Evaluation of Timber Foundation Piling in Marine Applications

Knowledge Based Computational Algorithms for Pile Evaluation Analysis

By Bogdan Zmeu, P.E., S.E.

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Evaluation of timber piling for "vintage" marine structures is a challenging task. Traditionally, timber piles have been widely used for supporting piers, wharves, seawalls, bridges and other structures. In a temperate marine environment, such as the New York harbor, and properly maintained, these structures have effectively supported waterfront infrastructures that are more than a century old. Like any other structure, over time, timber piles may undergo physical and material degradation due to a host of factors including wear-and-tear, freeze-thaw cycles, fungal rot, or marine borer attack. Consequently, for some of these structures the current capacity is less than the initial design capacity.

Attacking Organisms

A marine borer attack can happen relatively quickly, and has the potential for sudden and significant degradation of the affected pile. Marine borers are small organisms that burrow into the wood for food and shelter. According to *Aquatic & Wetland Structures*, published by the Timber Piling Council, marine borers are more active in warm coastal waters, with the highest activity in Florida, the Gulf States, and California. The teredo, commonly referred to as shipworm, is a mollusk, a small invertebrate animal that is two to eight inches long and is active inside the sapwood of the pile, above the low-water level. Resulting internal damage to the pile resembles a honeycombed structure. Another species, limnoria, attacks the timber from the outside, gradually reducing the pile diameter. Severe abrasion in combination with limnoria attack may rapidly reduce the pile cross-sectional area, leaving an hourglass shape with exposed heartwood at the center of the section (*Figure 1*).

Evaluation

If not addressed, these deteriorations may lead to a downgraded load-carrying capacity, causing escalated repair costs, shutdowns, and eventual closure and loss of the facility. Preservation of the structure can be accomplished through implementation of repairs that restore structural integrity to damaged piles. To be effective, repairs should be based on engineering investigations comparable to the Level II or Level III inspection routines described in the *Waterfront Inspection Guidelines Manual*, by the New York City Economic Development Corporation (NYCEDC). Establishing the state of structural health for marine piling is crucial for medium- and long-term management of waterfront infrastructures, and for establishing and implementing rational decisions with regard to rehabilitation or replacement of these structures.

Structural engineers are often called upon to evaluate marine piles for older piers, wharves, and seawalls. Assessing the load-carrying capacity of a damaged pile is a challenging task that requires knowledgeable professionals, reliable information, and state-of-the-art analysis. The evaluation begins with the most recent pile inspection report. Traditionally, inspection reports consist of various records including structure descriptions,

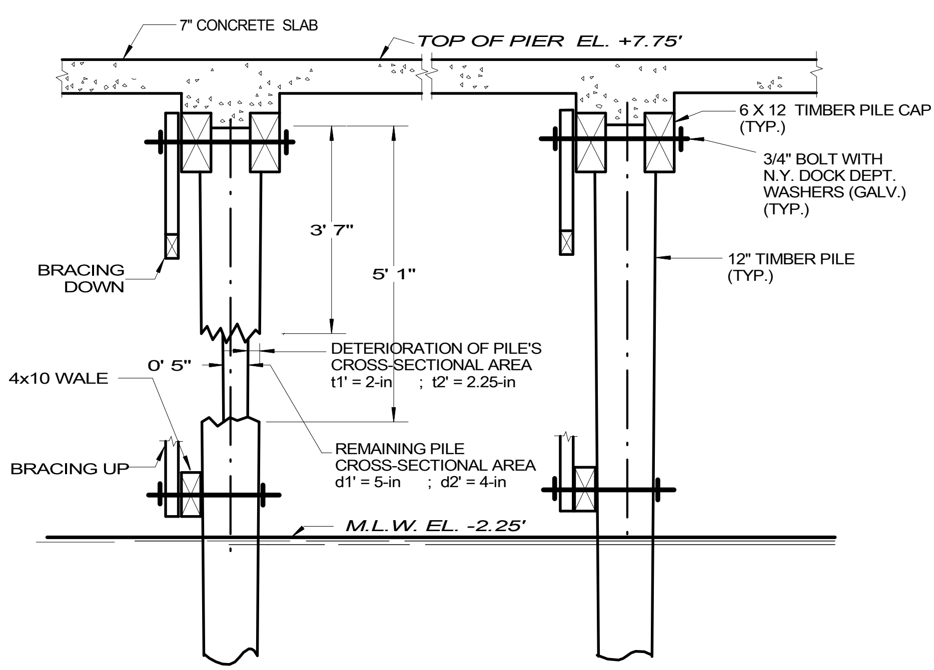

Figure 1: Typical pier.

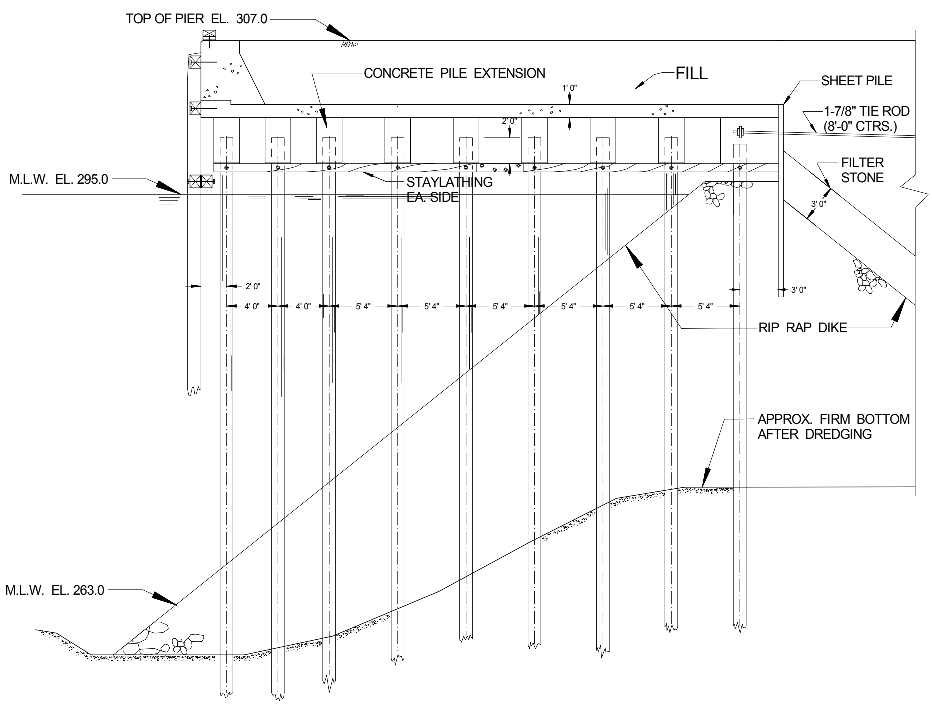

Figure 2: Typical wharf with low-level relieving platform.

photographs, probes, offsite laboratory test results, field notes, and sketches showing geometry and extent of deteriorations.

Not all of this information is available in every situation. In particular, often the position of the deteriorated segment of the pile with respect to the butt end, or the data needed to calculate the end eccentricities about the principal axes of the cross section, is missing. In such cases the engineer can employ estimates of section losses based on the photographic record, especially for routine or rapid assessment inspections, when the scope of work does not call for repair design or for the change of use of the facility. However, establishing rational decisions regarding the rehabilitation or the replacement of large structures, or portions of these structures, requires carefully planned inspection routines that can detect internal and external defects, along with rigorous analysis for all the structures that are being evaluated.

Pile Capacity Methodologies

The methodology for pile capacity evaluation that is presented here consists of two computational algorithms. The first algorithm is based on Equation 15.4-2, Wood Columns with Side Loads and Eccentricity, Special Loading Conditions, Section 15, *National Design Specification® (NDS®) for Wood Construction* (NDS-2005). This algorithm investigates the local buckling criterion for the deteriorated section of the pile by determining the direct compression load that an eccentrically loaded column can sustain. The second algorithm involves second-order elastic analysis of the pile. This analysis includes the degradation effects by considering a "hinge"-type discontinuity in lieu of the actual geometric properties of the reduced cross-sectional area of the pile. Additional considerations include an initial horizontal translation at the location of the hinge. Due to the large volume of computations, both analyses are performed by a desktop computer. Pre- and post-processing automation routines are employed for data transfer between the database and the processing modules. Detailed descriptions for each routine and typical runtime output with pile capacity calculations for a 28-pile dataset are included in the online version of the article (**www.STRUCTUREmag.org**).

The pile capacity analysis was used for typical foundation piling for a deep water pier and for a container wharf. Both are major waterfront structures similar to those encountered at port facilities throughout the United States. Typically, piers are open- or closed-type structures that extend perpendicular from the shore into navigable waters, with berthing on both sides. Wharfs are open-type marginal platforms that are parallel to the shoreline.

Figure 1 illustrates the heavy horizontal structure for a typical high-level platform. The pier deck is a 7-inch thick concrete slab and is set on two 6x12 timber pile caps. The pile bents are typically 12 to 16 feet on center for the full length of the pier, which can reach 800 feet or more. Typical pile spacing is 4 to 6 feet on center for the full width of the pier.

Figure 2 (page 19) illustrates typical wharf construction for a low-level relieving platform. This type of construction predates modern wharves, which are typically high-level platforms with reinforced concrete structures, by at least 45 years. The low-level relieving platform wharf is a massive, 6-foot thick horizontal structure. The platform is set on 8- by 5-foot pile grids to support a total service load of approximately 1,200 pounds per square foot. The top side is asphalt on gravel fill to withstand heavy container trucks. The bottom side is 1-foot thick reinforced concrete and is set directly on the pile extension structures as shown in *Figure 2*. The pile extensions are 22-inch (inside diameter) precast concrete pipes, filled with concrete and encasing the pile head over the top 2 feet of the pile. The minimum allowable capacity for these piles is 25 to 30 tons.

Data Collection Considerations

Pile inspection routines should provide detailed field sketches with dimensions for all deteriorations, as applicable. The evaluation analysis presented here requires five numeric variables (see below) for each top and bottom section of the deteriorated segment, for a total of ten numeric variables per pile and deterioration. This information can be obtained for external deteriorations when the pile is visible and accessible for measurements. *Figure 1* illustrates pile geometry and field measurements at sections directly below the pile cap, in the air draft zone of the pier.

Knowledge-Based Computer Analysis

Knowledge-based computer analysis is a capacity evaluation tool for existing marine piles. The system consists of a user file for problem inputs and three processing modules. The core processor has two computational algorithms, which are the problem-solving routines for local buckling and overall elastic buckling of the pile, and include the effects of timber deterioration. The following is a short description for each module with concentration on the capacity evaluation analysis and discussion of analysis results.

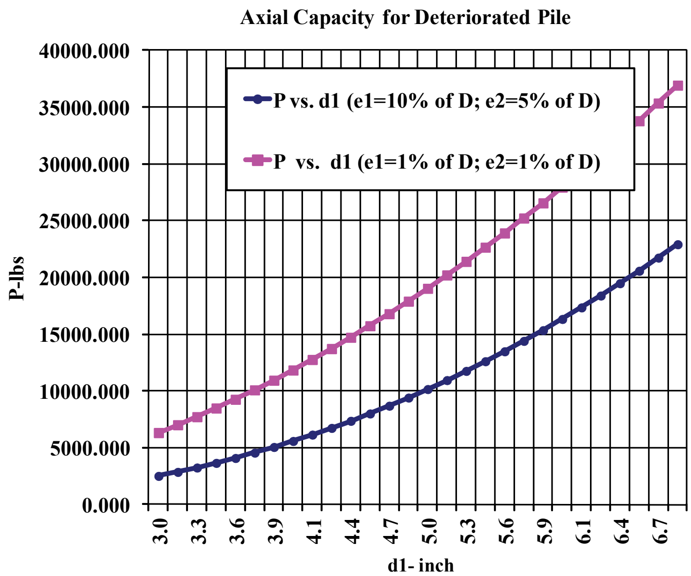

Figure 3: Allowable Bearing Capacity vs. Diameter (P vs. d1).

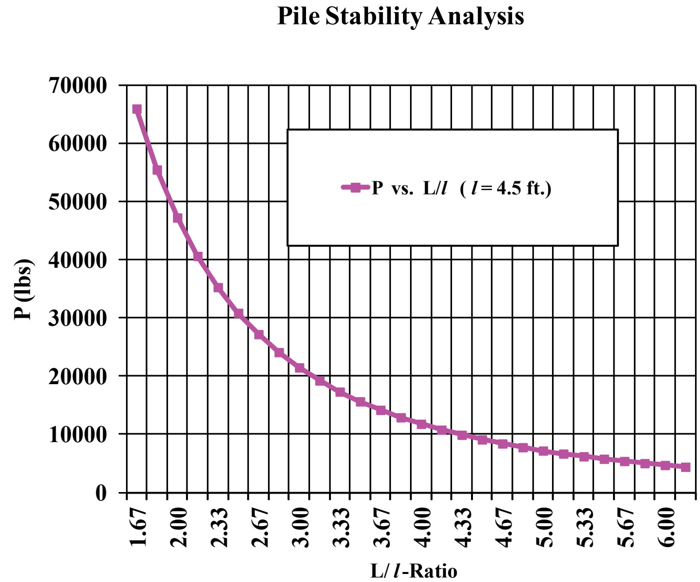

Figure 4: Allowable Bearing Capacity versus Pile Length Ratios (P vs. L/l).

User File

The User File is the first module of the pile evaluation system. Essentially, this is a large storage unit that contains the problem database; i.e., the inspection records for all piles and pile deteriorations, in numeric and alphanumeric format. The main feature is the free field input similar to current general structural analysis programs that are familiar to engineers. In this study, there are four pile datasets, with two sets for the local buckling algorithm and two for the overall elastic buckling algorithm. Each set includes 28 piles with various degrees of deterioration. The input consists of two alphanumeric and 13 numeric fields for a total of 15 input fields per row and pile. Thus, the input for pile A-1 is:

A-1 Pile D=12' Lp=12' H1=2.5' d1=3.00" t1=1.375" d2=2.75" t2=4"
H2=4.0' d1=3.25" t1=1.275" d2=2.75"t2=4"
Material= 1 (i.e. Pacific Coast Douglas Fir)

In the sample input presented here, the two alphanumeric inputs are A-1, the grid line, and pile, the type of structure (it can be a post, as well). The remaining 13 inputs are entirely numeric and are as follows: Lp is the length of the pile from the butt-end to the fixity-point, H1 and H2 are the dimensions from the butt end to the top and bottom of the deterioration, d1 and d2 are the remaining pile diameters along two orthogonal axes, t1 and t2 are the section loss thickness measured in the radial direction and corresponding to d1 and d2, and Material=1 is Pacific Coast Douglas Fir per the wood species designations of NDS-2005.

Pre-Processing

The Pre-Processing Module consists of automation algorithms for data input and output operations, and is developed in FORTRAN. This module performs the transfer of data from the user file to the processing unit. The Pre-Processor opens the user file, reads the pile records, performs record decomposition, and generates processor-ready input. The main features are the ability to read the free field inputs of the User File and to create the processor-ready input.

Processing

The Processing Module is also developed in FORTRAN. It has two computational algorithms that read the output generated by the pre-processor, perform the capacity analysis for local and overall elastic buckling, and create run-time output with the latest results of the analysis. Based on second-level counts, the processor differentiates the pile set into four subsets: piles, missing piles, posts, and missing posts.

The first computational algorithm checks for local instability at the deteriorated section of the pile. It determines the axial capacity at the pile's remaining cross section based on a modified version of NDS Equation 15.4-2. The modification assumes that the remaining pile's cross-sectional area is round, i.e. d1=d2, and employs the provisions of Section 3.7.3, Round Columns, to perform calculations based on an equivalent square column. The axial capacity is reported for two 28-pile datasets, for a total of 56 piles. Diameter d1, along the major axis of the cross-section, is varied incrementally from 3 to 7 inches for both pile sets. For the first pile set, eccentricity e1 about the major axis of the section is 10% of the nominal pile diameter, whereas eccentricity e2 about the minor axis is 5% of the nominal diameter. For the second set, both e1 and e2 are 1% of the nominal pile diameter. For all piles, the diameter is 12 inches and the length of the deteriorated segment is 1.5 feet.

The second computational algorithm checks for overall instability of the pile structure. It performs second-order elastic analysis for a pile model that has two structural modifications relative to the original as-built condition: a mechanical hinge and initial horizontal displacement at the deteriorated section of the pile. The pile fixity point is assumed below the mudline. The bottom wale has zero stiffness; i.e., the wale is assumed to be severely deteriorated or missing. The algorithm determines the critical buckling load, Pc, for two 28-pile datasets, for a total of 56 piles. The pile length ratio, L/l *l*, is varied incrementally from 1.7 to 6.3 for both pile sets. Analysis parameter l *l*, the length of the pile segment above the hinge, is 4.5 feet for the first pile set and 3.5 feet. for the second set. Run-time output includes each pile's axial capacity and both local and global buckling criteria for different values of d and L/l *l*. A sample computer output with pile capacity calculations for the 10% eccentricity dataset is included in the online version.

The Post-Processing Unit is a spreadsheet. Pile capacity curves are assembled for each computational algorithm.

Discussion of Results

Pile capacity curves for eccentricities of 1% and 10% of pile diameter, as calculated with NDS Equation 15.4-2, are shown in *Figure 3*. This illustrates the capacity degradation rate as the eccentricity of the applied axial load increases. Loss of capacity is due to bending moments introduced at the ends of the deteriorated portion of the pile. For the 10% curve and d1= 6 inches, i.e. an equivalent square area of 5.091x5.091 inches, the bearing capacity is 16,300 pounds (see web version with computer output for pile W-1). For this case, the bearing capacity of the pile is approximately 33 percent of the initial design capacity of 25 tons. For the 1% curve and d1= 6 inches, the capacity is 28,000 pounds, or 56 percent of the initial design capacity.

The pile capacity curve shown in *Figure 4* illustrates the variation of P, the allowable bearing capacity, for increasing pile length ratios L/*l* for the pile dataset for which the strut length *l* = 4.5 feet. For a 22.5-foot pile with the length ratio L/*l* = 4, the allowable capacity is 11,800 pounds, or approximately 24 percent of the initial design capacity of 25 tons.

Final Considerations

Based on Figure 2-7 in the NYCEDC *Waterfront Inspection Guidelines Manual*, the damage grade for advanced deteriorations is defined as a section loss of 25-50% of the undamaged cross-sectional area of the pile. Considering actual diameters d1=8.86 inches and d2=8.12 inches (i.e. an equivalent square area of 7.5x7.5 inches) which corresponds to a cross-sectional area that is half its original size, and extrapolating values for the 10% curve in *Figure 3*, the pile axial capacity is 43,000 pounds. This capacity is less than the initial pile design if a 25-ton pile is considered. Therefore, the pile classification is Severe Deterioration.

By contrast, the NYCEDC classification is still Advanced Damage and unchanged, since the section loss is still 50 percent of the original section. Hence, for piles with pronounced eccentricity at the damaged sections – end eccentricities of 10% of the nominal pile diameter or greater – the evaluation based strictly on loss of cross-sectional area can over-rate the structure. A Sever Degradation can pass as the lesser Advanced Degradation when the length of the deteriorated segment of the pile, and its end eccentricities, are not accounted for by the evaluation algorithm.

Conclusion

Structural analysis is a powerful method for the evaluation of deteriorated timber piling in older marine infrastructures. The power and versatility of the method is improved when multiple evaluation algorithms are used to determine the remaining capacity in a deteriorated structure. The dual algorithm approach presented here takes advantage of well researched code provisions such as NDS Equation 15.4-2, Section 15, Special Loading Conditions, and of traditional stability analysis for overall elastic buckling of column-type structures. Among notable features of this approach are: integral database that is periodically updated; consistency of evaluations; and, the opportunity to address large datasets by employing latest computer technology. For the most part, the analysis confirms the evaluation procedure recommended in the *Waterfront Inspection Guidelines Manual*. Exceptions are noted for the deteriorated pile sections displaying large eccentricities about the longitudinal axis of the pile.▪

```
**************************************************
*                                                *
*  EVALUATION OF TIMBER FOUNDATION PILING        *
*                                                *
*                                                *
* FILE NO.:   /0011.001                          *
*                                                *
* ENGINEER:   /BZ/         DATE: __/__/____      *
**************************************************
```

SUBJECT: 1
JOB NO. BZ_MK_AG_5_30_2

BULKHEAD STRUCTURE:

```
        STATION     =       .00
        GRADE ELEV. =     10.00 FT.
        MHW ELEV.   =      4.75 FT.
        MLW ELEV.   =       .00 FT.
        MUDLINE ELEV=     -1.00 FT.
```

SPECIES	Fc	Fb	Fv	Fcp	E	Emin
1	1250.	2450.	115.	230.	1500000.	790000.
2	1250.	2450.	115.	230.	1500000.	790000.
3	1200.	2400.	110.	250.	1500000.	790000.
4	1200.	2400.	110.	250.	1500000.	790000.

SUPORTS:

GRID	TYPE	SIZE	CAP	MAT	PEN
A1	PILE	12.000	PC1-AB	1	.125
B1	PILE	12.000	PC1-BC	1	.063
C1	PILE	12.000	PC1-CD	1	.031
D1	PILE	12.000	PC1-DE	1	1.000
E1	PILE	12.000	PC1-EF	1	.375
F1	PILE	12.000	PC1-FG	1	1.000
G1	PILE	12.000	PC1-GH	1	.500
H1	PILE	12.000	PC1-HI	1	.250
I1	PILE	12.000	PC1-IJ	1	.125
J1	PILE	12.000	PC1-JK	1	.063
K1	PILE	12.000	PC1-KL	1	.031
L1	PILE	12.000	PC1-LM	1	1.000
M1	PILE	12.000	PC1-MN	1	.375
N1	PILE	12.000	PC1-NO	1	1.000
O1	PILE	12.000	PC1-OP	1	.500
P1	PILE	12.000	PC1-PQ	1	.250

Q1	PILE	12.000	PC1-QR	1	.125
R1	PILE	12.000	PC1-RS	1	.063
S1	PILE	12.000	PC1-ST	1	.031
T1	PILE	12.000	PC1-TU	1	1.000
U1	PILE	12.000	PC1-UV	1	.375
V1	PILE	12.000	PC1-VX	1	1.000
X1	PILE	12.000	PC1-XY	1	.500
Y1	PILE	12.000	PC1-YZ	1	.250
Z1	PILE	12.000	PC1-ZA	1	.325
AA1	PILE	12.000	PC1-AA	1	.500
AB1	PILE	12.000	PC1-AB	1	.750
AC1	PILE	12.000	PC1-AC	1	.250

SUMMARY:

NUMBER OF PILES (AS BUILT):	28
PILES REMAINING :	28
POSTS REMAINING :	0
PILES MISSING :	0
POSTS MISSING :	0

ADJUSTMENT FACTORS, ASD/LRFD NDS-2005

COMPRESSION:			BENDING		
CD =	1.000	FT	CD =	1.000	FT
CM =	.910	IN	CM =	1.000	IN
Ct =	1.000	IN	Ct =	1.000	IN
Cu =	1.180	IN	CL =	1.180	IN
CF =	1.000	IN	CF =	1.000	IN
CP =	1.000	FT	Cfu=	1.000	FT
CCS =	1.100	IN	Ci =	1.000	IN
Cb =	1.000	IN	Cr =	1.000	IN
Csp =	.800	IN	Csp=	.770	IN

```
NEW ANALYSIS  :

GRID LINE     :     A1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     12.000 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =          4.500 FT
       D1 =          3.000 IN        D1 =          2.750 IN
       T1 =          3.300 IN        T1 =          3.250 IN
       D2 =          2.750 IN        D2 =          4.000 IN
       T2 =          4.025 IN        T2 =          2.000 IN
```

```
    Fc   =       1250.000 PSI       Fb   =       2450.000 PSI
    E    =    1500000.000 PSI       E    =    1500000.000 PSI
    Emin =     790000.000 PSI       Emin =     790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=     718900.000 PSI
    le   =         11.700 IN        le   =         36.976  IN
    FcE1 =      27971.288 PSI
    FcE2 =      27971.288 PSI

    FcE  =      27971.288 PSI       FbE  =      59387.646 PSI
    CP   =           .993           CL   =           .998
    Fc"  =       1173.472 PSI       Fb1  =       1883.416 PSI
                                    Fb2  =       1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       2.545 IN
                      e1  =       1.200 IN
                      d2  =       2.545 IN
                      e2  =        .600 IN
                      fc  =     388.625 PSI
                      Pcr =    2518.110 LBS
```

```
ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.287
                Lambda    =        .014 1/IN
                L/l       =       1.667
                Pcr       =  131860.040 LBS
                Pall      =   65930.020 LBS
```

```
         ****   END OF ANALYSIS PILE NO.  A1     ****
```

NEW ANALYSIS :

GRID LINE : B1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 12.750 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	3.143 IN	D1 =	2.750 IN
T1 =	3.229 IN	T1 =	3.250 IN
D2 =	2.881 IN	D2 =	4.000 IN
T2 =	3.960 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	30700.550 PSI		
FcE2 =	30700.550 PSI		
FcE =	30700.550 PSI	FbE =	62043.859 PSI
CP =	.994	CL =	.998
Fc" =	1174.176 PSI	Fb1 =	1883.551 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	2.667 IN
e1 =	1.200 IN
d2 =	2.667 IN
e2 =	.600 IN
fc =	403.829 PSI
Pcr =	2871.938 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.307
Lambda =	.013 1/IN
L/l =	1.833
Pcr =	110896.457 LBS
Pall =	55448.229 LBS

**** END OF ANALYSIS PILE NO. B1 ****

NEW ANALYSIS :

GRID LINE :	C1
STRUCTURE TYPE:	PILE
PILE DIAMETER :	12.000 IN
PILE LENGTH :	13.500 FT
SPECIES :	PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	3.286 IN	D1 =	2.750 IN
T1 =	3.157 IN	T1 =	3.250 IN
D2 =	3.012 IN	D2 =	4.000 IN
T2 =	3.894 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	33556.839 PSI		
FcE2 =	33556.839 PSI		
FcE =	33556.839 PSI	FbE =	64865.869 PSI
CP =	.995	CL =	.999
Fc" =	1174.787 PSI	Fb1 =	1883.683 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	2.788 IN
e1 =	1.200 IN
d2 =	2.788 IN
e2 =	.600 IN
fc =	418.284 PSI
Pcr =	3251.502 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.324
Lambda =	.012 1/IN
L/l =	2.000
Pcr =	94410.945 LBS
Pall =	47205.473 LBS

**** END OF ANALYSIS PILE NO. C1 ****

```
NEW ANALYSIS  :

GRID LINE     :     D1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     14.250 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =            4.500 FT
       D1 =          3.429 IN        D1 =            2.750 IN
       T1 =          3.086 IN        T1 =            3.250 IN
       D2 =          3.143 IN        D2 =            4.000 IN
       T2 =          3.829 IN        T2 =            2.000 IN
```

```
    Fc   =      1250.000 PSI       Fb   =       2450.000 PSI
    E    =   1500000.000 PSI       E    =    1500000.000 PSI
    Emin =    790000.000 PSI       Emin =     790000.000 PSI
    Emin"=    718900.000 PSI       Emin"=     718900.000 PSI
    le   =        11.700 IN        le   =         37.080  IN
    FcE1 =     36540.155 PSI
    FcE2 =     36540.155 PSI

    FcE  =     36540.155 PSI       FbE  =      67687.880 PSI
    CP   =          .995           CL   =           .999
    Fc"  =      1175.321 PSI       Fb1  =       1883.804 PSI
                                   Fb2  =       1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       2.909 IN
                      e1  =       1.200 IN
                      d2  =       2.909 IN
                      e2  =        .599 IN
                      fc  =     432.700 PSI
                      Pcr =    3662.591 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.339
                Lambda    =        .011 1/IN
                L/l       =       2.167
                Pcr       =   81218.186 LBS
                Pall      =   40609.093 LBS


         ****   END OF ANALYSIS PILE NO.  D1     ****
```

NEW ANALYSIS :

GRID LINE : E1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 15.000 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	3.571 IN	D1 =	2.750 IN
T1 =	3.014 IN	T1 =	3.250 IN
D2 =	3.274 IN	D2 =	4.000 IN
T2 =	3.763 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	39639.397 PSI		
FcE2 =	39639.397 PSI		
FcE =	39639.397 PSI	FbE =	70500.020 PSI
CP =	.995	CL =	.999
Fc" =	1175.789 PSI	Fb1 =	1883.914 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	3.030 IN
e1 =	1.201 IN
d2 =	3.030 IN
e2 =	.600 IN
fc =	446.225 PSI
Pcr =	4097.435 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L	=	1.353
Lambda	=	.011 1/IN
L/l	=	2.333
Pcr	=	70501.275 LBS
Pall	=	35250.638 LBS

**** END OF ANALYSIS PILE NO. E1 ****

```
NEW ANALYSIS  :

GRID LINE     :     F1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     15.750 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =           4.500 FT
       D1 =          3.714 IN        D1 =           2.750 IN
       T1 =          2.943 IN        T1 =           3.250 IN
       D2 =          3.405 IN        D2 =           4.000 IN
       T2 =          3.698 IN        T2 =           2.000 IN
```

```
    Fc    =      1250.000 PSI       Fb    =       2450.000 PSI
    E     =   1500000.000 PSI       E     =    1500000.000 PSI
    Emin  =    790000.000 PSI       Emin  =     790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le    =        11.700 IN        le    =         37.080  IN
    FcE1 =      42876.323 PSI
    FcE2 =      42876.323 PSI

    FcE  =      42876.323 PSI       FbE  =       73322.031 PSI
    CP   =           .996           CL   =            .999
    Fc"  =       1176.204 PSI       Fb1  =        1884.016 PSI
                                    Fb2  =        1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       3.152 IN
                      e1  =       1.200 IN
                      d2  =       3.152 IN
                      e2  =        .600 IN
                      fc  =     459.874 PSI
                      Pcr =    4567.601 LBS
```

```
ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.364
                Lambda    =        .010 1/IN
                L/l       =       2.500
                Pcr       =   61681.972 LBS
                Pall      =   30840.986 LBS
```

```
         ****   END OF ANALYSIS PILE NO.  F1     ****
```

NEW ANALYSIS :

GRID LINE	:	G1
STRUCTURE TYPE	:	PILE
PILE DIAMETER	:	12.000 IN
PILE LENGTH	:	16.500 FT
SPECIES	:	PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	3.857 IN	D1 =	2.750 IN
T1 =	2.871 IN	T1 =	3.250 IN
D2 =	3.536 IN	D2 =	4.000 IN
T2 =	3.632 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	46240.275 PSI		
FcE2 =	46240.275 PSI		
FcE =	46240.275 PSI	FbE =	76144.042 PSI
CP =	.996	CL =	.999
Fc" =	1176.572 PSI	Fb1 =	1884.110 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1	=	3.273 IN
e1	=	1.201 IN
d2	=	3.273 IN
e2	=	.600 IN
fc	=	472.778 PSI
Pcr	=	5064.184 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L	=	1.375
Lambda	=	.010 1/IN
L/l	=	2.667
Pcr	=	54341.461 LBS
Pall	=	27170.730 LBS

**** END OF ANALYSIS PILE NO. G1 ****

```
NEW ANALYSIS  :

GRID LINE     :     H1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     17.250 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =          4.500 FT
       D1 =          4.000 IN        D1 =          2.750 IN
       T1 =          2.800 IN        T1 =          3.250 IN
       D2 =          3.667 IN        D2 =          4.000 IN
       T2 =          3.567 IN        T2 =          2.000 IN
```

```
    Fc   =      1250.000 PSI       Fb   =       2450.000 PSI
    E    =   1500000.000 PSI       E    =    1500000.000 PSI
    Emin =    790000.000 PSI       Emin =     790000.000 PSI
    Emin"=    718900.000 PSI       Emin"=     718900.000 PSI
    le   =        11.700 IN        le   =         37.080  IN
    FcE1 =     49731.255 PSI
    FcE2 =     49731.255 PSI

    FcE  =     49731.255 PSI       FbE  =      78966.053 PSI
    CP   =          .996           CL   =           .999
    Fc"  =      1176.901 PSI       Fb1  =       1884.197 PSI
                                   Fb2  =       1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       3.394 IN
                      e1  =       1.200 IN
                      d2  =       3.394 IN
                      e2  =        .599 IN
                      fc  =     485.692 PSI
                      Pcr =    5595.284 LBS
```

```
ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.385
                Lambda    =        .009 1/IN
                L/l       =       2.833
                Pcr       =   48170.279 LBS
                Pall      =   24085.139 LBS


         ****   END OF ANALYSIS PILE NO.  H1     ****
```

```
NEW ANALYSIS  :

GRID LINE      :     I1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     18.000 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =          4.500 FT
       D1 =          4.143 IN        D1 =          2.750 IN
       T1 =          2.729 IN        T1 =          3.250 IN
       D2 =          3.798 IN        D2 =          4.000 IN
       T2 =          3.501 IN        T2 =          2.000 IN
```

```
    Fc   =       1250.000 PSI       Fb   =       2450.000 PSI
    E    =    1500000.000 PSI       E    =    1500000.000 PSI
    Emin =     790000.000 PSI       Emin =     790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=     718900.000 PSI
    le   =         11.700 IN        le   =         37.080  IN
    FcE1 =      53349.261 PSI
    FcE2 =      53349.261 PSI

    FcE  =      53349.261 PSI       FbE  =      81788.064 PSI
    CP   =           .997           CL   =           .999
    Fc"  =       1177.196 PSI       Fb1  =       1884.278 PSI
                                    Fb2  =       1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       3.515 IN
                      e1  =       1.200 IN
                      d2  =       3.515 IN
                      e2  =        .600 IN
                      fc  =     498.061 PSI
                      Pcr =    6155.208 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.393
                Lambda    =        .009 1/IN
                L/l       =       3.000
                Pcr       =   42935.718 LBS
                Pall      =   21467.859 LBS


         ****   END OF ANALYSIS PILE NO.  I1     ****
```

```
NEW ANALYSIS  :

GRID LINE      :     J1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     18.750 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                 SECTION  NO.  2:
       H1 =          3.000 FT         H2 =           4.500 FT
       D1 =          4.286 IN         D1 =           2.750 IN
       T1 =          2.657 IN         T1 =           3.250 IN
       D2 =          3.929 IN         D2 =           4.000 IN
       T2 =          3.436 IN         T2 =           2.000 IN
```

```
    Fc   =       1250.000 PSI       Fb   =        2450.000 PSI
    E    =    1500000.000 PSI       E    =     1500000.000 PSI
    Emin =     790000.000 PSI       Emin =      790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le   =         11.700 IN        le   =          37.080  IN
    FcE1 =      57094.295 PSI
    FcE2 =      57094.295 PSI

    FcE  =      57094.295 PSI       FbE  =       84610.075 PSI
    CP   =           .997           CL   =            .999
    Fc"  =       1177.461 PSI       Fb1  =        1884.354 PSI
                                    Fb2  =        1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       3.637 IN
                      e1  =       1.200 IN
                      d2  =       3.637 IN
                      e2  =        .600 IN
                      fc  =     510.082 PSI
                      Pcr =    6746.279 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.401
                Lambda    =        .008 1/IN
                L/l       =       3.167
                Pcr       =   38460.048 LBS
                Pall      =   19230.024 LBS


         ****   END OF ANALYSIS PILE NO.  J1     ****
```

```
NEW ANALYSIS  :

GRID LINE     :     K1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     19.500 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =          4.500 FT
       D1 =          4.429 IN        D1 =          2.750 IN
       T1 =          2.586 IN        T1 =          3.250 IN
       D2 =          4.060 IN        D2 =          4.000 IN
       T2 =          3.370 IN        T2 =          2.000 IN

    Fc   =       1250.000 PSI       Fb   =       2450.000 PSI
    E    =    1500000.000 PSI       E    =    1500000.000 PSI
    Emin =     790000.000 PSI       Emin =     790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=     718900.000 PSI
    le   =         11.700 IN        le   =         37.080  IN
    FcE1 =      60966.355 PSI
    FcE2 =      60966.355 PSI

    FcE  =      60966.355 PSI       FbE  =      87432.085 PSI
    CP   =           .997           CL   =           .999
    Fc"  =       1177.700 PSI       Fb1  =       1884.425 PSI
                                    Fb2  =       1886.500 IN


ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

                      d1  =       3.758 IN
                      e1  =       1.200 IN
                      d2  =       3.758 IN
                      e2  =        .600 IN
                      fc  =     521.765 PSI
                      Pcr =    7368.790 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2

                Lambda*L  =       1.408
                Lambda    =        .008 1/IN
                L/l       =       3.333
                Pcr       =   34605.631 LBS
                Pall      =   17302.815 LBS


         ****   END OF ANALYSIS PILE NO.  K1     ****
```

NEW ANALYSIS :

GRID LINE : L1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 20.250 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	4.571 IN	D1 =	2.750 IN
T1 =	2.514 IN	T1 =	3.250 IN
D2 =	4.190 IN	D2 =	4.000 IN
T2 =	3.305 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	64935.735 PSI		
FcE2 =	64935.735 PSI		
FcE =	64935.735 PSI	FbE =	90233.458 PSI
CP =	.997	CL =	.999
Fc" =	1177.916 PSI	Fb1 =	1884.490 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	3.878 IN
e1 =	1.201 IN
d2 =	3.878 IN
e2 =	.600 IN
fc =	532.841 PSI
Pcr =	8015.176 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.415
Lambda =	.007 1/IN
L/l =	3.500
Pcr =	31264.542 LBS
Pall =	15632.271 LBS

**** END OF ANALYSIS PILE NO. L1 ****

```
NEW ANALYSIS  :

GRID LINE     :     M1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     21.000 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =             4.500 FT
       D1 =          4.714 IN        D1 =             2.750 IN
       T1 =          2.443 IN        T1 =             3.250 IN
       D2 =          4.321 IN        D2 =             4.000 IN
       T2 =          3.239 IN        T2 =             2.000 IN

    Fc   =       1250.000 PSI       Fb   =        2450.000 PSI
    E    =    1500000.000 PSI       E    =     1500000.000 PSI
    Emin =     790000.000 PSI       Emin =      790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le   =         11.700 IN        le   =          37.080  IN
    FcE1 =      69060.920 PSI
    FcE2 =      69060.920 PSI

    FcE  =      69060.920 PSI       FbE  =       93055.469 PSI
    CP   =           .997           CL   =            .999
    Fc"  =       1178.113 PSI       Fb1  =        1884.552 PSI
                                    Fb2  =        1886.500 IN

ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

                      d1  =       4.000 IN
                      e1  =       1.200 IN
                      d2  =       4.000 IN
                      e2  =        .601 IN
                      fc  =     543.876 PSI
                      Pcr =    8700.892 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2

                Lambda*L  =       1.421
                Lambda    =        .007 1/IN
                L/l       =       3.667
                Pcr       =   28351.198 LBS
                Pall      =   14175.599 LBS

         ****   END OF ANALYSIS PILE NO.  M1     ****
```

NEW ANALYSIS :

GRID LINE :	N1
STRUCTURE TYPE:	PILE
PILE DIAMETER :	12.000 IN
PILE LENGTH :	21.750 FT
SPECIES :	PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:			SECTION NO. 2:		
H1 =	3.000	FT	H2 =	4.500	FT
D1 =	4.857	IN	D1 =	2.750	IN
T1 =	2.371	IN	T1 =	3.250	IN
D2 =	4.452	IN	D2 =	4.000	IN
T2 =	3.174	IN	T2 =	2.000	IN

Fc =	1250.000	PSI	Fb =	2450.000	PSI
E =	1500000.000	PSI	E =	1500000.000	PSI
Emin =	790000.000	PSI	Emin =	790000.000	PSI
Emin"=	718900.000	PSI	Emin"=	718900.000	PSI
le =	11.700	IN	le =	37.080	IN
FcE1 =	73313.132	PSI			
FcE2 =	73313.132	PSI			
FcE =	73313.132	PSI	FbE =	95877.480	PSI
CP =	.998		CL =	.999	
Fc" =	1178.293	PSI	Fb1 =	1884.611	PSI
			Fb2 =	1886.500	IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	4.121	IN
e1 =	1.201	IN
d2 =	4.121	IN
e2 =	.600	IN
fc =	554.601	PSI
Pcr =	9418.754	LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.427	
Lambda =	.007	1/IN
L/l =	3.833	
Pcr =	25797.036	LBS
Pall =	12898.518	LBS

**** END OF ANALYSIS PILE NO. N1 ****

NEW ANALYSIS :

GRID LINE : O1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 22.500 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	5.000 IN	D1 =	2.750 IN
T1 =	2.300 IN	T1 =	3.250 IN
D2 =	4.583 IN	D2 =	4.000 IN
T2 =	3.108 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	77692.372 PSI		
FcE2 =	77692.372 PSI		
FcE =	77692.372 PSI	FbE =	98699.491 PSI
CP =	.998	CL =	.999
Fc" =	1178.457 PSI	Fb1 =	1884.666 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	4.242 IN
e1 =	1.200 IN
d2 =	4.242 IN
e2 =	.600 IN
fc =	565.024 PSI
Pcr =	10168.968 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.432
Lambda =	.007 1/IN
L/l =	4.000
Pcr =	23546.610 LBS
Pall =	11773.305 LBS

**** END OF ANALYSIS PILE NO. O1 ****

```
NEW ANALYSIS  :

GRID LINE     :     P1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     23.250 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =          4.500 FT
       D1 =          5.143 IN        D1 =          2.750 IN
       T1 =          2.229 IN        T1 =          3.250 IN
       D2 =          4.714 IN        D2 =          4.000 IN
       T2 =          3.043 IN        T2 =          2.000 IN

    Fc   =       1250.000 PSI       Fb   =       2450.000 PSI
    E    =    1500000.000 PSI       E    =    1500000.000 PSI
    Emin =     790000.000 PSI       Emin =     790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=     718900.000 PSI
    le   =         11.700 IN        le   =         37.080  IN
    FcE1 =      82198.638 PSI
    FcE2 =      82198.638 PSI

    FcE  =      82198.638 PSI       FbE  =     101521.501 PSI
    CP   =           .998           CL   =           .999
    Fc"  =       1178.608 PSI       Fb1  =       1884.717 PSI
                                    Fb2  =       1886.500 IN


ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

                      d1  =       4.364 IN
                      e1  =       1.200 IN
                      d2  =       4.364 IN
                      e2  =        .600 IN
                      fc  =     575.352 PSI
                      Pcr =   10955.435 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2

                Lambda*L  =       1.437
                Lambda    =        .006 1/IN
                L/l       =       4.167
                Pcr       =   21554.701 LBS
                Pall      =   10777.350 LBS


         ****   END OF ANALYSIS PILE NO.  P1     ****
```

```
NEW ANALYSIS  :

GRID LINE      :     Q1
STRUCTURE TYPE:      PILE
PILE DIAMETER :      12.000 IN
PILE LENGTH   :      24.000 FT
SPECIES       :      PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                 SECTION  NO.  2:
       H1 =          3.000 FT         H2 =           4.500 FT
       D1 =          5.286 IN         D1 =           2.750 IN
       T1 =          2.157 IN         T1 =           3.250 IN
       D2 =          4.845 IN         D2 =           4.000 IN
       T2 =          2.977 IN         T2 =           2.000 IN
```

```
    Fc   =       1250.000 PSI       Fb   =        2450.000 PSI
    E    =    1500000.000 PSI       E    =     1500000.000 PSI
    Emin =     790000.000 PSI       Emin =      790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le   =         11.700 IN        le   =          37.080  IN
    FcE1 =      86831.931 PSI
    FcE2 =      86831.931 PSI

    FcE  =      86831.931 PSI       FbE  =      104343.512 PSI
    CP   =           .998           CL   =            .999
    Fc"  =       1178.747 PSI       Fb1  =        1884.766 PSI
                                    Fb2  =        1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       4.485 IN
                      e1  =       1.200 IN
                      d2  =       4.485 IN
                      e2  =        .601 IN
                      fc  =     585.006 PSI
                      Pcr =   11767.153 LBS
```

```
ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.441
                Lambda    =        .006 1/IN
                L/l       =       4.333
                Pcr       =   19784.136 LBS
                Pall      =    9892.068 LBS
```

```
         ****   END OF ANALYSIS PILE NO.  Q1     ****
```

NEW ANALYSIS :

GRID LINE	:	R1
STRUCTURE TYPE	:	PILE
PILE DIAMETER	:	12.000 IN
PILE LENGTH	:	24.750 FT
SPECIES	:	PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	5.429 IN	D1 =	2.750 IN
T1 =	2.086 IN	T1 =	3.250 IN
D2 =	4.976 IN	D2 =	4.000 IN
T2 =	2.912 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	91592.251 PSI		
FcE2 =	91592.251 PSI		
FcE =	91592.251 PSI	FbE =	107165.523 PSI
CP =	.998	CL =	.999
Fc" =	1178.874 PSI	Fb1 =	1884.813 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1	=	4.606 IN
e1	=	1.200 IN
d2	=	4.606 IN
e2	=	.600 IN
fc	=	594.778 PSI
Pcr	=	12619.591 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L	=	1.446
Lambda	=	.006 1/IN
L/l	=	4.500
Pcr	=	18204.138 LBS
Pall	=	9102.069 LBS

**** END OF ANALYSIS PILE NO. R1 ****

```
NEW ANALYSIS  :

GRID LINE      :      S1
STRUCTURE TYPE:       PILE
PILE DIAMETER :       12.000 IN
PILE LENGTH    :      25.500 FT
SPECIES        :      PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                  SECTION  NO.  2:
       H1 =          3.000 FT          H2 =           4.500 FT
       D1 =          5.571 IN          D1 =           2.750 IN
       T1 =          2.014 IN          T1 =           3.250 IN
       D2 =          5.107 IN          D2 =           4.000 IN
       T2 =          2.846 IN          T2 =           2.000 IN

    Fc    =       1250.000 PSI       Fb    =        2450.000 PSI
    E     =    1500000.000 PSI       E     =     1500000.000 PSI
    Emin =      790000.000 PSI       Emin =       790000.000 PSI
    Emin"=      718900.000 PSI       Emin"=       718900.000 PSI
    le    =         11.700 IN        le    =          37.080  IN
    FcE1 =       96462.282 PSI
    FcE2 =       96462.282 PSI

    FcE   =      96462.282 PSI       FbE   =      109977.663 PSI
    CP    =           .998           CL    =            .999
    Fc"   =       1178.992 PSI       Fb1   =        1884.857 PSI
                                     Fb2   =        1886.500 IN


ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

                      d1  =       4.727 IN
                      e1  =       1.201 IN
                      d2  =       4.727 IN
                      e2  =        .600 IN
                      fc  =     603.766 PSI
                      Pcr =   13491.407 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2

                Lambda*L  =       1.450
                Lambda    =        .006 1/IN
                L/l       =       4.667
                Pcr       =   16789.048 LBS
                Pall      =    8394.524 LBS


         ****   END OF ANALYSIS PILE NO.  S1     ****
```

```
NEW ANALYSIS  :

GRID LINE     :     T1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     26.250 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =           4.500 FT
       D1 =          5.714 IN        D1 =           2.750 IN
       T1 =          1.943 IN        T1 =           3.250 IN
       D2 =          5.238 IN        D2 =           4.000 IN
       T2 =          2.781 IN        T2 =           2.000 IN

    Fc   =       1250.000 PSI       Fb   =        2450.000 PSI
    E    =    1500000.000 PSI       E    =     1500000.000 PSI
    Emin =     790000.000 PSI       Emin =      790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le   =         11.700 IN        le   =          37.080  IN
    FcE1 =     101476.212 PSI
    FcE2 =     101476.212 PSI

    FcE  =     101476.212 PSI       FbE  =      112799.674 PSI
    CP   =           .998           CL   =            .999
    Fc"  =       1179.101 PSI       Fb1  =        1884.898 PSI
                                    Fb2  =        1886.500 IN


ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

                      d1  =       4.848 IN
                      e1  =       1.200 IN
                      d2  =       4.848 IN
                      e2  =        .600 IN
                      fc  =     613.018 PSI
                      Pcr =   14410.159 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2

                Lambda*L  =       1.453
                Lambda    =        .006 1/IN
                L/l       =       4.833
                Pcr       =   15517.345 LBS
                Pall      =    7758.672 LBS


         ****   END OF ANALYSIS PILE NO.  T1     ****
```

NEW ANALYSIS :

GRID LINE : U1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 27.000 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	5.857 IN	D1 =	2.750 IN
T1 =	1.871 IN	T1 =	3.250 IN
D2 =	5.369 IN	D2 =	4.000 IN
T2 =	2.715 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	106617.169 PSI		
FcE2 =	106617.169 PSI		
FcE =	106617.169 PSI	FbE =	115621.685 PSI
CP =	.998	CL =	.999
Fc" =	1179.202 PSI	Fb1 =	1884.938 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	4.970 IN
e1 =	1.201 IN
d2 =	4.970 IN
e2 =	.601 IN
fc =	621.634 PSI
Pcr =	15352.991 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.457
Lambda =	.005 1/IN
L/l =	5.000
Pcr =	14370.871 LBS
Pall =	7185.436 LBS

**** END OF ANALYSIS PILE NO. U1 ****

NEW ANALYSIS :

GRID LINE :	W1
STRUCTURE TYPE:	PILE
PILE DIAMETER :	12.000 IN
PILE LENGTH :	27.750 FT
SPECIES :	PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	6.000 IN	D1 =	2.750 IN
T1 =	1.800 IN	T1 =	3.250 IN
D2 =	5.500 IN	D2 =	4.000 IN
T2 =	2.650 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	111885.152 PSI		
FcE2 =	111885.152 PSI		
FcE =	111885.152 PSI	FbE =	118443.696 PSI
CP =	.998	CL =	.999
Fc" =	1179.296 PSI	Fb1 =	1884.976 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	5.091 IN
e1 =	1.200 IN
d2 =	5.091 IN
e2 =	.600 IN
fc =	630.399 PSI
Pcr =	16338.762 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.460
Lambda =	.005 1/IN
L/l =	5.167
Pcr =	13334.224 LBS
Pall =	6667.112 LBS

**** END OF ANALYSIS PILE NO. W1 ****

```
NEW ANALYSIS  :

GRID LINE      :     X1
STRUCTURE TYPE:      PILE
PILE DIAMETER :      12.000 IN
PILE LENGTH    :     28.500 FT
SPECIES        :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                 SECTION  NO.  2:
       H1 =          3.000 FT         H2 =           4.500 FT
       D1 =          6.143 IN         D1 =           2.750 IN
       T1 =          1.729 IN         T1 =           3.250 IN
       D2 =          5.631 IN         D2 =           4.000 IN
       T2 =          2.585 IN         T2 =           2.000 IN
```

```
    Fc   =       1250.000 PSI       Fb   =        2450.000 PSI
    E    =    1500000.000 PSI       E    =     1500000.000 PSI
    Emin =     790000.000 PSI       Emin =      790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le   =         11.700 IN        le   =          37.080  IN
    FcE1 =     117280.163 PSI
    FcE2 =     117280.163 PSI

    FcE  =     117280.163 PSI       FbE  =      121265.707 PSI
    CP   =           .998           CL   =            .999
    Fc"  =       1179.383 PSI       Fb1  =        1885.012 PSI
                                    Fb2  =        1886.500 IN
```

```
ANALYSIS I :   NDS-2005 (EQ. 15.4-2)
```

```
                      d1  =       5.212 IN
                      e1  =       1.200 IN
                      d2  =       5.212 IN
                      e2  =        .599 IN
                      fc  =     638.932 PSI
                      Pcr =   17358.427 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2
```

```
                Lambda*L  =       1.463
                Lambda    =        .005 1/IN
                L/l       =       5.333
                Pcr       =   12394.270 LBS
                Pall      =    6197.135 LBS


         ****   END OF ANALYSIS PILE NO.  X1     ****
```

NEW ANALYSIS :

GRID LINE : Y1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 29.250 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:			SECTION NO. 2:		
H1 =	3.000	FT	H2 =	4.500	FT
D1 =	6.286	IN	D1 =	2.750	IN
T1 =	1.657	IN	T1 =	3.250	IN
D2 =	5.762	IN	D2 =	4.000	IN
T2 =	2.519	IN	T2 =	2.000	IN

Fc =	1250.000	PSI	Fb =	2450.000	PSI
E =	1500000.000	PSI	E =	1500000.000	PSI
Emin =	790000.000	PSI	Emin =	790000.000	PSI
Emin"=	718900.000	PSI	Emin"=	718900.000	PSI
le =	11.700	IN	le =	37.080	IN
FcE1 =	122802.200	PSI			
FcE2 =	122802.200	PSI			
FcE =	122802.200	PSI	FbE =	124087.717	PSI
CP =	.999		CL =	.999	
Fc" =	1179.464	PSI	Fb1 =	1885.046	PSI
			Fb2 =	1886.500	IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	5.334	IN
e1 =	1.200	IN
d2 =	5.334	IN
e2 =	.600	IN
fc =	646.855	PSI
Pcr =	18401.128	LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.466	
Lambda =	.005	1/IN
L/l =	5.500	
Pcr =	11539.758	LBS
Pall =	5769.879	LBS

**** END OF ANALYSIS PILE NO. Y1 ****

```
NEW ANALYSIS  :

GRID LINE     :     Z1
STRUCTURE TYPE:     PILE
PILE DIAMETER :     12.000 IN
PILE LENGTH   :     30.000 FT
SPECIES       :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT        H2 =           4.500 FT
       D1 =          6.429 IN        D1 =           2.750 IN
       T1 =          1.586 IN        T1 =           3.250 IN
       D2 =          5.893 IN        D2 =           4.000 IN
       T2 =          2.454 IN        T2 =           2.000 IN

    Fc   =       1250.000 PSI       Fb   =        2450.000 PSI
    E    =    1500000.000 PSI       E    =     1500000.000 PSI
    Emin =     790000.000 PSI       Emin =      790000.000 PSI
    Emin"=     718900.000 PSI       Emin"=      718900.000 PSI
    le   =         11.700 IN        le   =          37.080  IN
    FcE1 =     128451.265 PSI
    FcE2 =     128451.265 PSI

    FcE  =     128451.265 PSI       FbE  =      126909.728 PSI
    CP   =           .999           CL   =            .999
    Fc"  =       1179.540 PSI       Fb1  =        1885.079 PSI
                                    Fb2  =        1886.500 IN


ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

                      d1  =       5.455 IN
                      e1  =       1.200 IN
                      d2  =       5.455 IN
                      e2  =        .599 IN
                      fc  =     654.947 PSI
                      Pcr =   19488.400 LBS

ANALYSIS II:   OVERALL ELASTIC BUCKLING: FS=2

                Lambda*L  =       1.469
                Lambda    =        .005 1/IN
                L/l       =       5.667
                Pcr       =   10761.007 LBS
                Pall      =    5380.504 LBS


         ****   END OF ANALYSIS PILE NO.  Z1     ****
```

NEW ANALYSIS :

GRID LINE : AA1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 30.750 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:			SECTION NO. 2:		
H1 =	3.000	FT	H2 =	4.500	FT
D1 =	6.571	IN	D1 =	2.750	IN
T1 =	1.514	IN	T1 =	3.250	IN
D2 =	6.024	IN	D2 =	4.000	IN
T2 =	2.388	IN	T2 =	2.000	IN

Fc =	1250.000	PSI	Fb =	2450.000	PSI
E =	1500000.000	PSI	E =	1500000.000	PSI
Emin =	790000.000	PSI	Emin =	790000.000	PSI
Emin"=	718900.000	PSI	Emin"=	718900.000	PSI
le =	11.700	IN	le =	37.080	IN
FcE1 =	134206.932	PSI			
FcE2 =	134206.932	PSI			
FcE =	134206.932	PSI	FbE =	129721.868	PSI
CP =	.999		CL =	.999	
Fc" =	1179.611	PSI	Fb1 =	1885.110	PSI
			Fb2 =	1886.500	IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	5.576	IN
e1 =	1.201	IN
d2 =	5.576	IN
e2 =	.600	IN
fc =	662.326	PSI
Pcr =	20591.026	LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.472	
Lambda =	.005	1/IN
L/l =	5.833	
Pcr =	10049.650	LBS
Pall =	5024.825	LBS

**** END OF ANALYSIS PILE NO. AA1 ****

NEW ANALYSIS :

```
GRID LINE      :     AB1
STRUCTURE TYPE:      PILE
PILE DIAMETER :      12.000 IN
PILE LENGTH    :     31.500 FT
SPECIES        :     PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:
       SECTION  NO. 1:                SECTION  NO.  2:
       H1 =          3.000 FT          H2 =           4.500 FT
       D1 =          6.714 IN          D1 =           2.750 IN
       T1 =          1.443 IN          T1 =           3.250 IN
       D2 =          6.155 IN          D2 =           4.000 IN
       T2 =          2.323 IN          T2 =           2.000 IN
```

```
    Fc    =       1250.000 PSI       Fb    =        2450.000 PSI
    E     =    1500000.000 PSI       E     =     1500000.000 PSI
    Emin =      790000.000 PSI       Emin =       790000.000 PSI
    Emin"=      718900.000 PSI       Emin"=       718900.000 PSI
    le    =         11.700 IN        le    =          37.080  IN
    FcE1 =      140109.606 PSI
    FcE2 =      140109.606 PSI

    FcE   =     140109.606 PSI       FbE   =      132543.879 PSI
    CP    =           .999           CL    =            .999
    Fc"   =       1179.677 PSI       Fb1   =        1885.140 PSI
                                     Fb2   =        1886.500 IN
```

ANALYSIS I :   NDS-2005 (EQ. 15.4-2)

```
                      d1  =       5.697 IN
                      e1  =       1.200 IN
                      d2  =       5.697 IN
                      e2  =        .599 IN
                      fc  =     670.008 PSI
                      Pcr =   21745.985 LBS
```

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

```
                Lambda*L  =       1.474
                Lambda    =        .005 1/IN
                L/l       =       6.000
                Pcr       =    9398.429 LBS
                Pall      =    4699.215 LBS
```

****   END OF ANALYSIS PILE NO. AB1   ****

NEW ANALYSIS :

GRID LINE : AC1
STRUCTURE TYPE: PILE
PILE DIAMETER : 12.000 IN
PILE LENGTH : 32.250 FT
SPECIES : PACIFIC COAST DOUGLAS FIR

CRITICAL X-SECTIONS:

SECTION NO. 1:		SECTION NO. 2:	
H1 =	3.000 FT	H2 =	4.500 FT
D1 =	6.857 IN	D1 =	2.750 IN
T1 =	1.371 IN	T1 =	3.250 IN
D2 =	6.286 IN	D2 =	4.000 IN
T2 =	2.257 IN	T2 =	2.000 IN

Fc =	1250.000 PSI	Fb =	2450.000 PSI
E =	1500000.000 PSI	E =	1500000.000 PSI
Emin =	790000.000 PSI	Emin =	790000.000 PSI
Emin"=	718900.000 PSI	Emin"=	718900.000 PSI
le =	11.700 IN	le =	37.080 IN
FcE1 =	146139.307 PSI		
FcE2 =	146139.307 PSI		
FcE =	146139.307 PSI	FbE =	135365.890 PSI
CP =	.999	CL =	.999
Fc" =	1179.740 PSI	Fb1 =	1885.169 PSI
		Fb2 =	1886.500 IN

ANALYSIS I : NDS-2005 (EQ. 15.4-2)

d1 =	5.818 IN
e1 =	1.201 IN
d2 =	5.818 IN
e2 =	.600 IN
fc =	677.115 PSI
Pcr =	22922.435 LBS

ANALYSIS II: OVERALL ELASTIC BUCKLING: FS=2

Lambda*L =	1.477
Lambda =	.004 1/IN
L/l =	6.167
Pcr =	8801.022 LBS
Pall =	4400.511 LBS

**** END OF ANALYSIS PILE NO. AC1 ****

```
   JOINT COORDINATES     :   60
   MEMBER INCIDENCES     :   30
   SUPPORTS              :   28
   MEMBER PROPERTIES     :   28
   UNIFORM MEMBER LOADS  :    2
```

Stop - Program Terminated