# Rymeg
**Consulting Group, Inc.**

March 11, 2016

Valley Storm Shelters
14628A US Highway 72 W
Scottsboro, Al 35768

Re: Impact Test Observations
Steel Constructed Shelters

Dear Sirs:

This is the report of our observations of the impact tests performed on (5) different storm shelters of various types of steel construction. These tests were performed on the afternoon of February 26 at a vacant industrial parking lot in Scottsboro, Alabama. These tests were performed to simulate the impact of debris under certain conditions and as a measure of the structural integrity of the shelters.

These impacts were performed by pushing a 4500-pound wheeled sled into the rear of the anchored shelters. The sled was fitted with a 3/4-inch steel blade on front which was arranged with the face being vertical and measuring 16” tall and 7'-0” wide and being 15” above the ground. This would make for the center of the impact being 23” above the ground.

The shelters were all constructed by Valley Storm Shelters as needed to emulate the shelters which are constructed and/or installed by other storm shelter manufacturing companies. The anchoring systems each reportedly followed the guidelines as detailed by the respective companies and included attachment to an approximately 40'x40' 4-inch thick concrete slab of 3500 psi strength. The first test was performed on one of the company's own specimens which included additional earth anchors.

The sled was propelled by a truck which pushed it along a specially designed, ground mounted track in a straight line for approximately 800 feet. The track was aligned to make for impact of the sled into the shelters squarely in the center of their rear walls –

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the wall opposite the opening for the door. The rear walls were in all cases on the long sides of the shelters. The speed at impact was gauged by a radar detector but was clocked by the speedometer of the truck to be 25 miles per hour.

The widest shelter was 6'-10" meaning that the 7'-0" width of the front blade of the sled was such that it's contact with the rear of the shelters would also engage their side walls. Therefore, the force(s) of the impacts were fairly well distributed among all the structural elements of the shelters as needed to help them maintain their structural integrity.

OBSERVATIONS

UNIT 1
This unit is one of Valley Storm Shelters standards. It is 4'-0" wide x 6'-0" long x 6'-3" tall and constructed of ¼" steel plates on all sides as well as roof and floor. The wall and roof plates were internally reinforced with an approximate 2'x2' grid of standard C4x7.25 steel channels with their webs facing inward and the edges of their flanges welded to the plates and with the intersections of the channels being butt welded together. The full length of the seams of the plates at the corners were externally reinforced with ¼" L-shaped plates with a minimum of 3-inches on each leg.

The anchors consisted of (9) ¾"x7" screw types installed rectangularly around the edge of the floor. (4 )additional earth anchors were installed, (2) of which were near the rear wall and (2) of which were installed along the mid-way line of the longitudinal axis. These earth anchors consisted of a 1"x28" threaded, hooked rod embedded into a 6" diameter x 2'-2" deep bell bottomed concrete shaft which was cast in place through the 4-inch slab.

The 4500-pound sled was clocked at 25 miles per hour upon impact with the rear of the shelter. The horizontal center of the 16" high x 7'-0" wide ¾" front plate of the sled struck at 23 inches above the ground.

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All (9) of the ¾“x7” anchors were bent about mid-depth and completely displaced from their holes. The 1” threaded rods were also displaced from the concrete of the earth anchors with rods nearest the impact wall protruding 9 inches. Surprisingly, the concrete of the earth anchors appeared to be undisturbed.

The shelter itself displaced 4” upward at the wall of the impact but only about 2 inches laterally. There was less than 1” of deflection of the impact wall itself being at a point about 24” above ground (sled impact height) and with one of the butt welds of the C4x7.25's being broken at about the same height.

UNIT 2

This unit was 2'-6” wide x 6'-10” long and consisted of 11 gage x 2'-0” wide steel panels which were aligned vertically and bolted together at their flanges. The flanges were formed by bending 2 inches of the panel edges at 90 degrees. There were (7) ¼” bolts per panel edge from bottom to top of the walls of the approximate 6'-3” tall structure. There was no floor to the structure.

There were (21) 3/8“ expansion anchors with about 3” of embedment into the concrete slab. They were approximately, evenly spaced around the edge of the walls and installed through the bottom flanges.

The 4500-pound sled was clocked at 25 miles per hour upon impact with the rear of the shelter. The horizontal center of the 16” high x 7'-0” wide ¾“ front plate of the sled struck at 23 inches above the ground.

Upon impact, all walls of the shelter completely collapsed and with the structure being pushed about 15 feet off of its foundation. The front and rear walls were basically pushed together.

Upon observation, (10) of the anchors were pulled from the concrete, (3) of the remaining ones were sheared off, (2) were bent without nuts and (6) had nuts and washers meaning that they pulled through the bottom flanges of the walls.

UNIT 3

This unit was 4'-0” wide x 6'-0” long and constructed of 3/16“ plates on walls and roof. There was no additional reinforcing and there was no floor.

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The structure was anchored with (10) 3/8” expansion anchors with about 3” of embedment into the 4” slab. The anchors were patterned at approximately equal spaces around the bottom edges of the walls.

The 4500-pound sled was clocked at 25 miles per hour upon impact with the rear of the shelter. The horizontal center of the 16” high x 7'-0” wide ¾“ front plate of the sled struck at 23 inches above the ground.

After impact, the rear wall displayed about a 4-inch deflection at impact height and about 1-foot from the side. The welds of the rear wall which joined the adjacent, side walls were broken from the bottom to about 3' above the bottom with full separation of these walls.

The structure broke free from the foundation and was pushed about 20 feet. Four of the anchors pulled free of the concrete and the remainder were either sheared or bent without nuts and washers.

UNIT 4

This was a 4'-0” wide x 6'-0” long shelter constructed of 11 gage steel. It was reinforced with 2”x2” square tubing running vertically along the walls at about 24” separation but with none at the corners and none installed horizontally. It also had the 2”x2” tubing around the corners of the roof. There was no floor.

It was anchored with (20) 3/8”x4” screw-types into the 4-inch slab. They were approximately evenly spaced around the edge of the walls.

The 4500-pound sled was clocked at 25 miles per hour upon impact with the rear of the shelter. The horizontal center of the 16” high x 7'-0” wide ¾“ front plate of the sled struck at 23 inches above the ground.

After impact, the structure displayed significant damage with a 12-inch deflection of the rear wall at impact height. It had separated walls with a broken weld a total of about 3 feet as measured from the bottom.

The structure broke free from the anchors and was pushed about 8 feet from its foundation. (18) of the anchors were totally displaced from the concrete, (1) was sheared and (1) remained though bent and without a nut.

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Unit 5

This was a 4'-0” wide x 6'-0” long shelter constructed with ¼“ steel plates. The walls and roof were reinforced with standard steel C4x5.4 channels on about a 2-foot grid. The webs of the channels were facing inward with the edge of the flanges welded to the plates and with their intersections being butt welded together. There was a ¼ “-inch steel plate floor. There were no reinforcements at the corners.

This shelter was anchored with (8) ½“x4” screw-types. (3) of the anchors were along the rear (impact) wall, (2) along each side but only (1) on the front wall.

The 4500-pound sled was clocked at 25 miles per hour upon impact with the rear of the shelter. The horizontal center of the 16” high x 7'-0” wide ¾“ front plate of the sled struck at 23 inches above the ground.

Upon impact, the structure broke free from its foundation and tumbled about 25 feet. All of the anchors were sheared.

On the structure there was a 3-inch deflection in the rear wall at about impact height immediately adjacent to the side wall and with a broken weld and separated walls at this location.

SUMMARY

As stated, the use of these tests was as a rudimentary measure of the structural integrity of storm shelters of differing steel construction upon impact of debris under certain conditions.

It's important to note that these tests were not performed in accordance with any known standards for testing or construction for storm shelters and were not used as any type of indication of the compliance of these shelters with applicable codes.

Significant observations include:

> The fact that Unit 1 was able to maintain it's approximate location with minimal deflection is indicative of the value of larger or more numerous anchors. Also, the use of the earth anchors appears to have been instrumental in preventing the

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shelter from tumbling. This is in spite of the fact that all of the anchors were displaced from their concrete embedments. This value is especially apparent when compared with the large displacement of UNIT 5 which had similar superstructure construction as UNIT 1 but only (8) ½“ anchors. Also, in comparison, UNIT 2, which had relatively light steel panels but (21) anchors was pushed only about 15 feet as compared to 25 feet for UNIT 5.

The use of the larger steel plates for the walls was instrumental in providing structural integrity for the structures. The 3/16“ plates of UNIT 3 displayed only about a 4-inch deflection at the level of impact. This is compared to the 11 gauge plates of UNITS 2 and 4 which had significant damage to all of the walls. UNIT 3 was however, pushed a significant amount of about 20 feet which undoubtedly lessened the damage to the walls as opposed to it's having been more securely anchored. The ¼“ steel plates of UNITS 1 and 5 displayed the less damage of all of the shelters although they were both backed with additional reinforcements.

The value of structural tubing or channel reinforcements, while significant is also dependent on their specific geometric placement throughout the structure. The vertical 2”x2” tubing used in UNIT 4, with11 gage wall construction fared better than UNIT 2 without any reinforcement although there was significant damage to the structure as seen with at 17-inch deflection at level of impact as well as crushing of the side walls. UNITS 1 and 5 which had the 2-foot grid of channel reinforcements displayed the least damage to their structures although they were both of ¼” plate wall construction as opposed to the 11 gage of UNIT 4.

Corner reinforcements also appear to be significant in providing stability. The corners of UNIT 1 were all reinforced with ¼“ L-shaped plates and displayed no cracking after impact. The corner welds of the wall of UNIT 5, which was of similar construction as UNIT 1 but without the corner reinforcements completely broke away and displayed a 3-inch separation at the level of impact. This is in spite of the fact that the unit was displaced a distance of about 25 feet which would have lessened the damage to the structure.

In all cases the anchors failed in shear either from the rupture of the concrete or the steel itself. This is explained in part by the fact that the impact was relatively

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low on the structure. In the cases where the anchors were pulled from their embedments the impact itself would have broken them free from the concrete at which point they had no strength in any direction.

CONCLUSIONS

As stated, the use of these tests was as a measure of the structural integrity of storm shelters of differing steel construction upon impact of debris under certain conditions. Obviously, those shelters utilizing greater wall thicknesses, wall and roof reinforcements and larger or more numerous anchors fared better.

The specific aspects which emerged from these impact tests include:

The anchoring system is of equal importance as the construction of the structure itself

Uplift is a significant factor. Earth anchors may play a vital role in the overall anchoring system

The use of thicker steel plates for walls and roofs is significant

The use of a steel floor is essential in distributing the forces to all of the anchors as well as the overall strength of the structure itself

Structural members used as wall and roof reinforcements are significant

The use of wall and roof corner reinforcements is significant

Regarding the impact of major pieces of debris to any one above-ground, steel constructed shelter there is a definite, optimal balance between the strength of the anchoring system and the structure itself although these tests were not extensive enough to determine what a good balance would be for any one unit. Also, as stated these tests do not reflect the applicability of any known codes for shelter construction nor the suitability of any of these structures to these codes. Further, these tests were in no way a measure of a shelter's reaction to wind forces alone.

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In conclusion, this is to certify that, to the best of my abilities as a structural engineer this report is an accurate account of the results of these tests as outlined above.

_____ March 14, 2016

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Structural Engineer

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