The Base Shear Formula

You will have to do a bit of arithmetic and use a very simple formula known as the base shear formula to determine exactly how many bolts, how much plywood, and how many shear transfer ties your house will need. This treatise is only for educational purposes. The way it is applied to actually houses is usually quite different because of existing building materials, framing methods use, and other factors.

Geologists are able to calculate an “anticipated” amount of force that will be generated by a major earthquake in a specific geographical region.

The base shear formula is:

$$V = 0.2\ (W)$$

V represents the shear force that will be generated at the base of a building.

0.2 represents earthquake force.

W represents the weight of the building. Single story homes weigh approximately 50 pounds per square foot. Two story homes weigh 80 pounds per square foot of the first floor area. These numbers vary a lot depending on the weight of the roof, interior wall coverings, and weight of the siding. All of these factors must be weighed when applying this formula to an actual house.

Example: We have a two-story house with a first story that is 25 feet by 40 feet. The first story is thus 1,000 square feet (25 x 40 = 1,000). If we multiply this times 80 pounds, we determine that the building weighs 80,000 pounds. Using this information and the base shear formula we can determine the amount of earthquake force expected to strike this building. We will want to design a retrofit that will resist this amount of force.

For our example we would use the base shear formula as follows:

V = 0.2 x weight of house
V = 0.2 x (area in square feet <u>of the first floor</u> x weight per square foot)
V = 0.2 x 1,000 sq. ft. x 80 pounds per sq. ft
V = 0.2 x 80,000 pounds
V = 16,000 pounds

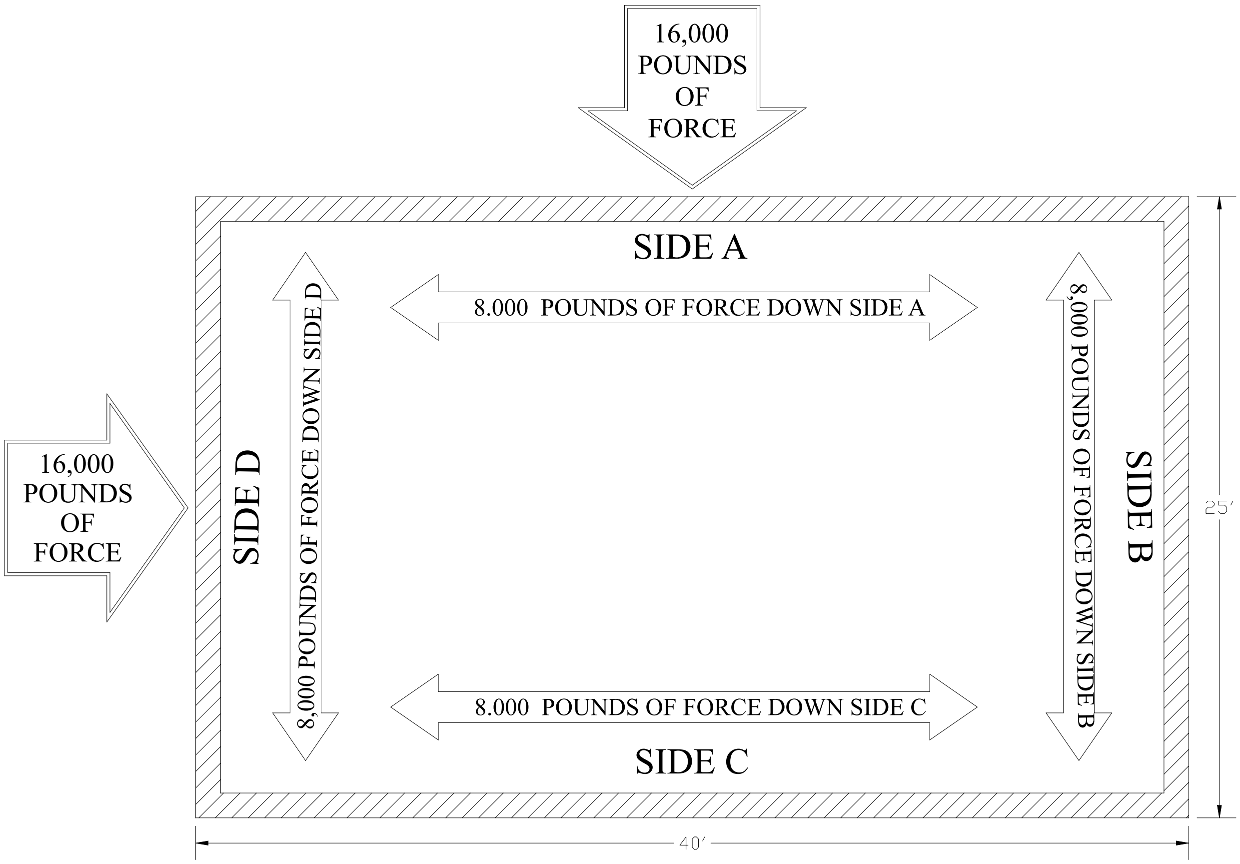


Diagram 8: Earthquake force against base of house

This means a properly designed retrofit for this house must have enough bolts to resist a minimum of 16,000 pounds of force where the mudsill sits on the foundation, AND enough plywood on the cripple walls to resist a minimum of 16,000 pounds force and keep the cripple walls from collapsing, AND enough shear transfer ties to resist a minimum of 16,000 pounds of force where the floor framing sits on top of the cripple wall.

All bolts, nails, plywood, shear transfer ties, etc., are rated in terms of the amount of earthquake force they can resist. For example, a 1/2-inch bolt with a mudsill plate and plate washer can resist 1,200 pounds of force. Each linear foot plywood bracing using the flush cut method can resist 600 pounds of force. Good shear transfer ties can also resist around 600 pounds of force.

The house in our example could be attacked by 16,000 pounds of earthquake force in any direction. We know that a 1/2-inch bolt with a plate washer and mudsill plate provides

1,200 pounds of earthquake resistance. To determine the number of 1/2-inch bolts we will need, we divide 16,000 by 1,200. The answer is 13.3 bolts. We round this up to 14 bolts. This means we need a total of 14 bolts to protect the house in the north-south direction and 14 bolts to protect it in the east-west direction. To protect this house we will need to install 7 bolts along each foundation wall. Bolts only need to be installed at plywood shear wall locations because practically all of the earthquake forces is absorbed by the plywood and transferred to the bolts located at the base of the shear wall.

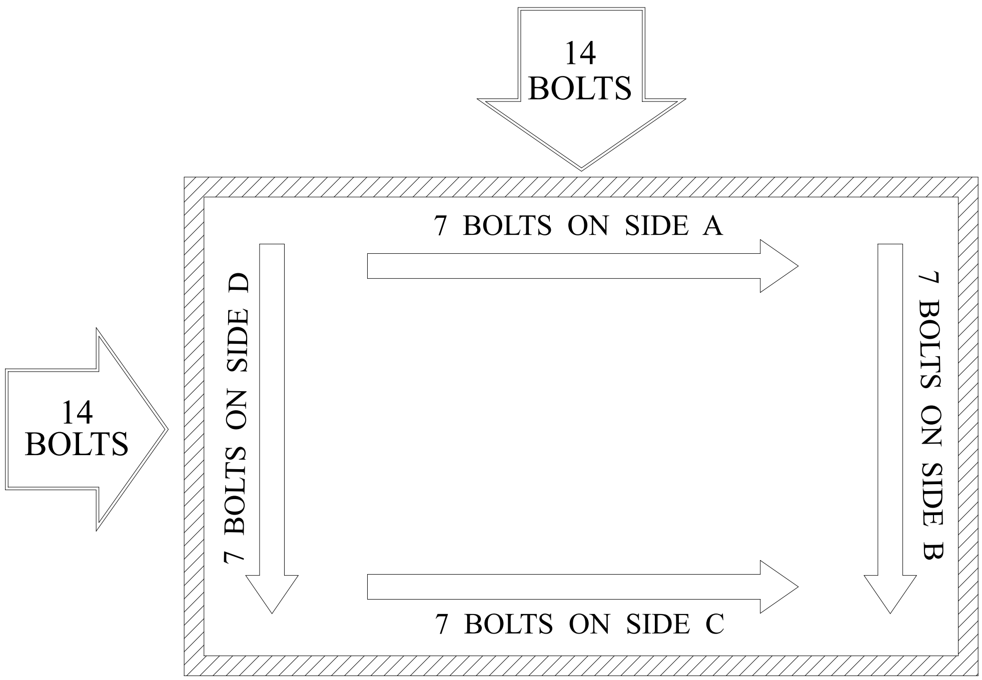


Diagram 9: Required number of bolts

Next we need to address the bracing of the cripple walls. Each linear foot of good plywood cripple wall bracing using 15/32" structural 1 plywood can resist 600 pounds of earthquake force for each linear foot of plywood. If we divide 16,000 by 600 we get 26.6. We may round this up to 28 because plywood comes in 2-foot length increments. This means we need 28 linear feet of 15/32" structural 1 plywood in the east-west direction and 28 linear feet of plywood in the north-south direction, or 14 feet of plywood on the cripple wall on each side of the house.

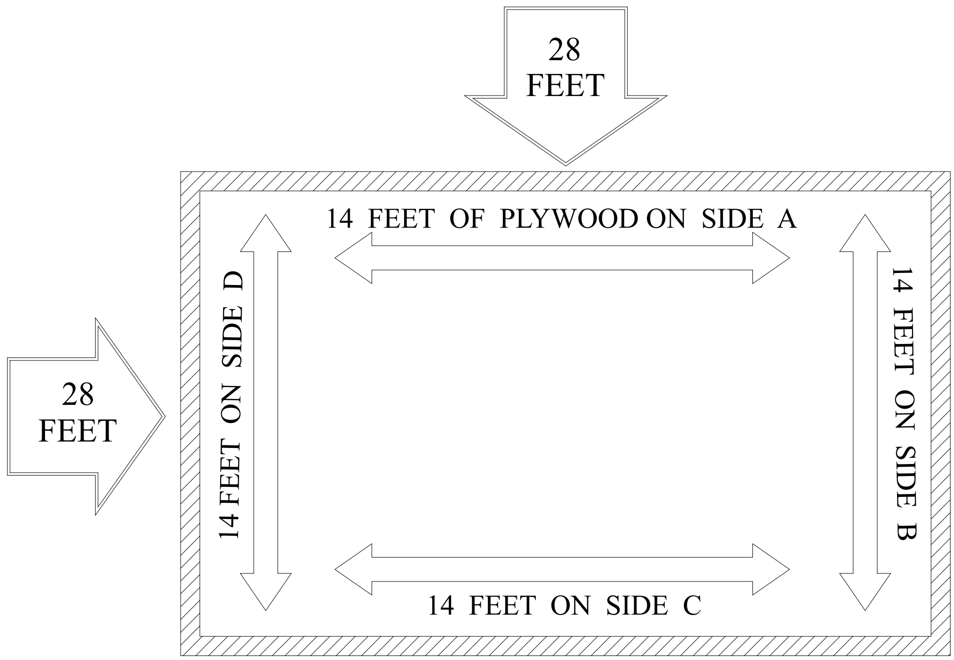


Diagram 10: Required linear footage of plywood

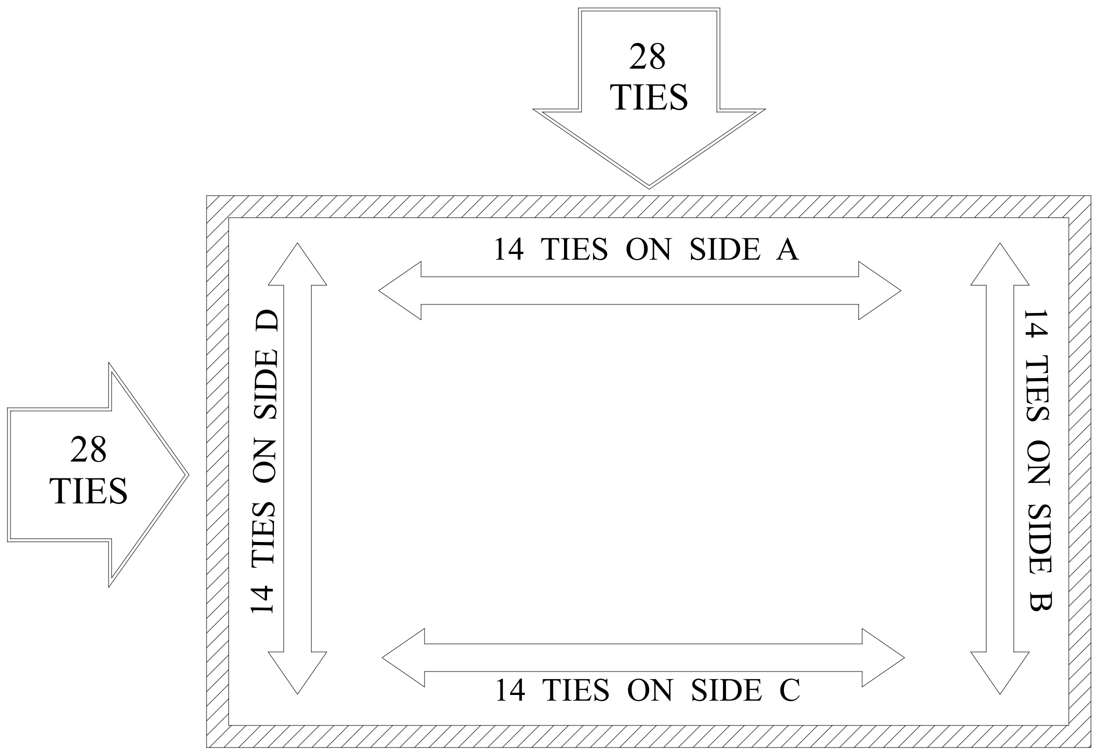


Diagram 11: Required number of shear transfer ties

The same method is used to determine the number of shear transfer ties needed to attach the floor framing to top of the cripple wall. Good shear transfer ties can resist 600 pounds of earthquake force. 16,000 divided by 600 equals 26.6. We round this up to 28 so that we can have an equal number of shear transfer ties on each side of the house. This means we need 28 shear transfer ties in the east-west direction and 28 in the north-south direction; or 14 shear transfer ties along each side of the house.

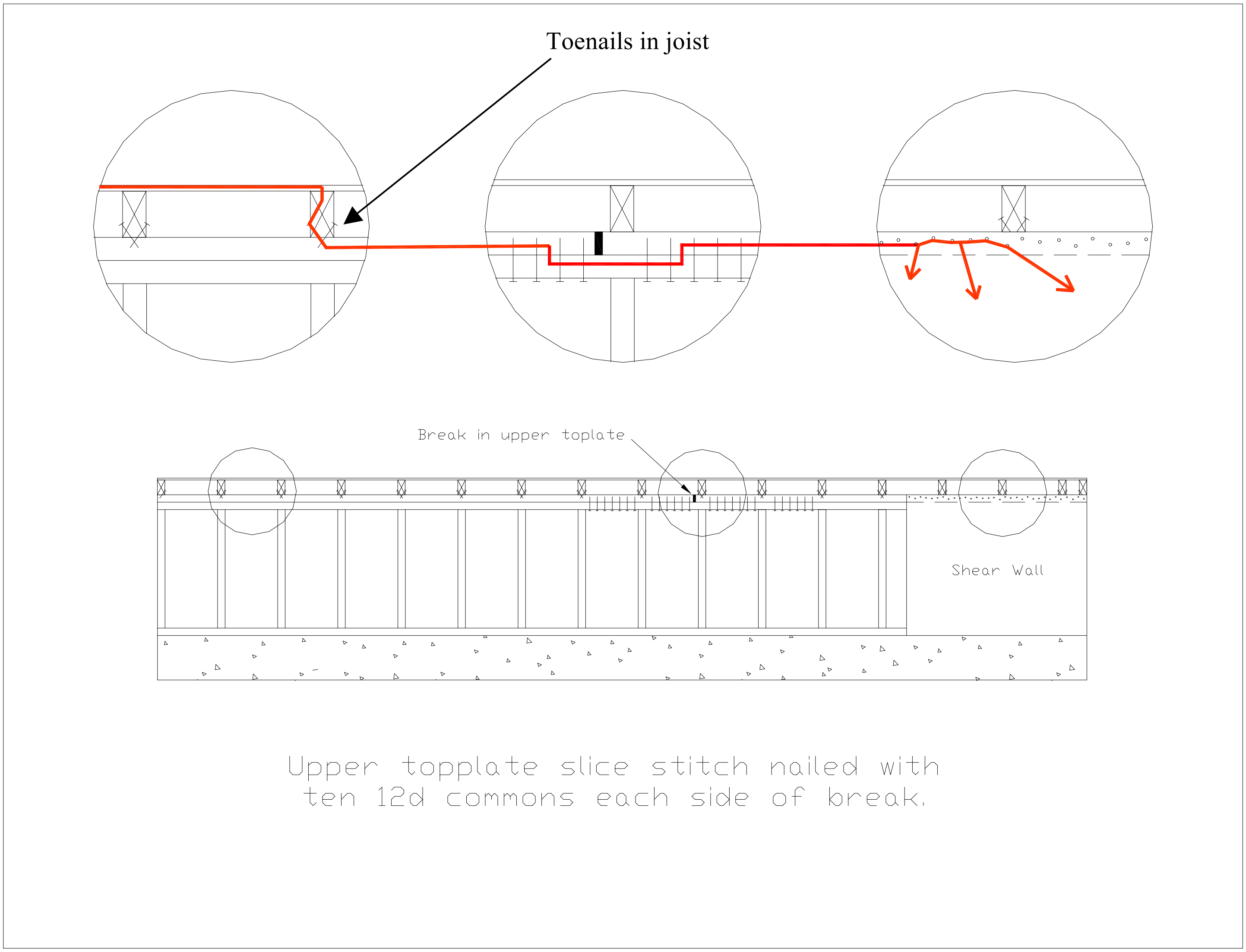
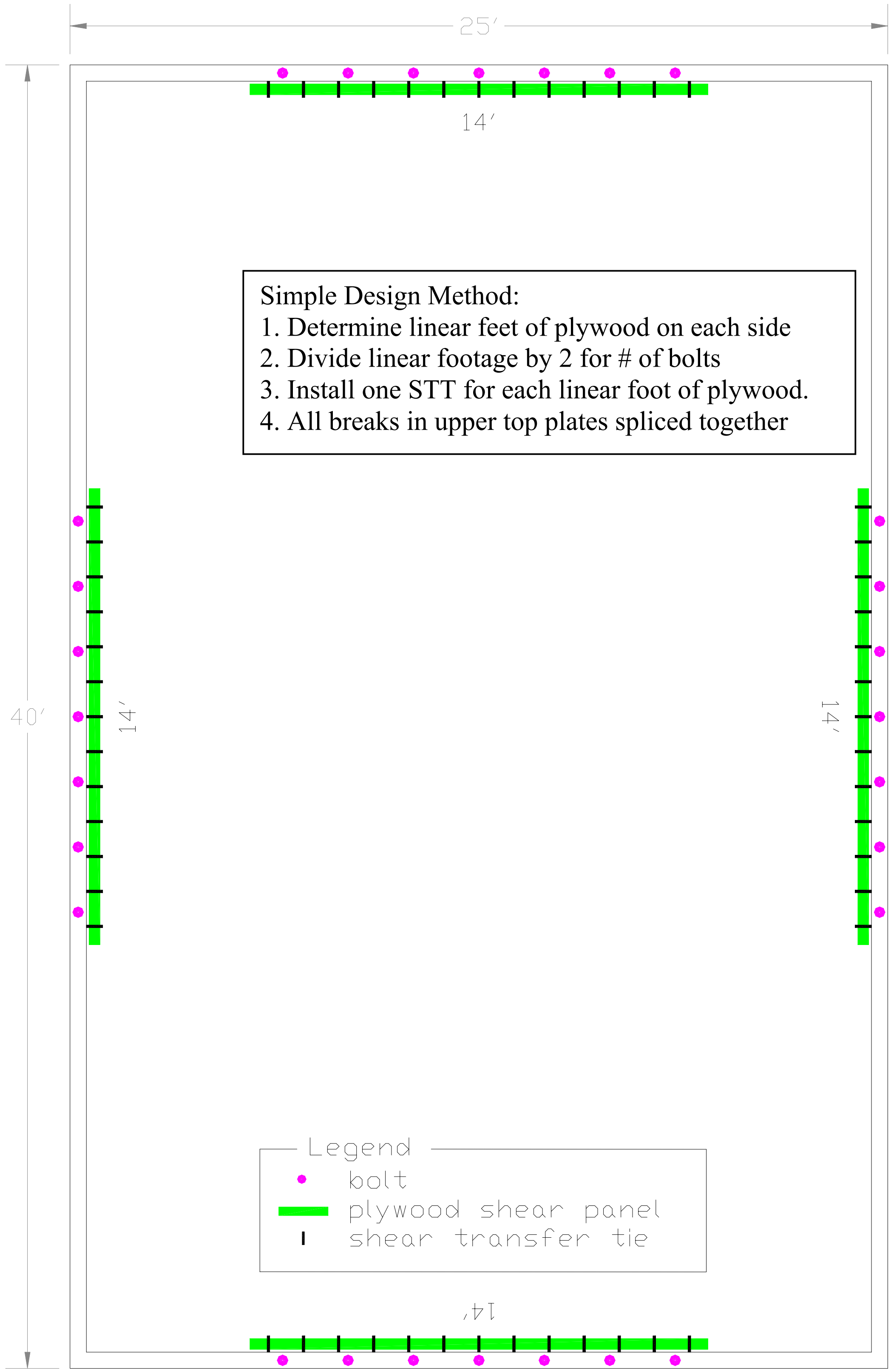


Diagram 12: Upper top plate splice

It is very important to connect make sure any breaks in the upper top plate are spliced together. This is because the movement of the floor is transferred through the toenails into the floor joists and the toe nails push and pull on the upper top plate. You want to make sure this movement is transferred to the shear wall.


25'
14'
Simple Design Method:
1. Determine linear feet of plywood on each side
2. Divide linear footage by 2 for # of bolts
3. Install one STT for each linear foot of plywood.
4. All breaks in upper top plates spliced together
40'
14'
14'
Legend
bolt
plywood shear panel
shear transfer tie
14'