

Oversized Base Plates – How They Work & Why Use Them

The normal design philosophy for Kinetics Noise Control, when designing a new seismic isolator or restraint, is to size the components to allow the smallest package when the isolator or bracket is to be attached to the structural steel of the building. This means that the mounting fasteners and the footprint of the isolator or bracket optimized for the attachment to steel. As a result, the maximum capacity of the isolator or bracket can not be utilized when it is to be attached to concrete using either wedge type anchors or even the undercut type concrete anchors.

An isolator or bracket that is designed to optimize the capacity of the concrete anchors would have a footprint and fastener requirement that would be way too large for efficient attachment to structural steel. Also, we at Kinetics Noise Control feel that it would be prohibitively expensive to design one complete line of isolators or brackets for attachment to steel, and another complete line of isolators or brackets for attachment to concrete. Therefore, we design to optimize the isolator or bracket for attachment to structural steel, and employ the appropriate oversized base plate for an application that specifies attachment to concrete.

The oversized base plate is typically a square piece of steel plate with four anchor holes in it. The isolator or bracket is welded more-or-less to the center of the plate with the recommended amount of weld for attaching the isolator or bracket to structural steel. This oversized base plate allows us to use an anchor size larger than would be allowed by the mounting holes in the isolator or bracket. Also, the oversized base plate will allow us to space the anchors far enough apart to take full advantage of the allowable loads published for the concrete anchors. A typical wedge type concrete anchor, when loaded, tends to produce a cone shaped stress field where the point of the cone is at the embedded end of the anchor, and the large end of the cone is at the surface of the concrete. When the anchors are too close together, these cone shaped stress fields will interact and reduce the allowable capacities of the anchors.

Basic Analysis for Oversized Base Plates:

Shown in Figure D5.2.1-1 is a typical oversized base plate with an isolator or bracket attached to it at the center of the plate. In this figure, L is the length and width of the base plate and t is the thickness of the base plate. The variable d represents the anchor size, or diameter, to be used with the base plate. The height H is the distance from mounting surface of the isolator or bracket to the center of the restraint. The seismic force is represented by F_h for the horizontal component of the seismic force, and F_v for the vertical component of the seismic force. The force component F_h is assumed to act at the center of the restraint, and the force component F_v acts at the center of the base plate. There will be three analyses, one for $F_v = 0$, one for $F_h = 0$, and one where $F_h = F_v$.

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D5.2.1



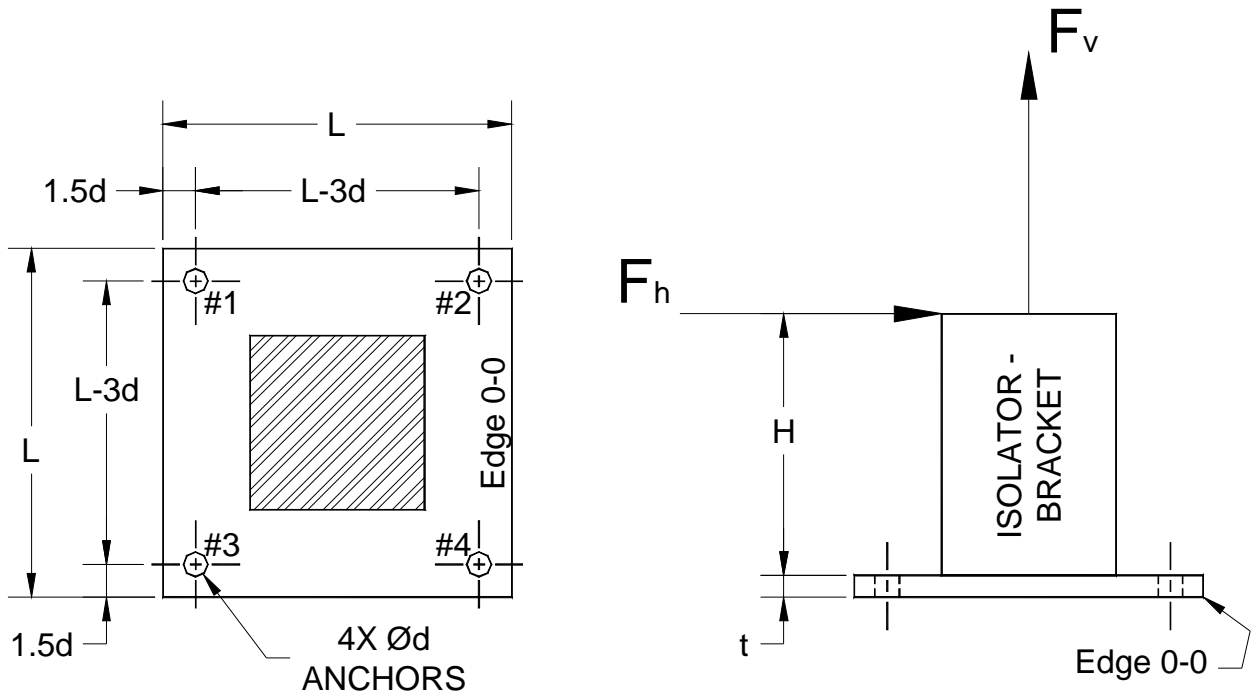


Figure D5.2.1-1: Typical Oversized Base Plate.

Case 1: $F_v = 0$

In this case, the base plate will tend to tip around Edge 0-0. The analysis is based on the following assumptions.

- 1.) The base plate acts as a rigid member.
- 2.) The anchors will remain elastic.
- 3.) The deflections and rotations of the base plate will be small.
- 4.) The tension in anchors #1 and #3 will be equal, $T_1 = T_3$.
- 5.) The tension in anchors #2 and #4 will be equal, $T_2 = T_4$.

Sum moments about Edge 0-0 to determine the tension in the anchors. Counter clockwise moments will be positive (+).

$$\sum M_{0-0} = 0 = 2 * T_1 * [L - (1.5 * d)] + 2 * T_2 * (1.5 * d) - F_h * (H + t) \quad (\text{Eq. D5.2.1-1})$$

And;

$$F_h * (H + t) = 2 * T_1 * [L - (1.5 * d)] + 2 * T_2 * (1.5 * d) \quad (\text{Eq. D5.2.1-2})$$

It is clear that anchors #1 and #3 will be more highly loaded than anchors #2 and #4. So,

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we will ultimately need to determine the tension in anchors #1 and #3. Through the assumptions it is possible to relate the tension in anchors #2 and #4 to the tension in anchors #1 and #3 in a linear fashion as follows.

$$T_2 = T_1 \{ (1.5*d) / [L - (1.5*d)] \} \quad (\text{Eq. D5.2.1-3})$$

Substitute Equation D5.2.1-3 into Equation D5.2.1-2, simplify and solve for T_1 .

$$F_h * (H+t) = 2 * T_1 * [L - (1.5*d)] + 2 * T_1 * \{ (1.5*d)^2 / [L - (1.5*d)] \} \quad (\text{Eq. D5.2.1-4})$$

$$F_h * (H+t) * [L - (1.5*d)] = 2 * T_1 * [L - (1.5*d)]^2 + 2 * T_1 * (1.5*d)^2 \quad (\text{Eq. D5.2.1-5})$$

$$T_1 = F_h * (H+t) * [L - (1.5*d)] / \{ 2 * [L - (1.5*d)]^2 + (1.5*d)^2 \} \quad (\text{Eq. D5.2.1-6})$$

The anchors will also be loaded in shear. Let's assume that all of the anchors are loaded equally in shear. The shear load on each anchor, P_1 , will be as follows.

$$P_1 = F_h / 4 \quad (\text{Eq. D5.2.1-7})$$

The base plate thicknesses were selected in order to make the anchors the limiting components for values of H up to and including 20 inches. The stress in the base plate is estimated by assuming that the base plate is a beam with both ends fixed, and a couple M_o applied to the center of the beam, as shown in Figure D5.2.1-2.

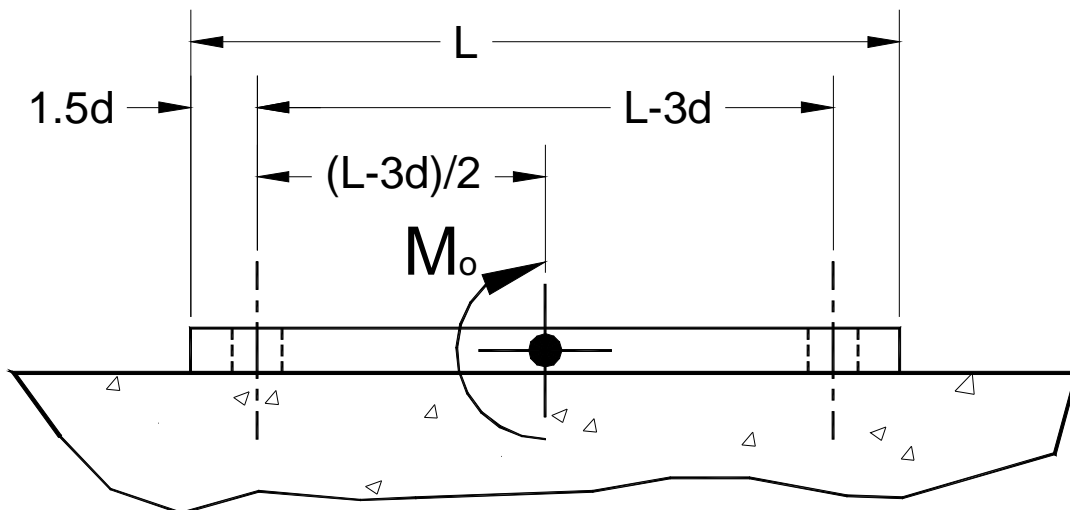


Figure D5.2.1-2: Assumed Base Plate Loading Arrangement for Case 1.

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Because the isolator or bracket will be rather large, the center of the base plate will not be subjected to a great deal of bending. The maximum bending will occur at the anchor holes. The maximum applied moment in the at the anchor holes is;

$$M = M_o / 4 \quad (\text{Eq. D5.2.1-8})$$

The applied moment may be approximated as;

$$M_o \approx F_h * H \quad (\text{Eq. D5.2.1-9})$$

Then;

$$M = F_h * H / 4 \quad (\text{Eq. D5.2.1-10})$$

In general, the bending stress, S_b , in the base plate is given by;

$$S_b = M * c / I \quad (\text{Eq. D5.2.1-11})$$

In this equation, c is the distance from the neutral axis to the outer fibers of the beam, and I is the area moment of inertia of the beam cross-section. For all of the cases presented in this document, I and c have the following values.

$$I = L * t^3 / 12 \quad (\text{Eq. D5.2.1-12})$$

And;

$$c = t / 2 \quad (\text{Eq. D5.2.1-13})$$

The final form of the bending stress equation will be as follows.

$$S_b = 3 * F_h * H / (2 * L * t^2) \quad (\text{Eq. D5.2.1-14})$$

The allowable bending stress, S_A , is;

$$S_A = 0.6 * S_y \quad (\text{Eq. D5.2.1-15})$$

S_y is the yield strength of the base plate.

The factors of safety for the anchors and the base plate are now computed. For each case they must be greater than or equal to **1.00**. For the anchors, the factor of safety is;

$$F.S. = \{1 / [(T_1 / T_A)^{5/3} + (P_1 / P_A)^{5/3}]\} \geq 1.00 \quad (\text{Eq. D5.2.1-16})$$

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In the above equation, T_A and P_A are the allowable tension and shear loads for the anchors being used. The factor of safety for the base plate is given by;

$$F.S. = S_A / S_b \geq 1.00 \quad (\text{Eq. D5.2.1-17})$$

Case 2: $F_h = 0$

Since the base plate has been assumed to be rigid and the deflections have been assumed to be small, there will be little or no prying action on the anchors due to the vertical component of the seismic force F_v . Also, since $F_h = 0$, there will be no shear forces acting on the anchors. The vertical component of the seismic force will be equally distributed between the four anchors, and;

$$T_1 = F_v / 4 \text{ and } P_1 = 0 \quad (\text{Eq. D5.2.1-18})$$

The maximum bending will occur at the anchor holes. The base plate loading for Case 2 is shown in Figure D5.2.1-3.

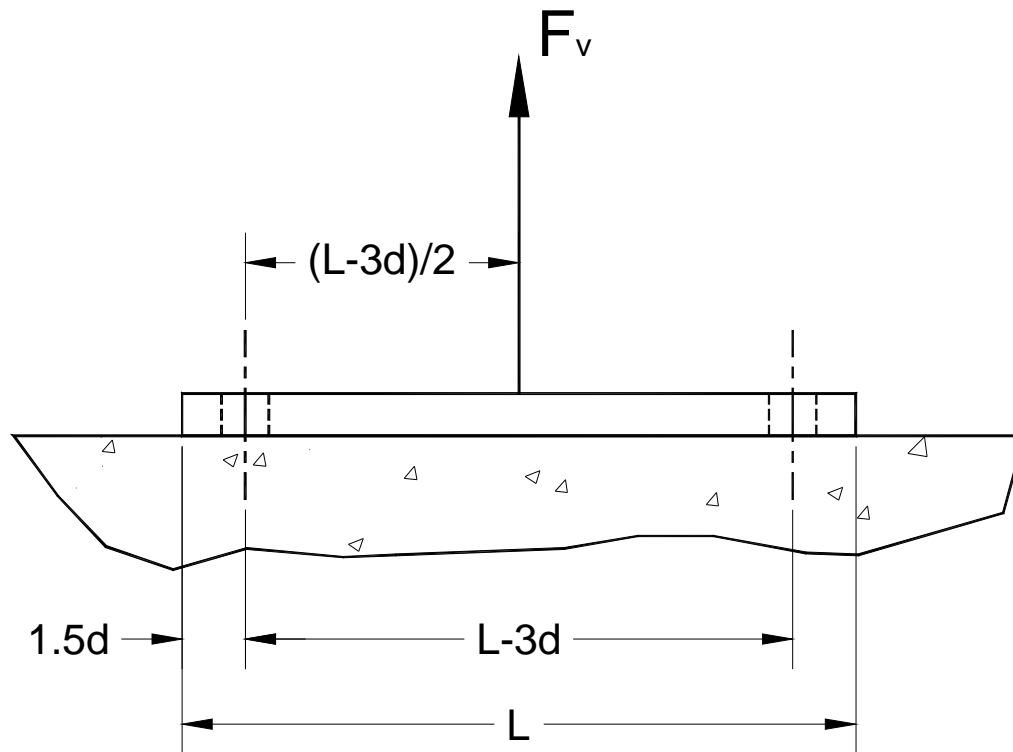


Figure D5.2.1-3: Assumed Base Plate Loading Arrangement for Case 2.

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The maximum applied moment in the at the anchor holes is;

$$M = F_v*(L-3*d) / 8 \quad (\text{Eq. D5.2.1-19})$$

Substitute Equations D5.2.1-12, D5.2.1-13, and D5.2.1-19 into Equation D5.2.1-11 to obtain the maximum bending stress in the base plate.

$$S_b = 3*F_v*(L-3*d) / (4*L*t^2) \quad (\text{Eq. D5.2.1-20})$$

Case 3: $F_h = F_v = F_c$

This is the combined loading case that helps determine the final shape of the capacity envelope for the base plate. Again, we will sum moments about Edge 0-0 to determine the maximum tension in the bolts. All of the assumptions that applied to Case 1 will apply for Case 3.

$$\sum M_{0-0} = 0 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d)-F_c*(H+t)- F_c*L/2 \quad (\text{Eq. D5.2.1-21})$$

And;

$$F_c*(2*H+2*t+L)/2 = 2*T_1*[L-(1.5*d)]+2*T_2*(1.5*d) \quad (\text{Eq. D5.2.1-22})$$

Substitute Equation D5.32.1-3 into Equation D5.2.1-22, solve for T_1 .

$$F_c*(2*H+2*t+L)/2 = 2*T_1*[L-(1.5*d)]+2*T_1*\{(1.5*d)^2 / [L-(1.5*d)]\} \quad (\text{Eq. D5.2.1-23})$$

$$F_c*(2*H+2*t+L)*[L-(1.5*d)]/2 = 2*T_1*[L-(1.5*d)]^2+2*T_1*(1.5*d)^2 \quad (\text{Eq. D5.2.1-24})$$

$$T_1 = F_c*(2*H+2*t+L)*[L-(1.5*d)] / \{4*[L-(1.5*d)]^2+(1.5*d)^2\} \quad (\text{Eq. D5.2.1-25})$$

The anchors will be also be loaded in shear, and this shear load may be estimated using Equation D5.2.1-7.

The maximum bending will occur at the anchor holes in this case as well. The base plate loading for Case 3 is shown in Figure D5.2.1-4. The maximum bending moment at the bolt holes will be,

$$M = M_c/4+F_c*(L-3*d)/8 \quad (\text{Eq. D5.2.1-26})$$

$$M_c = F_c*H \quad (\text{Eq. D5.2.1-27})$$

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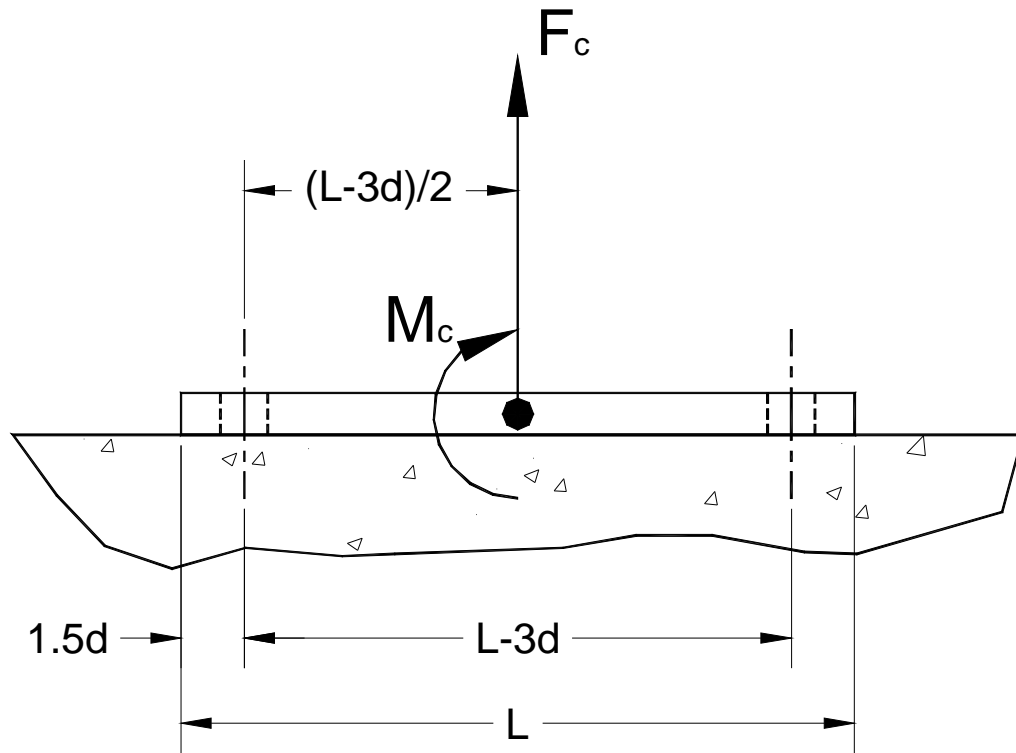


Figure D5.2.1-4: Assumed Base Plate Loading Arrangement for Case 3.

$$M = F_c * H / 4 + F_c * (L - 3 * d) / 8 \quad (\text{Eq. D5.2.1-28})$$

$$M = (F_c / 8) * [2 * H + L - 3 * d] \quad (\text{Eq. D5.2.1-29})$$

Substitute Equations D5.2.1-29, D5.2.1-12, and D5.2.1-13 into Equation D5.2.1-11 to obtain the bending stress in the base plate.

$$S_b = 3 * F_c * (2 * H + L - 3 * d) / (4 * L * t^2) \quad (\text{Eq. D5.2.1-30})$$

The results of this analysis are presented and their applications are discussed in Document D5.2.2.

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