PERFORMANCE OF CARDBOARD CARTON FORMS

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Abstract: Cardboard carton forms (void boxes) are commonly used to form the void space between the bottom of grade beams and slabs over expansive soils. However, other than laboratory compression tests and 100% humidity tests, there is little documentation for the actual performance of these boxes in place. This paper summarizes field tests done in an attempt to simulate actual conditions to answer the following questions:

- Do the boxes deteriorate at an acceptable rate?
- Does the wax coating or impregnation and a polyethylene vapor barrier affect deterioration?
- Will the boxes fail under heave conditions?
- Are trapezoidal boxes appropriate and do they perform in an acceptable manner?
- Which type of boxes are appropriate in each situation?
- What are some of the construction considerations necessary to insure proper function of the boxes?

I. Purpose of Test:

The strength of cardboard carton forms (void boxes) has been well documented by the box manufacturers. However, these tests are very specific and only give the capacity of the boxes dry with a uniform load on the box. The boxes are all wax coated or impregnated to aid in preventing deterioration due to moisture during construction. The design of structurally suspended slabs, beams and walls depend on these boxes being very strong during construction and to deteriorate quickly after the concrete has reached design strength. The question if the boxes deteriorate at an acceptable rate has not been satisfactorily answered in our opinion. Since the strength of the boxes exceeds 1000 pounds per square foot, it is very important that these boxes do deteriorate. Also, there is a common practice for contractors to cover the boxes with a polyethylene (poly) vapor barrier on top, bottom or all around and it was desireable to determine if this was a negative effect on the box deterioration rate. The purpose of these tests were to determine if the void boxes do deteriorate adequately. It was also desired to study the different configurations and type of boxes to determine the best type of box to use.

Two configurations of boxes were used: Vertical Cell and Diagonal Type. There are three major void box suppliers in the North Texas area: SureVoid, Savway, and Harris Packaging. SureVoid and Savway were chosen to be tested. Harris Packaging declined to provide us with boxes for testing and, therefore, were not tested at this time. In our observation, the Harris boxes are constructed similar to the Savway boxes. All the

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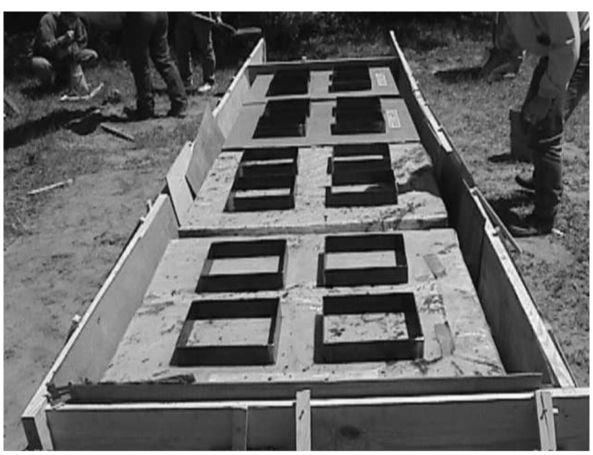
SureVoid boxes and the Savway slab boxes are of vertical cell configuration. The Savway beam boxes are of the diagonal type. It is not the intent of this paper to promote any one manufacturer over another, but to state facts from actual tests and experiences on actual projects. The hope is that the box manufacturers will take the lead from these simple tests and use the competitive process to provide further research and development to assist engineers and contractors in providing the best products for the industry.

II. Initial Test 1 procedure:

It was initially decided to pour a test slab over 4 sets of void boxes. Each box was 4 ft x 4 ft x 8 in deep. Concrete was poured on top and all around each box to simulate actual conditions. Four 1 ft x 1 ft steel forms were placed on top of each box for the purpose of loading each box at different intervals to determine if they had deteriorated. All boxes for the first test were SureVoid. Each box was placed with different conditions:

- Void box with no poly anywhere
- Void box with poly wrapped all around
- Void box with poly on top only
- Void box with poly on bottom only



Test set up with boxes and loading pads

Placing concrete over boxes

The procedure was to pour the concrete and test the capacity of the boxes once a week to determine the rate of deterioration.

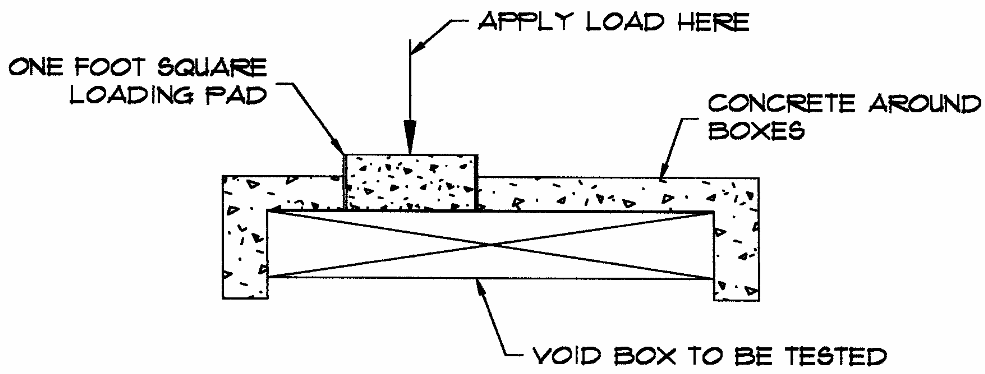


ILLUSTRATION OF INITIAL TEST PROCEDURE

Description of results:

- Week 1:
  Each box was loaded with 200 psf and no deflection was observed
- Week 2:
  Each box was loaded with 400 psf with no deflection
- Week 3:
  Each box was loaded with 400 psf with no deflection. The box with poly on bottom was flooded with water to accelerate deterioration
- Week 4:
  Each box was loaded with 400 psf
  The box that had been flooded with water had 3/8" deflection. All the other boxes had no deflection
- Week 5:
  The test pad on the boxes with no poly and the one with poly on bottom were removed to view the boxes. It was discovered that the top of the cardboard had stuck to the concrete causing the cardboard to span across the opening thus giving erroneous information. Both of the boxes appeared to have significant strength but were destroyed in the removal process and could not be tested.
- Week 6:
  The two remaining boxes, the one with poly all around and the one with poly on top had the concrete removed to expose the boxes. The boxes were tested with over 400 psf and still had plenty of capacity with little deterioration. The box with poly wrapped all around had a little water in the box, maybe a cupful, but this did not deteriorate the box. The source of the water is unknown, possibly from when the adjacent box was flooded with water.

III. Test 2 Procedure:

1. Two SureVoid boxes with no wax were buried in sand and uncovered after one week to view the rate of deterioration:

Two boxes with no wax were buried in sand

Box after one week sitting 50 pound block in middle

The boxes and loaded with a 50 pound weight and they failed immediately.

2. A SureVoid Beam Box (Vertical Cells) with wax and a Savway Beam Box (Diagonal Type) with wax were buried in sand for one week.. The buried boxes were tested by standing on them, there was nominal deflection which indicates the wax has a definite impact on the deterioration rate.

3. Two SureVoid boxes with wax were buried in sand for three weeks. One was completely covered in poly and the other had no poly. Both boxes showed no appreciable deterioration after three weeks. Since the boxes with no wax failed after one week under the same conditions, it is assumed that the wax and the poly significantly slow deterioration.

IV. Test 3 Procedure:

Two boxes, one Savway diagonal type box and one SureVoid with vertical cells were wrapped in poly with a cup of water added to simulate a 100% humidity condition. The next day, the SureVoid box collapsed immediately. The Savway box did not collapse except on the sides. A box with a capacity of only 200 psf was tested and failed with normal construction loads and therefore, considered not acceptable.

V. Summary of Observations From Tests 1-3:

1. Testing the boxes from the top gives unsatisfactory results.
2. The bottom of the boxes deteriorate first and destroys the glue between the verticals and the bottom on the SureVoid boxes.
3. Covering the bottom of the boxes with poly (the top of the sub-grade) slows down or stops the deterioration of the boxes.
4. There is not enough moisture coming out of the slab to deteriorate the boxes.
5. The Savway boxes are very weak on the sides and very strong in the middle.
6. The Savway boxes deteriorate slower because of the wax impregnation.
7. Boxes with no wax seem to deteriorate at an acceptable rate.
8. Covering the entire box with poly stopped any deterioration.

VI. Initial Conclusions:

1. Boxes should be tested from the bottom, not the top. Since expansive soil heaves, the boxes should be tested from the bottom. The initial deterioration is on the bottom and therefore, the box is weaker when loaded from the bottom.
2. Boxes under the slab should be constructed with no wax if possible.
3. Diagonal Type boxes which are wax impregnated and have strong vertical and diagonal members deteriorate much slower and they possibly stay too strong under slabs.
4. New tests were devised using waterbeds to load the void boxes from the bottom. Refer to the description of waterbed tests.

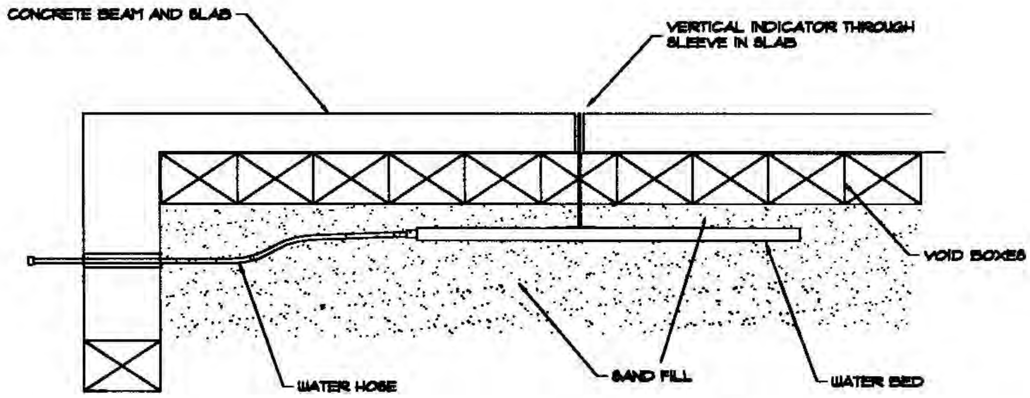
VII. Test 4: Water Bed Test

It was determined by the initial testing procedure that the void boxes need to be tested in place from the bottom. A 25 ft x 37 ft test slab was built with one of the purposes to test the void boxes and another purpose was to test analytical methods of designing flat slabs for houses.

Five waterbeds were placed below the sub-grade under the void boxes. One was queen size and four were twin size. Three of the waterbeds had SureVoid Boxes with no wax on top of them, one had fully waxed SureVoid beam boxes and one had a Savway slab box.

The purpose of using the waterbeds was an attempt to simulate actual heaving of soil and to test an in place situation on an actual project. The waterbed was buried in the subgrade while constructing the slab. After a period of time, the waterbeds were filled to see if the void boxes collapse or if pressure is exerted on the slab indicating full capacity boxes without deterioration.

Steel rods were welded to plates which rested on top of the sub-grade above the waterbed. This rod was sleeved through the slab with pvc pipe. The purpose of these indicator rods was that when the waterbed filled up, if the top of the rod raised up also, the void boxes collapsed.



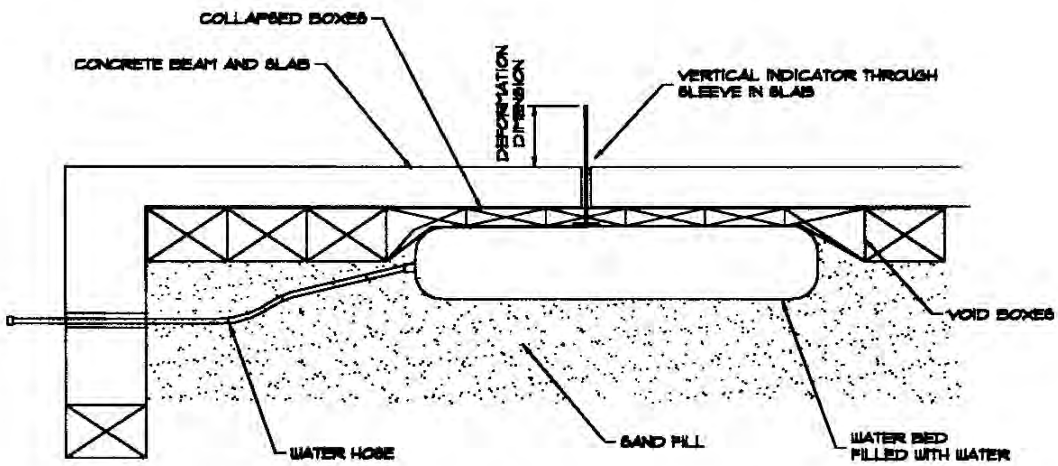
WATER BED TEST OF VOID BOXES-INITIAL SET UP

VIII. Results The Water Bed Test:

Three weeks after the slab was poured, the waterbeds were filled. All five waterbed indicators rose quickly and to a maximum height of 7 inches. The void boxes were 8 inches deep at these points, therefore, the boxes were fully collapsed. No deflection or distress was observed in the slab therefore, the test was successful.

Three of the test were done with a subgrade that had ¼ inch rain on it the night before placing the concrete. The waxed boxes were placed in a very dry, sandy subgrade in over 100 degree weather, trying to simulate the driest of conditions. Observation holes which were 4 inch in diameter were located to monitor the deterioration of the void boxes. It was observed that for approximately two weeks after the slab was poured, the humidity was very high in the void space with a great deal of heat generated.

Slab indicators showing the "heaving" of the soil and therefore the failure of the boxes



WATER BED TEST OF VOID BOXES-TEST RESULTS

IX. Conclusions From Water Bed Tests:

1. After three weeks all boxes had lost enough strength to protect the slab from pressure.
2. After three weeks, even boxes which are waxed will fail adequately. All boxes tested were of the vertical cell type.
3. This test was very successful and the use of waterbeds is an excellent method to test void boxes.

X. Test 5: Effect of Integral Retainers and Earth Forming:

As published in the Fall, 1997 Proceedings of the Texas Section of The American Society of Civil Engineers, Mr. Robert Davis, P.E. tested trapezoidal void boxes to determine if they fail under construction loads. His conclusion was that trapezoidal boxes of the diagonal type fail when used under a grade beam. We have also seen this in the field and agree with the findings. However, some engineers still use the integral concrete retainers. This test was to determine if earth formed grade beams with trapezoidal boxes and the integral concrete retainers are appropriate.

A testing apparatus was constructed to test different box and retainer configurations. The test was constructed to push up from the bottom with highly expansive fat clays below the simulated grade beam.

View of test apparatus

View of beam void box with retainers

Hydraulic jacks were used under the expansive soil to simulate the heaving of expansive soil. A weight equivalent to 200 psf was applied to the grade beam. The friction of the soil plus the bearing on the end of the concrete retainer caused the box to freely move upward.

View of displaced box

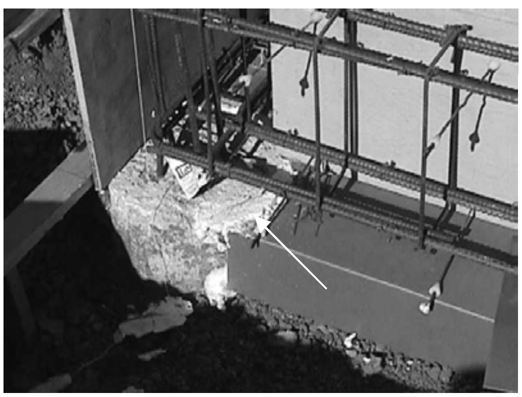
XI. Project Experience-Performance of Boxes under Grade Beams

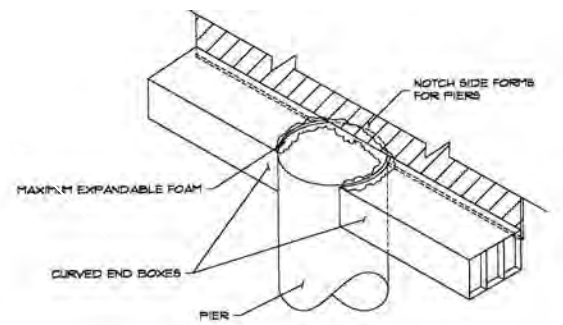
About the time of our tests, a construction project was completed using diagonal type beam boxes under formed concrete beams. Approximately 1000 feet of grade beams were set up in dry weather and normal conditions. The concrete was placed at 5 inch slump and vibrated. After the forms were removed, it was discovered that approximately 20 percent of the void boxes failed. The contractor was instructed to chip off all excess concrete that invaded the void space which took approximately three days to accomplish. The next 1000 feet of grade beams were set up using vertical cell boxes under the same conditions with the same contractor. No boxes failed on this second pour.

View of failed boxes

XII. Suggested Procedure for Filling Gaps

The weakest point of failure for void boxes is on the ends and especially at the intersection with piers. After experimenting with several methods, I have found that common expandable foam as found in hardware stores works excellent in filling gaps and providing a tight form during construction. I recommend all gaps and holes between boxes and at the intersection with piers be filled with this foam. The cost is nominal for a typical project.





Expandable Foam used to fill gaps

XIII. Final Conclusions and Recommendations

1. All boxes must have moisture in order to deteriorate properly. Therefore, the boxes should not be completely wrapped in poly which is a common practice of contractors.
2. The moisture from the subgrade plus the hydration of the concrete appear to provide adequate deterioration of the boxes. The void boxes appear to fail from the bottom to the top.
3. A moisture barrier (polyethylene) should not be used below the boxes because it does not allow deterioration from the subgrade below.
4. A moisture barrier (poly) on top of the boxes may affect the hydration of the concrete and therefore the humidity in the void space. This barrier also increases the probability of excessive shrinkage cracks and therefore should not be used for that reason. The question of if this barrier is necessary to prevent moisture

migration through the slab and thus affect any floor covering is not a subject of this paper. However, this author has not encountered this problem and therefore, does not recommend placing a vapor barrier on top of the boxes.

5. A layer of ¼ inch thick masonite should be used on top of all boxes under a slab area. This distributes the concentrated loads due to the rebar bolsters and construction loads. It is our experience that the cardboard cover sheets supplied by the box manufacturers are not adequate for the construction loads. Masonite of less thickness will curl and is not recommended. Plywood or OSB board is not recommended because of termites.
6. Trapezoidal boxes should not be used because the concrete retainers transfer forces from the expanding soil to the concrete beam above. There is also evidence that these boxes fail during construction if they are of the diagonal cell configuration.
7. Expandable foam should be used to fill all gaps between boxes and at pier locations.
8. The engineer should take an active roll in the construction procedures to insure that the void boxes do not fail during construction and that the boxes are installed in such a way to ensure that proper deterioration takes place. In my opinion, if the following guidelines are met, the above goal will be accomplished:
   - Use vertical cell boxes. SureVoid boxes appeared to be superior due to the wax coating and gluing of cells. However, the Savway and Harris slab boxes also are acceptable but are more difficult to install because when cut to fit a small space, they may lose their strength. They also do not provide curved end boxes. Do not use diagonal cell boxes under beams or slabs.
   - Use curved boxes at the piers and fill all gaps with expandable foam.
   - Do not use a vapor barrier below, above or around the boxes.
   - Do not use trapezoidal boxes under grade beams.
   - Use ¼ inch masonite over all slab boxes.
   - Do not allow earth forming and use separate earth retainers.
9. If the engineer desires to allow earth forming of beams and/or trapezoidal boxes, the following design should be done:
   - Determine the maximum uplift forces of the soil and calculate the capacity of the grade beams with that force applied to the bottom of the grade beams. If the dead load on the beam is equal or greater than the uplift force, no additional design needs to be done. If the uplift force is greater, the grade beam needs to be designed for this upward force minus the dead load and the piers must be designed for this uplift.
   - There are two uplift forces: bearing on the bottom of the beams and side friction between the soil and sides of the beam. One method of determining these forces is to provide swell tests to determine the surcharge needed for zero swell and use the shear capacity of the soil for the side friction. The actual determination of these forces is not in the scope of this report.
   - It would be a reasonable assumption that if the above items were accounted for and the actual forces are the same or lower than assumed, no void boxes would be necessary under beams.