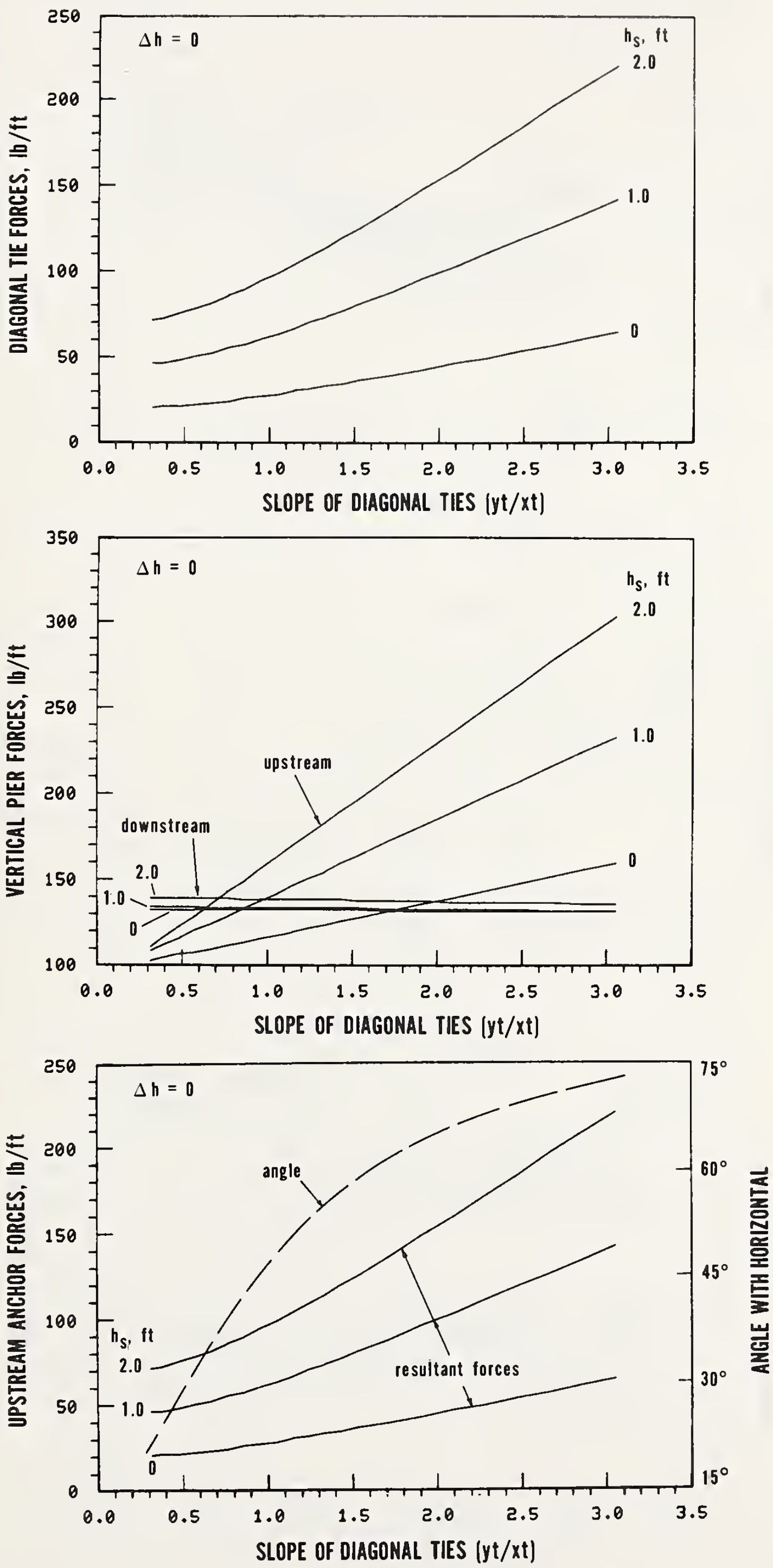

800
600
400
200
0
90°
85°
80°
75°
Δh,ft
resultant forces
angle
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)


200
150
100
50
0
Δ h=0
hs,ft
2.0
1.0
0.0
0.5
1.0
1.5
2.0
2.5
DIAGONAL TIE FORCES, lb
SLOPE OF DIAGONAL TIES (yt/xt)

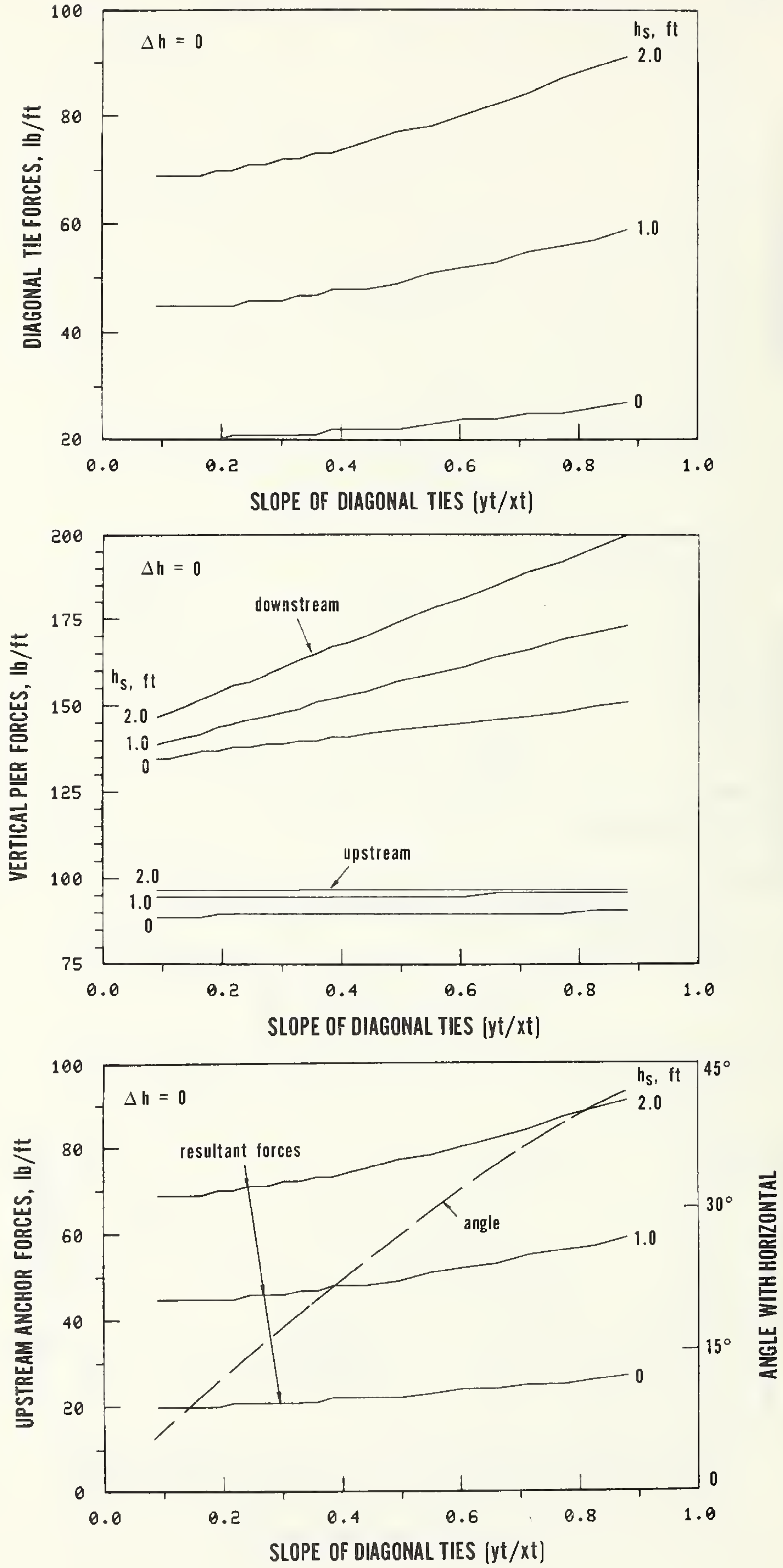

250
200
150
100
Δ h=0
2.0
1.0
0
hs, ft
2.0
1.0
0
downstream
upstream
0.0
0.5
1.0
1.5
2.0
2.5
VERTICAL PIER FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)


200
150
100
50
0
Δ h = 0
hs, ft
2.0
1.0
0
angle
resultant forces
60°
40°
20°
0.0
0.5
1.0
1.5
2.0
2.5
UPSTREAM ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)


100
80
60
40
20
Δ h = 0
h_s, ft
2.0
1.0
0
0.0
0.2
0.4
0.6
0.8
DIAGONAL TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
225
200
175
150
125
100
75
Δ h = 0
downstream
h_s, ft
2.0
1.0
0
upstream
2.0
1.0
0
VERTICAL PIER FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
Δ h = 0
h_s, ft
2.0
angle
resultant forces
1.0
0
40°
30°
20°
10°
0
UPSTREAM ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)

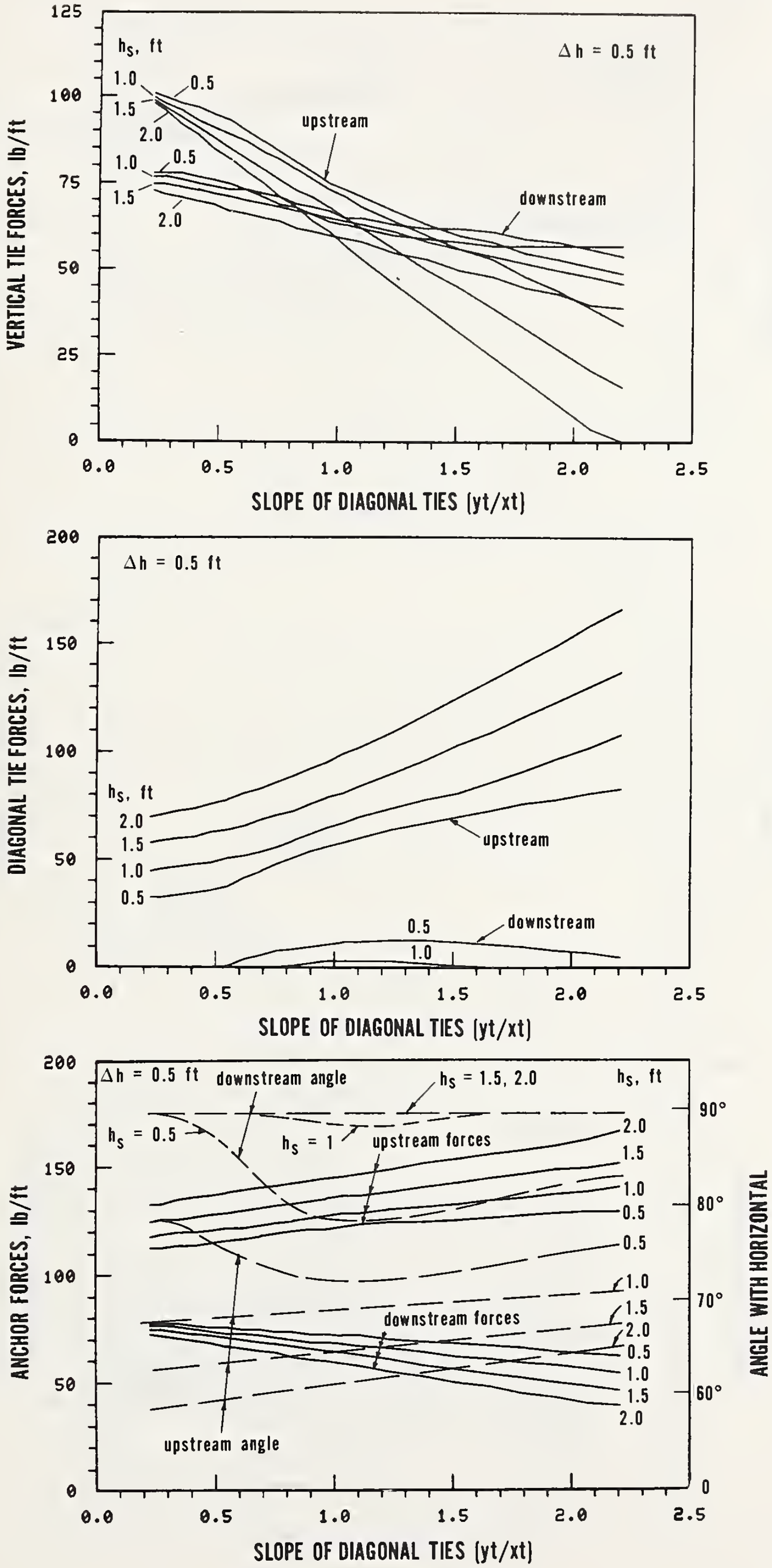

Δh = 0
hs, ft
2.0
1.0
0
DIAGONAL TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0
hs, ft
2.0
1.0
0
upstream
downstream
2.0
1.0
0
VERTICAL PIER FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0
angle
resultant forces
hs, ft
2.0
1.0
0
UPSTREAM ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)

20



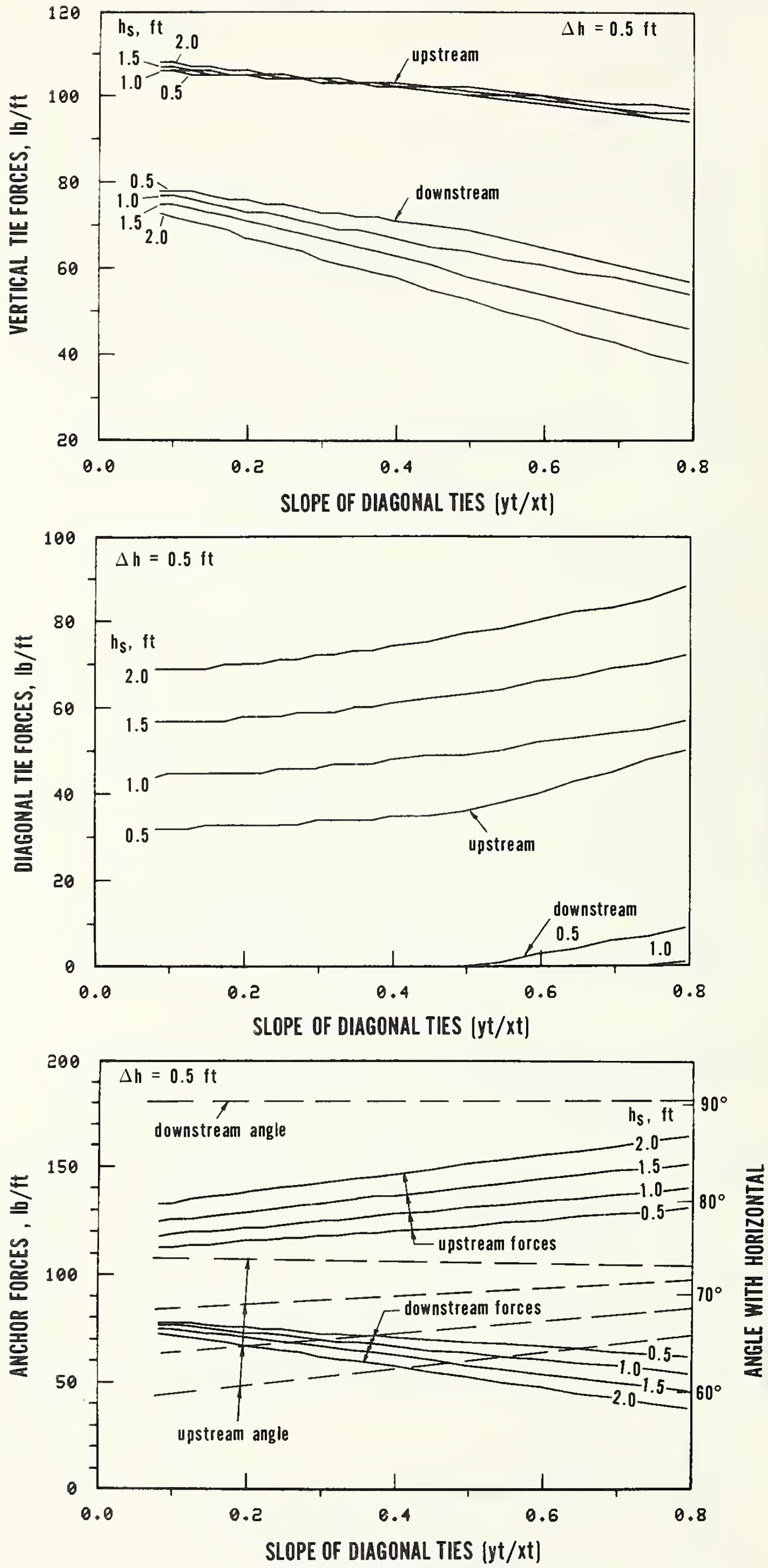
DIAGONAL TIE FORCES, lb/ft
Δh = 0
hs, ft
2.0
1.0
0
100
80
60
40
20
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)
VERTICAL PIER FORCES, lb/ft
Δh = 0
downstream
hs, ft
2.0
1.0
0
upstream
2.0
1.0
0
200
175
150
125
100
75
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)
UPSTREAM ANCHOR FORCES, lb/ft
Δh = 0
hs, ft
2.0
1.0
0
resultant forces
angle
ANGLE WITH HORIZONTAL
45°
30°
15°
0
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

21



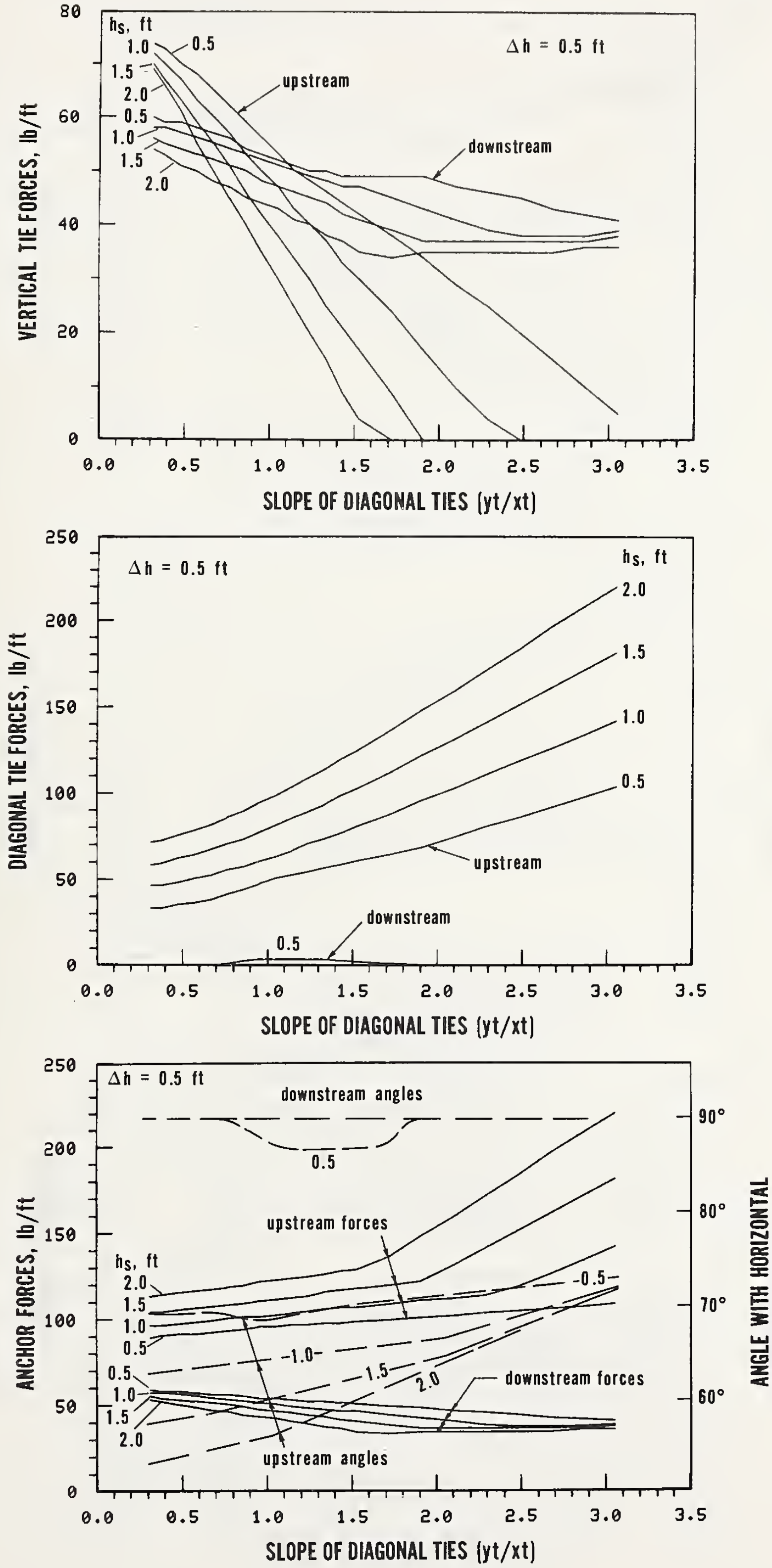
hs, ft
Δh = 0.5 ft
upstream
downstream
VERTICAL TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
DIAGONAL TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
downstream angle
hs = 1.5, 2.0
hs = 0.5
hs = 1
upstream forces
downstream forces
upstream angle
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)

22

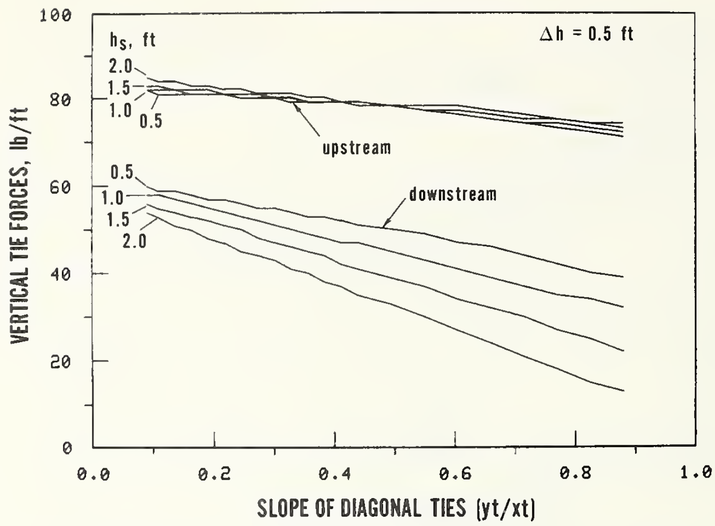


hs, ft
Δh = 0.5 ft
2.0
1.5
1.0
0.5
upstream
downstream
VERTICAL TIE FORCES, lb/ft
120
100
80
60
40
20
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0.5 ft
hs, ft
2.0
1.5
1.0
0.5
upstream
downstream
0.5
1.0
DIAGONAL TIE FORCES, lb/ft
100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0.5 ft
downstream angle
hs, ft
2.0
1.5
1.0
0.5
upstream forces
downstream forces
0.5
1.0
1.5
2.0
upstream angle
90°
80°
70°
60°
ANGLE WITH HORIZONTAL
ANCHOR FORCES , lb/ft
200
150
100
50
0
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)

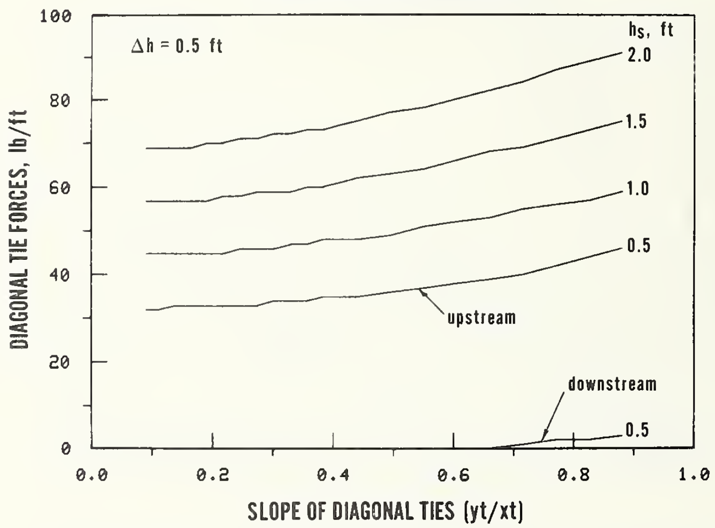
23



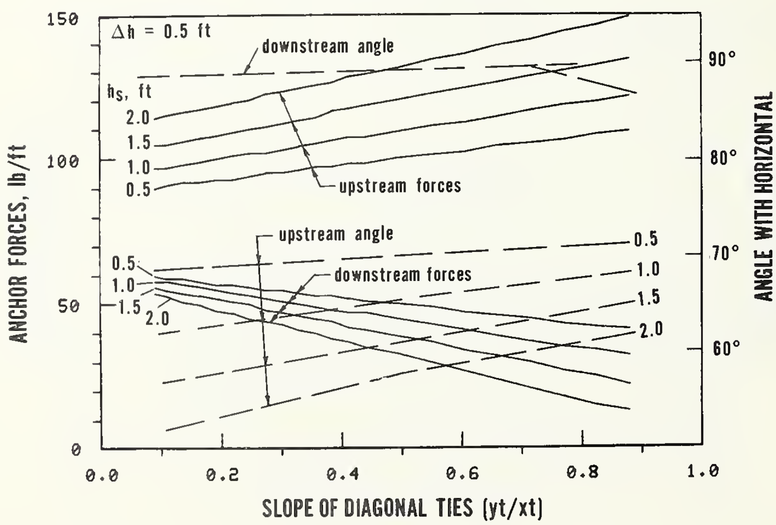
hs, ft
1.0
0.5
1.5
2.0
0.5
1.0
1.5
2.0
upstream
downstream
Δh = 0.5 ft
VERTICAL TIE FORCES, lb/ft
80
60
40
20
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0.5 ft
hs, ft
2.0
1.5
1.0
0.5
upstream
downstream
0.5
DIAGONAL TIE FORCES, lb/ft
250
200
150
100
50
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0.5 ft
downstream angles
0.5
upstream forces
hs, ft
2.0
1.5
1.0
0.5
-0.5-
-1.0-
-1.5-
2.0
0.5
1.0
1.5
2.0
downstream forces
upstream angles
ANCHOR FORCES, lb/ft
250
200
150
100
50
0
90°
80°
70°
60°
ANGLE WITH HORIZONTAL
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)



100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
VERTICAL TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
h_s, ft
Δh = 0.5 ft
2.0
1.5
1.0
0.5
upstream
downstream

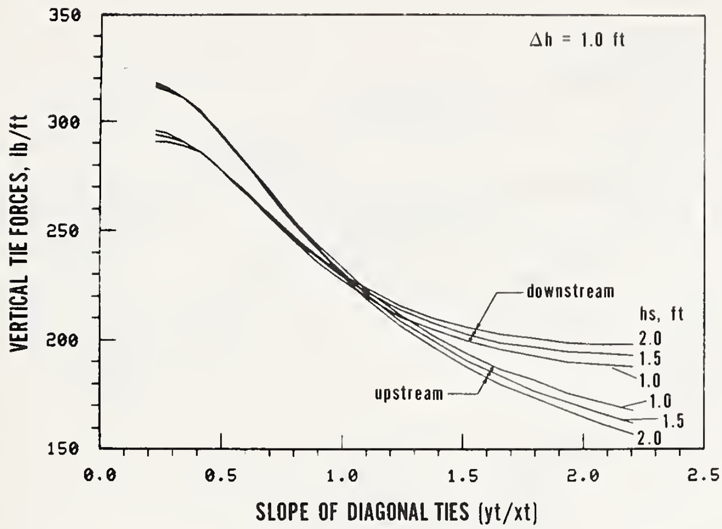


100
80
60
40
20
0
0.0
0.2
0.4
0.6
0.8
1.0
DIAGONAL TIE FORCES, lb/ft
SLOPE OF DIAGONAL TIES (yt/xt)
Δh = 0.5 ft
h_s, ft
2.0
1.5
1.0
0.5
upstream
downstream

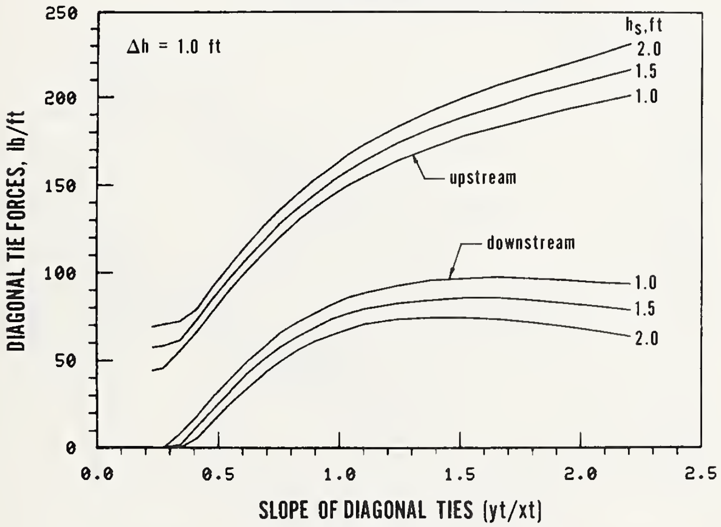


150
100
50
0
0.0
0.2
0.4
0.6
0.8
1.0
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
SLOPE OF DIAGONAL TIES (yt/xt)
90°
80°
70°
60°
Δh = 0.5 ft
downstream angle
h_s, ft
2.0
1.5
1.0
0.5
upstream forces
upstream angle
downstream forces

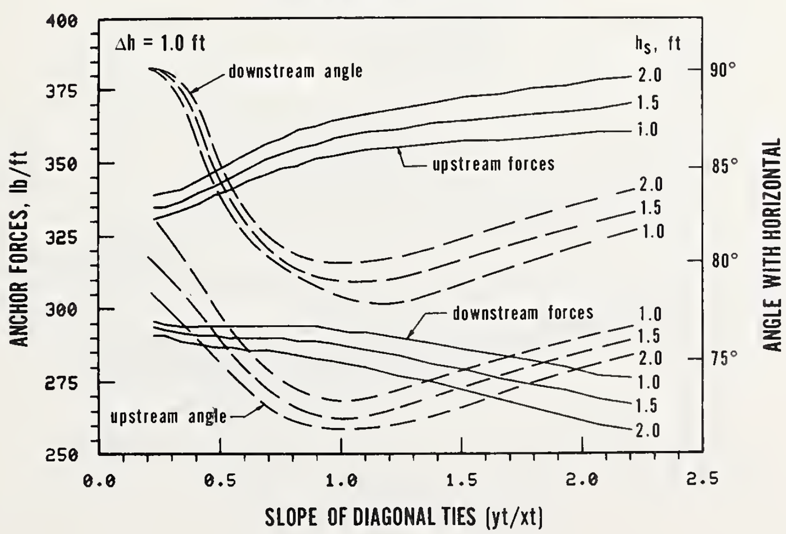
25



Δh = 1.0 ft
VERTICAL TIE FORCES, lb/ft
350
300
250
200
150
downstream
hs, ft
2.0
1.5
1.0
upstream
1.0
1.5
2.0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

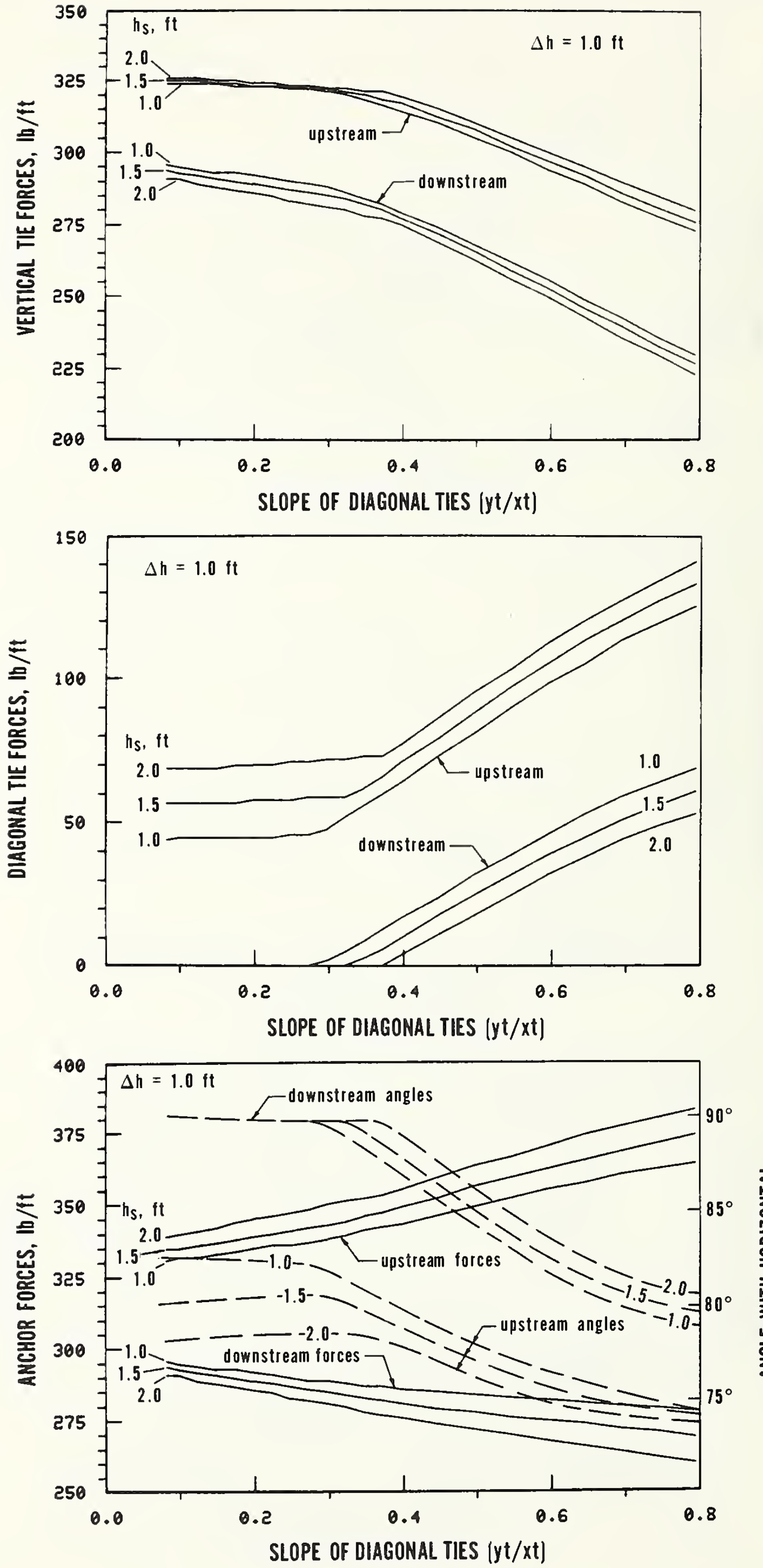


Δh = 1.0 ft
DIAGONAL TIE FORCES, lb/ft
250
200
150
100
50
0
hs,ft
2.0
1.5
1.0
upstream
downstream
1.0
1.5
2.0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

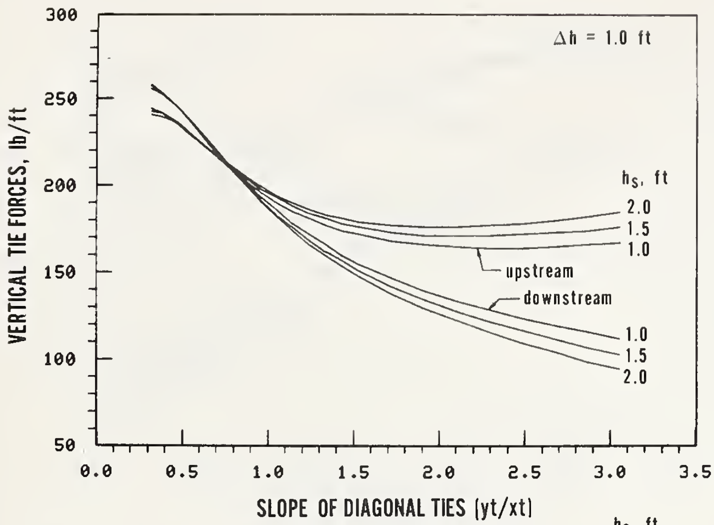


Δh = 1.0 ft
ANCHOR FORCES, lb/ft
400
375
350
325
300
275
250
hs, ft
downstream angle
2.0
1.5
1.0
upstream forces
2.0
1.5
1.0
downstream forces
1.0
1.5
2.0
1.0
1.5
2.0
upstream angle
90°
85°
80°
75°
ANGLE WITH HORIZONTAL
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

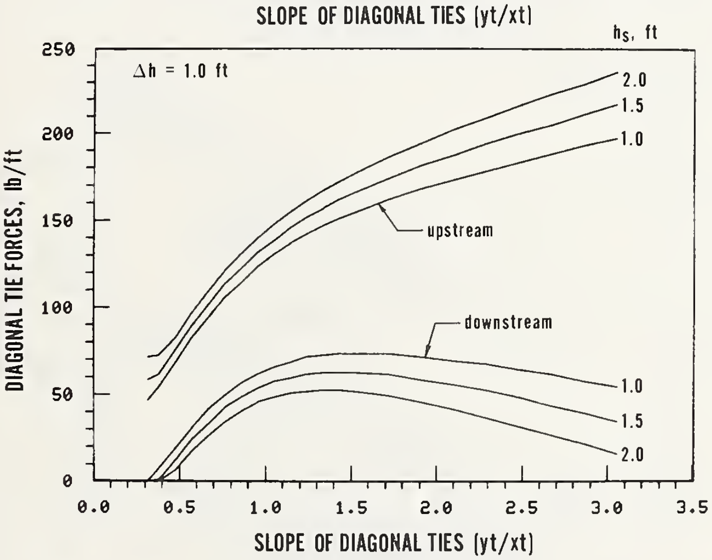
26



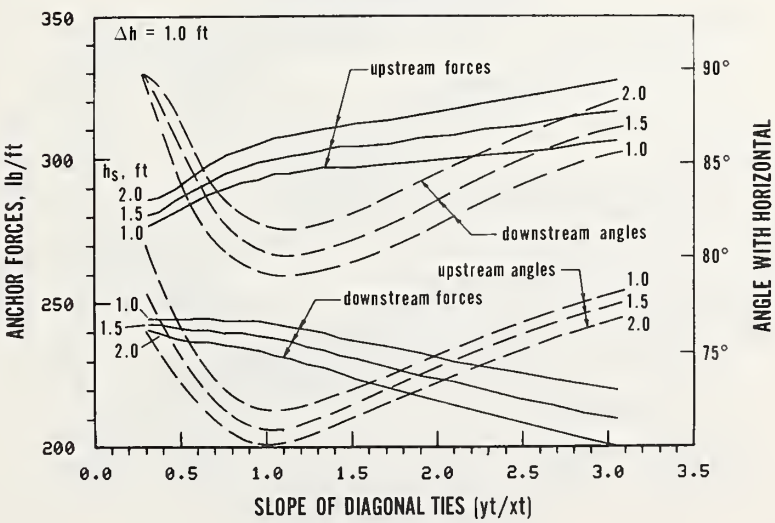
VERTICAL TIE FORCES, lb/ft
hs, ft
Δh = 1.0 ft
2.0
1.5
1.0
upstream
downstream
350
325
300
275
250
225
200
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)
DIAGONAL TIE FORCES, lb/ft
Δh = 1.0 ft
hs, ft
upstream
downstream
150
100
50
0
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
Δh = 1.0 ft
downstream angles
upstream forces
upstream angles
downstream forces
90°
85°
80°
75°
400
375



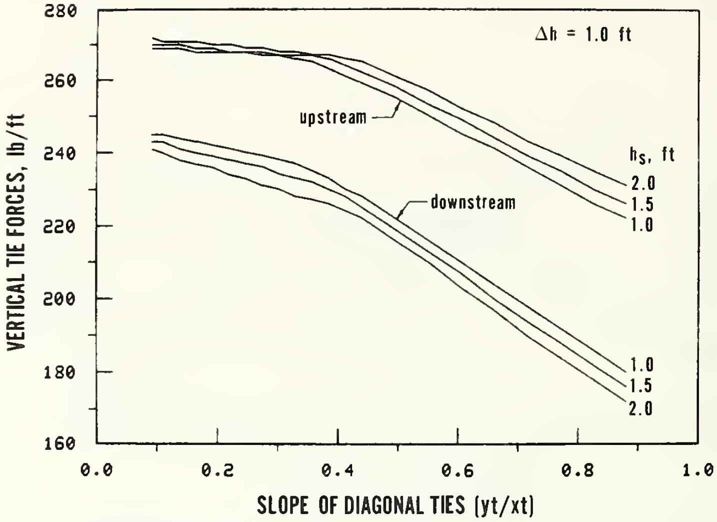
Δh = 1.0 ft
VERTICAL TIE FORCES, lb/ft
300
250
200
150
100
50
hs, ft
2.0
1.5
1.0
upstream
downstream
1.0
1.5
2.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

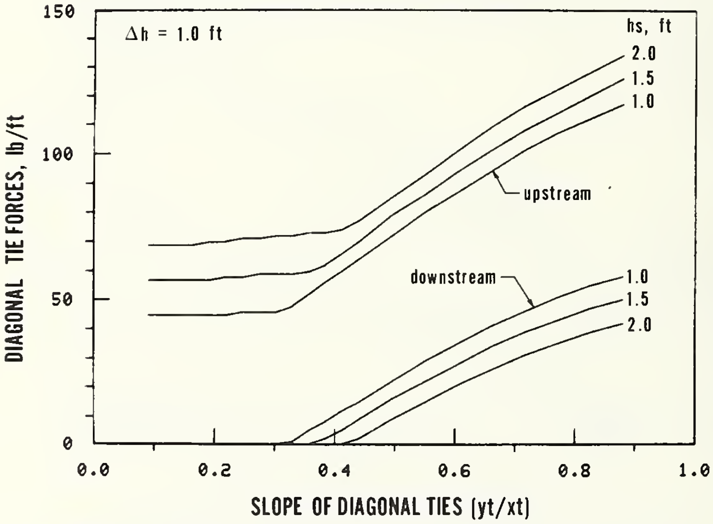


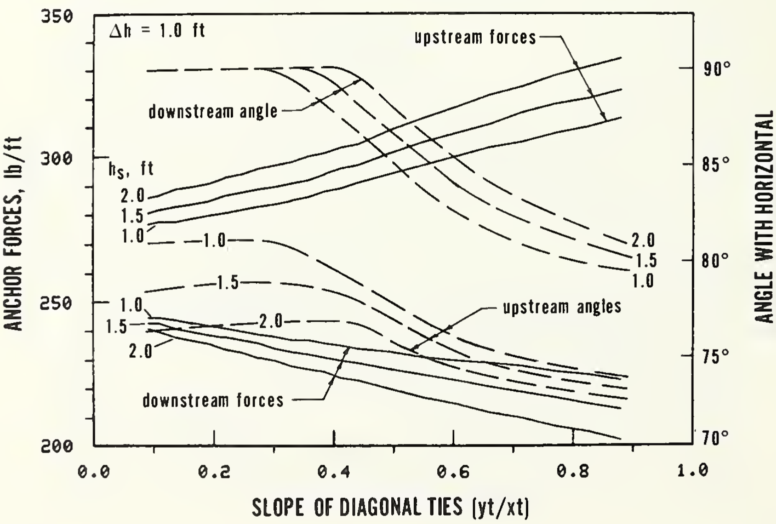
hs, ft
Δh = 1.0 ft
DIAGONAL TIE FORCES, lb/ft
250
200
150
100
50
0
2.0
1.5
1.0
upstream
downstream
1.0
1.5
2.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)



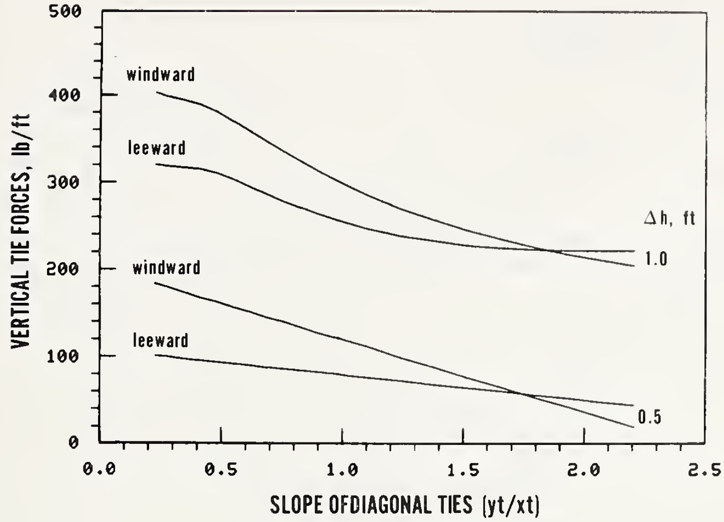
Δh = 1.0 ft
ANCHOR FORCES, lb/ft
350
300
250
200
upstream forces
hs, ft
2.0
1.5
1.0
downstream angles
upstream angles
downstream forces
1.0
1.5
2.0
90°
85°
80°
75°
ANGLE WITH HORIZONTAL
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)

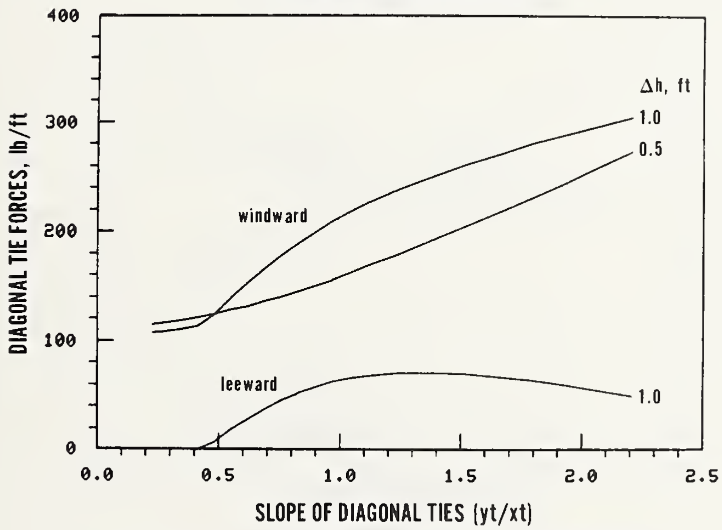

Δh = 1.0 ft
upstream
downstream
hs, ft
2.0
1.5
1.0
1.0
1.5
2.0
VERTICAL TIE FORCES, lb/ft
280
260
240
220
200
180
160
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

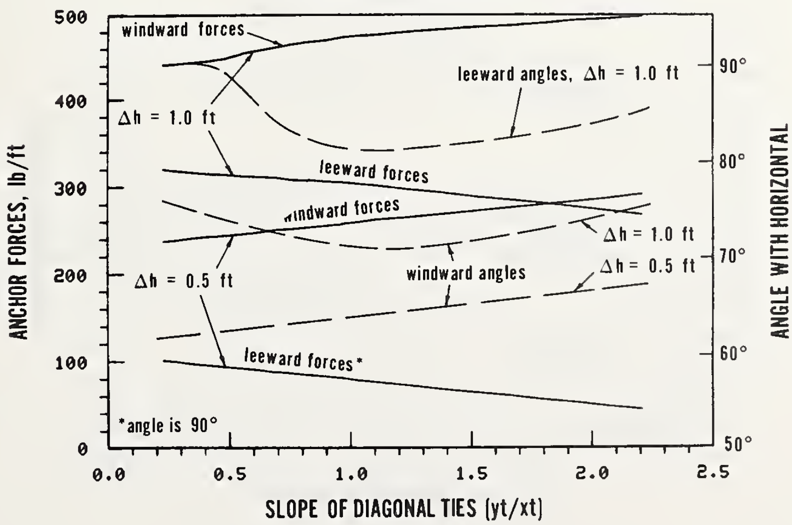

Δh = 1.0 ft
hs, ft
2.0
1.5
1.0
upstream
downstream
1.0
1.5
2.0
DIAGONAL TIE FORCES, lb/ft
150
100
50
0
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)


Δh = 1.0 ft
upstream forces
downstream angle
hs, ft
2.0
1.5
1.0
1.0
1.5
2.0
2.0
1.5
1.0
1.0
1.5
2.0
upstream angles
downstream forces
ANCHOR FORCES, lb/ft
350
300
250
200
ANGLE WITH HORIZONTAL
90°
85°
80°
75°
70°
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

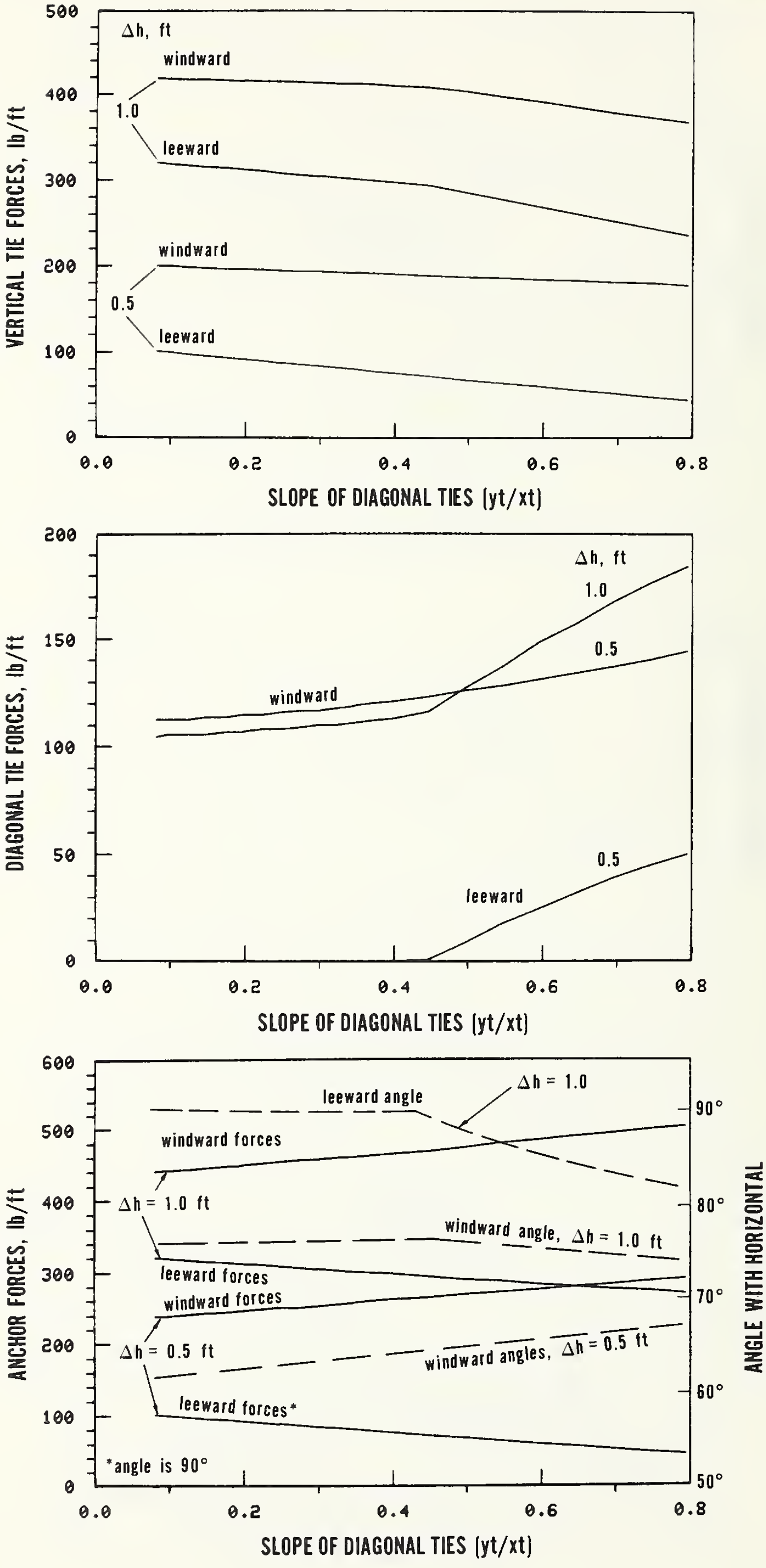
29


VERTICAL TIE FORCES, lb/ft
500
400
300
200
100
0
windward
leeward
windward
leeward
Δh, ft
1.0
0.5
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OFDIAGONAL TIES (yt/xt)

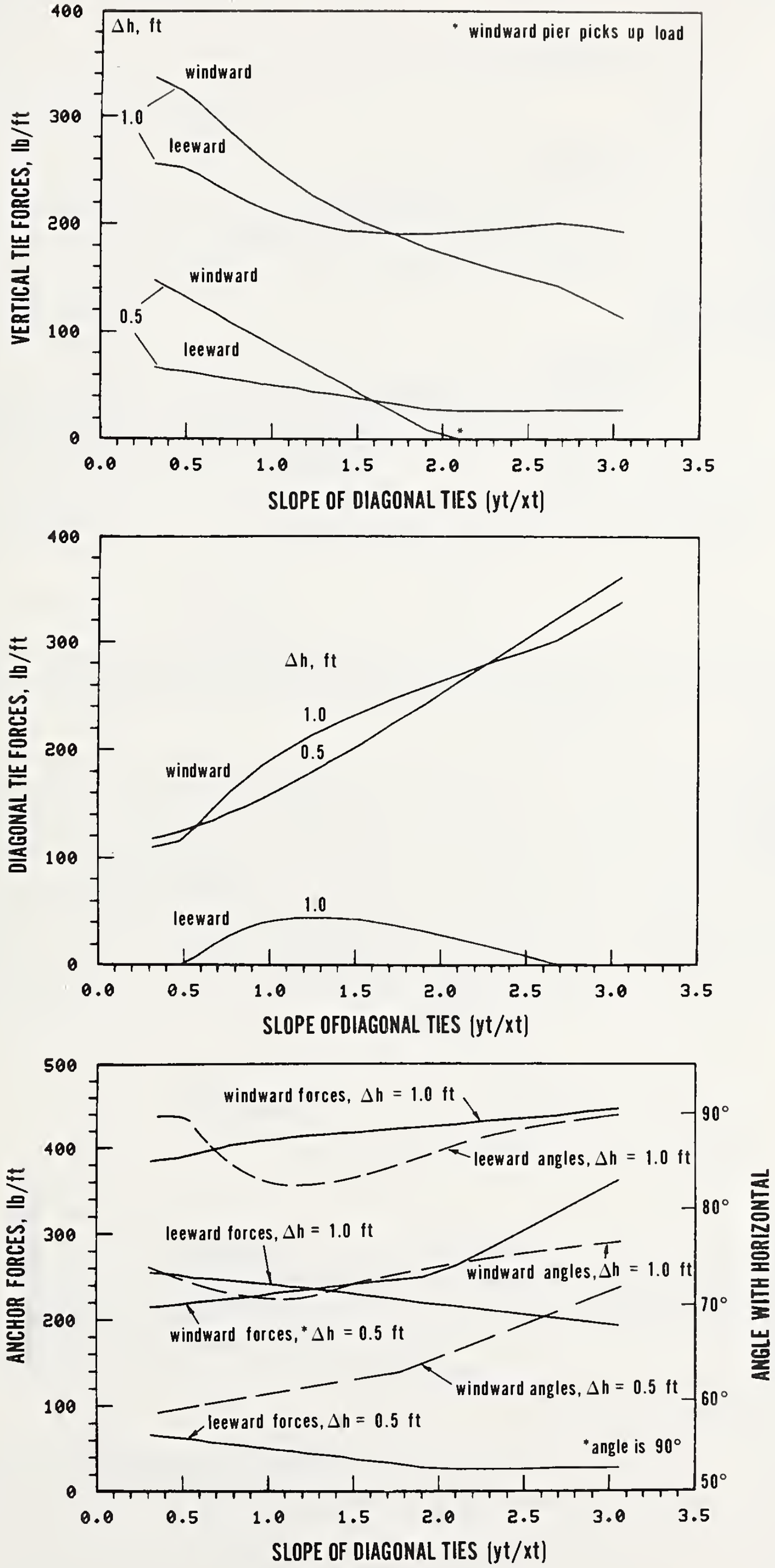

DIAGONAL TIE FORCES, lb/ft
400
300
200
100
0
Δh, ft
1.0
0.5
windward
leeward
1.0
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

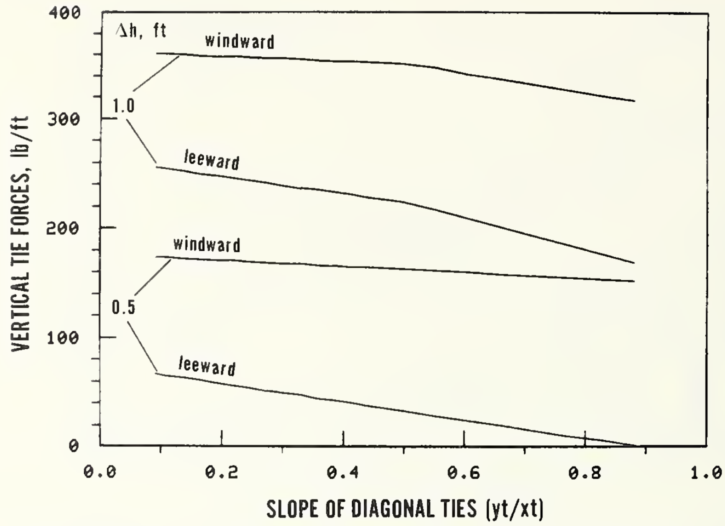

ANCHOR FORCES, lb/ft
500
400
300
200
100
0
windward forces
leeward angles, Δh = 1.0 ft
Δh = 1.0 ft
leeward forces
windward forces
Δh = 1.0 ft
windward angles
Δh = 0.5 ft
Δh = 0.5 ft
leeward forces*
*angle is 90°
ANGLE WITH HORIZONTAL
90°
80°
70°
60°
50°
0.0
0.5
1.0
1.5
2.0
2.5
SLOPE OF DIAGONAL TIES (yt/xt)

30

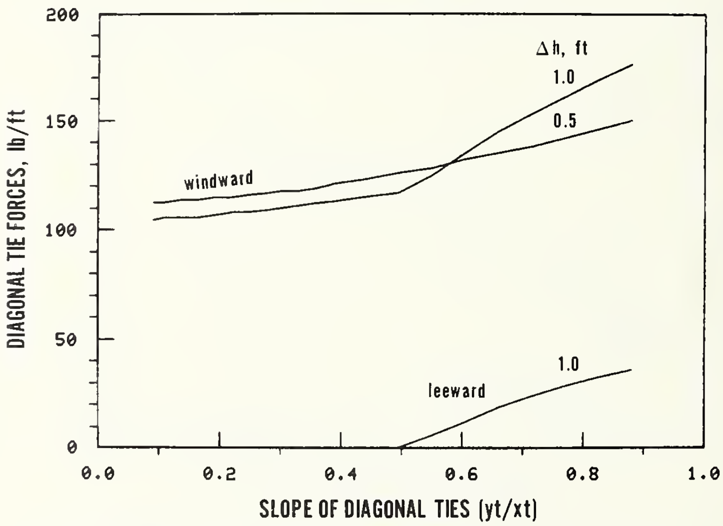

VERTICAL TIE FORCES, lb/ft
Δh, ft
windward
1.0
leeward
windward
0.5
leeward
500
400
300
200
100
0
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)
DIAGONAL TIE FORCES, lb/ft
Δh, ft
1.0
0.5
windward
0.5
leeward
200
150
100
50
0
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)
ANCHOR FORCES, lb/ft
ANGLE WITH HORIZONTAL
Δh = 1.0
leeward angle
windward forces
Δh = 1.0 ft
windward angle, Δh = 1.0 ft
leeward forces
windward forces
Δh = 0.5 ft
windward angles, Δh = 0.5 ft
leeward forces*
*angle is 90°
600
500
400
300
200
100
0
90°
80°
70°
60°
50°
0.0
0.2
0.4
0.6
0.8
SLOPE OF DIAGONAL TIES (yt/xt)

31

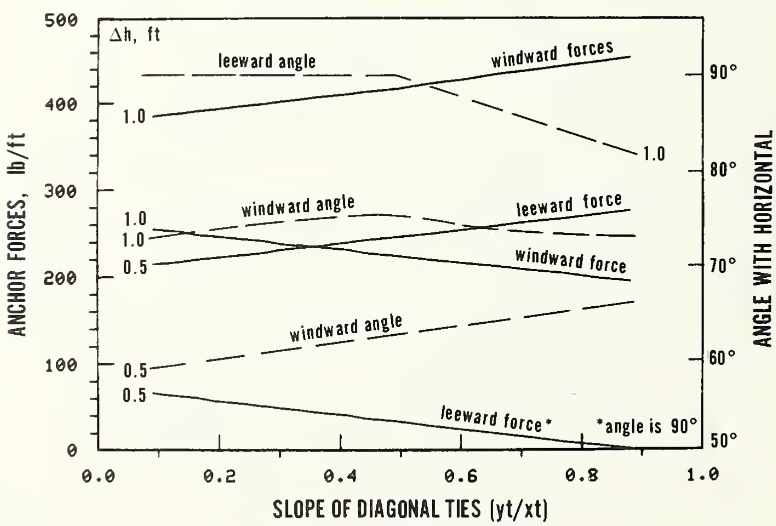

Δh, ft
* windward pier picks up load
windward
1.0
leeward
windward
0.5
leeward
VERTICAL TIE FORCES, lb/ft
400
300
200
100
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)
Δh, ft
1.0
0.5
windward
1.0
leeward
DIAGONAL TIE FORCES, lb/ft
400
300
200
100
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OFDIAGONAL TIES (yt/xt)
windward forces, Δh = 1.0 ft
leeward angles, Δh = 1.0 ft
leeward forces, Δh = 1.0 ft
windward angles, Δh = 1.0 ft
windward forces,* Δh = 0.5 ft
windward angles, Δh = 0.5 ft
leeward forces, Δh = 0.5 ft
*angle is 90°
ANCHOR FORCES, lb/ft
500
400
300
200
100
0
ANGLE WITH HORIZONTAL
90°
80°
70°
60°
50°
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
SLOPE OF DIAGONAL TIES (yt/xt)



VERTICAL TIE FORCES, lb/ft
400
300
200
100
0
Δh, ft
windward
1.0
leeward
windward
0.5
leeward
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)



DIAGONAL TIE FORCES, lb/ft
200
150
100
50
0
Δh, ft
1.0
0.5
windward
1.0
leeward
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)



ANCHOR FORCES, lb/ft
500
400
300
200
100
0
Δh, ft
leeward angle
windward forces
1.0
1.0
windward angle
leeward force
1.0
1.0
0.5
windward force
windward angle
0.5
0.5
leeward force*
*angle is 90°
90°
80°
70°
60°
50°
ANGLE WITH HORIZONTAL
0.0
0.2
0.4
0.6
0.8
1.0
SLOPE OF DIAGONAL TIES (yt/xt)

NBS-114A (REV. 2-80)

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5. AUTHOR(S)

Felix Y. Yokel, Charles W. C. Yancey and Christopher L. Mullen

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
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7. Contract/Grant No.

8. Type of Report & Period Covered

Final

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Department of Housing and Urban Development
Washington, DC 20410

Federal Insurance Administration
Washington, DC 20410

10. SUPPLEMENTARY NOTES

Library of Congress Catalog Card Number: 81-600025

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

Forces acting on the foundations of mobile homes subjected to wind and flood loads were calculated and are presented in a series of computer-generated charts. The loading conditions considered are the two levels of wind loads presently stipulated in the Federal Mobile Home Construction and Safety Standard, a hurricane windload recommended by the National Bureau of Standards (NBSIR 77-1289), buoyancy forces, and draft forces resulting from flood water flow. The calculated forces are compared with present anchoring requirements in ANSI Standard 119.3 (NFPA No. 501 A). It is concluded that diagonal ties are instrumental in resisting wind forces, and that vertical ties are more effective than diagonal ties in resisting flood forces.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Buoyancy forces; flood forces; foundations; hurricane forces; mobile home; soil anchors; standards; tiedown; wind forces.

13. AVAILABILITY

[XX] Unlimited

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JOURNAL OF RESEARCH—The Journal of Research of the National Bureau of Standards reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active. These include physics, chemistry, engineering, mathematics, and computer sciences. Papers cover a broad range of subjects, with major emphasis on measurement methodology and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Bureau's technical and scientific programs. As a special service to subscribers each issue contains complete citations to all recent Bureau publications in both NBS and non-NBS media. Issued six times a year. Annual subscription: domestic $13; foreign $16.25. Single copy, $3 domestic; $3.75 foreign.

NOTE: The Journal was formerly published in two sections: Section A "Physics and Chemistry" and Section B "Mathematical Sciences."

DIMENSIONS/NBS—This monthly magazine is published to inform scientists, engineers, business and industry leaders, teachers, students, and consumers of the latest advances in science and technology, with primary emphasis on work at NBS. The magazine highlights and reviews such issues as energy research, fire protection, building technology, metric conversion, pollution abatement, health and safety, and consumer product performance. In addition, it reports the results of Bureau programs in measurement standards and techniques, properties of matter and materials, engineering standards and services, instrumentation, and automatic data processing. Annual subscription: domestic $11; foreign $13.75.

NONPERIODICALS

Monographs—Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NBS under the authority of the National Standard Data Act (Public Law 90-396).

NOTE: The principal publication outlet for the foregoing data is the Journal of Physical and Chemical Reference Data (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St., NW, Washington, DC 20056.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The standards establish nationally recognized requirements for products, and provide all concerned interests with a basis for common understanding of the characteristics of the products. NBS administers this program as a supplement to the activities of the private sector standardizing organizations.

Consumer Information Series—Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

Order the **above** *NBS publications from: Superintendent of Documents, Government Printing Office, Washington, DC 20402.*

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Federal Information Processing Standards Publications (**FIPS PUB**)—Publications in this series collectively constitute the Federal Information Processing Standards Register. The Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

NBS Interagency Reports (**NBSIR**)—A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Services, Springfield, VA 22161, in paper copy or microfiche form.