CREEP DAMAGE TO STRUCTURES ON EXPANSIVE CLAY SLOPES

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RF 4079

a report
from the Texas A&M
RESEARCH FOUNDATION
College Station, Texas

Prepared for

U. S. Army Corps of Engineers
Waterways Experiment Station
Vicksburg, Mississippi

by

Department of Civil Engineering
Texas A&M University
College Station, Texas

March, 1980

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ABSTRACT

A damage survey of residences in subdivisions in San Antonio and Waco, Texas was conducted and a variety of site conditions were recorded. The damage was measured as the width, length, location and orientation of all cracks in the brick veneer exterior of each building. The site conditions included slope; drainage; size, number, type, and distance of each tree from the nearest wall; age; depth of the active zone; and various index properties of the soil.

Over one hundred residences were observed in each subdivision and correlations were made by non-linear regression analysis between the observed damage and the site conditions. The slope of the lot was among the more important variables in predicting the expected level of damage.

A Kelvin-model of downhill creep damage was hypothesized and non-linear regression analysis upon the measured crack widths, slopes, and sizes of the residences produced creep properties of the soil mass in the field. These field creep properties are compared with the same properties that were measured in a laboratory triaxial creep test.

Introduction

Buildings constructed on expansive clay slopes experience extensive damage because of the downhill creep of the soil. This damage is sometimes ascribed to the settlements of the fill placed on the downhill side of the structure which may be so if the fill is poorly compacted. However, even on a site in which the fill has been compacted properly, extensive damage may still be done. The engineering design of the foundations of buildings on these slopes is hazardous mainly because of the present inability to predict the downhill creep displacement and consequent damage to the building. This paper describes the development and verification of some of the analytical tools which will permit the required prediction of downhill creep and damage.

Damage Surveys

Detailed surveys of damage to the exterior walls of residences in Amarillo, Beaumont, College Station, San Antonio, and Waco Texas, were made by graduate students at Texas A&M University. At least 100 residences were surveyed in each city. The San Antonio and Waco surveys were deliberately chosen to gather data on damage due to downhill creep because of the range of slopes in the selected subdivisions. The width and length of each crack in the brick veneer walls of each building were measured, mapped, and classified into top tension, center tension, and bottom tension cracks. Detailed site condition data were also recorded including size and type of trees, their distance from the nearest wall, slope of the lot, drainage pattern, lawn care, age of the building, and soil properties of each stratum of soil on each site. The slopes in San Antonio are approximately normally distributed between 0 and 6 degrees. The slopes in Waco have a triangular distribution between 0 and 22 degrees. Samples of the soil were taken for detailed laboratory tests including complete hysteresis of loops of soil suction versus volume strain and water content as the soil was dried to air dry condition and then rewetted. Creep tests were made on trimmed samples on the soil at different levels of suction in a specially constructed triaxial test chamber. Table 1 shows the ranges of several of the pertinent variables observed in the surveys in San Antonio and Waco. The detailed data that were collected in San Antonio and Waco are given in Appendix I.

Table 1. Ranges of Measured Variables in the Damage Surveys

Variable	San Antonio Survey	Waco Survey
Slopes (degrees)	0 - 6	0 - 22
Crack Width (mm)		
Top Tension	0 - 12	0 - 75
Center Tension	0 - 6	0 - 6
Bottom Tension	0 - 5	0 - 30
Age (years)	2 - 13	2 - 13
Wall lengths, ft (m)	18 - 75 (5.5 - 23)	11 - 77 (3.5 - 23.5)
Plasticity Index (%)	8 - 40	13 - 51
Depth of Active Zone, ft. (m)	0 - 6 (0 - 1.81)	1.5 - 7 (0.5 - 2.1)
No. of walls with Visible Cracking	101	106

The subdivision in San Antonio is built on the Houston Black Clay which overlies the soft, weathered Anacacho limestone. The depth of the clay varies over the area of the subdivision as shown in Figure 1. Contours of equal depth (isopachs) were inferred from the 24 borings which are indicated in the figure. The Anacacho limestone contacts the surface in the shaded zones.

Logarithmic regression analysis was used to determine mathematical

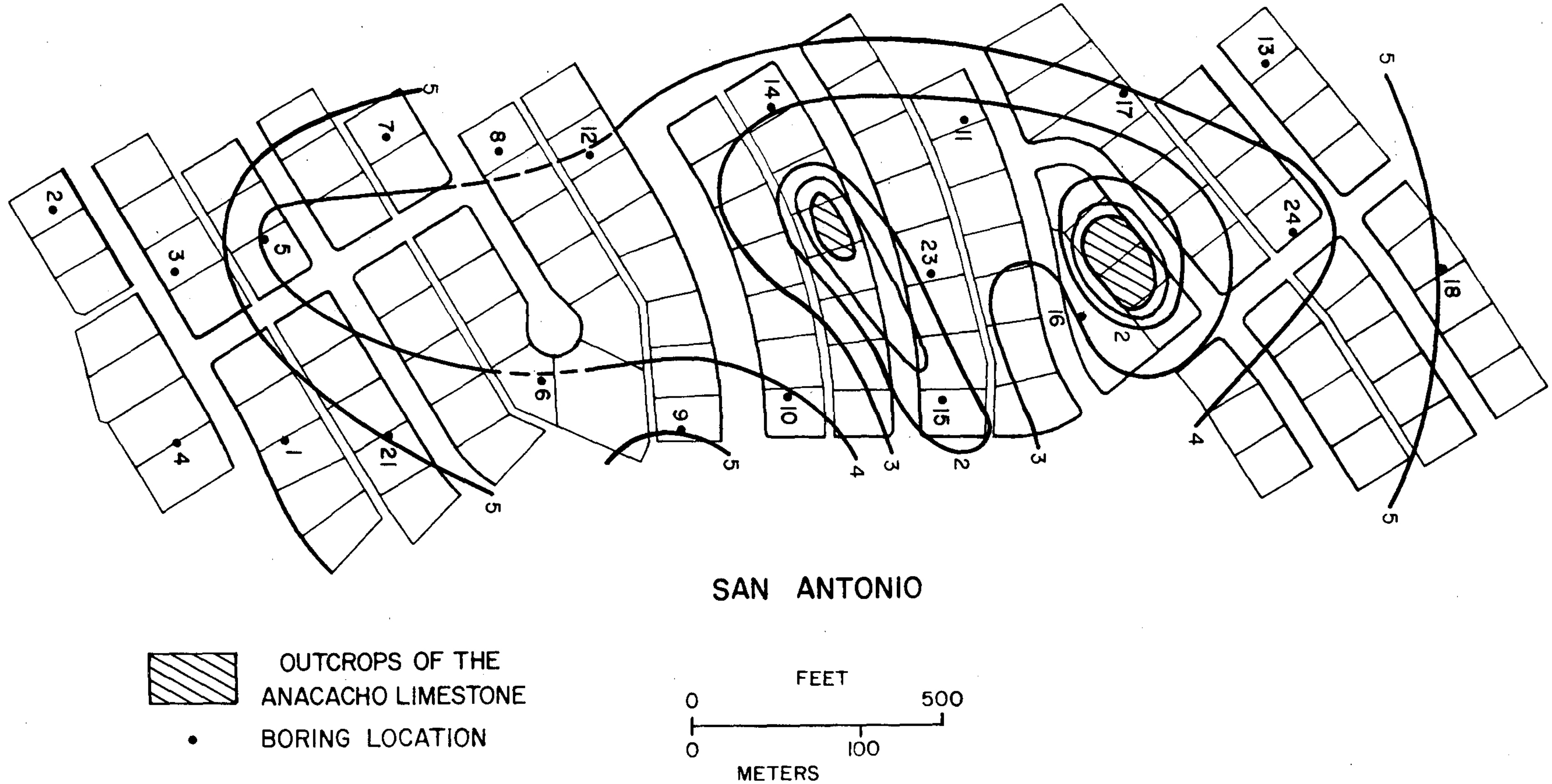

Figure 1. Isopach Map of the Houston Black Clay in the San Antonio Subdivision. The Cross-Hatched Areas are Anacacho Limestone Outcrops.

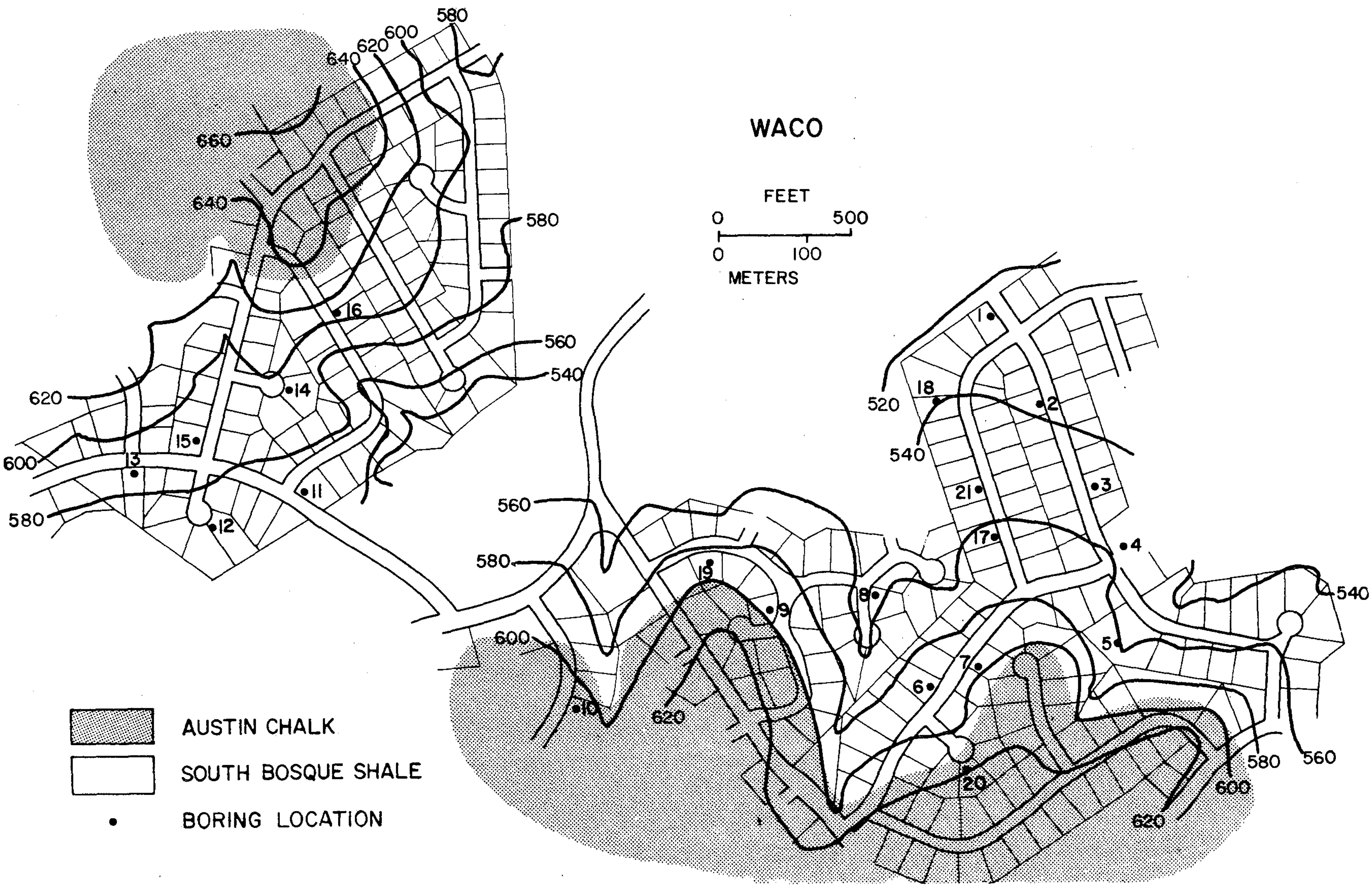

Figure 2. Geologic and Tographic Map of the Waco Study Site. The Shaded Areas are Austin Chalk Overlying the South Bosque Shale.

models of damage in each of the two subdivisions. The following equations predict the total area of cracking (in mm^2) in terms of the measured site conditions in San Antonio (Equation 1) and Waco (Equation 2).

$$
\begin{aligned}
TA = & -2.34\ (y)^{-1.6}(r)^{0.20}(da)^{2.5} \\
& +3.54\ (y)^{-1.7}(da)^{2.5} \\
& +0.53\ (r)^{0.21}(T)^{0.62}(y)^{-1.7}(da)^{3.0} \\
& -0.72\ (T)^{0.60}(y)^{-1.8}(da)^{2.9} \qquad + 1.87
\end{aligned} \tag{1}
$$

$$
\begin{aligned}
TA = & \ 8.86\ (n)^{0.22} + 1.05\ (c)^{0.25}(s)^{1.9} \\
& +0.12\ (s)^{1.3}(T)^{1.5} \\
& +0.0018\ (d)^{1.4}(s)^{1.4}(a)^{0.64}(T)^{1.2} \\
& -0.17\ (d)^{0.42}(s)^{1.4}(T)^{1.2}
\end{aligned} \tag{2}
$$

where TA = total area of cracking, in mm^2.

a = age, years

c = canopy, percent of lot covered by tree-sized vegetation at the time of the survey.

d = average distance of trees from the nearest wall, ft (= 0.305m)

da = depth of the active zone, ft (= 0.305m)

n = number of trees on a lot

r = antecedent rainfall ratio, (= 1.0 if rainfall in the two months prior to construction equals the average annual monthly rainfall, in inches (= 2.54 cm)

s = average plasticity index of the soil in the active zone, in percent

T = topographic relief on the lot in feet (= 0.305 m). A measure of slope.

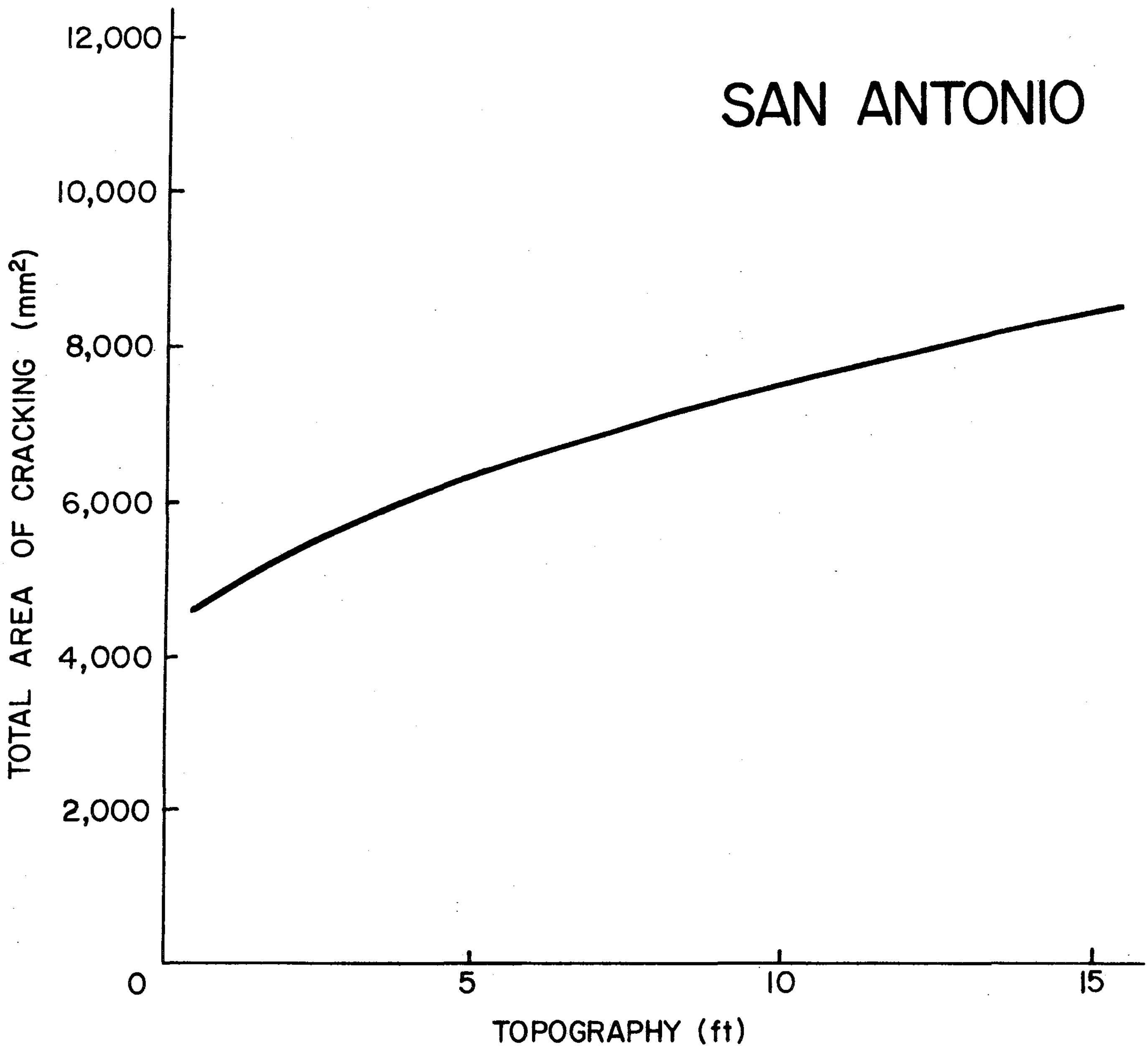

Figure 3. Cracking Damage as a Function of Slope in the San Antonio Sub-division

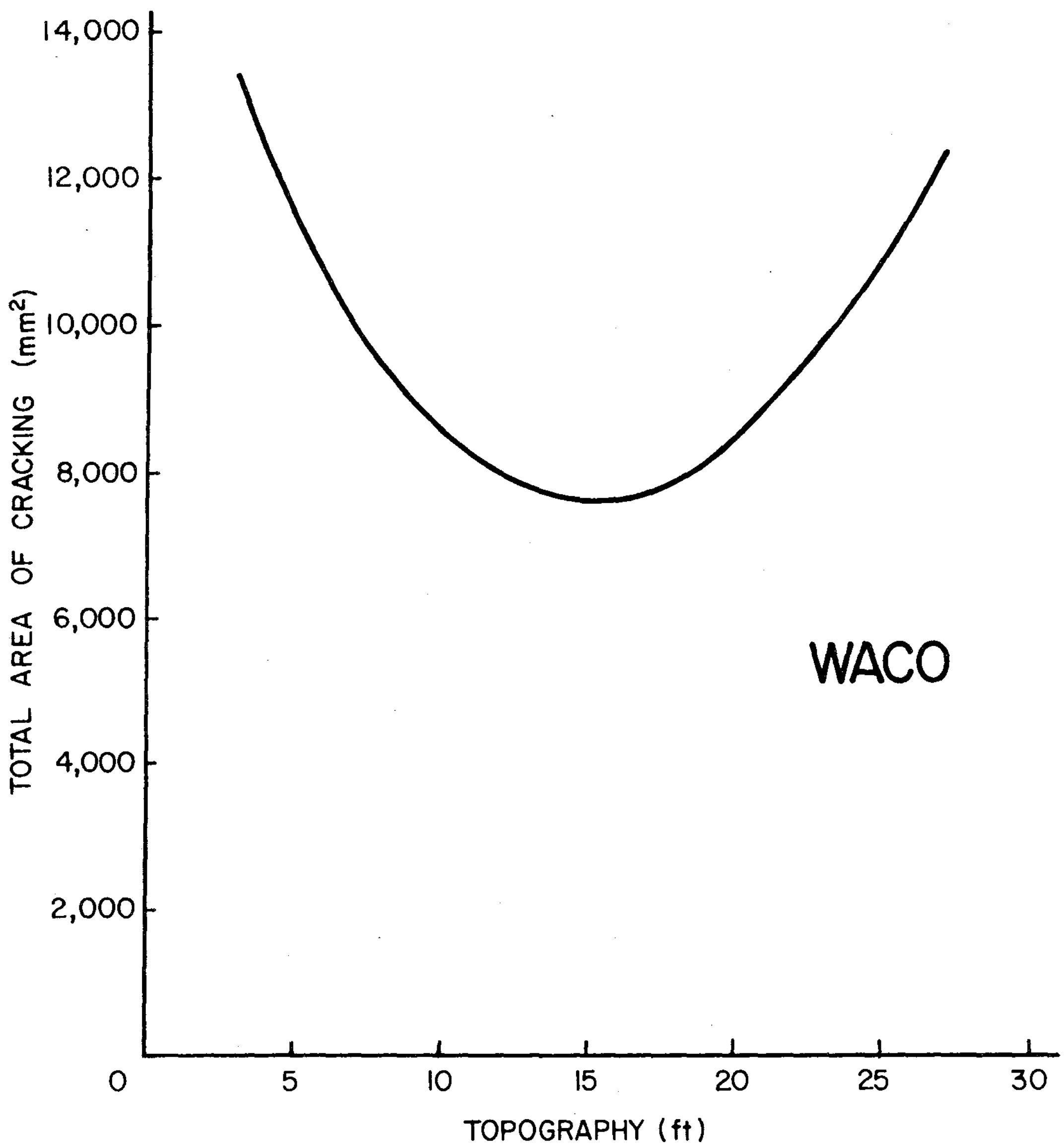

Figure 4. Cracking Damage as a Function of Slope in the Waco Sub-division

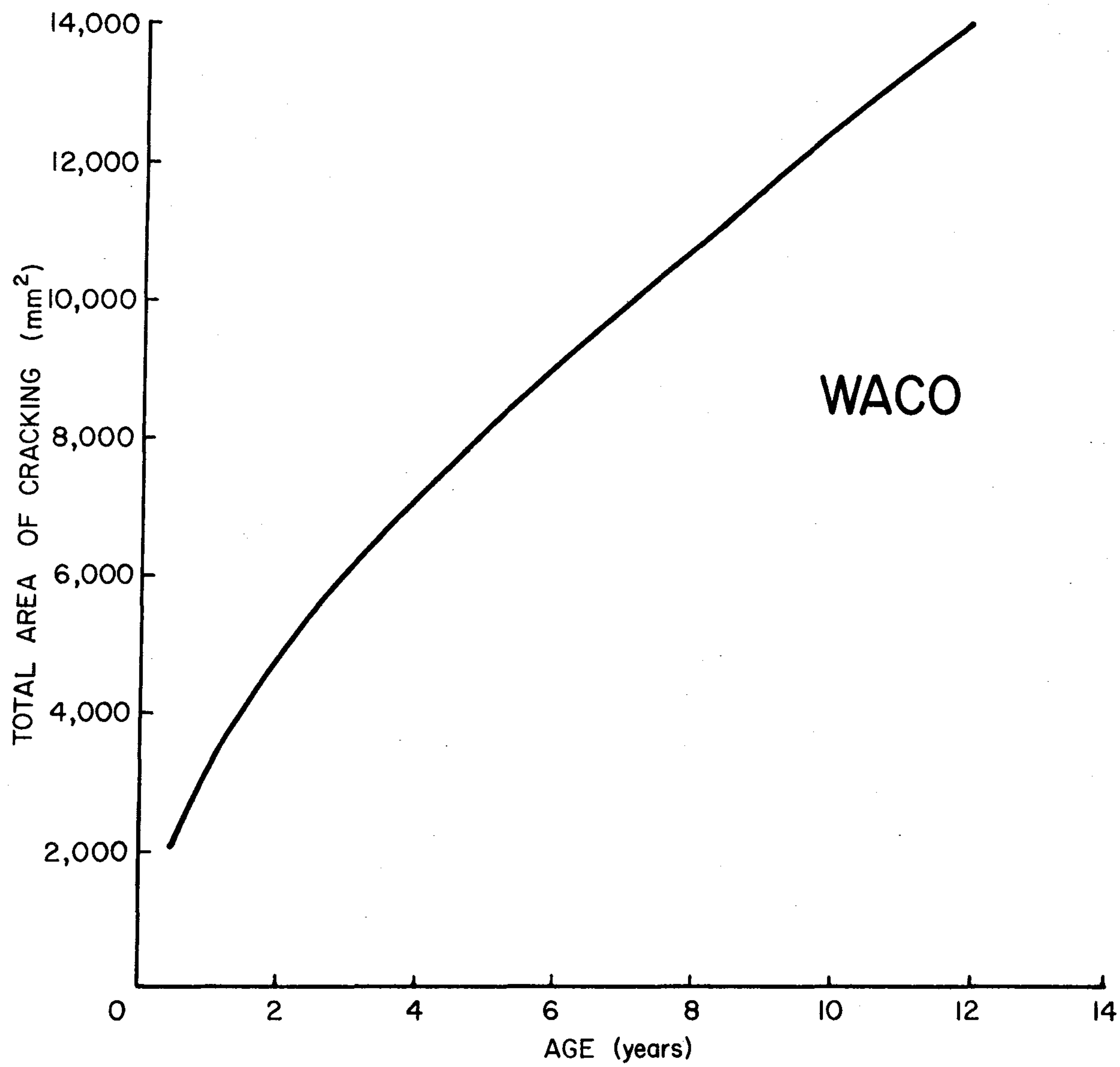

Figure 5. Effect of Age on Cracking Damage in the Waco Subdivision

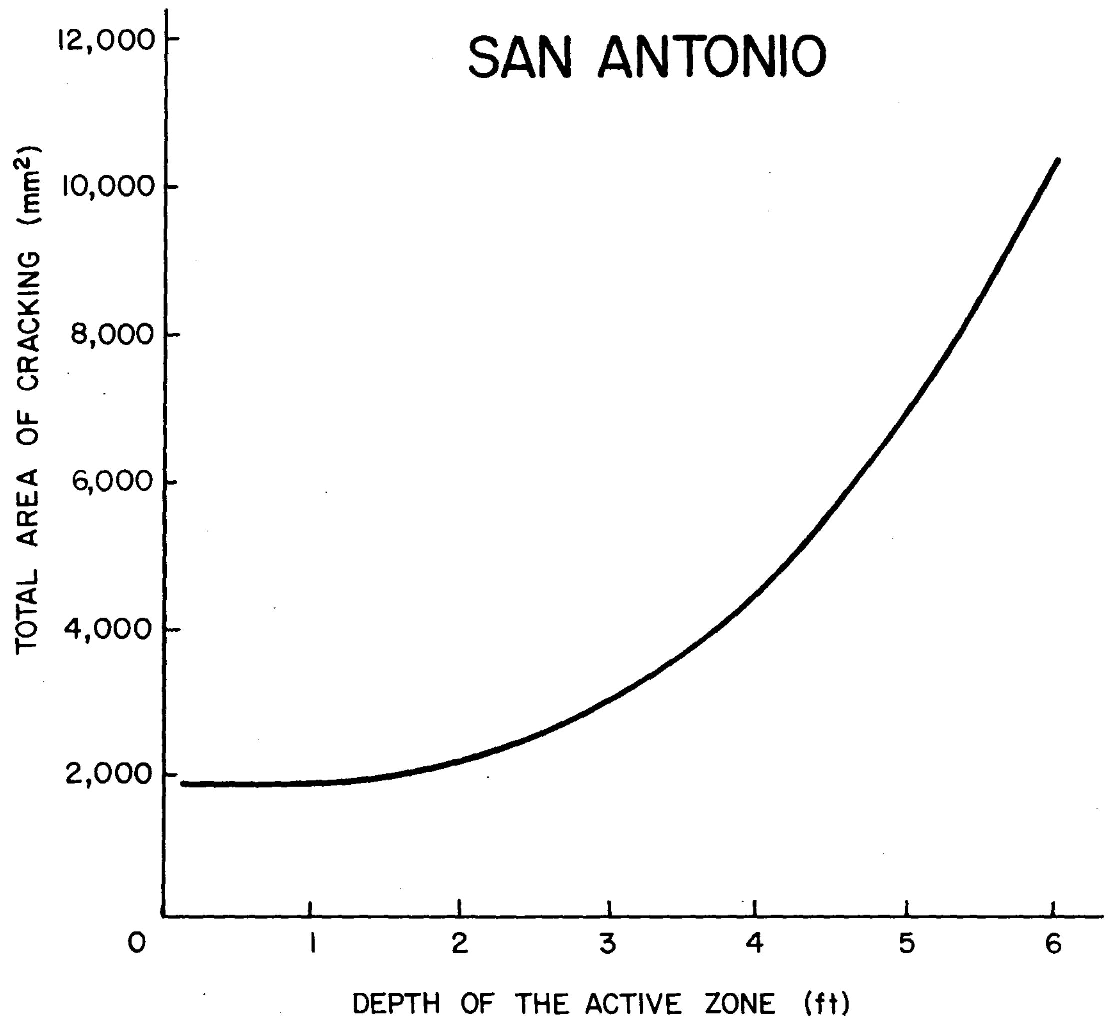

Figure 6. Effect of Depth of the Active Zone on Cracking Damage in the San Antonio Sub-division

y = yard maintenance rating (a subjective rating ranging from 1 = poor to 5 = good)

It is significant that although slope (T) enters into the damage equation for the San Antonio subdivision, the predicted value of cracking area is not sensitive to changes in slope over its full range between 0 and 6 degrees, indicating that the majority of damage is due to differential swelling and shrinking. A graph of the equation of damage as a function of topography is given in Figure 3. The damage is calculated by setting all of the other variables at their mean value and allowing the slope to vary over its full range. It is also significant that in the damage equation for Waco, which has numerous slopes above 5 degrees, the slope is a very sensitive variable. The equation for Waco produces the curve shown in Figure 4.

The U-shaped curve has a minimum at a topographic relief value of about 15 feet (4.5 m) or a slope angle of about 6 degrees. This indicates that there is a fundamental change of predominant damage mechanism when the slope reaches about 5 degrees: at lower slopes, differential shrinking and swelling dominates due to the likelihood of poor drainage conditions and above 5 degrees, downhill creep becomes more important.

The effect of the age of the building in Waco is shown in Figure 5, indicating that cracking damage increases with age.

The effect of a variation in the depth of the active zone in San Antonio is shown in Figure 6. These results and many others are reported in References (1,2). The following general conclusions may be drawn from these empirical studies.

1. Damage increases with slope angle to a power lower than 0.60 in San Antonio and higher than 1.2 in Waco.

2. Damage increases with time to a power higher than 0.60 in Waco and is independent of time in San Antonio.
3. Damage increases with depth of the active zone to a power higher than 2.5 in San Antonio and is independent of the active zone depth in Waco.

These empirical facts taken together point to a conclusion that much of the observed damage may be explained with a mathematical model of the downhill creep displacement of the soil mass and the consequent distortion of the foundations of these buildings.

Mathematical Model of Downhill Creep

A simple rheological model, the Kelvin solid, is proposed as the constitutive equation of the soil mass. The fundamental differential equation is:

$$G \frac{\partial u}{\partial z} + \lambda \frac{\partial \dot{u}}{\partial z} = \gamma_t (H_o - z) \sin \alpha \qquad (3)$$

where G = the shear modulus of the soil mass, typical units (lb/ft^2, kPa)

λ = the viscosity of the soil mass, typical units ($lb\text{-}yr/ft^2$, kPa-sec)

u = the downhill displacement parrallel to the ground surface

$\dot{u}$ = the downhill creep velocity

z = the height above a stable surface

γ_t = the unit weight of the soil

α = the slope angle

H_o = the depth of the active zone

Integration of this equation with depth below the surface, taking a foundation pressure, w_o, into account is

$$u(t) = \frac{T(z)}{G}\left(1 - e^{-\frac{G}{\lambda}t}\right) \quad (4)$$

where $$T(z) = \left[H_o z - \frac{z^2}{2} + w_o z\right] \gamma_t \sin\alpha \quad (5)$$

$T(z)$ = the total load per unit width acting at a point z units above the stable surface

w_o = the foundation pressure

The downhill creep displacement profile and the coordinates used in the derivation are shown in Figure 7.

If a building is to be constructed on such a sloping site, a flat surface is prepared by excavating the uphill side and placing fill on the downhill side of the building. The wall of a house built on this slope will be stretched and bent as the foundation soil creeps downhill as shown in Figure 8.

This type of distortion causes center tension (stretching) and top tension (bending) cracks to form in the brittle brick veneer walls as shown in Figure 9. Assuming that all of the relative downhill displacement between the uphill and downhill sides of the wall result in visible cracks, the following equations were developed to predict top tension (s(t)) and center tension (c(t)) cracks.

$$s(t) = \frac{1}{G}\left(1 - e^{-\frac{G}{\lambda}t}\right) H\ L\ \gamma_t \sin^4\alpha \quad (6)$$

$$c(t) = \frac{1}{G}\left(1 - e^{-\frac{G}{\lambda}t}\right) H\ L\ \gamma_t \sin^2\alpha \cos\alpha \quad (7)$$

$$h = (H_o - z_o) + \frac{w_o}{\gamma_t} - \frac{L}{2}\sin\alpha \quad (8)$$

z_o = the depth of the uphill edge of the wall.

In order for geometric compatibility to be maintained, the following con-

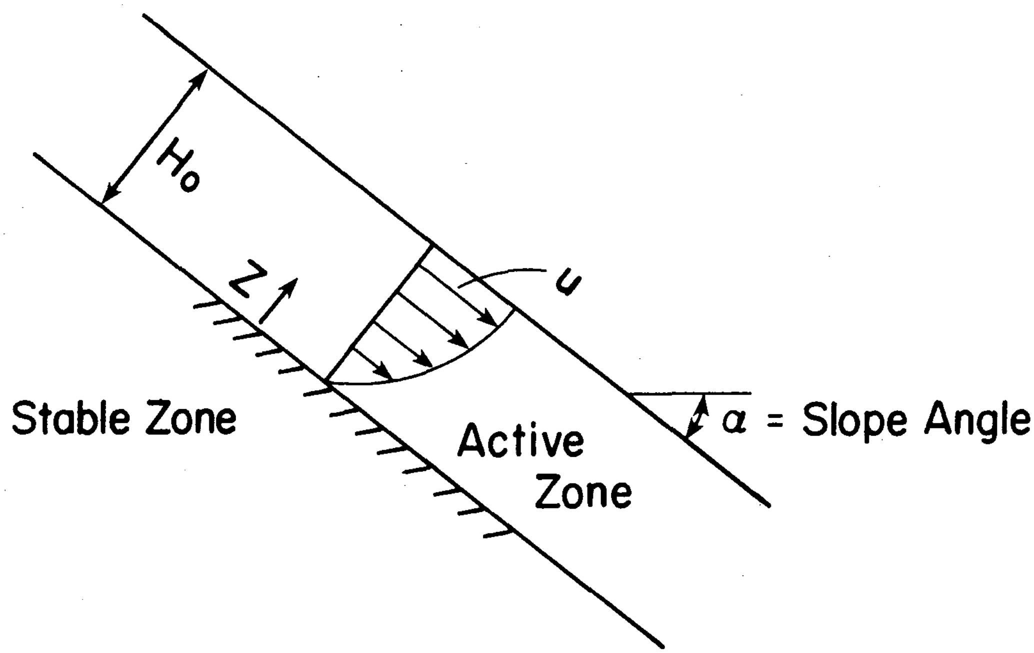

Figure 7. Downhill Creep Profile with the Kelvin Model

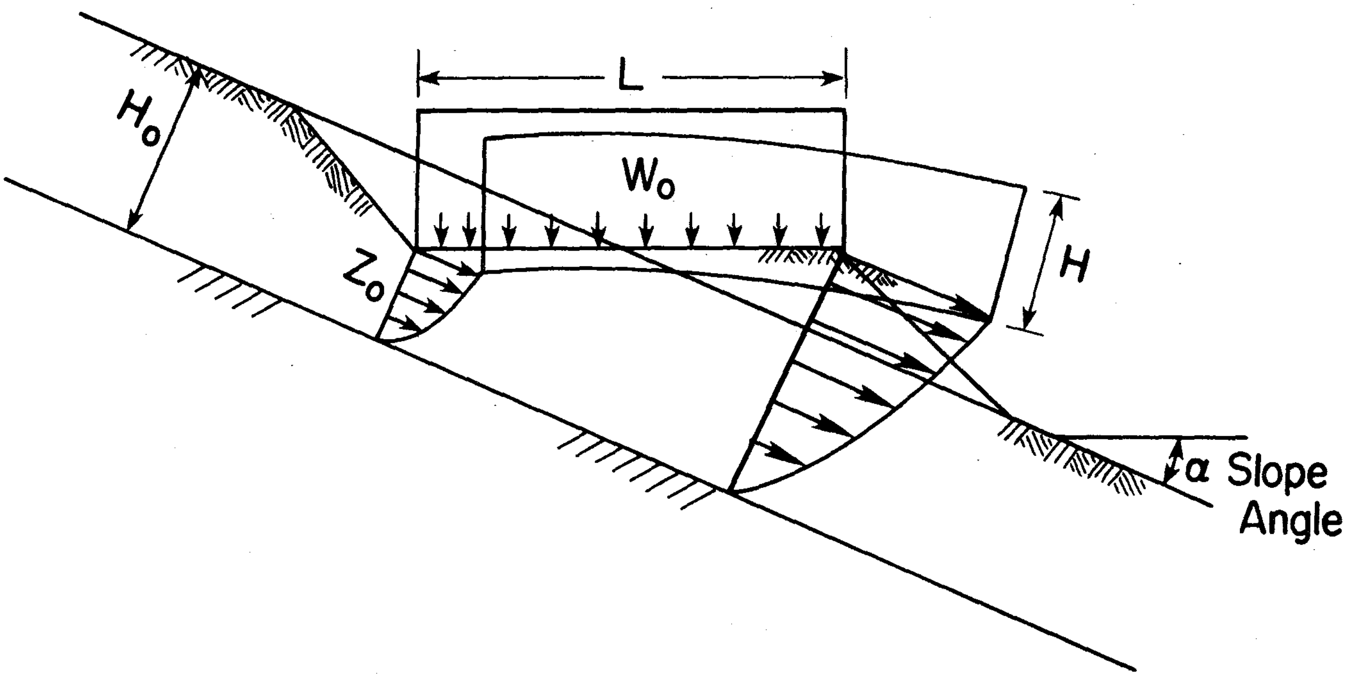

Figure 8. Distortion of a Wall Built on a Slope

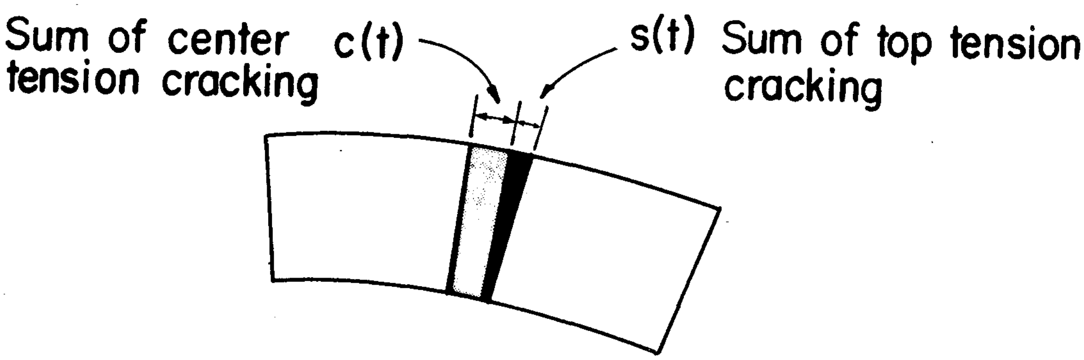

Figure 9. Analysis of Crack Patterns on the Distorted Wall

ition must hold:

$$h = \frac{c(t)}{s(t)} \frac{H \sin^2\alpha}{\cos \alpha} \tag{9}$$

In the analysis of the field cracking data, Equation (6) was used to determine the Kelvin properties of the soil mass and Equation (9) was used to determine depth of imbedment into the surface, $H_o - z_o$.

Assumptions Implicit In The Equations

More complicated equations could have been used in formulating a model of downhill creep but the form adopted here was used to simplify the non-linear regression analysis to be described subsequently. The assumptions that are implicit in this model are as follows: (1) there is no long-term flexural stiffness of the wall; (2) the downhill motion of a variable thickness of soil can be represented by an equation for u, the one-dimensional displacement parallel to the slope; (3) the downhill fill has the same creep properties as the natural soil. More detailed studies of the mechanics of layered viscoelastic continua on slopes would be required to investigate the error involved in these assumptions.

A fourth major assumption that has a significant effect on the results is as follows. The total top tension cracking width, s(t), is actually the sum of that due to downhill creep, $s_c(t)$ and that due to differential swelling, $s_s(t)$:

$$s(t) = s_c(t) + s_s(t) \tag{10}$$

The equation for $s_c(t)$ is Equation (6), whereas an approximate equation for $s_s(t)$ is

$$s_s(t) = \frac{8y_m H}{L} \left(1 - e^{-\theta t} \right) \tag{11}$$

where y_m = the differential movement of the foundation

Θ = the time rate constant for the increase of y_m, with dimensions, years^{-1}

The two differential movements occur simultaneously, producing the total top-tension cracking width, s(t). If these cracking data were analyzed as if they were due to only one cause, such as downhill creep, the inferred soil mass properties would be greatly in error. This erroneously calculated soil mass shear modulus, G', is less than the actual modulus, G. The relation between the two is

$$G' = \frac{G}{1 + (q/r)} \tag{12}$$

where $q = 8y_m G\,(1 - e^{-\Theta t})$ (13)

$$r = \gamma_t\, L^2 \sin^4\alpha\, (1 - e^{-\frac{G}{\lambda}t}) \tag{14}$$

This equation shows that the computed value of G' will decrease under the following conditions: (1) as y_m increases, (2) as Θ becomes greater than G/λ and (3) as the angle α approaches 0 degrees with y_m being non-zero.

Table 2. Typical Ratios of G/G' for Various Values of α and y_m.

y_m, ft (cm) / α, degrees	0.008 ft. (0.25 cm)	0.08 ft. (2.54 cm)
0	∞	∞
5	140	1400
10	9	90

The data were analyzed in two ways: (1) assuming that all top-tension cracking is due to downhill creep and then determining the probable size of the differential movement due to differential swelling and (2) determining G by non-linear regression analysis of Equation (12) substituted into Equation (6). The second method allows the program to search for three variables simultaneously, G, λ, and y_m.

Statistical Determination of Soil Mass Properties

A pattern-search method (3) was adopted to perform the required non-linear regression analysis. The method uses a systematic trial-and-error search along steepest gradient lines to find local minima in a computed error surface. The error surface is defined by the sum of squared errors between observed and predicted top-tension crack widths, as follows:

$$\varepsilon^2 = \left[s_{ci}(t) - \hat{s}_{ci}(t)\right]^2 \qquad (15)$$

where $s_{ci}(t)$ = the observed top-tension crack width of wall, i

$\hat{s}_{ci}(t)$ = the predicted value of top-tension crack width on the same wall, using Equation (6).

The sum of squared errors is minimized by altering the values of G and G/λ until convergence to a minimum is reached. The search was conducted to include a variety of slope angles to investigate the effect of slope on the prediction of the soil mass properties G and λ.

Analysis No. 1: All Cracking Assumed Due To Downhill Creep

The results of the first analysis which assumes that all cracking is due to downhill creep, is given in Table 3 below. The analysis produces a single value of G' and of G'/λ. The latter ratio is used to determine λ by dividing it into G'. The ratio was found to be insensitive in the analysis, remaining unchanged at 1.0×10^4/yr. during each trial-and-error search.

Table 3. Kelvin Model Soil Mass Properties From Pattern Search Regression Analysis

City	Slope Angle Degrees	Number of Observations	G' psf (kPa)	λ* lb-yr/ft^2 (kPa-sec x10^6)	Mean Square Error x 10^{-2}
San Antonio	>0°	101	170 (8.1)	0.017 (0.026)	0.013
San Antonio	>5°	6	243 (11.6)	0.024 (0.037)	0.005
Waco	>0°	106	20360 (975)	2.04 (3.07)	0.139
Waco	>5°	60	20370 (975)	2.04 (3.07)	0.242
Waco	>10°	16	24470 (1170)	2.45 (3.70)	0.113

* The ratio of G'/λ in all cases was 1.0 x 10^4/year.

The computed values of shear modulus, G', are expected to be lower than the actual values because of the effect of simultaneous differential movement and downhill creep. The actual values of the shear modulus, G, as corrected by Equation (12) are shown in Table (4) below.

Table 4. Corrected Values of Soil Mass Shear Modulus G, lb/ft^2 (kPa) x 10^6

City	Slope Angle degrees	Differential Movement, inches (cm)	
		0.1 (0.25)	1.0 (2.54)
Waco	>5	2.85 (0.135)	28.2 (1.35)
Waco	>10	0.22 (0.01)	2.15 (1.10)
San Antonio	>5	0.034 (0.002)	0.34 (0.016)

These values must no be compared with values of G and λ that were measured in the laboratory to determine whether they are reasonable.

Analysis No. 2: Cracking Due to Creep and Differential Movement

The second analysis used the following definition of squared error:

$$\varepsilon^2(t) = \left[y(t) - ac(1-e^{-bt})\right]^2 \qquad (16)$$

where

$$y(t) = \frac{s(t)}{\gamma_t \, H \, L \, \sin^4\alpha} \qquad (17)$$

$$a = 1/G \qquad (18)$$

$$b = G/\lambda \qquad (19)$$

$$c = (1 + q/r) \qquad (20)$$

The variables q and r are defined in Equations (13) and (14). The variable q includes y_m as a factor and the variable r includes b (G/λ) as a factor. The pattern search was made looking for values of a, b, and c which produced the minimum sum of squared errors.

Table 5 gives the results for Waco.

Comparing the results of the second analysis with those of the first, shows that the mean square error has been reduced in all cases, but not by very much. The value of y_m that was inferred from this analysis was aobut 0.066 in. (0.17 cm) which is for all practical purposes negligible.

Table 6 shows the results for San Antonio. To achieve these results, the G and λ values were set at the same numbers found in the previous analysis, (i.e., $G = 0.188 \times 10^6$ psf and $\lambda = 18.8$ lb-yr/ft^2) and the pattern search was made to find the best value of y_m.

Table 5. Kelvin Model Soil Mass Properties and Differential Swelling From Pattern Search Regression Analysis

City	Slope Angle	No. of Obser-	G, psf (kPa)x10^6	λ, lb-yr/ft^2 (kPa-Sec x10^6	y_m in (cm)	Mean Square Error x10^{-2}
Waco	>0°	106	0.186 (.009)	18.7 (28.2)	0.066	0.137
Waco	>5°	60	0.186 (0.009)	18.8 (28.4)	0.066	0.239
Waco	>10°	16	*0.294 x 10^7 (0.014 x 10^7)	*29.4 x 10^7 (44.4 x 10^7)	0.064	0.102

* Questionable Value

Table 6. Kelvin Model Soil Mass Properties and Differential Swelling From Pattern Search Regression Analysis.

City	Slope Angle	No. of Obser-vations	G*, psf (kPa)x10^6	λ*, lb-yr/ft^2 (kPa-sec x 10^6)	y_m in (cm)	Mean Square Error x 10^{-2}
San Antonio	>0°	101	0.188 (.009)	18.8 (28.4)	8.24 (20.9)	0.14
San Antonio	>5°	6	0.188 (.009	18.8 (28.4)	5.63 (14.3)	.014

*Values were not allowed to vary in the analysis.

The sizes of y_m were 5 - 8 inches which are clearly too large, and the mean square error is larger by a factor of 10. In order to reduce the mean square error, the sizes of G and λ must be reduced and y_m must be reduced as well. The exercise shown in Table 6 indicates that the soil mass at the San Antonio site is less stiff than that at the Waco site. The laboratory data, which will be considered next, indicate that for a given level of suction, the San Antonio soil is stiffer than that in Waco. This shows that the San Antonio soil mass must be wetter than that in Waco, a surmise which is made probable by the lower slopes and possible poor drainage in San Antonio.

Laboratory Creep Tests

A simple creep apparatus was used to measure the Kelvin properties of undisturbed soil samples from both cities. Trimmed soil samples were allowed to equilibrate to different levels of soil suction and then placed in a closed triaxial test chamber. Each sample was surrounded by water held at a constant pressure by a mercury manometer as shown in Figure 10. Vertical pressure was applied by dead weight and vertical displacement was measured with time. Three levels of deviatoric stress were applied on each sample and displacement measurements were carried out over a period of 7000-10,000 seconds. The suction of each sample was inferred from the water content versus suction curve which was measured for the full cycle of desorption and adsorption by equilibrating in a pressure plate apparatus with a silty loam of known water content versus soil suction characteristics. The ranges of test variables are shown in Table 7 below.

The complete set of test variables, Kelvin elastic moduli and viscosities, and creep compliances are given in Appendix II and III.

The Kelvin constants were determined directly from the test data by assuming that the vertical displacement, u, obeys the Kelvin model in Equation 26.

$$u = \frac{\ell(\sigma_1 - \sigma_3)}{E}\left(1 - e^{-\frac{E}{\lambda}t}\right) \qquad (21)$$

where ℓ = the length of the sample and E = the Kelvin elastic modulus of the sample. Taking a derivative with respect to time to get $\dot{u}$, the vertical velocity, and then taking the natural logarithm gives Equation (22).

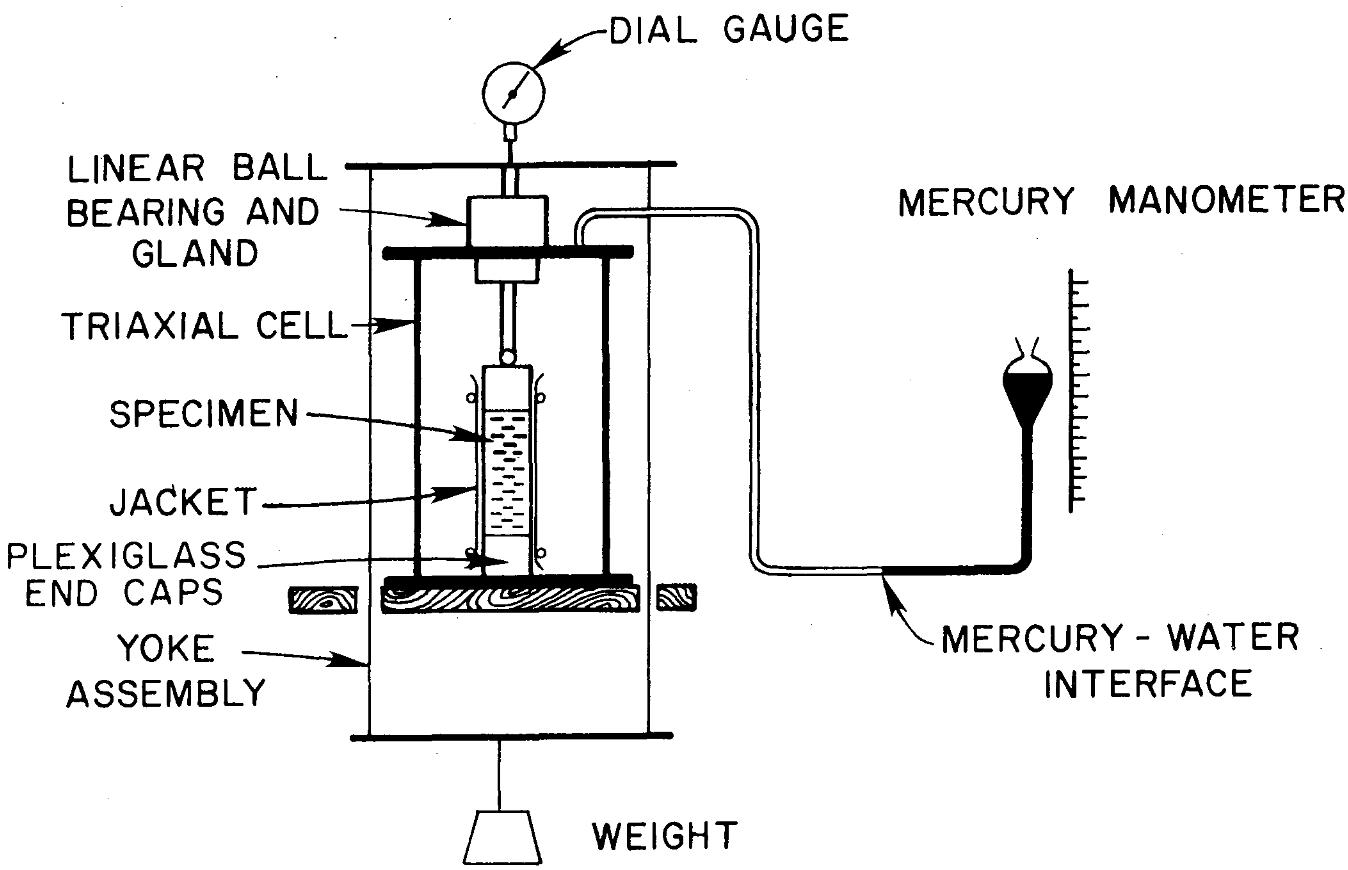

Figure 10. Creep Apparatus Used In Laboratory Tests

$$\ell n\ \dot{u} = \ell n\ \frac{\ell(\sigma_1 - \sigma_3)}{\lambda} - \frac{E}{\lambda} t \qquad (22)$$

A typical graph of $\ell n\ \dot{u}$ versus t is shown in Figure 11. The slope of this curve at around 5000 to 7000 seconds was used to determine the long-term values of E and λ for each sample. Measured ranges of E and λ are shown in Table 8.

Table 7. Ranges of Laboratory Test Variables

City	Soil	Deviatoric Stress, psi, (kPa)	Lateral Pressure psi, (kPa)	Soil Suction Bars (kPa)	Water Content,%
San Antonio	Houston Black Clay	2.0 - 5.0 (13.8 - 34.5)	0 (0)	-0.13 (-12.7)	29.3
Waco	South Bosque Shale	2.0 - 5.0 (13.8 - 34.5)	0 - 5.0 (0 - 34.5)	-13-0.27 (-12.7-26.4)	24.5-32.5

Table 8. Ranges of Laboratory Kelvin Elastic Modulus, E, and Viscosity, λ

City	Soil	Elastic Modulus, psi (kPa) x 10^3	Kelvin Viscosity, lb-sec/in^2(kPa-sec)x10^6
San Antonio	Houston Black Clay	0.90 - 2.00 (6.2 - 13.8)	1.0 - 6.8 (6.9 - 46.9)
Waco	South Bosque Shale	0.64 - 3.40 (4.4 - 23.4)	1.2 - 25.7 (8.3 - 177)

Equations for E and λ were developed from the laboratory data as follows:

$$E = b\ (|\ \psi\ |)^{3.06} \qquad (23)$$

$$\lambda = a\ (|\ \psi\ |)^{m} \qquad (24)$$

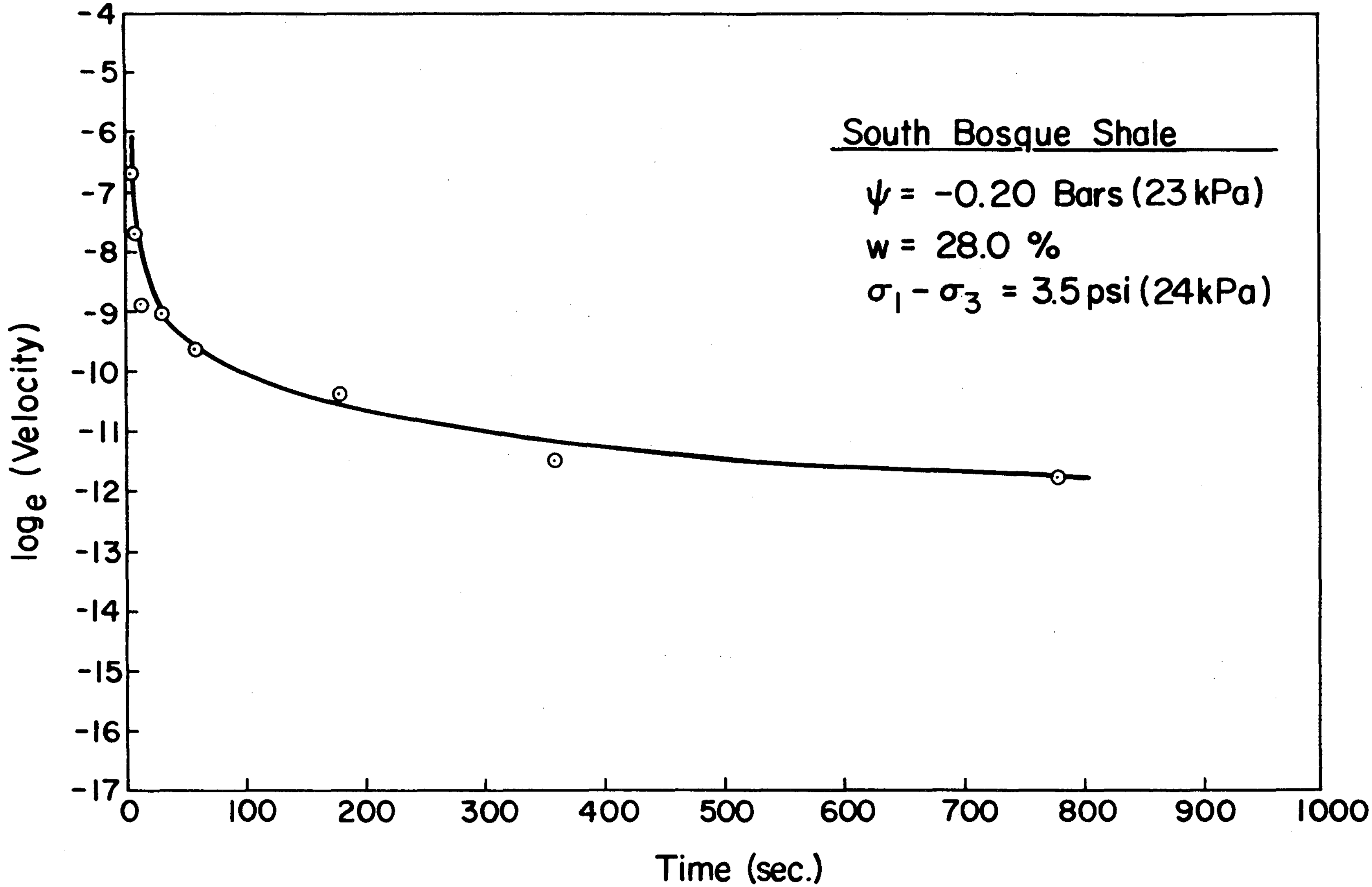

Figure 11. Typical Graph of $\ln \dot{u}$ versus Time (Seconds)

$$m = 4.33\ \sigma^{-0.23}$$

where $|\ \psi\ |$ = the absolute value of suction in bars (= 97.9 kPa)

σ = the mean principal stress in psi (= 6.895 kPa)

The material constants a and b are given in Table 9 below.

Table 9. Values of Material Constants a and b.

Mean Principal Stress, psi (kPa)	$a \times 10^9$	$b \times 10^5$
0.67 4.62)	5.24	1.60
1.17 (8.07)	3.59	1.60
1.67 (11.51)	3.95	1.60

The shear modulus is assumed to be related to the elastic modulus by Equation 26.

$$G = \frac{E}{2(1 + \mu)} \tag{26}$$

where μ = Poisson's ratio

Typical values of Poisson's ratio lead to the conclusion that shear modulus should be about 1/3 of the Kelvin elastic modulus.

In comparing the laboratory values of G with the field values inferred from the regression analysis, it appears that the San Antonio data, corrected for a differential movement of between 0.1 and 1.0 inches, will match the laboratory test data. On the other hand, the uncorrected Waco field data matches the lower end of the laboratory data very well. A comparison of these values is shown in Table 10.

Table 10. Comparison of Laboratory and Field Values of Kelvin Shear Modulus

City	Slope Angle	Field Values of G psi (kPa)	Lab Values psi (kPa)
San Antonio*	>5°	240 - 2360 (1630 - 16300)	300 - 670 (2070 - 4620)
Waco†	>5°	140 (970)	210 - 1130 (1450 - 7790)
Waco†	>10°	170 (1170)	210 - 1130 (1450 - 7790)

* Corrected for y_m between 0.1 and 1.0 inches (.25 and 2.5 cm)
† Uncorrected for differential movement.

The ratio of G/λ in both the laboratory and field data is around 1.0 x 10^4/year. The correspondence between the laboratory and field values of both G and λ is encouraging but must be viewed with circumspection because of the correction that must be made for differential swelling movements. On the surface of it, it appears that between 0.1 and 1.0 inches (0.25 and 2.5 cm) of differential movement are occurring in San Antonio and virtually no differential swelling is occurring in Waco. In fact, the absolute values of soil suction in the field in both San Antonio and Waco are probably higher than those used in the laboratory tests. This means that the actual field values of G and λ are probably higher than those measured in the lab and the amount of differential movement that actually occurs is larger than the 0.1 and 1.0 inch (0.25 to 2.5 cm) range used to correct the San Antonio data.

Another possible explanation can be given. The downhill creep may be occurring primarily in the cracks in the soil mass which remain at a lower suction level than the interior of the blocks and peds of the soil. The fact that the shear modulus inferred from the regression analysis corresponds to the lower levels of suction tends to confirm this interpretation.

Regardless of which interpretation is the correct one, this analysis shows that it is possible to use properties of the soil that can be measured in the laboratory to predict cracking damage due to downhill creep, differential movement, and the combination of the two. Although a number of simplifying assumptions have been made in developing this model of cracking damage, the results of such calculations may be expected to be realistic and perhaps on the conservative side.

Conclusions

Based upon the results of this study of laboratory and field data, it appears possible to predict downhill creep of expansive clay slopes and the consequent cracking damage to structures built on them. More precise analysis using layered viscoelastic continua is also possible, and even desirable from an analytical point of view. However, the advantage of the simple Kelvin model proposed here is that it makes possible routine design computations to determine the damage potential on a given site.

It is also apparent from these results that where slopes are greater than about 5 degrees above the horizontal, downhill creep becomes a probable damage mechanism. Laboratory-measured values of the Kelvin elastic modulus and viscosity can be used to predict downhill creep and damage.

Acknowledgements

The damage surveys and the development of the empirical damage equations was supported by National Science Foundation research contract No. ENG 75-09348. The analysis of downhill creep was supported by a U.S. Army Corps of Engineers Waterways Experiment Station research contract.

References

1. Dobson, B. Mark, "The Influence of Stratigraphy on the Behavior of Expansive Soils," Unpublished Masters Thesis, Texas A&M University, College Station, Texas, 1977.

2. Dyke, Lawrence D., "Mechanisms of Downhill Creep in Expansive Soils" Doctoral Dissertation, Texas A&M University, College Station, Texas, 1979.

3. Letto, Augustine R., "A Computer Program for Function Optimization Using Pattern Search and Gradient," Unpublished Master's Thesis, Texas A&M University, College Station, Texas 1968.

APPENDIX I

DAMAGE DATA USED IN THE ANALYSES

The following is an explanation of the codes used as column headings in the computerized data printout for San Antonio and Waco.

CODE	MEANING
ID	The house number
SA, WA	The city: San Antonio or Waco
#	The crack number. There may be several on one house.
AGE	The age of the house in years.
LEN	The length of the wall on which the cracks occurred. All walls used were aligned with the slope.
TOTAL WIDTH	The sum of the widths of the cracks on that wall, in mm.
TT	Top-tension cracking
BT	Bottom-tension cracking
CT	Center-tension cracking
MAX LENGTH	The maximum length of each crack type, in meters
SLOPE	The tangent of the slope angle

ID	#	AGE	LEN	TOTAL WIDTH TT	TOTAL WIDTH BT	TOTAL WIDTH CT	MAX. LENGTH TT	MAX. LENGTH BT	MAX. LENGTH CT	SLOPE
8/75/SA	1	4	37	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	4.Ø	Ø.Ø	Ø.Ø2Ø
8/75/SA	2	4	42	7.Ø	Ø.Ø	1.Ø	2.5	Ø.Ø	Ø.5	Ø.Ø2Ø
8/75/SA	3	4	3	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø2Ø
9/75/SA	1	4	55	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø5Ø
9/75/SA	2	4	42	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø5Ø
9/75/SA	3	4	2Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
1Ø/75/SA	1	4	25	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
1Ø/75/SA	2	4	28	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
1Ø/75/SA	3	4	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
1Ø/75/SA	4	4	39	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
1Ø/75/SA	5	4	37	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
11/75/SA	1	4	17	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
11/75/SA	2	4	32	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	3.Ø	Ø.Ø5Ø
11/75/SA	3	4	2Ø	2.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø5Ø
11/75/SA	4	4	47	Ø.Ø	Ø.Ø	1.5	Ø.Ø	Ø.Ø	1.5	Ø.Ø5Ø
11/75/SA	5	4	22	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø5Ø
12/75/SA	1	4	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
12/75/SA	2	4	34	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
12/75/SA	3	4	51	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
12/75/SA	4	4	19	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
14/75/SA	1	4	52	4.Ø	Ø.Ø	Ø.5	2.5	Ø.Ø	1.Ø	Ø.Ø4Ø
14/75/SA	2	4	17	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø4Ø
14/75/SA	3	4	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø4Ø
14/75/SA	4	4	47	Ø.5	Ø.Ø	Ø.Ø	Ø.2	Ø.Ø	Ø.Ø	Ø.Ø4Ø
15/75/SA	1	4	25	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø22
15/75/SA	2	4	33	1.Ø	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	Ø.Ø22
15/75/SA	3	4	55	1.Ø	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	Ø.Ø22
15/75/SA	4	4	11	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø22
16/75/SA	1	4	27	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø2Ø
16/75/SA	2	4	17	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.5	Ø.Ø2Ø
16/75/SA	3	4	52	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	1.5	Ø.Ø2Ø
3/76/SA	1	4	4Ø	2.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
3/76/SA	2	4	48	Ø.Ø	Ø.Ø	3.Ø	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø33
3/76/SA	3	4	1Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
9/76/SA	1	1	2Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
9/76/SA	2	1	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
9/76/SA	3	1	63	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	1.5	Ø.Ø5Ø
8/76/SA	1	4	1Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø8Ø
8/76/SA	2	4	63	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	1.5	Ø.Ø8Ø
8/76/SA	3	4	41	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø8Ø
8/76/SA	4	4	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø8Ø
11/76/SA	1	4	9	5.Ø	2.Ø	Ø.Ø	1.Ø	2.5	Ø.Ø	Ø.Ø25
11/76/SA	2	4	38	5.Ø	Ø.Ø	Ø.Ø	3.5	Ø.Ø	Ø.Ø	Ø.Ø25
11/76/SA	3	4	12	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø25
11/76/SA	4	4	48	1.Ø	6.Ø	Ø.Ø	1.5	1.5	Ø.Ø	Ø.Ø25
11/76/SA	5	4	23	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø25
12/76/SA	1	4	35	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	2.5	Ø.Ø25
12/76/SA	2	4	19	Ø.Ø	Ø.Ø	1.5	Ø.Ø	Ø.Ø	2.5	Ø.Ø25
12/76/SA	3	4	2Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø25
12/76/SA	4	4	2Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø25

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
12/76/SA	5	4	55	8.0	0.0	2.0	1.5	0.0	2.5	0.025
9/78/SA	1	4	75	6.0	0.0	1.5	2.5	0.0	2.5	0.044
9/78/SA	2	4	25	0.0	0.5	0.5	0.0	1.0	0.5	0.044
9/78/SA	3	4	18	1.0	0.0	0.5	1.0	0.0	1.0	0.044
9/78/SA	4	4	33	1.5	0.0	0.0	2.0	0.0	0.0	0.044
10/78/SA	1	4	23	5.0	0.0	1.5	2.5	0.0	2.5	0.050
10/78/SA	2	4	27	0.0	0.0	0.5	0.0	0.0	0.5	0.050
10/78/SA	3	4	20	1.5	0.0	0.0	0.5	0.0	0.0	0.050
10/78/SA	4	4	70	9.0	0.0	3.5	2.5	0.0	2.5	0.050
11/78/SA	1	4	23	0.0	0.0	0.0	0.0	0.0	0.0	0.067
11/78/SA	2	4	27	0.0	0.0	0.5	0.0	0.0	1.5	0.067
11/78/SA	3	4	25	0.0	0.5	0.0	0.0	0.5	0.0	0.067
11/78/SA	4	4	25	0.5	0.0	0.5	0.5	0.0	2.5	0.067
11/78/SA	5	4	55	0.0	0.0	0.5	0.0	0.0	1.0	0.067
12/78/SA	1	3	54	0.0	0.0	1.0	0.0	0.0	1.0	0.033
12/78/SA	2	3	20	0.5	0.0	0.0	0.5	0.0	0.0	0.033
12/78/SA	3	3	18	0.0	0.0	0.0	0.0	0.0	0.0	0.033
12/78/SA	4	3	57	4.0	0.0	0.0	2.5	0.0	0.0	0.033
6/79/SA	1	4	56	0.0	0.0	2.5	0.0	0.0	1.5	0.033
6/79/SA	2	4	40	0.0	0.0	1.0	0.0	0.0	1.5	0.033
6/79/SA	3	4	22	0.5	0.0	0.5	0.5	0.0	1.0	0.033
7/79/SA	1	4	25	0.5	0.0	0.0	1.0	0.0	0.0	0.025
7/79/SA	2	4	28	4.5	0.0	0.0	1.5	0.0	0.0	0.025
7/79/SA	3	4	20	0.0	0.0	0.0	0.0	0.0	0.0	0.025
7/79/SA	4	4	73	12.0	0.0	3.0	2.5	0.0	2.5	0.025
8/79/SA	1	4	27	1.5	0.0	0.0	2.5	0.0	0.0	0.067
8/79/SA	2	4	50	0.5	0.0	0.0	1.0	0.0	0.0	0.067
8/79/SA	3	4	54	0.5	0.0	0.0	0.5	0.0	0.0	0.067
8/79/SA	4	4	22	0.5	0.0	0.0	0.5	0.0	0.0	0.067
9/79/SA	1	4	20	0.0	0.0	0.5	0.0	0.0	1.0	0.050
9/79/SA	2	4	17	0.0	0.0	0.0	0.0	0.0	0.0	0.050
9/79/SA	3	4	12	0.0	0.0	1.0	0.0	0.0	1.0	0.050
9/79/SA	4	4	20	0.0	0.0	0.0	0.0	0.0	0.0	0.050
9/79/SA	5	4	51	0.5	0.5	2.0	0.5	0.5	2.5	0.050
9/79/SA	6	4	19	0.0	0.5	0.0	0.0	2.0	0.0	0.050
10/79/SA	1	4	28	0.0	0.5	10.5	0.0	0.5	1.5	0.100
10/79/SA	2	4	34	0.0	1.5	0.0	0.0	2.0	0.0	0.100
10/79/SA	3	4	43	0.0	0.0	0.0	0.0	0.0	0.0	0.100
10/79/SA	4	4	56	10.0	0.0	0.5	2.5	0.0	0.5	0.100
11/79/SA	1	4	7	0.0	0.0	0.5	0.0	0.0	0.5	0.050
11/79/SA	2	4	38	0.0	0.5	0.0	0.0	3.5	0.0	0.050
11/79/SA	3	4	46	0.0	1.5	0.0	0.0	2.5	0.0	0.050
12/79/SA	1	3	23	0.0	0.0	0.0	0.0	0.0	0.0	0.100
12/79/SA	2	3	39	0.0	0.0	0.5	0.0	0.0	1.5	0.100
12/79/SA	3	3	55	1.0	0.0	0.5	1.0	0.0	1.5	0.100
13/79/SA	1	3	40	0.0	0.0	0.0	0.0	0.0	0.0	0.100
13/79/SA	2	3	33	0.0	0.0	0.0	0.0	0.0	0.0	0.100
13/79/SA	3	3	16	0.0	0.0	0.0	0.0	0.0	0.0	0.100
14/79/SA	1	2	16	0.0	0.0	0.5	0.0	0.0	0.5	0.100
14/79/SA	2	2	34	0.0	0.5	0.0	0.0	1.0	0.0	0.100

ID	#	AGE	LEN	TOTAL WIDTH			MAX. LENGTH			SLOPE
				TT	BT	CT	TT	BT	CT	
14/79/SA	3	2	47	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ
15/79/SA	1	2	56	12.Ø	1.Ø	Ø.Ø	2.Ø	2.Ø	Ø.Ø	Ø.Ø67
15/79/SA	2	2	42	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
15/79/SA	3	2	17	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
16/79/SA	1	3	31	1.Ø	Ø.5	Ø.Ø	Ø.5	Ø.5	Ø.Ø	Ø.Ø67
16/79/SA	2	3	21	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
16/79/SA	3	3	41	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
16/79/SA	4	3	52	Ø.Ø	Ø.5	3.Ø	Ø.Ø	Ø.5	1.Ø	Ø.Ø67
25/21/SA	1	13	59	2.Ø	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	Ø.Ø27
25/21/SA	2	13	45	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø27
25/21/SA	3	13	32	Ø.5	Ø.Ø	Ø.Ø	1.5	Ø.Ø	Ø.Ø	Ø.Ø27
26/21/SA	1	12	53	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø16
26/21/SA	2	12	19	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø16
26/21/SA	3	12	53	Ø.Ø	Ø.Ø	5.5	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø16
26/21/SA	4	12	19	Ø.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	Ø.Ø16
27/21/SA	1	13	75	Ø.Ø	7.Ø	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø2Ø
27/21/SA	2	13	75	Ø.Ø	Ø.5	1.Ø	Ø.Ø	2.5	2.5	Ø.Ø2Ø
28/21/SA	1	12	72	1.Ø	Ø.Ø	1.5	2.4	Ø.Ø	2.5	Ø.Ø2Ø
28/21/SA	2	12	72	Ø.5	Ø.5	Ø.5	1.Ø	1.5	2.5	Ø.Ø2Ø
29/21/SA	1	12	37	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	3.Ø	Ø.Ø2Ø
29/21/SA	2	12	17	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø2Ø
29/21/SA	3	12	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø2Ø
29/21/SA	4	12	22	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø2Ø
29/21/SA	5	12	25	2.Ø	Ø.Ø	Ø.Ø	1.5	Ø.Ø	Ø.Ø	Ø.Ø2Ø
29/21/SA	6	12	3Ø	Ø.5	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	Ø.Ø2Ø
3Ø/21/SA	1	12	75	2.5	Ø.Ø	2.5	2.Ø	Ø.Ø	2.5	Ø.Ø2Ø
3Ø/21/SA	2	12	26	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø2Ø
3Ø/21/SA	3	12	49	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø2Ø
31/21/SA	1	12	58	1.Ø	Ø.Ø	Ø.Ø	1.5	Ø.Ø	Ø.Ø	Ø.Ø16
31/21/SA	2	12	58	Ø.5	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	Ø.Ø16
2/22/SA	1	12	68	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	1.Ø	Ø.ØØ5
2/22/SA	2	12	36	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.ØØ5
2/22/SA	3	12	32	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.Ø	Ø.ØØ5
3/22/SA	1	13	72	15.Ø	Ø.Ø	1.Ø	2.5	Ø.Ø	1.Ø	Ø.Ø4Ø
3/22/SA	2	13	72	2.Ø	Ø.Ø	1.5	1.5	Ø.Ø	1.5	Ø.Ø4Ø
4/22/SA	1	12	44	2.Ø	Ø.5	Ø.Ø	Ø.5	Ø.5	Ø.Ø	Ø.Ø4Ø
4/22/SA	2	12	21	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø4Ø
4/22/SA	3	12	65	11.5	Ø.Ø	Ø.5	2.Ø	Ø.Ø	1.5	Ø.Ø4Ø
6/22/SA	1	12	48	5.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	Ø.Ø27
6/22/SA	2	12	18	2.Ø	Ø.Ø	Ø.5	1.Ø	Ø.Ø	2.Ø	Ø.Ø27
6/22/SA	3	12	29	3.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	Ø.Ø27
7/22/SA	1	13	38	2.Ø	Ø.5	1.Ø	1.Ø	Ø.5	2.Ø	Ø.Ø4Ø
7/22/SA	2	13	38	Ø.5	Ø.Ø	5.5	2.Ø	Ø.Ø	2.Ø	Ø.Ø4Ø
8/22/SA	1	12	43	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø4Ø
8/22/SA	2	12	47	1.5	4.Ø	Ø.Ø	1.Ø	2.Ø	Ø.Ø	Ø.Ø4Ø
1/23/SA	1	11	59	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø16
1/23/SA	2	11	16	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø16
1/23/SA	3	11	23	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø16
1/23/SA	4	11	52	3.Ø	Ø.Ø	Ø.Ø	1.5	Ø.Ø	Ø.Ø	Ø.Ø16
2/23/SA	1	12	42	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	2.5	Ø.Ø	Ø.Ø13

ID	#	AGE	LEN	TOTAL WIDTH TT	TOTAL WIDTH BT	TOTAL WIDTH CT	MAX. LENGTH TT	MAX. LENGTH BT	MAX. LENGTH CT	SLOPE
2/23/SA	2	12	42	0.0	0.0	1.5	0.0	0.0	2.5	0.013
3/23/SA	1	13	22	0.0	0.0	1.5	0.0	0.0	2.5	0.027
3/23/SA	2	13	20	0.0	0.0	4.0	0.0	0.0	2.5	0.027
3/23/SA	3	13	21	1.0	0.0	0.0	1.0	0.0	0.0	0.027
3/23/SA	4	13	29	2.0	0.0	0.5	1.5	0.0	1.5	0.027
4/23/SA	1	12	31	3.0	1.0	0.0	3.5	1.5	0.0	0.020
4/23/SA	2	12	31	1.5	0.0	0.0	0.5	0.0	0.0	0.020
5/23/SA	1	13	13	0.0	0.0	0.0	0.0	0.0	0.0	0.053
5/23/SA	2	13	29	0.0	2.0	0.0	0.0	2.5	0.0	0.053
5/23/SA	3	13	42	5.0	0.0	0.0	2.0	0.0	0.0	0.053
16/23/SA	1	9	15	0.0	1.0	0.0	0.0	0.5	0.0	0.030
16/23/SA	2	9	15	0.0	0.0	0.0	0.0	0.0	0.0	0.030
16/23/SA	3	9	44	0.0	0.0	0.5	0.0	0.0	0.5	0.030
16/23/SA	4	9	32	0.0	0.5	0.0	0.0	1.0	0.0	0.030
16/23/SA	5	9	42	0.0	0.0	0.0	0.0	0.0	0.0	0.030
18/23/SA	1	5	23	0.0	0.0	0.0	0.0	0.0	0.0	0.020
18/23/SA	2	5	52	0.0	0.0	0.0	0.0	0.0	0.0	0.020
18/23/SA	3	5	20	0.0	0.0	0.0	0.0	0.0	0.0	0.020
18/23/SA	4	5	29	0.0	0.0	0.0	0.0	0.0	0.0	0.020
18/23/SA	5	5	26	0.0	0.0	0.0	0.0	0.0	0.0	0.020
19/23/SA	1	7	34	0.0	0.0	0.0	0.0	0.0	0.0	0.050
19/23/SA	2	7	29	0.0	0.5	0.0	0.0	2.0	0.0	0.050
19/23/SA	3	7	55	0.5	0.0	0.5	1.5	0.0	1.5	0.050
21/23/SA	1	5	24	1.5	0.0	0.0	1.0	0.0	0.0	0.050
21/23/SA	2	5	50	0.5	0.0	0.0	0.5	0.0	0.0	0.050
21/23/SA	3	5	22	0.0	0.0	0.0	0.0	0.0	0.0	0.050
21/23/SA	4	5	12	0.0	0.0	0.0	0.0	0.0	0.0	0.050
21/23/SA	5	5	22	0.0	0.0	0.0	0.0	0.0	0.0	0.050
21/23/SA	6	5	19	0.0	0.0	0.0	0.0	0.0	0.0	0.050
22/23/SA	1	5	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
22/23/SA	2	5	25	0.0	1.0	0.0	0.0	2.0	0.0	0.050
22/23/SA	3	5	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
22/23/SA	4	5	20	0.0	0.0	0.0	0.0	0.0	0.0	0.050
22/23/SA	5	5	47	1.5	0.5	0.5	2.3	1.5	1.5	0.050
23/23/SA	1	5	20	0.0	0.0	0.0	0.0	0.0	0.0	0.030
23/23/SA	2	5	23	0.0	0.0	0.0	0.0	0.0	0.0	0.030
23/23/SA	3	5	50	0.5	0.0	0.5	0.5	0.0	1.5	0.030
35/23/SA	1	9	74	2.5	0.0	0.0	2.5	0.0	0.0	0.060
35/23/SA	2	9	22	0.5	0.0	0.0	1.5	0.0	0.0	0.060
35/23/SA	3	9	19	0.0	0.0	0.0	0.0	0.0	0.0	0.060
35/23/SA	4	9	32	3.0	0.5	0.0	2.0	1.0	0.0	0.060
36/23/SA	1	9	64	0.5	0.0	0.0	1.0	0.0	0.0	0.070
36/23/SA	2	9	23	0.0	2.0	0.0	0.0	1.0	0.0	0.070
36/23/SA	3	9	45	0.0	0.0	0.0	0.0	0.0	0.0	0.070
37/23/SA	1	10	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
37/23/SA	2	10	36	0.0	0.0	0.0	0.0	0.0	0.0	0.050
37/23/SA	3	10	17	0.0	0.0	0.0	0.0	0.0	0.0	0.050
37/23/SA	4	10	24	0.0	0.0	0.0	0.0	0.0	0.0	0.050
37/23/SA	5	10	50	0.0	0.0	1.0	0.0	0.0	2.5	0.050
39/23/SA	1	11	21	0.0	0.0	0.0	0.0	0.0	0.0	0.040

ID	#	AGE	LEN	TOTAL WIDTH TT	TOTAL WIDTH BT	TOTAL WIDTH CT	MAX. LENGTH TT	MAX. LENGTH BT	MAX. LENGTH CT	SLOPE
39/23/SA	2	11	29	0.0	0.0	0.0	0.0	0.0	0.0	0.040
39/23/SA	3	11	36	0.0	0.0	0.0	0.0	0.0	0.0	0.040
39/23/SA	4	11	86	0.0	0.0	0.0	0.0	0.0	0.0	0.040
40/23/SA	1	12	19	0.0	0.0	0.0	0.0	0.0	0.0	0.040
40/23/SA	2	12	52	0.0	0.0	0.0	0.0	0.0	0.0	0.040
40/23/SA	3	12	20	0.0	0.0	0.5	0.0	0.0	2.5	0.040
40/23/SA	4	12	12	0.0	0.0	0.5	0.0	0.0	2.5	0.040
40/23/SA	5	12	21	0.0	0.0	0.5	0.0	0.0	1.0	0.040
40/23/SA	6	12	20	0.0	0.0	0.0	0.0	0.0	0.0	0.040
41/23/SA	1	10	18	0.0	0.0	0.0	0.0	0.0	0.0	0.040
41/23/SA	2	10	44	0.0	0.0	0.0	0.0	0.0	0.0	0.040
41/23/SA	3	10	28	0.0	0.0	0.0	0.0	0.0	0.0	0.040
41/23/SA	4	10	13	0.0	0.0	0.0	0.0	0.0	0.0	0.040
41/23/SA	5	10	10	0.0	0.0	0.0	0.0	0.0	0.0	0.040
41/23/SA	6	10	21	0.0	0.0	0.0	0.0	0.0	0.0	0.040
42/23/SA	1	10	26	0.0	0.0	0.0	0.0	0.0	0.0	0.050
42/23/SA	2	10	50	3.0	0.5	0.0	2.5	0.5	0.0	0.050
42/23/SA	3	10	45	0.0	0.0	2.0	0.0	0.0	2.5	0.050
42/23/SA	4	10	27	1.0	2.0	0.0	2.0	1.0	0.0	0.050
34/23/SA	1	9	73	1.0	0.5	0.0	1.0	0.5	0.0	0.050
34/23/SA	2	9	41	0.5	0.0	0.0	0.5	0.0	0.0	0.050
34/23/SA	3	9	32	0.0	0.0	0.0	0.0	0.0	0.0	0.050
44/23/SA	1	12	23	0.0	0.0	0.0	0.0	0.0	0.0	0.050
44/23/SA	2	12	52	0.0	0.5	0.0	0.0	1.5	0.0	0.050
44/23/SA	3	12	75	2.0	0.5	1.5	2.5	1.5	2.5	0.050
45/23/SA	1	11	20	0.0	0.0	0.0	0.0	0.0	0.0	0.050
45/23/SA	2	11	19	0.0	0.0	0.0	0.0	0.0	0.0	0.050
45/23/SA	3	11	38	2.0	0.0	1.0	1.5	0.0	1.0	0.050
45/23/SA	4	11	30	0.0	0.0	0.0	0.0	0.0	0.0	0.050
45/23/SA	5	11	25	0.0	0.0	0.0	0.0	0.0	0.0	0.050
45/23/SA	6	11	22	0.5	0.0	0.5	1.5	0.0	0.5	0.050
46/23/SA	1	11	52	0.0	0.0	0.0	0.0	0.0	0.0	0.060
46/23/SA	2	11	16	0.0	0.0	0.0	0.0	0.0	0.0	0.060
46/23/SA	3	11	20	0.0	0.0	0.0	0.0	0.0	0.0	0.060
46/23/SA	4	11	30	0.0	0.0	0.0	0.0	0.0	0.0	0.060
47/23/SA	1	12	82	0.0	0.0	3.0	0.0	0.0	1.0	0.050
47/23/SA	2	12	49	0.0	0.5	1.0	0.0	2.0	2.5	0.050
47/23/SA	3	12	33	0.0	0.0	0.0	0.0	0.0	0.0	0.050
48/23/SA	1	8	20	0.0	0.0	0.0	0.0	0.0	0.0	0.050
48/23/SA	2	8	34	0.0	0.0	0.0	0.0	0.0	0.0	0.050
48/23/SA	3	8	67	0.5	0.0	0.0	1.0	0.0	0.0	0.050
48/23/SA	4	8	29	0.0	0.0	0.5	0.0	0.0	2.0	0.050
48/23/SA	5	8	23	1.5	0.0	0.0	2.5	0.0	0.0	0.050
54/23/SA	1	12	17	0.0	0.0	0.0	0.0	0.0	0.0	0.030
54/23/SA	2	12	51	0.0	0.0	1.0	0.0	0.0	2.5	0.030
54/23/SA	3	12	44	0.0	0.0	0.0	0.0	0.0	0.0	0.030
54/23/SA	4	12	23	0.0	0.0	1.0	0.0	0.0	1.5	0.030
55/23/SA	1	12	23	0.0	0.0	0.0	0.0	0.0	0.0	0.030
55/23/SA	2	12	41	0.0	0.0	0.0	0.0	0.0	0.0	0.030
55/23/SA	3	12	65	0.0	0.0	0.0	0.0	0.0	0.0	0.030

ID	#	AGE	LEN	TOTAL WIDTH TT	TOTAL WIDTH BT	TOTAL WIDTH CT	MAX. LENGTH TT	MAX. LENGTH BT	MAX. LENGTH CT	SLOPE
56/23/SA	1	12	20	0.0	0.0	0.0	0.0	0.0	0.0	0.030
56/23/SA	2	12	54	2.0	0.5	0.0	2.5	1.0	0.0	0.030
56/23/SA	3	12	49	3.0	0.0	0.5	1.5	0.0	2.5	0.030
56/23/SA	4	12	26	0.0	4.0	0.5	0.0	2.0	1.5	0.030
57/23/SA	1	6	38	0.0	0.0	0.0	0.0	0.0	0.0	0.020
57/23/SA	2	6	16	0.0	0.0	0.0	0.0	0.0	0.0	0.020
57/23/SA	3	6	21	0.0	0.0	0.0	0.0	0.0	0.0	0.020
57/23/SA	4	6	21	2.0	0.0	0.0	1.0	0.0	0.0	0.020
57/23/SA	5	6	25	0.0	0.0	0.0	0.0	0.0	0.0	0.020
57/23/SA	6	6	30	0.0	2.0	0.0	0.0	1.0	0.0	0.020
58/23/SA	1	10	25	0.0	0.5	0.0	0.0	0.5	0.0	0.040
58/23/SA	2	10	28	0.0	0.0	0.0	0.0	0.0	0.0	0.040
58/23/SA	3	10	13	0.0	0.0	0.0	0.0	0.0	0.0	0.040
58/23/SA	4	10	30	0.5	0.0	0.5	0.5	0.0	2.5	0.040
58/23/SA	5	10	35	0.0	0.0	0.0	0.0	0.0	0.0	0.040
9/29/SA	1	10	31	0.0	0.0	1.0	0.0	0.0	1.0	0.020
9/29/SA	2	10	50	1.0	0.0	0.0	1.5	0.0	0.0	0.020
9/29/SA	3	10	52	0.0	0.0	0.5	0.0	0.0	0.5	0.020
9/29/SA	4	10	28	0.0	0.0	0.5	0.0	0.0	1.0	0.020
10/29/SA	1	11	76	0.0	0.0	0.0	0.0	0.0	0.0	0.023
10/29/SA	2	11	52	0.0	0.0	0.5	0.0	0.0	2.5	0.023
10/29/SA	3	11	23	0.0	0.0	0.0	0.0	0.0	0.0	0.023
11/29/SA	1	11	56	0.0	0.0	0.0	0.0	0.0	0.0	0.023
11/29/SA	2	11	21	0.5	0.0	0.0	0.5	0.0	0.0	0.023
11/29/SA	3	11	50	0.0	0.0	0.0	0.0	0.0	0.0	0.023
12/29/SA	1	11	60	0.5	0.0	0.0	0.5	0.0	0.0	0.020
12/29/SA	2	11	60	0.0	0.0	1.5	0.0	0.0	2.5	0.020
13/29/SA	1	12	73	2.5	0.0	2.5	2.5	0.0	2.5	0.016
13/29/SA	2	12	41	0.0	0.0	0.0	0.0	0.0	0.0	0.016
13/29/SA	3	12	21	0.0	0.0	0.0	0.0	0.0	0.0	0.016
13/29/SA	4	12	12	0.0	0.0	0.0	0.0	0.0	0.0	0.016
1/66/SA	1	5	23	0.0	0.0	0.5	0.0	0.0	0.5	0.050
1/66/SA	2	5	26	0.0	0.0	0.0	0.0	0.0	0.0	0.050
1/66/SA	3	5	22	0.0	0.0	0.5	0.0	0.0	0.5	0.050
1/66/SA	4	5	70	0.0	0.0	0.0	0.0	0.0	0.0	0.050
2/66/SA	1	3	24	0.0	0.0	0.0	0.0	0.0	0.0	0.050
2/66/SA	2	3	30	0.0	0.0	0.0	0.0	0.0	0.0	0.050
2/66/SA	3	3	23	0.0	0.0	0.0	0.0	0.0	0.0	0.050
2/66/SA	4	3	37	0.0	0.0	0.5	0.0	0.0	0.5	0.050
2/66/SA	5	3	23	0.0	0.0	0.0	0.0	0.0	0.0	0.050
3/66/SA	1	4	73	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/66/SA	2	4	32	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/66/SA	3	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/66/SA	4	4	20	0.0	0.0	0.0	0.0	0.0	0.0	0.067
4/66/SA	1	2	21	0.0	0.0	0.0	0.0	0.0	0.0	0.067
4/66/SA	2	2	15	0.0	0.0	0.0	0.0	0.0	0.0	0.067
4/66/SA	3	2	24	0.0	0.0	0.0	0.0	0.0	0.0	0.067
4/66/SA	4	2	60	0.0	0.0	0.0	0.0	0.0	0.0	0.067
7/66/SA	1	4	26	0.0	0.0	0.5	0.0	0.0	0.5	0.040
7/66/SA	2	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.040

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
7/66/SA	3	4	33	0.0	0.0	0.0	0.0	0.0	0.0	0.040
9/66/SA	1	5	58	0.0	0.0	0.0	0.0	0.0	0.0	0.040
9/66/SA	2	5	36	0.0	0.0	0.5	0.0	0.0	0.5	0.040
9/66/SA	3	5	22	0.0	0.0	0.0	0.0	0.0	0.0	0.040
11/66/SA	1	4	50	0.0	0.0	0.0	0.0	0.0	0.0	0.033
11/66/SA	2	4	22	0.0	0.0	0.0	0.0	0.0	0.0	0.033
11/66/SA	3	4	23	0.0	0.0	0.0	0.0	0.0	0.0	0.033
11/66/SA	4	4	18	0.0	0.0	0.0	0.0	0.0	0.0	0.033
11/66/SA	5	4	31	0.0	0.0	0.0	0.0	0.0	0.0	0.033
12/66/SA	1	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.067
12/66/SA	2	4	31	0.0	0.0	0.5	0.0	0.0	2.0	0.067
12/66/SA	3	4	17	0.5	0.0	0.0	1.0	0.0	0.0	0.067
12/66/SA	4	4	19	0.0	0.0	0.5	0.0	0.0	2.5	0.067
12/66/SA	5	4	56	0.0	0.0	1.0	0.0	0.0	1.0	0.067
13/66/SA	1	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
13/66/SA	2	4	33	0.0	0.0	1.0	0.0	0.0	2.5	0.050
13/66/SA	3	4	16	0.0	0.0	0.0	0.0	0.0	0.0	0.050
13/66/SA	4	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
13/66/SA	5	4	28	0.0	0.0	0.0	0.0	0.0	0.0	0.050
13/66/SA	6	4	22	0.0	0.0	0.0	0.0	0.0	0.0	0.050
14/66/SA	1	4	30	0.0	0.0	0.0	0.0	0.0	0.0	0.040
14/66/SA	2	4	32	0.0	0.0	0.0	0.0	0.0	0.0	0.040
14/66/SA	3	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.040
14/66/SA	4	4	24	0.0	0.0	0.5	0.0	0.0	1.0	0.040
14/66/SA	5	4	32	0.0	0.0	1.0	0.0	0.0	2.5	0.040
1/67/SA	1	3	15	0.0	0.0	0.5	0.0	0.0	0.5	0.067
1/67/SA	2	3	34	2.0	0.0	0.0	1.0	0.0	0.0	0.067
1/67/SA	3	3	15	0.0	0.0	0.5	0.0	0.0	3.0	0.067
1/67/SA	4	3	23	0.0	2.0	0.0	0.0	1.5	0.0	0.067
1/67/SA	5	3	54	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/67/SA	1	3	14	0.0	0.0	0.0	0.0	0.0	0.0	0.100
3/67/SA	2	3	33	0.0	0.0	0.0	0.0	0.0	0.0	0.100
3/67/SA	3	3	33	0.5	0.5	0.0	1.5	1.5	0.0	0.100
3/67/SA	4	3	81	0.0	0.0	1.0	0.0	0.0	1.5	0.100
5/67/SA	1	3	25	0.0	0.0	0.0	0.0	0.0	0.0	0.067
5/67/SA	2	3	37	0.0	0.0	0.0	0.0	0.0	0.0	0.067
5/67/SA	3	3	57	3.0	0.0	0.0	1.0	0.0	0.0	0.067
5/67/SA	4	3	20	0.0	0.0	0.0	0.0	0.0	0.0	0.067
6/67/SA	1	3	80	0.0	0.0	0.5	0.0	0.0	1.0	0.067
6/67/SA	2	3	80	0.0	0.0	4.0	0.0	0.0	1.0	0.067
7/67/SA	1	3	59	0.5	0.0	0.5	0.5	0.0	0.5	0.040
7/67/SA	2	3	58	0.5	0.0	0.0	1.0	0.0	0.0	0.040
9/67/SA	1	4	50	0.0	0.0	0.0	0.0	0.0	0.0	0.050
9/67/SA	2	4	50	0.0	0.0	0.0	0.0	0.0	0.0	0.050
13/67/SA	1	3	48	0.0	0.0	2.0	0.0	0.0	3.5	0.067
13/67/SA	2	3	12	0.0	0.0	0.0	0.0	0.0	0.0	0.067
13/67/SA	3	3	25	0.5	0.0	0.0	0.5	0.0	0.0	0.067
13/67/SA	4	3	25	0.0	0.0	0.0	0.0	0.0	0.0	0.067
13/67/SA	5	3	17	0.0	0.0	0.0	0.0	0.0	0.0	0.067
13/67/SA	6	3	43	0.0	0.0	0.0	0.0	0.0	0.0	0.067

ID	#	AGE	LEN	TOTAL WIDTH TT	TOTAL WIDTH BT	TOTAL WIDTH CT	MAX. LENGTH TT	MAX. LENGTH BT	MAX. LENGTH CT	SLOPE
15/67/SA	1	4	19	0.0	0.0	0.0	0.0	0.0	0.0	0.067
15/67/SA	2	4	55	0.0	0.0	0.0	0.0	0.0	0.0	0.067
15/67/SA	3	4	19	0.0	0.0	0.0	0.0	0.0	0.0	0.067
15/67/SA	4	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.067
15/67/SA	5	4	25	0.0	0.0	0.5	0.0	0.0	1.5	0.067
16/67/SA	1	5	23	0.0	0.5	0.5	0.0	2.0	0.5	0.100
16/67/SA	2	5	19	0.0	0.0	0.0	0.0	0.0	0.0	0.100
16/67/SA	3	5	26	0.5	0.0	0.0	2.0	0.0	0.0	0.100
16/67/SA	4	5	16	0.0	0.0	1.5	0.0	0.0	1.5	0.100
16/67/SA	5	5	52	0.5	0.0	1.0	1.0	0.0	2.5	0.100
17/67/SA	1	4	22	0.0	0.0	0.0	0.0	0.0	0.0	0.100
17/67/SA	2	4	29	0.0	0.0	0.0	0.0	0.0	0.0	0.100
17/67/SA	3	4	24	0.0	0.0	0.0	0.0	0.0	0.0	0.100
17/67/SA	4	4	24	0.0	0.0	0.0	0.0	0.0	0.0	0.100
17/67/SA	5	4	10	0.0	0.0	0.5	0.0	0.0	2.0	0.100
17/67/SA	6	4	37	0.0	0.0	0.5	0.0	0.0	2.0	0.100
1/68/SA	1	4	48	0.0	0.0	0.0	0.0	0.0	0.0	0.100
1/68/SA	2	4	30	2.0	0.0	0.0	2.0	0.0	0.0	0.100
1/68/SA	3	4	18	0.0	0.0	0.0	0.0	0.0	0.0	0.100
2/68/SA	1	3	55	0.0	0.0	1.5	0.0	0.0	1.5	0.067
2/68/SA	2	3	25	0.0	0.0	0.0	0.0	0.0	0.0	0.067
2/68/SA	3	3	19	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/68/SA	1	3	53	0.5	0.0	0.0	2.0	0.0	0.0	0.067
3/68/SA	2	3	26	0.5	0.0	0.0	2.0	0.0	0.0	0.067
3/68/SA	3	3	29	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/68/SA	4	3	24	0.0	0.0	0.0	0.0	0.0	0.0	0.067
3/68/SA	5	3	32	0.5	0.0	0.0	2.0	0.0	0.0	0.067
5/74/SA	1	4	6	0.0	0.0	0.5	0.0	0.0	1.5	0.025
5/74/SA	2	4	51	4.0	0.0	0.0	2.0	0.0	0.0	0.025
5/74/SA	3	4	38	0.0	0.0	0.0	0.0	0.0	0.0	0.025
5/74/SA	4	4	15	0.0	5.0	0.0	0.0	10.0	0.0	0.025
6/74/SA	1	4	8	0.0	0.0	0.5	0.0	0.0	1.0	0.025
6/74/SA	2	4	56	5.0	0.0	0.0	2.0	0.0	0.0	0.025
6/74/SA	3	4	36	0.0	0.0	0.5	0.0	0.0	2.0	0.025
6/74/SA	4	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.025
7/74/SA	1	4	7	0.0	0.0	0.5	0.0	0.0	1.0	0.050
7/74/SA	2	4	48	0.0	0.0	0.0	0.0	0.0	0.0	0.050
7/74/SA	3	4	57	1.0	0.0	0.5	2.0	0.0	2.0	0.050
7/74/SA	4	4	12	0.0	0.0	0.0	0.0	0.0	0.0	0.050

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
1 WA	1	2	73	0.0	0.0	0.0	0.0	0.0	0.0	0.010
1 WA	2	2	73	0.0	0.0	0.0	0.0	0.0	0.0	0.010
2 WA	1	5	54	0.0	2.0	1.0	0.0	2.0	2.0	0.017
2 WA	2	5	35	0.0	0.0	0.0	0.0	0.0	0.0	0.017
2 WA	3	5	22	0.0	0.0	0.0	0.0	0.0	0.0	0.017
3 WA	1	4	19	0.0	0.0	0.0	0.0	0.0	0.0	0.009
3 WA	2	4	21	0.0	0.0	0.0	0.0	0.0	0.0	0.009
3 WA	3	4	24	0.0	0.0	0.0	0.0	0.0	0.0	0.009
3 WA	4	4	19	0.0	0.0	0.0	0.0	0.0	0.0	0.009
4 WA	1	7	54	0.0	0.0	0.5	0.0	0.0	1.0	0.033
4 WA	2	7	32	0.0	0.0	0.5	0.0	0.0	1.0	0.033
4 WA	3	7	21	0.0	0.0	0.0	0.0	0.0	0.0	0.033
5 WA	1	6	54	0.0	0.0	1.0	0.0	0.0	1.5	0.033
5 WA	2	6	17	0.0	0.0	0.0	0.0	0.0	0.0	0.033
5 WA	3	6	15	0.0	0.0	0.0	0.0	0.0	0.0	0.033
5 WA	4	6	22	0.0	0.0	0.0	0.0	0.0	0.0	0.033
6 WA	1	5	52	0.0	0.0	0.0	0.0	0.0	0.0	0.025
6 WA	2	5	24	0.0	0.0	0.0	0.0	0.0	0.0	0.025
6 WA	3	5	29	0.0	0.0	0.0	0.0	0.0	0.0	0.025
7 WA	1	10	71	0.0	0.0	1.0	0.0	0.0	2.0	0.050
7 WA	2	10	49	0.0	0.0	0.0	0.0	0.0	0.0	0.050
7 WA	3	10	23	2.0	0.0	0.0	2.0	0.0	0.0	0.050
8 WA	1	7	71	0.0	0.0	0.5	0.0	0.0	1.5	0.022
8 WA	2	7	48	0.0	0.0	0.0	0.0	0.0	0.0	0.022
8 WA	3	7	23	0.0	0.0	0.0	0.0	0.0	0.0	0.022
9 WA	1	17	40	0.0	0.0	0.5	0.0	0.0	2.0	0.067
9 WA	2	17	29	0.0	0.0	0.0	0.0	0.0	0.0	0.067
9 WA	3	17	11	0.0	0.0	0.0	0.0	0.0	0.0	0.067
10 WA	1	8	29	0.0	0.0	0.0	0.0	0.0	0.0	0.050
10 WA	2	8	45	0.0	0.0	0.0	0.0	0.0	0.0	0.050
10 WA	3	8	74	2.0	0.0	2.5	2.0	0.0	2.5	0.050
11 WA	1	7	55	0.0	0.0	0.0	0.0	0.0	0.0	0.033
11 WA	2	7	22	0.0	0.0	0.0	0.0	0.0	0.0	0.033
11 WA	3	7	33	0.0	0.0	0.0	0.0	0.0	0.0	0.033
12 WA	1	6	71	0.5	0.5	1.0	2.0	2.0	1.5	0.050
12 WA	2	6	39	1.0	0.0	0.0	1.0	0.0	0.0	0.050
12 WA	3	6	32	0.5	1.0	0.5	1.0	2.0	1.5	0.050
13 WA	1	5	56	0.5	0.0	1.0	2.0	0.0	2.0	0.033
13 WA	2	5	27	0.0	0.0	1.0	0.0	0.0	1.5	0.033
13 WA	3	5	29	1.0	0.0	3.0	1.0	0.0	3.0	0.033
14 WA	1	2	55	0.0	0.0	0.0	0.0	0.0	0.0	0.017
14 WA	2	2	22	0.0	0.0	0.0	0.0	0.0	0.0	0.017
14 WA	3	2	33	0.0	0.0	0.5	0.0	0.0	1.5	0.017
15 WA	1	5	44	0.5	0.0	0.0	1.0	0.0	0.0	0.050
15 WA	2	5	29	0.0	0.0	0.0	0.0	0.0	0.0	0.050
15 WA	3	5	52	0.5	0.0	0.0	1.0	0.0	0.0	0.050
15 WA	4	5	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
16 WA	1	5	63	0.5	0.0	0.0	1.0	0.0	0.0	0.050
16 WA	2	5	35	5.0	1.0	0.0	2.5	2.5	0.0	0.050
16 WA	3	5	33	1.0	0.0	0.0	1.0	0.0	0.0	0.050

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
17 WA	1	9	56	0.0	0.5	0.5	0.0	1.5	1.0	0.050
17 WA	2	9	22	0.0	0.0	0.0	0.0	0.0	0.0	0.050
17 WA	3	9	34	0.0	0.0	0.0	0.0	0.0	0.0	0.050
18 WA	1	8	24	0.0	0.5	0.0	0.0	1.5	0.0	0.050
18 WA	2	8	30	0.0	0.0	0.5	0.0	0.0	1.0	0.050
18 WA	3	8	32	1.0	0.0	0.0	1.0	0.0	0.0	0.050
18 WA	4	8	22	0.0	0.0	0.0	0.0	0.0	0.0	0.050
19 WA	1	9	59	0.5	0.0	0.5	0.5	0.0	0.5	0.067
19 WA	2	9	60	0.5	0.0	0.0	0.5	0.0	0.0	0.067
20 WA	1	9	56	1.0	0.0	1.0	1.0	0.0	1.0	0.025
20 WA	2	9	22	0.0	0.0	0.0	0.0	0.0	0.0	0.025
20 WA	3	9	34	0.0	0.0	0.0	0.0	0.0	0.0	0.025
21 WA	1	6	30	5.5	0.5	1.0	1.0	2.0	1.0	0.025
21 WA	2	6	37	1.5	0.0	1.5	0.5	0.0	2.0	0.025
21 WA	3	6	67	1.0	0.0	1.5	2.5	0.0	2.5	0.025
22 WA	1	5	48	0.0	0.0	0.0	0.0	0.0	0.0	0.018
22 WA	2	5	23	0.0	0.0	0.0	0.0	0.0	0.0	0.018
22 WA	3	5	25	0.0	0.0	0.0	0.0	0.0	0.0	0.018
23 WA	1	7	55	0.5	0.0	0.0	2.0	0.0	0.0	0.067
23 WA	2	7	33	0.0	0.0	0.0	0.0	0.0	0.0	0.067
23 WA	3	7	22	0.0	0.0	0.0	0.0	0.0	0.0	0.067
24 WA	1	12	50	0.0	0.0	0.0	0.0	0.0	0.0	0.067
24 WA	2	12	32	0.5	0.0	0.0	1.0	0.0	0.0	0.067
24 WA	3	12	18	0.0	0.0	0.0	0.0	0.0	0.0	0.067
25 WA	1	2	29	0.0	0.0	0.0	0.0	0.0	0.0	0.040
25 WA	2	2	25	0.0	0.0	0.0	0.0	0.0	0.0	0.040
25 WA	3	2	12	0.0	0.0	0.0	0.0	0.0	0.0	0.040
25 WA	4	2	69	1.0	0.0	0.0	1.5	0.0	0.0	0.040
26 WA	1	3	29	0.0	0.0	0.0	0.0	0.0	0.0	0.067
26 WA	2	3	34	0.0	0.0	0.0	0.0	0.0	0.0	0.067
26 WA	3	3	53	0.0	0.0	0.0	0.0	0.0	0.0	0.067
26 WA	4	3	10	0.0	0.0	0.0	0.0	0.0	0.0	0.067
27 WA	1	5	21	0.0	0.0	0.0	0.0	0.0	0.0	0.050
27 WA	2	5	35	0.0	0.0	0.0	0.0	0.0	0.0	0.050
27 WA	3	5	54	0.0	0.0	0.0	0.0	0.0	0.0	0.050
28 WA	1	7	57	3.0	0.0	3.0	2.5	0.0	2.5	0.050
28 WA	2	7	21	1.0	0.0	0.0	2.0	0.0	0.0	0.050
28 WA	3	7	36	1.0	0.0	1.0	1.5	0.0	2.5	0.050
29 WA	1	13	14	0.0	0.0	0.0	0.0	0.0	0.0	0.200
29 WA	2	13	18	0.0	0.0	0.0	0.0	0.0	0.0	0.200
29 WA	3	13	13	0.0	0.0	0.0	0.0	0.0	0.0	0.200
29 WA	4	13	24	0.0	0.0	0.0	0.0	0.0	0.0	0.200
29 WA	5	13	18	0.0	0.0	0.0	0.0	0.0	0.0	0.200
29 WA	6	13	6	0.0	0.0	0.0	0.0	0.0	0.0	0.200
30 WA	1	12	57	0.0	0.0	0.0	0.0	0.0	0.0	0.200
30 WA	2	12	4	0.0	0.0	0.0	0.0	0.0	0.0	0.200
30 WA	3	12	26	0.0	0.0	0.0	0.0	0.0	0.0	0.200
30 WA	4	12	24	0.5	0.0	0.0	1.0	0.0	0.0	0.200
31 WA	1	3	31	0.0	0.0	0.0	0.0	0.0	0.0	0.040
31 WA	2	3	40	0.5	0.0	0.0	1.0	0.0	0.0	0.040

ID	#	AGE	LEN	TOTAL WIDTH TT	TOTAL WIDTH BT	TOTAL WIDTH CT	MAX. LENGTH TT	MAX. LENGTH BT	MAX. LENGTH CT	SLOPE
31 WA	3	3	9	0.0	0.0	0.0	0.0	0.0	0.0	0.040
31 WA	4	3	32	0.0	0.0	0.0	0.0	0.0	0.0	0.040
31 WA	5	3	31	0.0	0.0	0.0	0.0	0.0	0.0	0.040
32 WA	1	6	28	0.0	0.0	0.0	0.0	0.0	0.0	0.045
32 WA	2	6	32	0.0	5.0	0.0	0.0	2.5	0.0	0.045
32 WA	3	6	57	0.0	3.0	0.0	0.0	2.5	0.0	0.045
33 WA	1	14	45	0.5	0.0	0.0	1.0	0.0	0.0	0.200
33 WA	2	14	35	0.0	0.0	0.0	0.0	0.0	0.0	0.200
33 WA	3	14	58	5.0	3.0	0.5	2.0	1.0	1.0	0.200
34 WA	1	6	23	0.0	0.0	0.0	0.0	0.0	0.0	0.050
34 WA	2	6	42	0.0	0.0	0.0	0.0	0.0	0.0	0.050
35 WA	1	16	36	10.0	6.5	0.5	4.0	4.0	2.0	0.200
35 WA	2	16	30	0.0	0.0	0.0	0.0	0.0	0.0	0.200
35 WA	3	16	7	4.0	0.0	0.0	1.5	0.0	0.0	0.200
36 WA	1	7	51	0.0	0.0	0.0	0.0	0.0	0.0	0.070
36 WA	2	7	22	0.0	0.0	0.0	0.0	0.0	0.0	0.070
36 WA	3	7	29	2.0	0.0	0.0	0.5	0.0	0.0	0.070
37 WA	1	14	53	0.5	0.0	1.0	1.0	0.0	1.0	0.133
37 WA	2	14	53	1.0	0.0	0.0	0.5	0.0	0.0	0.133
38 WA	1	14	28	0.5	1.0	0.0	1.0	1.0	0.0	0.111
38 WA	2	14	28	0.0	2.0	0.0	0.0	2.5	0.0	0.111
39 WA	1	9	47	7.0	0.0	0.0	2.5	0.0	0.0	0.100
39 WA	2	9	12	0.5	0.5	0.0	1.0	3.5	0.0	0.100
39 WA	3	9	25	0.0	0.0	0.0	0.0	0.0	0.0	0.100
39 WA	4	9	33	0.0	0.0	0.0	0.0	0.0	0.0	0.100
39 WA	5	9	25	0.0	0.0	0.0	0.0	0.0	0.0	0.100
39 WA	6	9	8	0.5	0.0	0.0	1.5	0.0	0.0	0.100
40 WA	1	7	24	0.0	0.0	0.0	0.0	0.0	0.0	0.025
40 WA	2	7	22	0.0	0.0	0.0	0.0	0.0	0.0	0.025
40 WA	3	7	34	0.0	0.0	0.0	0.0	0.0	0.0	0.025
40 WA	4	7	22	0.0	0.0	0.0	0.0	0.0	0.0	0.025
41 WA	1	8	77	0.0	0.0	0.0	0.0	0.0	0.0	0.033
41 WA	2	8	77	2.0	0.0	0.0	1.0	0.0	0.0	0.033
42 WA	1	6	34	0.5	0.0	0.5	1.0	0.0	1.0	0.033
42 WA	2	6	21	0.0	0.0	0.5	0.0	0.0	1.0	0.033
42 WA	3	6	9	0.0	0.0	0.0	0.0	0.0	0.0	0.033
42 WA	4	6	22	0.0	0.0	0.5	0.0	0.0	1.0	0.033
42 WA	5	6	24	0.0	0.0	0.0	0.0	0.0	0.0	0.033
43 WA	1	17	45	0.0	0.0	0.0	0.0	0.0	0.0	0.100
43 WA	2	17	26	0.0	0.0	0.0	0.0	0.0	0.0	0.100
43 WA	3	17	13	0.0	0.0	0.0	0.0	0.0	0.0	0.100
44 WA	1	30	73	1.5	0.0	0.0	1.5	0.0	0.0	0.400
44 WA	2	30	73	0.0	0.0	0.0	0.0	0.0	0.0	0.400
45 WA	1	4	20	0.5	0.0	0.0	1.0	0.0	0.0	0.050
45 WA	2	4	35	0.0	0.0	0.0	0.0	0.0	0.0	0.050
45 WA	3	4	56	0.0	0.5	0.0	0.0	1.0	0.0	0.050
46 WA	1	16	14	0.0	0.0	0.0	0.0	0.0	0.0	0.100
46 WA	2	16	26	0.0	0.0	0.0	0.0	0.0	0.0	0.100
46 WA	3	16	26	0.0	0.0	0.0	0.0	0.0	0.0	0.100
46 WA	4	16	14	0.0	0.0	0.0	0.0	0.0	0.0	0.100

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
47 WA	1	20	31	1.0	0.0	0.0	2.0	0.0	0.0	0.200
47 WA	2	20	38	1.0	0.0	0.0	2.0	0.0	0.0	0.200
48 WA	1	24	29	1.0	0.0	0.0	1.5	0.0	0.0	0.218
48 WA	2	24	29	0.0	0.0	0.0	0.0	0.0	0.0	0.218
49 WA	1	15	47	0.5	0.0	0.5	2.0	0.0	2.0	0.136
49 WA	2	15	31	0.0	0.0	0.0	0.0	0.0	0.0	0.136
49 WA	3	15	21	0.0	0.0	0.0	0.0	0.0	0.0	0.136
50 WA	1	5	32	0.0	0.0	0.0	0.0	0.0	0.0	0.045
50 WA	2	5	32	0.0	0.0	0.0	0.0	0.0	0.0	0.045
51 WA	1	8	27	0.0	7.0	0.0	0.0	5.0	0.0	0.073
51 WA	2	8	23	0.5	0.0	0.0	1.0	0.0	0.0	0.073
51 WA	3	8	35	2.5	0.0	0.5	1.5	0.0	1.5	0.073
52 WA	1	2	51	0.0	0.0	0.5	0.0	0.0	1.0	0.018
52 WA	2	2	24	0.0	0.0	0.0	0.0	0.0	0.0	0.018
52 WA	3	2	27	2.0	0.0	0.0	1.5	0.0	0.0	0.018
53 WA	1	6	27	0.0	0.0	0.0	0.0	0.0	0.0	0.054
53 WA	2	6	35	0.0	3.5	0.0	0.0	2.0	0.0	0.054
53 WA	3	6	11	0.0	0.0	0.0	0.0	0.0	0.0	0.054
53 WA	4	6	34	3.0	5.0	0.0	2.0	2.0	0.0	0.054
53 WA	5	6	7	0.0	0.0	0.0	0.0	0.0	0.0	0.054
54 WA	1	18	72	0.0	0.0	0.0	0.0	0.0	0.0	0.164
54 WA	2	18	25	0.0	0.0	0.0	0.0	0.0	0.0	0.164
54 WA	3	18	34	0.0	0.0	0.0	0.0	0.0	0.0	0.164
54 WA	4	18	13	0.0	0.0	0.0	0.0	0.0	0.0	0.164
55 WA	1	10	44	0.5	0.0	0.0	1.0	0.0	0.0	0.090
55 WA	2	10	38	0.0	0.0	0.0	0.0	0.0	0.0	0.090
56 WA	1	15	21	0.0	0.0	1.5	0.0	0.0	1.0	0.136
56 WA	2	15	19	0.0	0.0	0.0	0.0	0.0	0.0	0.136
56 WA	3	15	32	1.0	0.0	0.0	2.5	0.0	0.0	0.136
57 WA	1	3	45	0.5	0.0	0.0	0.5	0.0	0.0	0.027
57 WA	2	3	32	0.0	0.0	0.0	0.0	0.0	0.0	0.027
57 WA	3	3	12	5.0	0.0	0.0	2.5	0.0	0.0	0.027
58 WA	1	5	43	0.5	0.0	0.0	1.0	0.0	0.0	0.045
58 WA	2	5	7	3.0	0.0	0.0	1.5	0.0	0.0	0.045
58 WA	3	5	43	0.0	0.5	0.0	0.0	1.5	0.0	0.045
58 WA	4	5	7	0.0	0.0	0.0	0.0	0.0	0.0	0.045
59 WA	1	5	51	0.0	0.0	0.0	0.0	0.0	0.0	0.045
59 WA	2	5	16	0.0	0.0	0.0	0.0	0.0	0.0	0.045
59 WA	3	5	16	0.0	0.0	0.0	0.0	0.0	0.0	0.045
59 WA	4	5	51	0.0	0.0	0.5	0.0	0.0	2.5	0.045
60 WA	1	17	22	0.0	0.0	0.5	0.0	0.0	2.5	0.200
60 WA	2	17	48	21.0	0.0	1.0	2.0	0.0	1.0	0.200
60 WA	3	17	15	0.0	0.0	1.0	0.0	0.0	1.5	0.200
60 WA	4	17	21	0.0	0.0	0.0	0.0	0.0	0.0	0.200
60 WA	5	17	25	7.0	0.0	0.0	2.5	0.0	0.0	0.200
61 WA	1	8	37	0.0	0.0	0.0	0.0	0.0	0.0	0.067
61 WA	2	8	16	0.0	2.0	0.0	0.0	1.0	0.0	0.067
61 WA	3	8	53	0.0	4.0	0.0	0.0	3.0	0.0	0.067
62 WA	1	6	72	0.0	0.0	0.0	0.0	0.0	0.0	0.100
62 WA	2	6	21	0.0	0.0	0.0	0.0	0.0	0.0	0.100

ID		#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
62	WA	3	6	51	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.1ØØ
63	WA	1	6	37	2.Ø	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
63	WA	2	6	11	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø5Ø
63	WA	3	6	27	Ø.Ø	3.Ø	Ø.Ø	Ø.Ø	2.5	Ø.Ø	Ø.Ø5Ø
64	WA	1	1Ø	37	4Ø.Ø	3Ø.Ø	2.Ø	4.Ø	4.Ø	2.Ø	Ø.133
64	WA	2	1Ø	11	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	5.Ø	Ø.133
64	WA	3	1Ø	26	25.Ø	Ø.Ø	Ø.Ø	4.Ø	Ø.Ø	Ø.Ø	Ø.133
65	WA	1	15	39	8.Ø	Ø.Ø	1.5	2.Ø	Ø.Ø	2.Ø	Ø.133
65	WA	2	15	34	18.Ø	Ø.Ø	Ø.Ø	3.Ø	Ø.Ø	Ø.Ø	Ø.133
65	WA	3	15	1Ø	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.5	Ø.133
66	WA	1	8	57	4.5	1.Ø	Ø.Ø	1.5	1.5	Ø.Ø	Ø.133
66	WA	2	8	23	Ø.5	3.Ø	Ø.Ø	Ø.5	1.5	Ø.Ø	Ø.133
66	WA	3	8	8Ø	12.Ø	5.Ø	Ø.Ø	2.5	1.5	Ø.Ø	Ø.133
67	WA	1	3	87	2.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
67	WA	2	3	87	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
68	WA	1	25	24	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.4ØØ
68	WA	2	25	25	1Ø.5	Ø.Ø	Ø.5	3.Ø	Ø.Ø	1.5	Ø.4ØØ
68	WA	3	25	24	13.Ø	Ø.Ø	Ø.Ø	3.5	Ø.Ø	Ø.Ø	Ø.4ØØ
68	WA	4	25	28	3.Ø	Ø.Ø	Ø.Ø	2.5	Ø.Ø	Ø.Ø	Ø.4ØØ
69	WA	1	1Ø	45	Ø.Ø	Ø.Ø	1Ø.Ø	Ø.Ø	Ø.Ø	2.5	Ø.Ø67
69	WA	2	1Ø	3Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
69	WA	3	1Ø	51	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
69	WA	4	1Ø	24	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø67
7Ø	WA	1	12	24	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ
7Ø	WA	2	12	41	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.Ø	2.5	Ø.1ØØ
71	WA	1	14	56	4.Ø	5.Ø	Ø.Ø	2.5	2.Ø	Ø.Ø	Ø.2ØØ
71	WA	2	14	36	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.2ØØ
71	WA	3	14	17	Ø.Ø	Ø.Ø	1Ø.Ø	Ø.Ø	Ø.Ø	1.Ø	Ø.2ØØ
71	WA	4	14	29	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.2ØØ
72	WA	1	13	33	Ø.5	Ø.5	1.Ø	1.Ø	1.5	1.Ø	Ø.Ø33
72	WA	2	13	35	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø33
72	WA	3	13	67	Ø.Ø	Ø.Ø	1.Ø	Ø.Ø	Ø.Ø	1.5	Ø.Ø33
73	WA	1	12	26	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.2ØØ
73	WA	2	12	25	Ø.Ø	Ø.Ø	3.Ø	Ø.Ø	Ø.Ø	1.5	Ø.2ØØ
73	WA	3	12	47	1Ø.Ø	1.Ø	Ø.Ø	2.5	2.5	Ø.Ø	Ø.2ØØ
73	WA	4	12	1Ø	3Ø.Ø	Ø.Ø	Ø.Ø	2.5	Ø.Ø	Ø.Ø	Ø.2ØØ
74	WA	1	11	32	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.4ØØ
74	WA	2	11	32	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.4ØØ
75	WA	1	1Ø	38	Ø.5	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	Ø.1ØØ
75	WA	2	1Ø	28	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ
75	WA	3	1Ø	62	3.Ø	Ø.Ø	Ø.5	2.5	Ø.Ø	2.Ø	Ø.1ØØ
76	WA	1	25	28	Ø.5	Ø.Ø	1.Ø	1.Ø	Ø.Ø	1.5	Ø.1ØØ
76	WA	2	25	41	Ø.5	Ø.Ø	6.Ø	1.5	Ø.Ø	2.5	Ø.1ØØ
76	WA	3	25	7Ø	Ø.5	Ø.5	Ø.5	1.5	1.5	1.5	Ø.1ØØ
77	WA	1	13	3Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ
77	WA	2	13	4Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.Ø	Ø.Ø	Ø.1ØØ
77	WA	3	13	26	Ø.Ø	Ø.Ø	Ø.5	Ø.Ø	Ø.Ø	2.5	Ø.1ØØ
77	WA	4	13	85	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ
77	WA	5	13	23	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ
78	WA	1	1Ø	32	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.Ø	Ø.1ØØ

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
78 WA	2	10	28	0.0	0.0	0.0	0.0	0.0	0.0	0.100
79 WA	1	12	34	0.0	0.0	6.5	0.0	0.0	2.0	0.133
79 WA	2	12	41	6.0	0.0	5.0	2.5	0.0	2.5	0.133
80 WA	1	17	33	2.0	0.0	0.0	3.0	0.0	0.0	0.133
80 WA	2	17	49	0.5	0.0	3.0	0.5	0.0	3.0	0.133
80 WA	3	17	64	12.0	2.0	0.0	3.0	2.0	0.0	0.133
80 WA	4	17	11	2.0	0.0	0.0	2.0	0.0	0.0	0.133
81 WA	1	10	27	0.5	1.0	0.0	1.0	2.5	0.0	0.133
81 WA	2	10	31	2.5	0.0	0.0	1.0	0.0	0.0	0.133
81 WA	3	10	7	40.0	0.0	0.0	1.5	0.0	0.0	0.133
81 WA	4	10	4	8.0	1.5	0.0	1.0	1.0	0.0	0.133
82 WA	1	10	41	24.0	0.0	13.0	2.5	0.0	1.0	0.133
82 WA	2	10	33	0.0	0.0	0.5	0.0	0.0	1.5	0.133
83 WA	1	14	30	2.0	0.0	0.0	2.0	0.0	0.0	0.127
83 WA	2	14	26	0.0	0.0	0.0	0.0	0.0	0.0	0.127
84 WA	1	11	29	5.0	0.0	0.0	1.5	0.0	0.0	0.100
84 WA	2	11	33	0.0	1.0	0.0	0.0	1.5	0.0	0.100
85 WA	1	15	56	75.0	0.0	0.0	3.0	0.0	0.0	0.136
85 WA	2	15	22	0.0	31.0	0.0	0.0	1.5	0.0	0.136
85 WA	3	15	14	0.0	0.0	0.0	0.0	0.0	0.0	0.136
85 WA	4	15	14	4.0	0.0	0.0	1.5	0.0	0.0	0.136
86 WA	1	8	61	0.0	0.0	0.0	0.0	0.0	0.0	0.073
86 WA	2	8	29	0.0	0.0	0.0	0.0	0.0	0.0	0.073
86 WA	3	8	24	0.0	0.0	0.0	0.0	0.0	0.0	0.073
87 WA	1	9	29	1.0	0.0	0.0	0.5	0.0	0.0	0.082
87 WA	2	9	25	0.0	0.0	0.0	0.0	0.0	0.0	0.082
87 WA	3	9	54	0.0	0.0	0.0	0.0	0.0	0.0	0.082
88 WA	1	5	55	5.5	0.0	0.0	1.5	0.0	0.0	0.045
88 WA	2	5	55	2.0	0.0	0.0	1.5	0.0	0.0	0.045
89 WA	1	10	60	0.0	0.0	2.0	0.0	0.0	2.0	0.091
89 WA	2	10	25	0.0	0.0	0.0	0.0	0.0	0.0	0.091
89 WA	3	10	39	0.5	0.0	0.5	1.0	0.0	1.5	0.091
90 WA	1	10	39	0.0	0.0	0.0	0.0	0.0	0.0	0.091
90 WA	2	10	22	1.0	0.0	0.0	0.5	0.0	0.0	0.091
90 WA	3	10	62	4.5	0.0	0.0	2.0	0.0	0.0	0.091
91 WA	1	10	56	0.0	0.0	0.0	0.0	0.0	0.0	0.091
91 WA	2	10	56	0.0	0.0	0.0	0.0	0.0	0.0	0.092
92 WA	1	16	49	0.0	0.0	0.0	0.0	0.0	0.0	0.145
92 WA	2	16	21	0.0	0.0	0.0	0.0	0.0	0.0	0.145
92 WA	3	16	29	0.0	0.0	0.0	0.0	0.0	0.0	0.145
93 WA	1	5	31	0.0	0.0	0.0	0.0	0.0	0.0	0.045
93 WA	2	5	28	0.0	0.0	0.0	0.0	0.0	0.0	0.045
93 WA	3	5	58	0.0	0.0	0.0	0.0	0.0	0.0	0.045
94 WA	1	4	29	0.0	0.0	0.0	0.0	0.0	0.0	0.036
94 WA	2	4	26	0.0	0.0	0.0	0.0	0.0	0.0	0.036
94 WA	3	4	54	0.0	0.0	0.0	0.0	0.0	0.0	0.036
95 WA	1	11	31	1.0	0.0	0.0	2.5	0.0	0.0	0.100
95 WA	2	11	33	0.0	0.0	0.0	0.0	0.0	0.0	0.100
95 WA	3	11	64	0.0	0.0	0.0	0.0	0.0	0.0	0.100
96 WA	1	11	53	0.5	0.0	0.0	0.5	0.0	0.0	0.100

ID	#	AGE	LEN	TOTAL WIDTH TT	BT	CT	MAX. LENGTH TT	BT	CT	SLOPE
96 WA	2	11	30	0.5	0.0	0.0	1.0	0.0	0.0	0.100
96 WA	3	11	23	0.0	0.0	0.0	0.0	0.0	0.0	0.100
97 WA	1	5	25	0.0	0.0	0.0	0.0	0.0	0.0	0.045
97 WA	2	5	20	0.0	0.0	0.0	0.0	0.0	0.0	0.045
97 WA	3	5	41	1.0	0.0	0.0	1.0	0.0	0.0	0.045
98 WA	1	10	27	0.0	1.0	0.0	0.0	1.5	0.0	0.091
98 WA	2	10	22	0.0	0.0	0.5	0.0	0.0	2.5	0.091
98 WA	3	10	54	0.5	0.0	0.0	1.5	0.0	0.0	0.091
99 WA	1	10	62	28.0	0.0	0.0	2.0	0.0	0.0	0.091
99 WA	2	10	62	12.0	0.0	0.5	3.0	0.0	2.5	0.091
100 WA	1	9	29	1.0	0.0	0.0	2.0	0.0	0.0	0.082
100 WA	2	9	25	0.0	0.0	0.0	0.0	0.0	0.0	0.082
100 WA	3	9	54	0.0	0.0	0.0	0.0	0.0	0.0	0.082

APPENDIX II

Kelvin Model Parameters From Laboratory Test Data

Test Variables					Kelvin Model Parameters			
					t = 120 - 720 sec		t = 5000-7000 sec	
Sample No.	σ_1-σ_3 (psi)	σ_3 (psi)	Water Content w, %	Suction, ψ, (Bars)	E(psi) x 10^2	λ(psi-sec) x 10^5	E(psi) x 10^2	λ(psi-sec) x 10^6
*CSBS3	2.0	0	24.5	-0.27	10.14	4.23	18.88	10.26
	3.5	0			28.87	8.59	33.85	19.07
	5.0	0			23.23	7.45	29.20	25.66
CSBS4	2.0	0	28.0	-0.20	5.95	1.96	10.54	2.48
	3.5	0			6.94	3.10	11.66	4.85
	5.0	0			6.13	1.99	13.32	8.89
CSBS5	2.0	0	30.6	-0.16	6.85	2.38	14.51	5.44
	3.5	0			6.09	2.17	8.76	2.44
	5.0	0			2.85	1.03	6.39	3.46
CSBS6	2.0	0	31.3	-0.15	4.96	1.77	6.73	5.05
	3.5	0			4.01	1.39	9.07	3.93
	5.0	0			2.52	0.94	6.59	2.73
CSBS9	2.0	0	32.7	-0.13	2.34	0.81	7.19	2.85
	3.5	0			1.77	0.61	7.39	4.75
	5.0	0			1.37	0.58	2.86	1.17
CSB11	2.0	5	32.5	-0.13	5.17	2.53	4.38	2.40
	3.5	5			9.31	3.81	11.27	5.24
	5.0	5			5.22	1.81	11.15	8.35
†CHB 1	2.0	0	29.3	-0.13	6.57	2.45	15.94	5.17
	3.5	0			17.14	6.40	19.98	4.87
	5.0	0			11.27	6.13	9.02	1.75
CHB 2	2.0	0	29.4	-0.13	6.59	1.96	11.17	6.83
	3.5	0			8.09	5.95	6.79	1.01
	5.0	0			10.83	6.30	13.73	6.16

*CSB samples are from the South Bosque Clay-Shale in Waco.

†CHB samples are from the Houston Black Clay in San Antonio.

APPENDIX III

Creep Compliance Properties of the Soils

From Laboratory Test Data

Creep compliance is the ratio of the axial strain, $\varepsilon(t)$ measured at any time, t, to the stress which is applied to the sample, $(\sigma_1 - \sigma_3)$, and which stays constant with time.

$$D(t) = \frac{\varepsilon(t)}{(\sigma_1 - \sigma_3)}$$

A standard way of representing the creep compliance is in the form of a power law, as follows:

$$D(t) = D_1 t^n$$

The constant D_1 was found to vary with the mean principal stress, σ, in psi; and the absolute value of suction, in bars. The constant n was found to depend upon the same two variables. The general equation for the two constants is as follows:

$$D_1 = a\ (\sigma)^b\ (|\psi|)^c$$

$$n = d\ (\sigma)^e\ (|\psi|)^f$$

The material constants are as follows:

Material Constants	Waco South Bosque Clay-Shale	San Antonio Houston Black Clay
a	3.23×10^{-7}	1.667×10^{-8}
b	-0.89	-1.80
c	-5.08	?
d	0.259	0.141
e	0.482	0.631
f	0.468	?

Not enough data were available to obtain material constants c and f for the Houston Black clay from San Antonio.

Test Variables					Creep Compliance Parameters	
Sample No.	$(\sigma_1-\sigma_3)$ (psi)	σ_3 (psi)	Water Content, w, %	Suction ψ, Bars	D_1 $x10^{-3}$	n
*CSBS3	2.0	0	24.5	-0.27	0.52	0.115
	3.5	0			0.11	0.190
	5.0	0			0.11	0.190
CSBS4	2.0	0	28.0	-0.20	2.08	0.071
	3.5	0			0.84	0.102
	5.0	0			0.74	0.136
CSBS5	2.0	0	30.6	-0.16	1.32	0.093
	3.5	0			0.89	0.125
	5.0	0			1.33	0.148
CSBS6	2.0	0	31.3	-0.15	1.04	0.144
	3.5	0			0.90	0.153
	5.0	0			2.10	0.110
CSBS9	2.0	0	32.7	-0.13	6.0	0.062
	3.5	0			3.8	0.131
	5.0	0			3.3	0.139
CSB 11	2.0	5	32.5	-0.13	1.09	0.154
	3.5	5			0.31	0.212
	5.0	5			0.60	0.150
†CHB 1	2.0	0	29.3	-0.13	1.05	0.090
	3.5	0			0.29	0.163
	5.0	0			0.23	0.174
CHB 2	2.0	0	29.4	-0.13	0.78	0.128
	3.5	0			0.35	0.159
	5.0	0			0.21	0.207

* CSB Samples are from the South Bosque clay-shale in Waco

† CHB Samples are from the Houston Black clay in San Antonio

APPENDIX IV

Rate Process Models of Creep From Laboratory Test Data

A study of the rate process constants was made on the South Bosque shale. The general formula for the strain rate, $\overset{\circ}{\varepsilon}$, is as follows:

$$\overset{\circ}{\varepsilon} = 2s \frac{kT}{h} e^{-\frac{\Delta E}{kT}} \cdot e^{\frac{f\lambda}{2kT}}$$

where

s = the number of bond contacts per unit length

k = Boltzmann's constant

T = the absolute temperature

h = Planck's constant

ΔE = a change of free energy

f = the shearing force

λ = distance between successive equilibrium positions.

The free energy term can be sub-divided into two parts, one of which depends upon the suction, or soil water potential, and the other of which depends upon the mean principal stress. The relation is as follows:

$$\frac{\Delta E}{kT} = N_1 \frac{\psi gm}{RT} - \frac{N_2 \sigma \phi}{kT}$$

where ψ = the soil water potential or soil suction

g = the acceleration due to gravity

m = the molecular weight of water

R = the universal gas constant

σ = the mean principal stress

ϕ = the number of bonds per unit area (typically, 10^{10} bonds/sq.cm)

N_1 = a constant of proportionality that ranges from 0 to 1. When $N_1 = 0$, there is no influence of the soil water potential term.

$N_2 = 1 - N_1$

The creep compliance constants that are found in the previous appendix

(Appendix III) were used to determine the rate process constants, as follows.

$$\frac{\varepsilon(t)}{(\sigma_1 - \sigma_3)} = D(t) = D_1 t^n \qquad \text{(IV-1)}$$

$$\frac{\overset{\circ}{\varepsilon}(t)}{(\sigma_1 - \sigma_3)} = \frac{\partial}{\partial t} D(t) = \frac{nD_1}{t^{1-n}} \qquad \text{(IV-2)}$$

The form of the strain-rate equation was assumed to be

$$\overset{\circ}{D}(t) = \frac{nD_1}{t^{1-n}} = a \, e^{b\sigma} \, e^{c \, \tau_{oct}} \, e^{d|\psi|} \qquad \text{(IV-3)}$$

By setting t at 10,000 seconds and taking the logarithms of both sides of Equation IV-3, it is possible to obtain the material constants a, b, c, and d by linear regression analysis. The results are as follows:

Rate Process Material Constants At t = 10,000 Seconds

Material Constants	Values of Constants[1]	Values of Constants[2]	Values of Constants[3]
a	2.904×10^{-4}	2.904×10^{-4}	2.904×10^{-4}
b	0.374	0.374	0.000
c	0.000	0.000	0.264
d	-0.941	-13.35	-0.941

1 σ in lb/in^2, $|\psi|$ in lb/in^2.

2 σ in lb/in^2, $|\psi|$ in bars

3 τ_{oct} in $lb/in.^2$, $|\psi|$ in lb/in^2.

The values of the mean principal stress, σ, and octahedral shear stress, τ_{oct}, are interchangeable in this equation because one was always a constant ratio of the other in the tests that were analyzed (CSBS3-CSBS9).

$$\tau_{oct} = \frac{\sqrt{2}}{3} (\sigma_1 - \sigma_3) \quad \text{(IV-4)}$$

$$\sigma = \frac{1}{3} (\sigma_1 + 2\sigma_3) \quad \text{(IV-5)}$$

$$\frac{\sigma}{\tau_{oct}} = \frac{\sqrt{2}}{2} \quad \text{(IV-6)}$$

The statistics of this model are as follows:

Number of observations = 15

Coefficient of determination, R^2 = 0.85

Root Mean Square Error = 0.32

The constants in the table are significant. A unit decrease in suction, ψ, will decrease the compliance rate, $\overset{\circ}{D}(t)$, by $\frac{0.941}{0.374} = 2.5$ times as much as a unit decrease in mean principal stress, indicating that at the level of suction at which these tests were made, suction is 2.5 times as effective in changing the compliance rate of the soil.

The slope of the creep compliance curve, n, was found to depend upon σ and ψ in the same series of tests. Regression analysis found the following equation:

$$n = 0.259 (\sigma)^{0.482} (|\psi|)^{0.468} \quad \text{(IV-7)}$$

where σ is in lb/in.^{2}, and ψ is in bars. In this case, a change of suction by 1 lb/in.^{2} would change the slope, n, by much less than would a 1 lb/in.^{2} change of mean principal stress. The statistics for this regression analysis are as follows:

Number of observations = 15

Coefficient of determination = 0.49

Root mean sqaure residual (log n) = 0.11

Neither the San Antonio data nor the Waco test data with a lateral confining pressure of 5 psi was analyzed because the number of data points was too small to permit reliable regressions.

APPENDIX V

Derivation of Equations of Motion of Flexible Slabs on Slopes

Two equations of motion of a loaded slab on a slope are developed in this appendix. The first assumes the soils is a Maxwell liquid with a constitutive equation as follows:

$$\overset{\circ}{\gamma} = \frac{\overset{\circ}{\tau}}{G} + \frac{\tau}{\eta} \qquad \text{(V-1)}$$

where

$\overset{\circ}{\gamma}$ = the shearing strain rate

τ = the shearing stress

$\overset{\circ}{\tau}$ = the rate of change of shearing stress

G = the Maxwell liquid shear modulus

η = the Maxwell liquid viscosity

The second equation of motion assumes that the soil is a Kelvin solid with a constitutive equation as follows:

$$\tau = G\gamma + \lambda\overset{\circ}{\gamma} \qquad \text{(V-2)}$$

where τ = the shearing stress

γ = the shearing strain

$\overset{\circ}{\gamma}$ = the shearing strain rate

G = the Kelvin shear modulus

λ = the Kelvin viscosity

The coordinate system used in these derivations is shown in Figure V.1. At any point, z, beneath the slab the shearing stress is found to be

$$\tau(z) = \gamma_t \sin \alpha \, (H_o + \frac{w_o}{\gamma_t} - z) \qquad \text{(V-3)}$$

where γ_t = the total unit weight of the soil. Because the shearing stress does not change with time, $\overset{\circ}{\tau} = 0$.

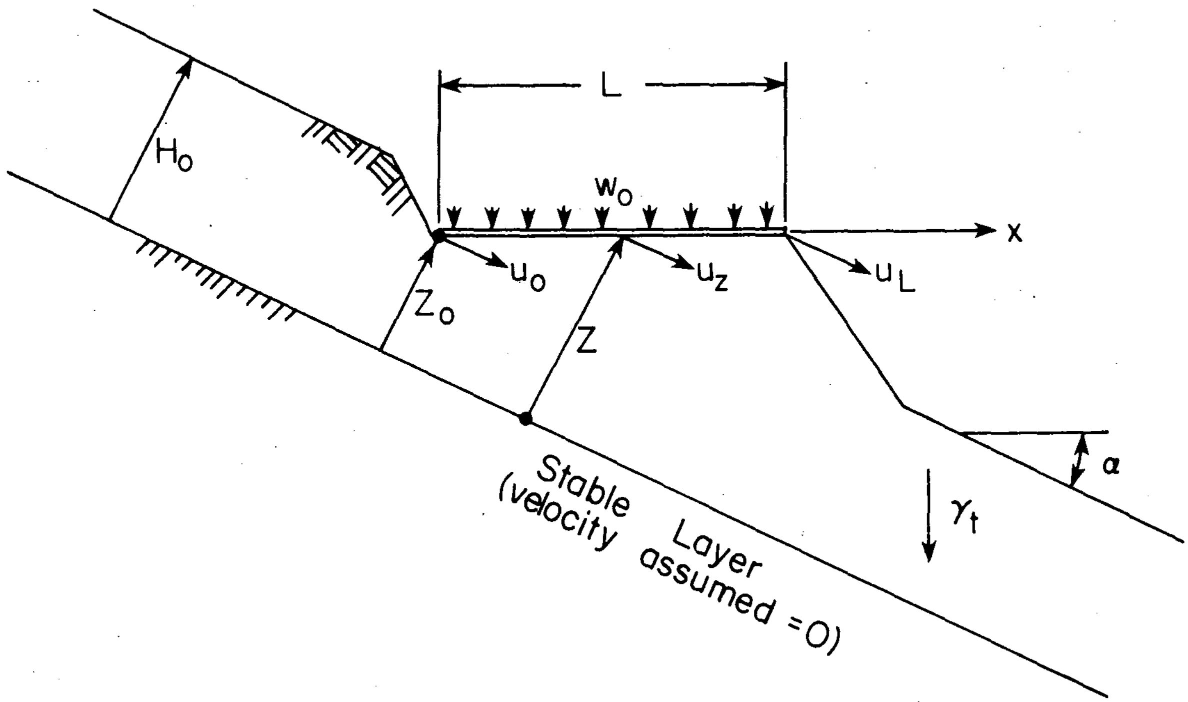

Figure V. 1. Notation for Derivation of Equations of Motion.

Equations of Motion-Maxwell Liquid

With $\overset{\circ}{\tau} = 0$, Equation (V-1) becomes

$$\frac{\partial \overset{\circ}{u}}{\partial z} = \frac{\tau}{\eta} \tag{V-4}$$

Integrating Equation V-4 with depth, z, produces and equation for the downhill velocity, $\overset{\circ}{u}$.

$$\overset{\circ}{u}(z) = \frac{\gamma_t}{2\eta} \sin \alpha \left(2 H_o z + \frac{2w_o}{\gamma_t} z - z^2\right) \tag{V-5}$$

Integration of this equation with time gives on equation for the downhill displacement, u.

$$u(z) = \frac{\gamma_t t}{\eta} \left(2 H_o z + \frac{2w_o}{\gamma_t} z - z^2\right) \tag{V-6}$$

where t = the time, in consistent units, after the slab was placed The difference between u_o and u_L projected onto the plane of the slab gibes the amount of stretching the slab experiences, which is assumed equal to the amount of center tension cracking, c(t)

$$c(t) = (u_L - u_o) \cos \alpha \tag{V-7}$$

Because neither z_o nor z_L are known in the analysis, the following relations are substituted into Equation (V-7):

$$z_L - z_o = L \sin \alpha \tag{V-8}$$

$$z_L^2 - z_o^2 = L \sin \alpha \, (2 z_o + L \sin \alpha) \tag{V-9}$$

The results is as follows:

$$c(t) = \frac{\gamma_t t}{\eta} \, . \, L \sin^2\alpha \cos \alpha \; 2(H_o - z_o) + \frac{w_o}{\gamma_t} - L \sin \alpha \tag{V-10}$$

The curvature of the slab is found first by writing the equation of the displacement normal to the plane of the slab, w(z), as a function of the downhill displacement

$$w(z) = u(z) \sin \alpha \qquad \text{(V-11)}$$

Then changing to the x-coordinate system in the plane of the slab and making the following subsitution into Equation (V-6):

$$z = x \sin \alpha + z_0 \qquad \text{(V-12)}$$

and taking two successive derivatives of the resulting equation gives:

$$\frac{\partial^2 w(z)}{\partial x^2} = -\frac{\gamma_t t}{2} \cdot 2 \sin^4 \alpha \qquad \text{(V-13)}$$

Another measure of the curvature is found from the width of top-tension cracking, s(t). If H is the height of the crack, the central angle subtended by the crack, θ, is

$$\frac{s}{H} = \theta \qquad \text{(V-14)}$$

Similarly, the central angle subtended by the entire wall is again, θ

$$\frac{L}{R} = \theta \qquad \text{(V-15)}$$

The term R is the radius of curvature of the wall which is assumed, as in beam theory, to be

$$R = \frac{1}{\frac{d^2 w}{dx^2}} \qquad \text{(V-16)}$$

Combining the previous three equations gives an expression for curvature in terms of the width and length of top-tension cracking:

$$\frac{d^2 w}{dx^2} = \frac{s(t)}{H\, L} \qquad \text{(V-17)}$$

Setting Equations (V-13) and (V-17) equal gives

$$\frac{s(t)}{H\,L} = \frac{\gamma_t\, t}{2\eta} \cdot 2 \sin^4\alpha \qquad \text{(V-18)}$$

In order for both Equations (V-10) and (V-18) to be true the following geometric condition must hold:

$$\frac{2\,c(t)\,H}{H} \cdot \frac{\sin^2\alpha}{\cos\alpha} = 2(H_0 - z_0) - L\sin\alpha + 2\,\frac{w_0}{\gamma_t} \qquad \text{(V-19)}$$

This expression allows a determination to be made of the distance $(H_0 - z_0)$, the distance the foundation is benched into the slope.

Equation of Motion-Kelvin Solid

The development of the equations of motion for the Kelvin Solid is very similar to that for the Maxwell liquid. The differential equation to be solved is

$$G\,\frac{\partial u}{\partial z} + \lambda\,\frac{\partial \mathring{u}}{\partial z} = \tau(z) \qquad \text{(V-20)}$$

with the shearing stress as defined before in Equation (V-3). The solution for the downhill displacement at any distance, z, above the stable layer is

$$u(z,t) = (1 - e^{-(G/\lambda)t})\,\frac{\gamma_t}{2G}\,\sin\alpha\,\left(2H_0 z + \frac{2w_0 z - z^2}{\gamma_t}\right) \qquad \text{(V-21)}$$

The equation for the center tension cracking width, c(t), is

$$c(t) = (1 - e^{-(G/\lambda)t}\,\frac{\gamma_t}{2G}\,L\sin^2\alpha\cos\alpha\,(2(H_0 - z_0) + \frac{2w_0}{\gamma_t} - L\sin\alpha) \qquad \text{(V-22)}$$

The equation for the top-tension cracking width, s(t), is

$$\frac{s(t)}{HL} = (1 - e^{-(G/\lambda)t} \cdot \frac{\gamma_t}{2G} \qquad \text{(V-23)}$$

The geometric condition Equation (V-19) also holds for the Kelvin Solid.

Regression Equations to Determine Soil Mass Material Properties.

The regression analysis to obtain the Maxwell liquid viscosity of a soil mass is simple linear regression, since the form of the equation is:

$$s(t) = 0 + \left(\frac{1}{\eta}\right) \cdot \gamma_t \, t \, H \, L \sin^4\alpha \qquad \text{(V-24)}$$

which is of the form:

$$y = 0 + b\,x \qquad \text{(V-25)}$$

In this equation, the dependent variable y, is s(t) and the independent variable x, is

$$x = \gamma_t \, H \, L \sin^4\alpha \qquad \text{(V-26)}$$

The constant of proportionality, b, is the reciprocal of the Maxwell viscosity

$$b = \frac{1}{\eta} \qquad \text{(V-27)}$$

A non-linear pattern search regression analysis was required for the Kelvin solid. The procedure followed for that analysis has been described in the body of the report.