An Evaluation of Elastizell Concrete as a Lightweight Fill Material

David L. Allen* Bobby W. Meade†
AN EVALUATION OF ELASTIZELL CONCRETE
AS A LIGHTWEIGHT FILL MATERIAL

by

David L. Allen
Chief Research Engineer

and

Bobby W. Meade
Engineering Technician

Kentucky Transportation Research Program
College of Engineering
University of Kentucky

in cooperation with

Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U. S. Department of Transportation

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Kentucky, the Federal Highway Administration or the Kentucky Transportation Cabinet. This report does not constitute a standard, specification, or regulation.

April 1984
INTRODUCTION

Near Northern Kentucky University in Campbell County, Kentucky, access ramps connecting I 275 and 3-Mile Road (shown in Figure 1) were constructed. During construction of those ramps, additional embankments were to be placed on an existing 6-foot by 5-foot box culvert. Both ramps, hereafter referred to as NKU-1 (the exit ramp from I 275) and NKU-2 (the entrance ramp to I 275), cross the culvert. The new embankments would result in fill heights, over the culvert, of 30 feet at Station 39+14 of NKU-1 (Figure 2) and 47 feet at Station 11+68 of NKU-2 (Figure 3). The original fill height was approximately 11 feet at NKU-1 and 29 feet at NKU-2. With the use of conventional fill material, loading on the culvert would exceed that which the structure was designed to support. To avoid replacing the existing culvert, a lightweight fill material was needed.

Elastizell lightweight concrete was chosen for construction of the embankments. This concrete is made by blending a preformed Elastizell foam with a cement-water slurry. The resulting fluid forms a discrete cellular concrete that may be placed at densities as low as 20 pounds per cubic foot with a relatively high compressive strength. Elastizell concrete is identified by class and, generally, a lower class indicates a lower density. Because the material is a thin liquid, it may readily be pumped through hoses from the mixing equipment into formed basins (Figure 4). Some common applications for low-density concrete are: roof fills, thermal insulation, fire protection, and stabilizing fills.

This study was performed to determine the engineering properties of this material during and after placement, observe construction procedures for placing the material, and to evaluate its performance as a lightweight fill material.

CONSTRUCTION

At both sites, a portion of the existing fill was removed in preparation for placement of the concrete fill (Figure 5). Earth cuts were used as forms whenever possible. Elsewhere, plywood forms were placed to provide for lifts of 2 feet (Figure 6). On succeeding lifts, the forms were placed so that one continuous vertical joint would not occur. Before the concrete cured, a rippled or notched board was drawn across the surface of each lift (Figure 7).

Special care was taken to keep water out of the site; and in the case of rain, placement of the concrete was delayed until water could be removed. At NKU-1, perforated pipe surrounded by aggregate was constructed prior to the placement of plastic sheeting (Figure 8) to facilitate drainage of the material surrounding the concrete fill. Each lift was allowed to set overnight, usually 12 to 24 hours, before placement of an additional lift. After the entire concrete fill was completed, plastic sheeting was placed over all exposed surfaces. Spaces between earth cuts and the completed concrete fill were backfilled and compacted using a tracked backhoe. When the earth backfill around the concrete was completed, a pad of earth 2 feet in depth was placed over the concrete before heavy equipment was allowed on it.

The lightweight and fluid nature of the Elastizell was beneficial in some respects and a problem in others. Forming was quickly and easily
placed and supported by stakes driven in the existing earth fill or the previous lift of concrete. The concrete was readily pumped into place through hoses, and workmen, wearing wading boots, could manuever hoses or finish the surface by wading (Figure 9).

Several problems were encountered during construction. At NKU-1, rain delayed placement of the concrete and necessitated removal and replacement of the instrumentation. At both sites, the fluid nature of the concrete presented a problem in that forms were not sufficiently tight to prevent flow-through. Excavation at NKU-1 resulted in a steep embankment parallel to the guardrail of I 275 (Figure 10). Subsequent sloughing of the embankment undermined the shoulder and guardrail. Concrete from the first pour was hosed over the embankment to stabilize it (Figure 11).

Elastizell appears to be very sensitive to disturbances during curing. At NKU-2, several areas collapsed, leaving dish-like depressions several inches deep and 4 to 5 feet in diameter. Blasting during removal of rock at a nearby cut caused one recently placed lift at NKU-1 to collapse to approximately 16 inches of its original 24-inch depth. At both sites, collapsed areas were filled during placement of the next lift.

It was discovered during placement of the concrete that, in some instances, the size of an individual pour needed to be reduced. The amount of time required to complete such large pours permitted the concrete to begin curing before the pour was completed. The problem was solved by using additional forms to halve larger areas.

INSTRUMENTATION

To monitor the load generated by the Elastizell concrete and movement of the underlying fill, several instruments were installed: Carlson earth pressure meters, horizontal slope inclinometers, and multipoint settlement gages. At each ramp, two earth pressure cells, one horizontal slope inclinometer, and one settlement gage were installed. A single monitoring station for each ramp was established and instrumentation leads were extended to it. After completion of all construction at the sites, additional instrumentation such as vertical slope inclinometers may be installed. It should be noted that all work and installation was performed at the convenience and discretion of the contractors.

Horizontal slope inclinometers and settlement gages were installed to monitor fill movement. Those instruments were placed at the interface of the Elastizell concrete and the underlying earth fill. Precautions were taken to keep the gages from being embedded in the concrete and therefore measuring only movement of the concrete. This was accomplished by placing the instruments below the plastic liner and securing them to the earth fill (Figure 12). All settlement instruments were successfully installed and were in working order throughout the Elastizell concrete placement but did not survive subsequent backfilling operation by the general contractor.

Earth pressure meters were installed to monitor the loading on the underlying earth caused by the Elastizell concrete. At each site, two meters were installed. One was placed beneath the centerline of the ramp. The other meter, at each site, was situated beneath the concrete and nearer the edge of the ramp (Figure 13). All meters were in good
working order immediately after installation; however, at NKU-1, the one near the edge of the ramp was destroyed during the backfilling operation.

Each meter was placed with its sensing face toward the earth fill and resting on a pad of fine granular material (Figure 14). The readout cable was then placed inside a protective conduit and extended to the monitoring station. In addition to measuring earth pressure, the meter has temperature sensing capabilities.

FIELD DATA

Initial data were obtained on all instruments; but soon thereafter, all settlement monitoring instruments and one earth pressure meter were destroyed. Both earth pressure meters at NKU-2 and the one under the centerline of the ramp at NKU-1 remained intact.

Using typical sections to determine fill heights, the expected pressure on the earth fill beneath the lightweight concrete was calculated to be 7.34 pounds per square inch at NKU-1 and 6.72 pounds per square inch at NKU-2. Stress meter data indicate pressures of 6.55 pounds per square inch near the edge of the concrete and 20.10 pounds per square inch beneath the centerline at NKU-2 (Figure 15). At NKU-1, the remaining meter, beneath the center of the fill, indicated a pressure of 22.17 pounds per square inch. That exceeded the pressure that would be expected from a conventional fill.

The earth pressure meters were also used to collect temperature data. The meters, located beneath the concrete fill, probably do not reflect the temperatures occurring in the center of the concrete mass. Information received from the U. S. Department of Transportation concerning an Elastizell concrete fill in West Virginia indicated temperatures in the fill in excess of 180 degrees Fahrenheit approximately 16 hours after placement (Figure 16). No data were obtained during a 96-hour period immediately after placement of concrete at NKU-1 or NKU-2; however, long-term monitoring indicated elevated temperatures for several weeks (Figure 17).

LABORATORY TESTS

Laboratory efforts to evaluate Elastizell lightweight concrete consisted primarily of density determinations, permeability, compressive strength, and freeze-thaw characteristics. Efforts were hampered by the limited number of samples and the need to determine proper testing procedures.

Permeability tests were conducted using a method similar to one described by the U. S. Army Corp of Engineers (1). Tests were conducted under varied conditions of pressure-head differential and confining pressure. Those variances had no obvious influence on test results. After the air had been removed by vacuuming, each sample was allowed to saturate for a minimum of 24 hours prior to testing. After the permeability was determined, each sample was weighed and tested for compressive strength in its saturated state.

Data obtained from those tests varied considerably, but generally indicated a decrease in permeability as density increased (Figure 18).
The specification for this material was for a permeability coefficient of 0.000001 centimeters per second for Class IV concrete. No specifications were submitted for Class II concrete. Permeability coefficients of 0.0000068 centimeters per second and 0.0000024 centimeters per second for Class IV concrete were measured.

Density of the concrete as placed, cured, and in a saturated state was studied. Placement density was determined by the contractor and the information transmitted to this agency, along with the samples. Class II placement density ranged from 25 to 29 pounds per cubic foot, and was 36.8 pounds per cubic foot for the single set of Class IV samples (Table 1). Specifications for the placement density were a maximum of 30 pounds per cubic foot for Class II and 42 pounds per cubic foot for Class IV.

The density of the concrete continued to decrease after it was removed from the molds. To permit the samples to reach a stable density, they were allowed to age a minimum of 80 days before calculating a cured density. Class II cured densities ranged from 20.5 to 24.2 pounds per cubic foot and the Class IV cured density was 30.0 pounds per cubic foot (Table 2). The average decrease in density from placement to after curing was 5.3 pounds per cubic foot for Class II and 6.8 pounds per cubic foot for Class IV.

After samples had been saturated by permeability testing, they were weighed and their densities were determined. When saturated, the density of the two classes were similar. Saturated densities ranged from 59.5 pounds per cubic foot to 79.0 pounds per cubic foot (Table 2).

Compressive strength specifications for the lightweight concrete were a minimum of 40 pounds per square inch for Class II and 120 pounds per square inch for Class IV. Strength tests were conducted on cured samples in air dried and saturated conditions. All lightweight concrete cylinders, in the dry cured state, exceeded compressive strength specifications. Class II cylinders ranged from 66.0 to 171.7 pounds per square inch. Class IV cylinder compressive strength was 238.9 pounds per square inch (Figure 19). Tests conducted by the Kentucky Department of Highways, Division of Materials, produced data that verify these findings (Table 3).

When saturated, compressive strengths of Class II cylinders averaged 49.6 percent of their dry compressive strengths. The Class IV saturated sample attained 70.5 percent of its dry strength (Figure 20). Class II cylinders, under saturated conditions (in some cases), would not meet specifications.

Due to the shortage of Class IV cylinders, and lack of specifications for Class II cylinders, an in-depth freeze-thaw resistance study was not attempted. However, three Class II samples were subjected to 20 cycles of temperature changes from 0 to 70 degrees Fahrenheit. The samples totally disintegrated (Figures 21, 22, and 23). Four samples (three Class II and one Class IV) were subjected to temperature variations of 0 to 40 degrees Fahrenheit. Those cycles were of short duration, and consequently, the cylinders did not completely thaw. However, the Class II samples showed significant deterioration (Figure 24). In Figure 24, the Class IV sample is at far left and the leftmost Class II sample had the highest density of the three Class II samples.

Samples were saturated with distilled water for permeability testing and with tap water for freeze-thaw testing. When the freeze-thaw samples were removed from the saturation tank, they were discolored and had acquired a deposit of gelatinous material. Samples saturated in distilled water showed no changes.
CONCLUSIONS

In the dry cured state, Elastizell lightweight concrete exceeded compressive-strength specifications and was 25 to 30 percent the density of conventional earth fill. Permeability test results indicated an apparent ability to absorb water readily and increase the weight of the concrete. If the concrete were to absorb water until saturated, it would weigh 60 to 70 percent as much as conventional earth fill.

A problem associated with water absorption is the approximate 50-percent loss of compressive strength, after saturation. Results of compressive strength tests indicated some of the material, if saturated, may not meet strength specifications. The concrete most likely to become saturated would be at the bottom of the fill. Cylinders with the lowest compressive strengths were samples of concrete placed in the first lifts at NKU-2.

Plastic sheeting was placed over all exposed surfaces of the concrete to minimize the absorption of water. The sheeting was not sealed and, in some cases, was torn away during the earth-filling operation. More care should be taken to seal the sheeting and maintain a pad of protective material during subsequent backfilling operations.

Because the data indicated elevated temperatures, consideration should be given to delaying placement of additional lifts to allow dissipation of heat. On this project, some concrete was placed before the underlying concrete had time to attain maximum temperature. That is could result in a build-up of temperature and may adversely affect the engineering properties of the concrete. A minimum time interval of 24 hours before placing an additional lift would allow some heat dissipation.

Earth pressure data indicated pressures immediately under the concrete fill exceeded the weight of the material above the meters. The measured pressure exceeded that which would be expected to result from the same depth of conventional fill. That excess pressure is not due entirely to the weight of the fill above the meters but may be the result of differential settlement of the fill. The soil prisms on either side of the concrete fill may have settled more than the concrete fill. The down-drag of the adjoining soil would shift additional load to the concrete fill. That phenomenon is addressed in the Costes procedure discussed by Allen and Russ (2). Pressure measured at meter depth plus the weight of the fill beneath the meters could exceed the design capabilities of the culvert.

Due to the altered coloring and a deposit left on cylinders placed in a water tank to saturate, future research concerning Elastizell concrete might address the interaction of the concrete with chemicals or minerals found in the surrounding materials.

REFERENCES

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>PLACEMENT DENSITY*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-C</td>
<td>26.0</td>
</tr>
<tr>
<td>4-C</td>
<td>25.0</td>
</tr>
<tr>
<td>5-C</td>
<td>25.0</td>
</tr>
<tr>
<td>9-C</td>
<td>25.6</td>
</tr>
<tr>
<td>11-C</td>
<td>25.8</td>
</tr>
<tr>
<td>13-C</td>
<td>26.8</td>
</tr>
<tr>
<td>15-C</td>
<td>28.0</td>
</tr>
<tr>
<td>18-C</td>
<td>29.0</td>
</tr>
<tr>
<td>19-C</td>
<td>27.0</td>
</tr>
<tr>
<td>21-C</td>
<td>27.4</td>
</tr>
<tr>
<td>23-C</td>
<td>26.5</td>
</tr>
<tr>
<td>31-A</td>
<td>27.2</td>
</tr>
<tr>
<td>43-A</td>
<td>26.6</td>
</tr>
<tr>
<td>52-A</td>
<td>36.8</td>
</tr>
</tbody>
</table>

* Pounds per Cubic Foot
** Class IV Concrete
TABLE 2. CURED AND SATURATED DENSITIES
OF ELASTIZELL CONCRETE

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>CURED DENSITY</th>
<th>SATURATED DENSITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-C-1</td>
<td>20.5</td>
<td>72.0</td>
</tr>
<tr>
<td>11-C-2</td>
<td>20.5</td>
<td>67.9</td>
</tr>
<tr>
<td>15-C-1</td>
<td>24.2</td>
<td>73.6</td>
</tr>
<tr>
<td>15-C-3</td>
<td>23.8</td>
<td>74.9</td>
</tr>
<tr>
<td>19-C-1</td>
<td>21.1</td>
<td>59.5</td>
</tr>
<tr>
<td>19-C-2</td>
<td>21.1</td>
<td>70.5</td>
</tr>
<tr>
<td>21-C-1</td>
<td>21.2</td>
<td>77.0</td>
</tr>
<tr>
<td>21-C-3</td>
<td>21.2</td>
<td>58.0</td>
</tr>
<tr>
<td>43-A-1</td>
<td>20.5</td>
<td>67.6</td>
</tr>
<tr>
<td>52-A-3**</td>
<td>30.0</td>
<td>79.0</td>
</tr>
<tr>
<td>52-A-4**</td>
<td>30.0</td>
<td>73.9</td>
</tr>
</tbody>
</table>

* Pounds per Cubic Foot
** Class IV Concrete
TABLE 3. BLASTIZELL CONCRETE  
COMPRESSIVE STRENGTH

<table>
<thead>
<tr>
<th>SAMPLE NO.</th>
<th>COMPRESSIVE STRENGTH*</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-A</td>
<td>133</td>
</tr>
<tr>
<td>32-A</td>
<td>108</td>
</tr>
<tr>
<td>33-A</td>
<td>104</td>
</tr>
<tr>
<td>34-A</td>
<td>119</td>
</tr>
<tr>
<td>35-A</td>
<td>100</td>
</tr>
<tr>
<td>36-A</td>
<td>102</td>
</tr>
<tr>
<td>37-A</td>
<td>130</td>
</tr>
<tr>
<td>38-A</td>
<td>102</td>
</tr>
<tr>
<td>39-A</td>
<td>118</td>
</tr>
<tr>
<td>40-A</td>
<td>114</td>
</tr>
<tr>
<td>41-A</td>
<td>109</td>
</tr>
<tr>
<td>42-A</td>
<td>94</td>
</tr>
<tr>
<td>44-A</td>
<td>100</td>
</tr>
<tr>
<td>45-A</td>
<td>99</td>
</tr>
<tr>
<td>46-A</td>
<td>94</td>
</tr>
<tr>
<td>47-A</td>
<td>81</td>
</tr>
<tr>
<td>48-A</td>
<td>99</td>
</tr>
<tr>
<td>49-A</td>
<td>80</td>
</tr>
<tr>
<td>50-A</td>
<td>79</td>
</tr>
<tr>
<td>51-A**</td>
<td>207</td>
</tr>
<tr>
<td>53-A**</td>
<td>337</td>
</tr>
<tr>
<td>54-A**</td>
<td>219</td>
</tr>
</tbody>
</table>

* Pounds per Square Inch  
** Class IV Concrete
Figure 1. Access Ramps (NKU-1 and NKU-2) at I 275 and 3-Mile Road in Campbell County, Kentucky.
Figure 2. Approximate Section through Conduit at Sta 39+14, Ramp NKU-1.
Figure 3. Approximate Section through Conduit at Sta 11+68, Ramp NKU-2.
Figure 4. The Elastizell Mixing Equipment and Hoses Conveying Concrete to the Forms.

Figure 5. Excavation at NKU-2 in Preparation for Placement of Concrete Fill.
Figure 6. Plywood and Earth Cuts Used as Forms at NKU-2.

Figure 7. Rippled Surface of a Completed Concrete Pour at NKU-2.
Figure 8. Perforated Pipe, Covered with Aggregate, Is Placed near Base of Concrete Fill Fill at NKU-1.

Figure 9. Workman Finishes Surface of a Lift at NKU-2.
Figure 10. Excavation at NKU-1 Undermined Guardrail and Shoulders.

Figure 11. Cut Stabilized with Elastizell Concrete.
Figure 12. Instrumentation in Place and Protected by Plastic Prior to Placement of Concrete at NKU-2.

Figure 13. Relative Positions of Earth Pressure Meters (circled) at NKU-2.
Figure 14. Earth Pressure Meter Placed on a Pad of Fine Granular Material with Its Read-Out Cable Placed Inside Conduit.
Figure 15. Earth Pressure Immediately Beneath Concrete Fill.
Figure 16. Temperature in Concrete Fill (West Virginia)
Figure 17. Temperature at Earth-Concrete Interface.
Figure 18. Relationship of Permeability to Pour Density.
Figure 19. Relationship of Compressive Strength to Pour Density.
Figure 20. Compressive Strength (Saturated versus Dry).
Figure 21. Class II Concrete Cylinder after 20 Freeze-Thaw Cycles (0 to 70 Degrees Fahrenheit).

Figure 22. Class II Concrete Cylinder after 20 Freeze-Thaw Cycles (0 to 70 Degrees Fahrenheit).
Figure 23. Class II Concrete Cylinder after 20 Freeze-Thaw Cycles (0 to 70 Degrees Fahrenheit).

Figure 24. Concrete Cylinders after Freeze-Thaw Cycles (0 to 40 Degrees Fahrenheit). (Left Cylinder--Class IV Concrete; Three Right Cylinders--Class II Concrete).