EVALUATION OF ANALYSIS PROCEDURES FOR THE DESIGN OF SHELL TYPE EXPANSION ANCHORED PLATE ASSEMBLIES IN CONCRETE

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January 2, 1980

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1.0 PURPOSE

The purpose of this report is to demonstrate that rigid plate analysis procedures may be used in the design of shell type expansion anchored baseplate assemblies when appropriate amplification factors are applied to the resultant anchor forces to account for baseplate flexibility. It will subsequently be shown that amplification factors may be derived in conjunction with the actual load versus displacement curve using a finite element solution to properly account for baseplate flexibility.

Baseplate flexibility may result in increased anchor forces over and above those determined by rigid plate analysis for the following reasons:

A. Prying action forces acting between the baseplate and the concrete surface.

B. Unequal load distribution in plate assemblies in which the applied load is not equidistant to each anchor in the assembly.

This report presents the amplification factors for three typical shell type expansion anchor baseplate assemblies used to support mechanical components in nuclear power stations. These amplification factors are subsequently applied to anchor reactions based upon rigid plate analysis to conservatively account for the effects of baseplate flexibility. The finite element model used to determine the amplification factors utilizes conservative load-displacement curves for shell type expansion anchors based upon manufacturer's data. The analysis also considers the complete range of applied tension/moment load combinations.

2.0 METHOD OF ANALYSIS

The effect of baseplate flexibility on the anchor reaction was analyzed using a finite element idealization of the baseplate. The ratio of maximum anchor reaction to the anchor reaction obtained by the rigid plate analysis is defined as the amplification factor. Amplification factors were obtained for the applied load acting as a pure tension load on the plate as well as at an eccentricity of three inches, and making an angle ϕ with the plane of the baseplate. By varying the angle ϕ, various combinations of tension and moment load were considered.

The concrete was modeled with unidirectional springs which resist compression only. This behavior introduces nonlinearity into analysis, and makes the amplification factors dependent on the magnitude of applied loading. For each value of the angle ϕ, a series of analyses were performed by varying the magnitude of the applied loading, such that the most stressed anchor was loaded from $P_u/12$ to $P_u/4$, where P_u is the manufacturer's recommended ultimate load.

The results of this study indicate that, in this range, the amplification factors are rather insensitive to the load amplitude. All the results presented subsequently correspond to the most conservative values which were thus obtained.

In the analysis, the anchors were modeled as truss members, the stiffness of which was conservatively determined from the manufacturer's test results described in Section 4.0 of this report.

3.0 ASSEMBLIES CONSIDERED

Three typical assemblies, consisting of one each of four, six and eight anchors, as shown in Figure 1, were considered in the analysis.

4.0 LOAD-DISPLACEMENT DIAGRAMS FOR ANCHORS

Shell type anchors show a nonlinear softening type behavior. Manufacturer's test data indicate that shell type expansion anchored plates do not behave as rigid supports; as the anchor load increases, the anchor displaces, thus reducing the effects of prying action.

In this report, a conservative bilinear idealization was used for the load-displacement behavior of anchors. The initial slope (k_1) was selected to correspond to the highest initial slope of the manufacturer's curves for that anchor diameter. The second slope (k_2) was chosen as the average slope of the clearly curving portion of the test results. The ultimate load of the anchor was assumed to equal the ultimate load value recommended by the manufacturer.

The conservative idealized load-displacement diagrams established for 1/2-inch and 3/4-inch diameter anchors are shown in Figure 2. Values of load and corresponding displacement at the knee and ultimate for these idealizations are listed in Table 1.

5.0 RESULTS

Calculated amplification factors are given in Table 2. It will be noted that the amplification factors for the four anchor assembly is equal to unity for all values of ϕ. The prying action forces are relieved in this assembly due to the load-displacement characteristic of the anchor. This conslusion can be generalized to a two anchor assembly, also.

For the six anchor assembly, the maximum amplification factor is 2.1 for the pure tension case. The most stressed anchor in this case is the middle anchor. It is evident that this is due to unequal distribution of loads on the anchors in the pure tension case. For other values of ϕ, amplification factors are smaller.

For the eight anchor assembly, the maximum amplification factor is 1.88 for the pure moment case for the four anchors nearest to the plate centerline. For other angles of load application, the amplification factor is 1.67.

These amplification factors, when applied to anchor reactions computed by rigid plate analysis, conservatively give the effect of plate flexibility.

Diameter (inches)	Values at Knee		k_1	Values at Ultimate		k_2
	P kips	δ inches	kips/inch	P kips	δ inches	kips/inch
1/2	6	0.0344	174	8.5	0.0995	38.4
3/4	9	0.0374	241	16.2	0.213	41.0

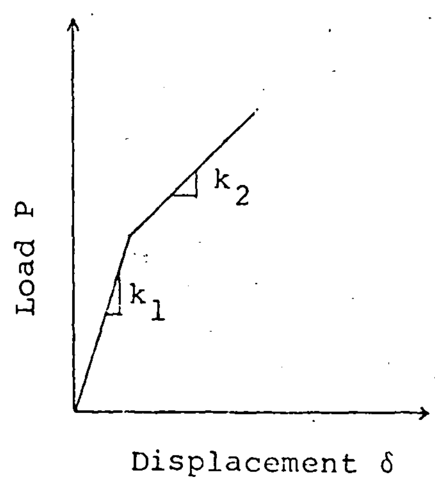


TABLE 1 Parameters of Idealized Load-Displacement Diagrams for Shell Type Anchors

AMPLIFICATION FACTORS

Angle	Anchor Assembly 1	Anchor Assembly 2	Anchor Assembly 3
0	1.0	1.0	1.88
15°	1.0	1.0	1.67
30°	1.0	1.0	1.67
60°	1.0	1.5	1.67
90°	1.0	2.1	1.67

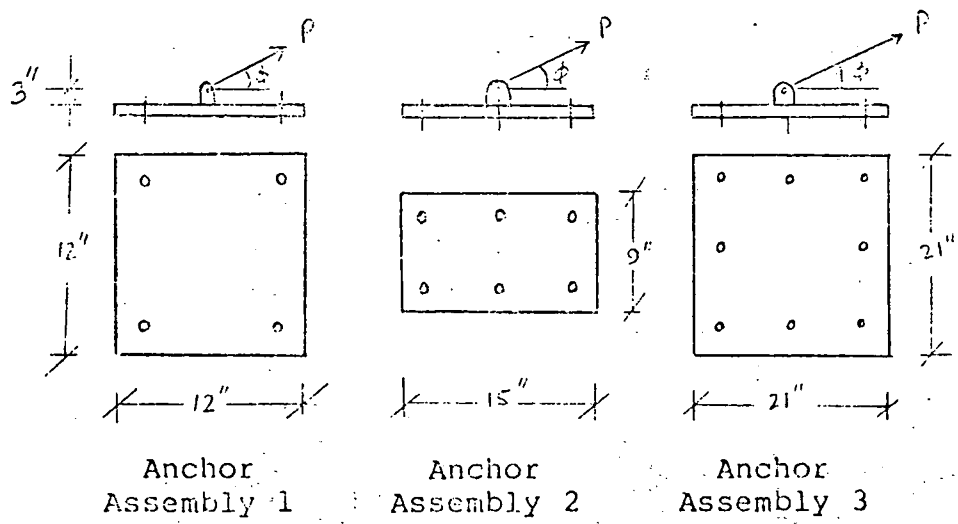
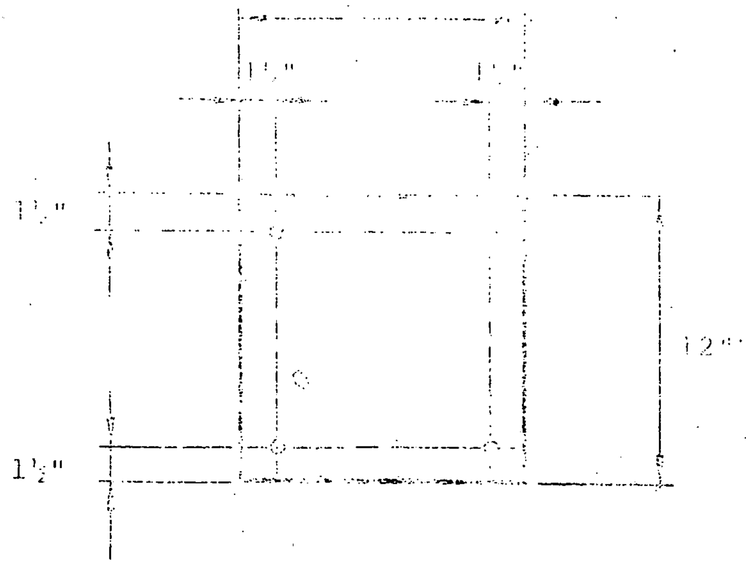


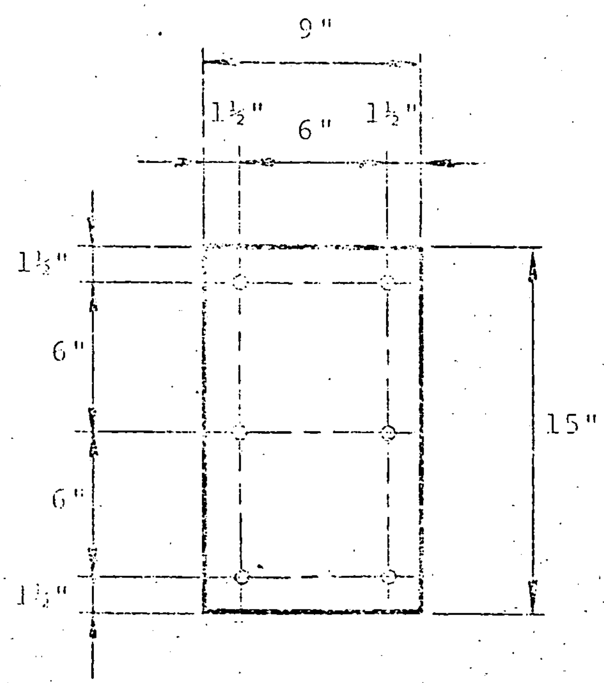
TABLE 2 Results of Analysis for Baseplates with Shell Type Anchors



ASSEMBLY NO. 1

Plate 3/4" × 12" × 12"

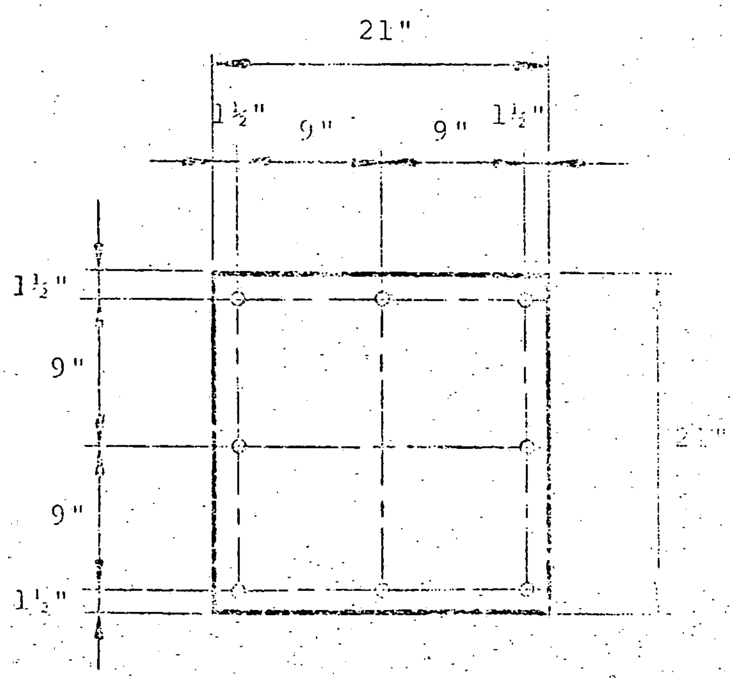
Four 3/4-inch Diameter Anchors



ASSEMBLY NO. 2

Plate 1/2" × 9" × 15"

Six 1/2-inch Diameter Anchors



ASSEMBLY NO. 3

Plate 3/4" × 21" × 21"

Eight 3/4-inch Diameter An

FIGURE 1 Types of Expansion Anchor Assemblies

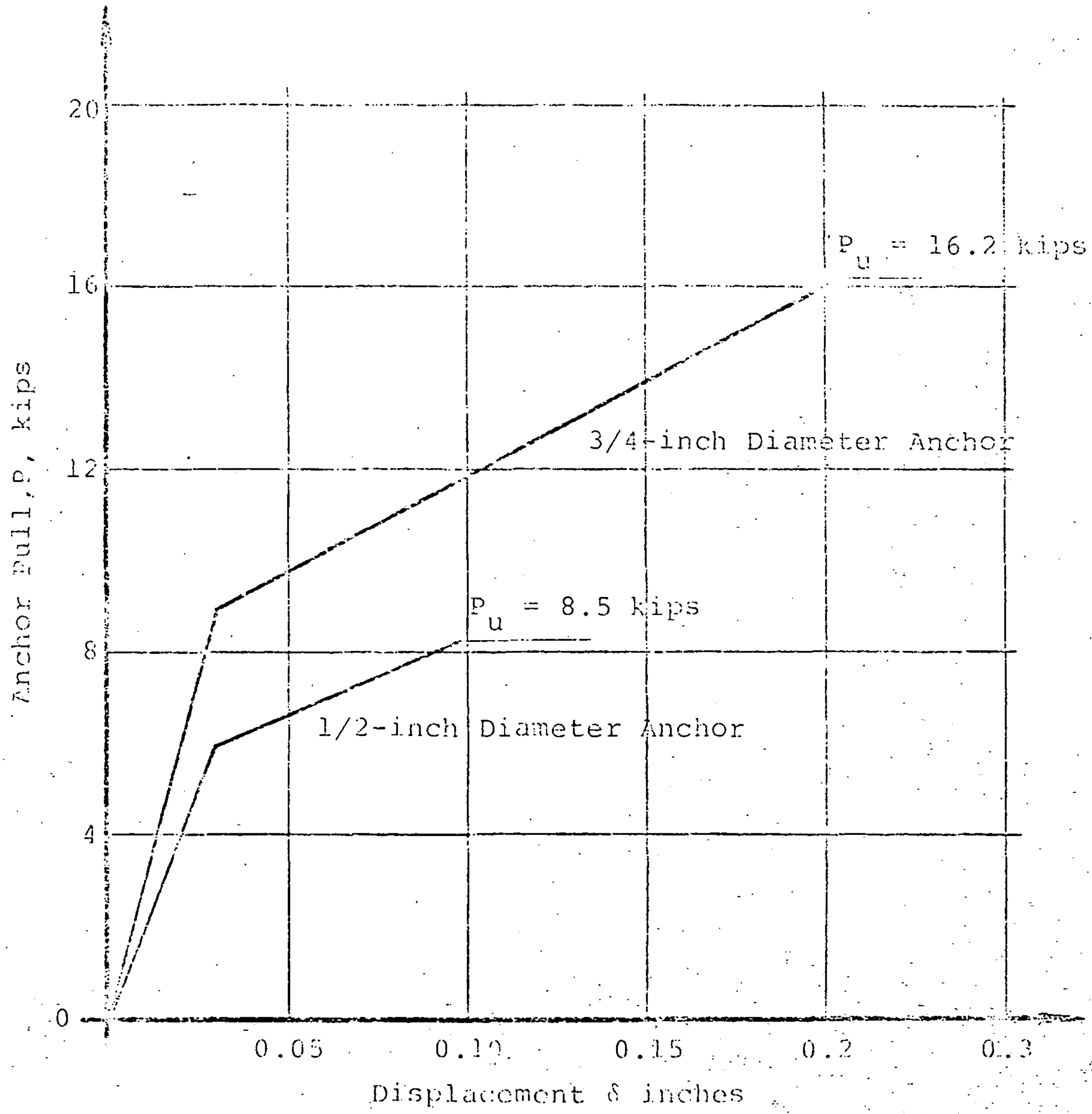


FIGURE 2 Idealized Load-Deformation Diagrams for Shell Type Anchors