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Terrazzo Cracking: Causes and Remedies

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TERRAZZO CRACKING: CAUSES AND REMEDIES

A Thesis Presented
by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>viii</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Project Outline</td>
<td>2</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW AND BACKGROUND INFORMATION</td>
<td>3</td>
</tr>
<tr>
<td>2.1 Overview of Logan Airport Elevated Walkway Cracking</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Terrazzo Materials</td>
<td>6</td>
</tr>
<tr>
<td>2.2.1 Cementitious Terrazzo</td>
<td>7</td>
</tr>
<tr>
<td>2.2.2 Epoxy Terrazzo</td>
<td>8</td>
</tr>
<tr>
<td>2.2.3 Aggregate</td>
<td>9</td>
</tr>
<tr>
<td>2.2.4 Divider Strips</td>
<td>9</td>
</tr>
<tr>
<td>2.3 Research at Logan International Airport</td>
<td>11</td>
</tr>
<tr>
<td>2.3.1 Determine the Nature of Cracking</td>
<td>11</td>
</tr>
<tr>
<td>2.3.2 Develop Design Specifications</td>
<td>12</td>
</tr>
<tr>
<td>2.3.3 Recommend Practical Corrective Actions</td>
<td>12</td>
</tr>
<tr>
<td>2.3.4 Recommend Quality Assurance Inspection Techniques</td>
<td>13</td>
</tr>
<tr>
<td>2.4 Results of Investigation at Logan International Airport</td>
<td>13</td>
</tr>
<tr>
<td>2.4.1 Investigation of Existing Cracking</td>
<td>13</td>
</tr>
<tr>
<td>2.4.2 E Bridge</td>
<td>15</td>
</tr>
<tr>
<td>2.4.3 A Bridge</td>
<td>36</td>
</tr>
<tr>
<td>2.4.4 B and C Bridges</td>
<td>39</td>
</tr>
<tr>
<td>2.4.5 Nature of Cracking</td>
<td>42</td>
</tr>
<tr>
<td>2.4.5.1 Divider Strips</td>
<td>42</td>
</tr>
<tr>
<td>2.4.5.2 Moving Walkway Ends</td>
<td>43</td>
</tr>
<tr>
<td>2.4.5.3 Expansion Joints</td>
<td>44</td>
</tr>
</tbody>
</table>
2.4.5.4 Bumper Supports.................................................................................. 44
2.4.5.5 Vent Openings...................................................................................... 46
2.5 Reasons for Terrazzo Cracking at Logan International Airport...................... 47
2.6 Crack Prevention Methods............................................................................ 50
2.7 Recommended Repair Methods..................................................................... 54
2.8 Evaluation of Existing Specifications............................................................. 57

3 EXPERIMENTAL SETUP AND TESTING............................................................ 65

3.1 Compressive Strength Tests........................................................................... 65
3.2 Linear Shrinkage Tests.................................................................................. 67
3.3 Durability Tests.............................................................................................. 69

3.3.1 Durability Test Setup.................................................................................. 70
3.3.2 Durability Test Parameters......................................................................... 73
3.3.3 Durability Test Procedure.......................................................................... 74

4 RESULTS ............................................................................................................. 77

4.1 Compressive Strength Tests........................................................................... 77
4.2 Linear Shrinkage Tests.................................................................................. 78
4.3 Wheel Durability Tests.................................................................................. 83

4.3.1 Material Comparison.................................................................................. 86
4.3.2 Wheel Direction Comparison..................................................................... 87
4.3.3 Wheel Size Comparison............................................................................ 88
4.3.4 Gap Size Comparison............................................................................... 89
4.3.5 Vertical Offset Comparison....................................................................... 90
4.3.6 Weight Comparison.................................................................................. 91

5 FINITE ELEMENT ANALYSIS OF TERRAZZO SHRINKAGE........................... 115

5.1 Summary of Reentrant Corner Cracking Problem........................................... 115
5.2 Summary of Cementitious Terrazzo Properties.............................................. 116
5.3 Preliminary Finite Element Model................................................................. 117
5.4 Results From Preliminary Finite Element Model .......................................... 119
5.5 Continued Finite Modeling.......................................................................... 122

6 CONCLUSIONS.................................................................................................. 127

APPENDIX A SELECTED TERRAZZO GUIDE SPECIFICATIONS....................... 131

REFERENCES...................................................................................................... 181
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Crack Prevention Methods Summary</td>
<td>54</td>
</tr>
<tr>
<td>3.1: Wheel Durability Test Parameters</td>
<td>74</td>
</tr>
<tr>
<td>3.2 Wheel Durability Testing Outline</td>
<td>76</td>
</tr>
<tr>
<td>4.1 Compressive Strength of Terrazzo Samples</td>
<td>77</td>
</tr>
<tr>
<td>4.2 Average Linear Shrinkage Data, Samples Poured 10/10/2007</td>
<td>80</td>
</tr>
<tr>
<td>4.3 Average Linear Shrinkage Data, Samples Poured 11/1/2007</td>
<td>82</td>
</tr>
<tr>
<td>4.4 Wheel Durability Test Damage Outline</td>
<td>86</td>
</tr>
<tr>
<td>5.1 Material Properties Used in Finite Modeling</td>
<td>117</td>
</tr>
<tr>
<td>5.2 Stresses in Terrazzo Adjacent to Vent Corner from ADINA</td>
<td>119</td>
</tr>
<tr>
<td>5.3 Rough Check of Principal Stresses</td>
<td>120</td>
</tr>
<tr>
<td>5.4 Average Terrazzo Stresses Adjacent to Vent Corner</td>
<td>123</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1: Aerial View of Logan Airport Elevated Walkways</td>
<td>5</td>
</tr>
<tr>
<td>2.2: Exterior View of Typical Elevated Walkway</td>
<td>5</td>
</tr>
<tr>
<td>2.3: Artistic Inlay on E Bridge</td>
<td>6</td>
</tr>
<tr>
<td>2.4 Sand Cushion Terrazzo, courtesy NTMA</td>
<td>8</td>
</tr>
<tr>
<td>2.5 Epoxy Terrazzo</td>
<td>9</td>
</tr>
<tr>
<td>2.6 Plan View of E Bridge (Adapted from Ref. 4)</td>
<td>16</td>
</tr>
<tr>
<td>2.7 Large Crack, Beginning of E Bridge (from Ref. 4)</td>
<td>17</td>
</tr>
<tr>
<td>2.8 Beginning of E Bridge, View 1, 6/2006</td>
<td>17</td>
</tr>
<tr>
<td>2.9 Beginning of E Bridge, View 2, 1/2007</td>
<td>17</td>
</tr>
<tr>
<td>2.10 Beginning of E Bridge, View 3, 6/2006</td>
<td>17</td>
</tr>
<tr>
<td>2.11 Beginning of E Bridge, View 4, 1/2007</td>
<td>18</td>
</tr>
<tr>
<td>2.12 Beginning of E Bridge, View 5, 1/2007</td>
<td>18</td>
</tr>
<tr>
<td>2.13 Beginning of E Bridge, View 6, 1/2007</td>
<td>18</td>
</tr>
<tr>
<td>2.14 Separation from Divider Strip near Terminal E, View 1, 6/2006</td>
<td>19</td>
</tr>
<tr>
<td>2.15 Separation from Divider Strip near Terminal E, View 2, 6/2006</td>
<td>19</td>
</tr>
<tr>
<td>2.16 Separation from Divider Strip near Terminal E, View 3, 6/2006</td>
<td>19</td>
</tr>
<tr>
<td>2.17 End of First Moving Walk of E Bridge, View 1, 6/2006</td>
<td>20</td>
</tr>
<tr>
<td>2.18 End of First Moving Walk of E Bridge, View 2, 6/2006</td>
<td>20</td>
</tr>
<tr>
<td>2.19 End of First Moving Walk of E Bridge, View 3, 1/2007</td>
<td>21</td>
</tr>
<tr>
<td>2.20 Acceptable Separation, Barely Visible, 6/2006</td>
<td>21</td>
</tr>
<tr>
<td>2.21 Expansion Joint, South Node, E Bridge, 4/2000 (From Ref. 4)</td>
<td>22</td>
</tr>
</tbody>
</table>
2.22 Expansion Joint in South Node of E Bridge, 6/2006 ........................................ 23
2.23 Start of Second Walkway, E Bridge, 4/2000 (From Ref 8) ......................... 24
2.24 Start of Second Walkway, E Bridge, View 1, 6/2006 ................................... 25
2.25 Start of Second Walkway, E Bridge, View 2, 1/2007 ............................... 25
2.26 Start of Second Walkway, E Bridge, View 3, 6/2006 ............................... 26
2.27 Start of Second Walkway, E Bridge, View 4, 1/2007 ............................... 26
2.28 Start of Second Walkway, E Bridge, View 5, 6/2006 ............................... 26
2.29 Start of Second Walkway, E Bridge, View 6, 1/2007 ............................... 27
2.30 Start of Second Walkway, E Bridge, View 7, 6/2006 ............................... 27
2.31 50’ From Start of Second Walk, E Bridge, 6/2006 .................................. 28
2.32 Bumper Crack, End of Second Walk, E Bridge, 6/2006 ......................... 29
2.33 Bumper Crack, End of Second Span, E Bridge, 1/2007 .......................... 29
2.34 Bumper Crack, Start of Second Span, E Bridge, 6/2006 ......................... 30
2.35 End of Second Walkway, E Bridge, View 1, 6/2006 ............................... 31
2.36 End of Second Walkway, E Bridge, View 2, 6/2006 ............................... 31
2.37 End of Second Walkway, E Bridge, View 3, 1/2007 ............................... 31
2.38 End of Second Walkway, E Bridge, View 4, 6/2006 ............................... 31
2.39 End of Second Walkway, E Bridge, View 5, 1/2007 ............................... 31
2.40 Start of Third Walkway, E Bridge, 6/2006 ............................................. 32
2.41 Separation at Start of Third Walkway, E Bridge, 6/2006 ......................... 32
2.42 Repair with Color Mismatch, E Bridge, 6/2006 ..................................... 33
2.43 Repair near Middle of Third Walk, E Bridge, 6/2006 ............................. 34
2.44 Separation near Middle of Third Walk, E Bridge, 6/2006 ....................... 34
2.45 Expansion Joint at E Bridge and Garage, 4/2000 (From Ref. 4) ....................... 35
2.46 Plan View of A Bridge (Adapted from Ref. 4) ..................................................... 36
2.47 Discoloration, A Bridge, 6/2006 ......................................................................... 37
2.48 13’ From Start of Walkway, A Bridge, View 1, 6/2006 ...................................... 37
2.49 13’ From Start of Walkway, A Bridge, View 2, 1/2007 ...................................... 37
2.50 End of Walkway, A Bridge, View 1, 6/2006 ..................................................... 38
2.51 End of Walkway, A Bridge, View 2, 6/2006 ..................................................... 38
2.52 End of Walkway, A Bridge, View 3, 1/2007 ..................................................... 38
2.53 Walkway Cover Plate Joint, 6/2006 .................................................................. 39
2.54 Soft Joint at Moving Walkway End on C Bridge, 1/2007 ................................. 40
2.55 Crack at Quarter-span on Eastern B Bridge, 6/2006 .......................................... 41
2.56 Large Crack Approaching Terminal B, 6/2006 .................................................. 41
2.57 Divider Separation, Example 1, 6/2006 .............................................................. 42
2.58 Divider Separation, Example 2, 6/2006 .............................................................. 42
2.59 Discoloration, 6/2006 ........................................................................................ 43
2.60 Moving Walkway End Repair, E Bridge, Example 1, 6/2006 .......................... 43
2.61 Moving Walkway End Repair, E Bridge, Example 2, 6/2006 .......................... 43
2.62 Moving Walkway End Repair, E Bridge, Example 3, 6/2006 .......................... 44
2.63 Expansion Joint, E Bridge, 4/2000 (From Ref. 4) ............................................ 44
2.64 Bumper Support Crack, E Bridge, Example 1, 6/2006 ....................................... 45
2.65 Bumper Support Repair, E Bridge, 6/2006 .......................................................... 45
2.66 Bumper Support Crack, E Bridge, Example 2, 6/2006 ....................................... 46
2.67 Vent Opening Crack, E Bridge, Example 1, 6/2007 ......................................... 46
2.68 Flexible Soft Joint, C Bridge, 6/2006 ............................................................... 51
2.69 Expansion Joint Detail ...................................................................................... 52
3.1 Cube Molds ......................................................................................................... 66
3.2 Terrazzo Cubes for Compression Testing ........................................................... 67
3.3 Linear Shrinkage Bar Molds ............................................................................... 68
3.4 Terrazzo Bars for Linear Shrinkage Testing ....................................................... 68
3.5 DEMEC Gauge ................................................................................................... 69
3.6 Terrazzo Tiles for Wheel Durability Test ......................................................... 70
3.7 Terrazzo Tile Placement ..................................................................................... 71
3.8 Wheel Durability Test Setup Drawing ............................................................... 72
3.9 Wheel Durability Test Setup ............................................................................... 72
3.10 Wheels Used In Test ......................................................................................... 73
4.1 Shrinkage Curves, Samples poured 10/10/2007 ................................................. 79
4.2 Shrinkage Curves, Samples poured 11/1/2007 ................................................. 79
4.3 Cracked and Repaired Linear Shrinkage Bar .................................................... 82
4.4 Average Shrinkage Curve of All Samples ....................................................... 83
4.5 Damage Scale ................................................................................................... 85
4.6 Test 1 Pull 93
4.7 Test 1 Push ........................................................................................................ 94
4.8 Test 2 Push ........................................................................................................ 95
4.9 Test 2 Pull 96
4.10 Test 3 Push .................................................................................................... 97
4.11 Test 3 Pull ....................................................................................................... 98
4.12 Test 4 Push ........................................................................................................ 99
4.13 Test 4 Pull ...................................................................................................... 100
4.14 Test 5 Push .................................................................................................... 101
4.15 Test 5 Pull ..................................................................................................... 102
4.16 Test 6 Push .................................................................................................... 103
4.17 Test 6 Pull ..................................................................................................... 104
4.18: Test 7 Push ................................................................................................... 105
4.19: Test 7 Pull ................................................................................................... 106
4.20 Test 8 Push .................................................................................................... 107
4.21 Test 8 Pull ...................................................................................................... 108
4.22 Test 9 Push .................................................................................................... 109
4.23 Test 9 Pull ...................................................................................................... 110
4.24 Test 10 Push .................................................................................................. 111
4.25 Test 10 Pull ................................................................................................... 112
4.26 Test 11 Push .................................................................................................. 113
4.27 Test 11 Pull ................................................................................................... 114
5.1 Vent Hole Crack ............................................................................................. 116
5.2 Geometry and Mesh Refinement of Preliminary FE Model ......................... 118
5.3 Principal Stress Directions of Element 546 .................................................. 120
5.4 First Principal Stress (Tension) ...................................................................... 121
5.5 Third Principal Stress (Compression) .......................................................... 121
5.6 Tensile Stress in Finite Element Models ...................................................... 124
5.7 Compressive Stress in Finite Element Models ............................................. 125
CHAPTER 1
INTRODUCTION

1.1 Background
Terrazzo is a material often used for flooring and consists of an aggregate (typically marble, though glass or other materials are common) in a matrix of cementitious or epoxy material. The aggregate is exposed and the surface ground smooth. By using colorful aggregates and a variety of matrix pigmentations an infinite variety of colorations can be obtained, with a very pleasing and visually exciting final appearance. The cast-in-place nature allows for the use of terrazzo in delineated patterns and artistic renderings. Terrazzo is therefore often preferred as a flooring material by architects, though it can be more expensive than traditional flooring materials. Terrazzo is generally a versatile, durable and low maintenance flooring material. For these and other reasons, terrazzo is the preferred flooring material for several Massachusetts Transportation Agencies and was used exclusively in recent projects at Logan International Airport.

However, widespread terrazzo cracking has occurred in several elevated pedestrian bridge walkways at Logan International Airport. Some cracking was reported shortly after opening of the walkways, but some new cracking has appeared after a period of time in service. Throughout the construction of these bridges, installation techniques and methods were altered to mitigate problems as they were discovered. While the extent of cracking varies widely in the elevated pedestrian bridge walkways, some cracking has occurred in all structures.
1.2 Project Outline
This project began as an investigation into the causes of terrazzo cracking specific to the elevated walkways at Logan International Airport. Its purpose was to examine the causes of cracking, recommend methods to prevent or repair cracking, and serve as documentation of some of the advancements in construction practice implemented in Massachusetts Port Authority (MassPort) projects. Additional testing and computer modeling was performed to further examine the properties of terrazzo and address cracking.

Compressive strength tests were performed on terrazzo samples in order to establish a minimum strength guideline for cementitious terrazzo. Linear shrinkage and finite element modeling was used to determine the effects of shrinkage on the performance of terrazzo. Also, a durability test was performed on terrazzo tiles to simulate the exposure to pedestrian and suitcase traffic at Logan International Airport.
A literature review was compiled to examine the properties of terrazzo and its installation. Included in this chapter are the methods and results from the preliminary investigation at Logan International Airport. The information obtained from this investigation guided further research performed in the laboratory and described in chapters three and four.

2.1 Overview of Logan Airport Elevated Walkway Cracking

The bridges at Logan International Airport provide an indoor path for pedestrians from the central parking garage to terminals A, B, C, and E. (Figure 2.1: ) The bridges from parking to terminals A and E were constructed first and have experienced significant cracking while the bridges from parking to terminals B and C have minimal terrazzo cracking. Cracking in the A bridge and a portion of the E bridge has been repaired. Terrazzo cracking is typical throughout the remainder of the E bridge at the corners of vent openings, bumper supports, and moving walkway ends. The terrazzo cracking detracts from the overall visual effect of the intricate terrazzo artwork. The bridges are an important aesthetic feature of Logan. This is highlighted in Figure 2.2 and Figure 2.3.

The A bridge is 385 feet (117.3 m) long. There are three spans with the outer spans at 123 feet (37.5 m) and the inner span at 139 feet (42.4 m) in length. Support
structures, or nodes occur at the ends of internal spans. The E bridge is 688 feet (209.7 m) in total length. There are five spans with the outer two at 147.6 feet (45.0 m) and the inner three spans at 121 feet (36.9 m) long. Both bridges are 24 feet (7.3 m) wide and their height from top to bottom chord is 18 feet (5.5 m). The A and E bridges were completed on September 8, 1998.\(^1\) Completed two years later, the B and C bridges have longer spans but show almost no terrazzo cracking. The B bridge spans are 213, 244, and 260 feet (64.9, 74.4, and 79.2 m, respectively) in length. The C Bridge has two spans which are 119 and 173 feet (36.3 and 52.7 m) long. Both bridges have a height from top to bottom chord of 18 feet (5.5m) and a width of 24 feet (7.3 m).

Structures are steel truss bridges with a composite concrete deck. The flooring material is generally cementitious based terrazzo with a sand cushion underbed. Epoxy terrazzo was used where there are decorative accent features because it offered an unlimited number of colors for the artist who created aquatic image designs in the flooring. Sections of epoxy terrazzo were installed over a sand cushion to provide continuity in the finished floor elevation.
Figure 2.1: Aerial View of Logan Airport Elevated Walkways

Figure 2.2: Exterior View of Typical Elevated Walkway
2.2 Terrazzo Materials

Terrazzo is a finishing material that comprises marble, glass, or other decorative materials bound in a cement or epoxy matrix. Once used primarily in flooring systems, it is now often used on stairs and walls as well. Many of the standards used in the industry are based on standards developed by the National Terrazzo and Mosaic Association (NTMA).

Although terrazzo systems can be used in a vast number of applications, there are only two basic types of terrazzo. The two different types of terrazzo differ in the matrix that is used to bind the aggregate. The terrazzo matrix can be cement or epoxy based, and in some special situations a combination of the two. Cementitious terrazzo is typically placed on a sand cushion to absorb any defects in the sub floor. The sand bed is usually 1.5 to 2.5 inches (35 to 65 mm) thick and the terrazzo topping is typically ½ inch (13mm) thick. The other predominant terrazzo matrix is epoxy. This can be placed directly on the concrete slab and ranges from ¼ to 3/8 inch (5 to 10 mm). This system is thinner, lighter, more colorful, and is more durable. In the cases of the bridges
studied, epoxy terrazzo was placed over a sand cushion to provide continuity in the finished floor elevation with the adjacent cementitious terrazzo.

2.2.1 Cementitious Terrazzo

In cementitious terrazzo, Portland Cement is used as the binding matrix. White cement is preferred because, unlike grey cement, it does not interfere with or dull the colors of pigment and aggregate used in the terrazzo. For use in terrazzo floors, the cement should exceed the minimum standards of ASTM C-150.

The cementitious terrazzo used on the bridges at Logan International Airport is supported by a sand cushion. A misnomer, the sand cushion is not just a layer of sand. It is typically one part Portland Cement to four parts sand with just enough water to provide workability. The sand cushion is not intended to provide structural strength, but is placed over the concrete slab to absorb any defects in the slab and prevent cracks in the slab from propagating into the terrazzo topping. This is intended to provide more freedom in divider strip spacing as the strips do not need to be placed directly over corresponding concrete slab joints. Directly over the concrete slab is a thin dusting of sand and/or then an isolation membrane, separating the sand cushion and terrazzo surface from the slab. This can be seen in Figure 2.4.

The terrazzo topping used on a cementitious flooring system is generally recommended to be composed of one 94 pound (43 kg) bag of Portland Cement per 200 pounds (91 kg) of marble chips. Color pigment can be added, if desired, and water should be added to produce a workable mix while maintaining the lowest slump possible. (9)
2.2.2 Epoxy Terrazzo

According to the National Terrazzo and Mosaic Association (NTMA), epoxy terrazzo has “Unlimited matrix colors, color control, resiliency, chemical resistance and tensile-compressive strengths not found in cement based systems. [It is] excellent for multi-colored patterns and designs. [Its] light weight and flexibility make it ideal for multi-story use. It has the lowest maintenance cost due to non-absorbency. In sanitary areas [it] can be installed with minimal dividers providing seamless characteristics. When used in conjunction with a flexible membrane as a specified extra, it can absorb horizontal concrete crack or control joint movement. It also has the quickest pour to grind installation time. [It] can also be used over properly installed and prepared plywood. Glass and other decorative aggregates increase costs.” (7)

Epoxy terrazzo includes a resinous two-part binding matrix. This is used in thin-set terrazzo flooring systems and does not require a sand bed underneath, although one could be provided. The minimum physical properties can be found in the
Polyacrylate Terrazzo Specification from the NTMA. (8) Figure 2.5 shows the anatomy of a typical epoxy terrazzo floor.

The epoxy should be mixed following its manufacturer’s guidelines. By volume, one part epoxy should be mixed with three parts marble chips. The marble chips should be a blend of 60% #1 chip and 40% #0 chip. (8)

![Figure 2.5 Epoxy Terrazzo](image)

### 2.2.3 Aggregate

Marble chips are the primary aggregate used in terrazzo. Standard sizes are ¼ and 3/8 inch (5 and 10 mm) but for special applications can be as large as 9/8 inch (30 mm). Marble can also be replaced with onyx, travertine, and some serpentine rocks. Color is the deciding factor when choosing which aggregate to use. Epoxy terrazzo uses marble chips from 1/8 to 3/8 inch (3 to 10 mm). Glass chips, frequently recycled, can also be used in terrazzo. (12)

### 2.2.4 Divider Strips

The purpose of divider strips in a terrazzo floor system is twofold. The primary reason for using divider strips is to allow movement, such as shrinkage or thermal
expansion of the terrazzo and/or substrate, without damaging the terrazzo. This is accomplished by using divider strips evenly throughout the floor. The spacing of the divider strips depends upon the type of terrazzo being used. Terrazzo is expected to shrink, so divider strips are spaced such that the total shrinkage is spread over many small separations, similar to control joints in concrete placements. Divider strips are also placed at trouble locations such as expansion joints and sharp corners. The second reason to use divider strips is to separate different terrazzo mixes for use in decorative artwork. This allows manufacturers to produce elaborate patterns and images on the terrazzo floor.

White alloy of zinc, brass, or plastic divider strips are used for function and aesthetics. For sand cushion terrazzo 1.25 inch (30 mm) deep brass or zinc divider strips at 14, 16, or 18 gauge widths are often used. Heavy top divider strips can also be used. Brass and plastic may have a reaction with some resinous materials and should be used only if deemed safe by the supplier of the resin.

Per the NTMA guideline, the recommended spacing of divider strips for cementitious terrazzo is 5 feet (1500 mm) (7, 9). However, in 1964, the recommended divider strip spacing for cementitious terrazzo was even less. “A reduction in cracking would represent a considerable technical improvement of terrazzo and might also lead to economy by permitting an increase in the spacing of divider strips above the usual 2 to 3 feet (600 to 900 mm).” (13) This increase in divider strip spacing is most likely the result of improved terrazzo materials and installation practices which allowed for larger divider strip spacing. The NTMA guideline does not specify a divider strip spacing for epoxy terrazzo.
When a sand cushion is used the divider strip is set in the sand cushion, otherwise the divider strip is set in a saw cut control joint or an angle section can be placed on the underlying slab.

2.3 Research at Logan International Airport

Objectives of the research project were to determine the causes of terrazzo cracking at the walkway bridge structures at Logan International Airport, develop specifications for terrazzo installation to prevent cracking in future structures and develop guidelines for repairing existing cracks. In order to provide a means for impacting current practice, QA/QC and implementation procedures were also addressed.

2.3.1 Determine the Nature of Cracking

In order to evaluate the status of cracking and repairs, the research team made several visits to Logan International Airport. Data collected included a memo describing cracking in April 2000. The research team compared this to observations from site visits in June 2006, January 2007, and April 2007. The research team contacted representatives from many of those involved in the design and construction of the bridges, including MassPort, C7A, Weidlinger Associates, and DePaoli. Information collected included anecdotal comments and specific documentation of memos and details. Unfortunately, some information such as as-built installation and construction schedules were not available. Therefore, some anecdotal comments on temperature effects during construction could not be verified and are not included in the results of
this report. Terrazzo crack changes were examined and compared over time, temperature, location, and crack type.

An extensive literature review of manufacturer literature was collected to determine typical recommendations on specifications and construction practice. The NTMA member list was used as a primary source of manufacturers and installers. Contact with manufacturers and installers was made and guide specifications were requested.

An additional literature review was performed to find available technical information on terrazzo performance and practice. However, very limited technical literature was found to exist in the field.

2.3.2 Develop Design Specifications

Existing design specifications for the installation and application of terrazzo were obtained and evaluated. Almost all specifications use the NTMA Guide Specifications as a basis, and so this Guide Specification is used as the baseline specification in this report. An evaluation of applicability of this specification for elevated walkways was made. Conversations with Terrazzo Installers and Architects influenced the scope of the proposed recommendations, to ensure that recommendations were not perceived as overly prescriptive.

2.3.3 Recommend Practical Corrective Actions

Currently repair has consisted of minor grinding and cleaning of cracks prior to the installation of a terrazzo epoxy resin in a matching shade. A combination of conversations with architects, terrazzo contractors, and MassPort was undertaken to
determine the effective repair procedures used in the past. Several examples of repairs that are showing excellent performance and others that are deteriorating can be found in the Logan pedestrian bridges. These were used as a basis for recommendations.

2.3.4 Recommend Quality Assurance Inspection Techniques

Quality assurance and inspection guidelines were addressed in order to minimize the likelihood of terrazzo cracking due to installation or design issues. These were based on critical aspects of design, contracting, and inspection that appeared to prevent or lead to terrazzo cracking in the bridges. Evaluations of existing specifications were used to clarify recommendations.

2.4 Results of Investigation at Logan International Airport

The results of all findings from the investigation at Logan International Airport are presented in this section. This includes the evaluation of terrazzo conditions and repairs at the site, determining types and causes of damage, comparing existing specifications, and providing recommendations for specifications and repair methods for future projects.

2.4.1 Investigation of Existing Cracking

The architect for the terrazzo floors, Cambridge Seven Associates, Inc. (C7A), reported on January 18, 2001 (4) the nature of existing terrazzo cracking in elevated walkways A and E at that time. The review of the terrazzo cracking documented in this C7A report took place on April 24, 2000.
Another investigation of the terrazzo cracking on the bridges took place on June 15, 2006 during a visit to Logan International Airport by the Research Team. During this visit, photographs were taken of visible cracks and their locations were recorded.

The Research Team took another trip on January 26, 2007. This day was chosen because it the air temperature was 13 degrees F at 3:00pm. Existing cracking was compared to photographs from the June, 2006 visit, along with the record from April, 2000. The purpose of this second trip was to observe thermal effects on the bridges and floors.

The following compares the extent of documented terrazzo cracking on April 24, 2000 with the terrazzo cracking present on the A and E bridges on June 15, 2006. Records of the condition of the B and C bridges prior to June, 2006 have not been reported, but a comparison was made between the terrazzo cracking on the A and E bridges to the current condition of the B and C bridges. Also compared are the various types of terrazzo repairs throughout the bridges.

For each section, a plan view of the bridge is shown with arrows depicting the starting location and direction of travel during the inspection corresponding the order or cracks mentioned in this report. All close-up pictures of the floors are oriented with the direction of travel in the top of the photo unless otherwise noted. If the orientation of the bridge is clear from surrounding features such as moving walkways, expansion joints, and bumpers direction of travel is not indicated on the individual photo.

It is important to note that basic flooring terrazzo (generally light to dark gray) is cementitious terrazzo over a sand cushion, while all artwork (variety of colors and patterns) is epoxy based terrazzo over a sand cushion. Epoxy terrazzo was used where
there are decorative accent features because it offered an unlimited number of colors for
the artist who created aquatic image designs in the flooring. Sections of epoxy terrazzo
were installed over a sand cushion to provide continuity in the finished floor elevation.

2.4.2 E Bridge

During the visit to the airport in June, 2006, the investigation of the A and E
bridges began at the E terminal side of the E bridge and continued towards the parking
garage. It then resumed on the other side of the garage and stopped at the A terminal.
This sequence of travel is followed below.

Figure 2.6 shows a plan view of the E bridge. The arrows depict the starting
location and direction of travel during the inspection corresponding the order or cracks
mentioned.
At the beginning of the moving walkway nearest to terminal E, there was “major cracking at divider strip” reported in 2000 (4). The state of repairs at that time is shown in Figure 2.7. Since then, that major crack has been repaired with grout (Figure 2.8 through Figure 2.13). The repair shows at least two different grout types were used in the repair. The repair is currently cracked and uneven, filling a gap that is, in places, as large as two inches (50 mm) in width. The feathered edges of patch materials led to additional cracking and chipping from luggage and carts. The dissimilar patch material also detracts from the aesthetic quality of the terrazzo. This also highlights the necessity for repair materials to have compatible material properties with the terrazzo, such as its coefficient of thermal expansion or modulus of elasticity, to provide effective long term repairs. Separation at the divider strip was also noted (and Figure 2.13). There was no variation in separation width between the two dates with significantly different ambient temperatures. It is noted that the interior of all bridges is temperature controlled, but the overall structure is subject to thermal expansion and contraction due to ambient temperature changes.
Figure 2.7 Large Crack, Beginning of E Bridge (from Ref. 4)

Figure 2.8 Beginning of E Bridge, View 1, 6/2006

Figure 2.9 Beginning of E Bridge, View 2, 1/2007

Figure 2.10 Beginning of E Bridge, View 3, 6/2006
There were no indications of terrazzo cracking between the ends of the moving walkways closest to Terminal E in 2000 (4). Currently, there are signs of very minor terrazzo cracking and separation. Figure 2.14 shows almost no separation from the divider strip. It is barely visible, approximately 1/16 in (1.5mm) and represents an acceptable amount of separation. A chip can be seen missing from Figure 2.15, most certainly a piece of aggregate. This was most likely chipped out from a suitcase wheel as a result of the minor separation that is shown. There was also slight terrazzo separation approximately 65 feet (20 m) from the walkway cutout. This can be seen in Figure 2.16.
There were signs of terrazzo cracking in 2000 at the end of the moving walkways just before reaching the support node (4). The node is essentially an enclosed pier that supports the bridge, unlike the majority of the columns which are exposed. This was described as “minor chipping” but Figure 2.17 shows not only minor chipping
from the corner of the plate, but also noticeable separation of the terrazzo from the
divider strip along with grout repairs. Figure 2.17, Figure 2.18, and Figure 2.19 show
significant separation along the divider strip at the end of the first walkway. This is
located along the divider strip at the edge of the cover plates. Minor repairs were made
with grout.

It is very important to note that similar angles (both acute and obtuse) of divider
strips are shown in Figure 2.18 and Figure 2.19 separating epoxy (lighter) and
cementitious (darker) based terrazzo materials. Although separation from the divider
strip is similar in both materials, only the cementitious based materials have required
repairs.

Figure 2.17 End of First Moving Walk of E Bridge, View 1, 6/2006

Figure 2.18 End of First Moving Walk of E Bridge, View 2, 6/2006
Slight separation is also noticeable in the node, so small that it is only noticeable when looking at the divider strip very closely. This acceptable separation is shown in Figure 2.20. This can be compared to the wider separations of Figure 2.18 and Figure 2.19 which are clearly visible.

During construction, a major repair was made to terrazzo abutting the expansion joint at column line E5 in the South Node along bridge E (4). It was noticed that the edges of the expansion joint were not level and the contractor removed and reinstalled three inches (75mm) from the south side of the expansion joint with terrazzo. This repair is labeled “Construction Repair” in Figure 2.21 and Figure 2.22.

Based on the evaluation in 2000 (4) the construction repair performed very well, with no deterioration. However, there were, “major cracks, spalling on this side of expansion joint” referring to the side that was not repaired during construction. This deterioration can be seen in Figure 2.21 from that report. Since then, a repair has been
completed similar to the construction repair. Approximately 3 in (75 mm) of terrazzo topping was removed and replaced to mirror the repair that had been made during construction. This can be clearly seen in the visit in 2006 (Figure 2.22). Both repairs have held up very well.

Figure 2.21 Expansion Joint, South Node, E Bridge, 4/2000 (From Ref. 4)
Figure 2.22 Expansion Joint in South Node of E Bridge, 6/2006
Moving onward past the node, heading towards the parking garage, in 2000 there were “cracks at edge of escalator plate and divider strip.” (Figure 2.23) (4) Since then, multiple repair techniques have been used, including up to three different types of mortar or grout and a poorly applied epoxy, as shown in Figure 2.24 to Figure 2.29. The grout repairs have separated and cracked. The epoxy repair was not completed, and is neither level with the surrounding terrazzo floor nor smooth. New grout material was placed between the 2006 and 2007 site visits (Figure 2.27). This gives the appearance of a continual maintenance issue at this location. Along the same divider strip, which is even with the corners of each walkway plate, there is significant separation (approximately 0.5 in (13 mm)) present between the divider and abutting terrazzo. (Figure 2.30) This is not apparent from the 2000 report (4), although some separation may have been seen and simply placed under the vague description of “cracks at edge of escalator plate and divider strip.”

Figure 2.23 Start of Second Walkway, E Bridge, 4/2000 (From Ref 8)
Figure 2.24 Start of Second Walkway, E Bridge, View 1, 6/2006

Figure 2.25 Start of Second Walkway, E Bridge, View 2, 1/2007
Figure 2.26 Start of Second Walkway, E Bridge, View 3, 6/2006

Figure 2.27 Start of Second Walkway, E Bridge, View 4, 1/2007

Figure 2.28 Start of Second Walkway, E Bridge, View 5, 6/2006
There is some minor terrazzo cracking evident at approximately 52 feet (16 m) from the start of the second walkway. (Figure 2.31) This terrazzo cracking appears to be from shrinkage, as it has separated just slightly from the divider strip. However, this gap is greater than the normally desired separation in divider strips. This was one of the few locations where a larger separation was noted in the epoxy based material. In almost every other case, if there was a difference, the cementitious material showed a greater separation. This is partly due to larger spacing of divider strips in the cementitious
placements, but was shown to be larger in at least some locations where divider spacing was identical in both materials.

No terrazzo cracking was mentioned near the bumpers in 2000 (4), but are now present. It is not clear whether these cracks were not present or were not considered to be significant. Bumper supports show different types of terrazzo cracking. The cracking appears to be related to the bumper support geometry, position of the support relative to a divider strip and difficulty in placing and finishing terrazzo at the supports. Below are three examples, all from the second span of the E bridge. The first example shows a support that was built at the end of a divider strip (Figure 2.32). This support shows some cracking behind the bumper where there is no divider strip. The second example shows a support installed away from any divider strips and terrazzo cracking is very

Figure 2.31 50’ From Start of Second Walk, E Bridge, 6/2006

No separation

Separation

Epoxy

Cementitious
noticeable. (Figure 2.33) Figure 2.34 shows a support installed approximately 6 inches (150 mm) away from a walkway plate. A large crack runs from the support directly to the plate. It is noted that all bumper supports are rectangular with sharp corners, which would cause stress concentrations should terrazzo contract. Cracking generally initiated at these corners.

Figure 2.32 Bumper Crack, End of Second Walk, E Bridge, 6/2006

Figure 2.33 Bumper Crack, End of Second Span, E Bridge, 1/2007
At the end of the moving walkways on the second span of the E bridge, the January report stated that the terrazzo near the plates was “ok.” Without a photograph provided, it is difficult to ascertain a concise meaning of the word, “ok.” As of June 15, 2006, there is significant separation from the divider strip (Figure 2.35, Figure 2.36, and Figure 2.37) and a poor repair method in Figure 2.38 and Figure 2.39. This repair appears incomplete, with epoxy terrazzo including marble chips placed on top of the damaged area, but with apparently minimal surface preparation or subsequent grinding. It is interesting to that the separation between terrazzo and divider strip is significantly greater on the left-hand side of Figure 2.35 through Figure 2.38 than the right-hand side. Separation was much greater in the cementitious based (dark gray) than the epoxy based (lighter, blue) terrazzo as indicated by repairs to the cementitious material in Figure 2.38 and Figure 2.39. Also, there is no visible difference in the magnitude of separation from 6/2006 to 1/2007, dates of extreme ambient temperature variation.
Figure 2.35 End of Second Walkway, E Bridge, View 1, 6/2006

Figure 2.36 End of Second Walkway, E Bridge, View 2, 6/2006

Figure 2.37 End of Second Walkway, E Bridge, View 3, 1/2007

Figure 2.38 End of Second Walkway, E Bridge, View 4, 6/2006

Figure 2.39 End of Second Walkway, E Bridge, View 5, 1/2007
Moving onto the third span, the start of the final set of moving walkways was also deemed “ok” in 2000 (4), and this appears to still be the case today. The terrazzo that was placed around the corner of the walkway plate is an epoxy terrazzo used in the surrounding artwork. (Figure 2.40) This led to a shorter divider strip spacing, which, in addition to the use of an epoxy matrix, may be responsible for the crack prevention at this location. Along the same divider strip, separation was visible at locations of cementitious terrazzo (Figure 2.41). This separation was not mentioned by C7A in 2000 (4). Some repairs have occurred in the E bridge starting at this location.

![Figure 2.40 Start of Third Walkway, E Bridge, 6/2006](image)

![Figure 2.41 Separation at Start of Third Walkway, E Bridge, 6/2006](image)

The following three pictures show examples of damage that were not listed by C7A in 2000 (4). They all occur along the span of the E bridge closest to the parking
garage. The first two pictures show assumed repairs of similar crack patterns, namely a circular crack around the intersection of divider strips. These were likely similar to that shown in Figure 2.18 and Figure 2.19. First is an example of a repair that was done properly, with the exception of color-matching (Figure 2.42). It appears that the epoxy terrazzo of nearby artwork was used as a repair, likely during construction. A very well matched repair is shown in Figure 2.43. The third is the only example of terrazzo separation from a divider strip that runs perpendicular to the longitudinal direction on any bridge (Figure 2.44). Separation is approximately 0.02 inch (0.5 mm).
Figure 2.43 Repair near Middle of Third Walk, E Bridge, 6/2006

Figure 2.44 Separation near Middle of Third Walk, E Bridge, 6/2006
A description of “major cracking, spalling at expansion joint” where bridge E meets the parking garage was noted in 2000 (Figure 2.45). This has since been repaired.

Figure 2.45 Expansion Joint at E Bridge and Garage, 4/2000 (From Ref. 4)
2.4.3 A Bridge

Figure 2.46 shows the start location at the parking garage and the direction of travel corresponds to the order of the following pictures of Bridge A. A contract for repairs to the terrazzo within this structure (as well as the last section of the E bridge) had been completed prior to the start of this project.

There is a slight discoloration apparent in the terrazzo near the divider strips seen in Figure 2.47. This may be associated with applying the terrazzo too soon after the underlying sand cushion was installed, allowing excessive bleeding of moisture through the terrazzo.

Figure 2.46 Plan View of A Bridge (Adapted from Ref. 4)
Bridge A shows two repairs that were not only well done with terrazzo, but also incorporate a soft neoprene cushion between two divider strips. Such a divider was not provided at any locations in the E bridge. The first repair is near 13 feet (4 m) from the start of the walkway on the garage-side of the bridge. (Figure 2.48 and Figure 2.49) The second example of this is at a similar location at the opposite end of Bridge A. (Figure 2.50) These appear to have been very effective for crack prevention.
A crack is mentioned in the January report by the walkway plate as “cracking at corner.” This damage has since been repaired (Figure 2.52 and Figure 2.52). The repair is smooth, well matched and no further terrazzo cracking has developed since the repair was made.
2.4.4 B and C Bridges

B and C bridges have almost no cracking present in the terrazzo. Improvements in installation and specifications were made during the construction of the B and C bridges. Two major changes include the use of flexible material between a double divider strip at critical locations. Details are similar to the repaired divider strip in the A bridge that was shown in Figure 2.48 through Figure 2.50. Another example occurs at the moving walkway corner and is shown in Figure 2.53. Once again, divider strips with flexible material infill were used in the entire region where cracking was significant in the E bridge. The terrazzo on the bridge to terminal C has a lighter shade and a lighter soft-joint material was used for color matching (Figure 2.54). This mitigated the problems found in the E bridge. Details and comparative performance can be compared between Figure 2.53 and Figure 2.7, Figure 2.17, Figure 2.25, Figure 2.37, and Figure 2.52. Similar details were used throughout the B and C bridges.
There are only two major cracks found on the B and C bridges. One is located at approximately quarter-span from the node to parking terminal of the eastern-most of the B bridges and is shown in Figure 2.55. It is noted that this indicates a separation that occurred along the divider strip across the rest of the bridge. At the point of the crack there was no separation from the divider strip. It is likely that there was adhesion between the terrazzo and divider strip at this location of sufficient magnitude to force the crack to develop within the terrazzo. Subsequent traffic has led to additional deterioration along this crack, with extent of deterioration largest at the surface of the terrazzo. Cracking of this type may be prevented by providing a bond inhibitor on divider strip surfaces. The rest of the B bridges do not exhibit similar cracking.
There is also a 3/8 inch (10 mm) separation located approximately 33 feet (10 m) from Terminal B shown in Figure 2.56. This separation has been recently filled with grout.

There is no other significant terrazzo cracking on the B and C bridges, although some minor cracking at bumper supports and vent opening locations has occurred. These are not readily visible to users of the structure.
2.4.5 Nature of Cracking

The terrazzo cracking on bridges at Logan International Airport can be categorized into five basic types referenced to their locations. These are divider strip separation and cracks, moving walkway end cracks, expansion joint cracks, bumper support cracks, and vent opening cracks.

2.4.5.1 Divider Strips

Although much of the terrazzo cracking adjacent to divider strips also happens to be located near walkway ends, the following shows typical examples of terrazzo separation near divider strips that are isolated from walkway ends. (Figure 2.57 and Figure 2.58) Once occurring, wider separations are prone to additional deterioration from traffic on the bridge, such as luggage wheels.

Figure 2.57 Divider Separation, Example 1, 6/2006

Figure 2.58 Divider Separation, Example 2, 6/2006

Figure 2.59 shows discoloration near divider strips on bridge A. This discoloration is from bleeding of moisture from the sand cushion underbed, most likely
during curing. This would likely weaken the terrazzo at these locations as well as provide a visual disparity. Discoloration occurred frequently on bridge A.

2.4.5.2 Moving Walkway Ends

There is frequent terrazzo cracking located at the ends of the moving walkways. Figure 2.60, Figure 2.61, and Figure 2.62 are typical walkway-end cracks on bridge E.
2.4.5.3 Expansion Joints

Typical cracking at an expansion joint is shown in Figure 2.63. These locations have all been repaired in the Logan International Airport bridges.

2.4.5.4 Bumper Supports

Bumper support locations exhibit different types of terrazzo cracking. The cracking initiates at the corner of the support and seems to be related to the position of the support relative to a divider strip. Below are three examples, all from the second
span of the E bridge. The first example shows a support that was built at the end of a divider strip. This support shows minimal terrazzo cracking just behind it. (Figure 2.64) The second example shows what appears to be a relocated bumper support. A core appears to have been removed from placed terrazzo and a new support installed. It is interesting to note that there is no cracking surrounding this patch. (Figure 2.65) The third example shows a support installed approximately 6 inches (150mm) away from the walkway plate (Figure 2.66) with cracks again initiating at the corner of the support.

Figure 2.64 Bumper Support Crack, E Bridge, Example 1, 6/2006

Figure 2.65 Bumper Support Repair, E Bridge, 6/2006
2.4.5.5 Vent Openings

Figure 2.67 shows a typical crack that propagates from the corners of vent openings. These cracks were very common on the E bridge, but occurred fairly frequently in all bridge structures.
2.5 Reasons for Terrazzo Cracking at Logan International Airport

Just as there are many different types of cracks, there are also various reasons for terrazzo cracking. These can be described as cracking due to stress concentrations, cracking due to differential movement, and cracking due to impact loads.

Stress concentrations typically occur at sharp re-entrant corners of slabs. These re-entrant corners occur at the edge of bumper supports, corners of vent openings, and some details around walkway openings. Shrinkage of the terrazzo would cause a tension stress at the corner location. Tension stresses can also build up due to shrinkage between divider strips if there is any restraint to free contraction, such as if bond develops between the divider strip and terrazzo. Differential movement could occur when a crack occurs in a slab and there is no sand cushion between the slab and terrazzo topping. Adhesion between the terrazzo and slab could cause a stress concentration at the crack location, propagating the crack through the terrazzo. This has been mitigated at the Logan International Airport bridges through the use of a sand cushion in all terrazzo applications. Another form of differential movement exists when terrazzo panels shrink away from divider strips and adjacent strips. This provides a separation at these locations relative to the spacing of divider strips. If a gap exists in the terrazzo, such as at a crack or separation from divider strips, traffic across this gap can impact the terrazzo and cause significant deterioration, loosely defined as “cracking” in this report. Typically, aggregate is loosened by luggage wheels. Missing aggregate provides a wider gap, increasing the impact loads from foot traffic and suitcase wheels. Any repairs at these locations which have feathered edges (in thickness) are easily cracked and deteriorate rapidly.
Separation of the terrazzo from the divider strips occurred throughout the bridges, although predominantly on the A and E bridges. Most of these cracks were very small and went unnoticed except under the most careful eye. This indicates uniform shrinkage and is the goal of proper terrazzo installation. The divider strip spacing is typically 80 inches (2000 mm) in the Logan International Airport bridge structures. However, for cementitious terrazzo typical specifications require a maximum divider strip spacing of 60 inches (1500 mm) or less (9). Wider spacing will result in larger separations and is very likely to cause the noticeably uneven separation from divider strips found in the bridge structures. Subsequent deterioration at these locations is likely due to impact loads from traffic.

The ends of the moving walkways house the motors that drive them. These are located underneath large metal plates that cover the motor and its housing. Cracks found near these covers typically start at the corner away from the start of the walkway and run laterally across the floor, following the divider strip, and sometimes reach the adjacent moving walkway. These cracks typically are associated with separation from the divider strip and subsequent terrazzo cracking from impact loads. The structural slab would likely include a control joint along this location, though this could not be verified for the bridge structures as control joints were not marked on construction drawings. However, the openings for the motors extend through the structural slab and would cause stress concentrations at the corners. Therefore there is the likelihood that differential movement could be significant at these locations due to presence of control joints. Use of divider strips at these locations which had a flexible fill to accommodate differential movements did not exhibit any cracking.
Vibrations from the motors are not likely to cause these particular cracks. Upon visiting the site, no vibration was detected near the walkway ends due to motors. The motors rest on dampers that reduce vibration transmitted to the structure. Vibrations due to wind load were much more prominent during the visits. Installed walkways are also required to meet vibration standards, per Reference 1, which should not cause cracking of the surrounding terrazzo. Wind induced vibrations highlight the more flexible nature of these structures (as compared to the terminal buildings), which may warrant more stringent specification criteria.

Expansion joints are another place where severe terrazzo cracking takes place. The purpose of expansion joints is to allow for expansion and contraction between adjacent sections of the structure. In addition to post-construction shrinkage, normal expansion and contraction on the bridge causes separation from the joint. Once the terrazzo separates from the joint, even slightly, it is more apt to be broken from suitcase wheels and normal wear and tear. Another major factor is the fact that expansion joints include a very flexible seal covering at the edge of the terrazzo flooring rather than a continuity of solid flooring. At this location there is a likelihood of differential height of materials and bounce of wheel loads.

Bumper supports in these structures are rectangular with relatively sharp corners. These corners result in stress concentrations in the terrazzo. Some are placed in line with divider strips while others are not. Supports that are not in line with divider strips have more significant terrazzo cracking, as they are guaranteed to have re-entrant corners. Further spacing to the nearest divider strip results in additional shrinkage at these locations, resulting in higher stresses.
The corners of vent openings are cracking because of their sharp corners. Cracks found at vents typically start at the corners and run outward. The sharp corners are more prone to cracking due to stress concentrations. It has not been determined whether or not the cracks at the corners of vent openings occurred during curing or post-construction, but it is suspected to be during construction.

2.6 Crack Prevention Methods

Prevention of cracks is based on the mitigation of the causes of cracking noted in the previous section. This includes limiting stresses, differential movement, and impact load effects.

To eliminate terrazzo cracking near other divider strips it is important to follow the NTMA specification recommendations on divider strip spacing. Strips should be placed at 5 feet (1500 mm) or less with cementitious terrazzo. Due to the flexible nature of pedestrian bridge structures, it may be advisable to maintain a closer divider strip spacing of 4 feet (1200 mm) or less as recommended for installation of terrazzo on flexible metal formwork. (10) Divider spacing on epoxy floors is bound only by the artwork planned for the terrazzo, although judgment is required to minimize excessively long spacing. Divider strips should also be placed at all locations of control joints in structural slabs, even when a sand cushion is provided. At locations where significant differential movement is possible, such as at control joints, divider strips provided with a flexible fill should be provided. These should routinely be provided incrementally along a structure (such as at every 3rd or 4th divider strip location) to avoid the possibility of separation being concentrated at specific locations. A bond breaker, whether non-
adhering strip material or dustings of sand dust, should be provided at all divider strips to avoid cracks propagating into the terrazzo adjoining the divider strip.

Divider strips including a flexible fill should comprise a composite divider with neoprene or silicone rubber in between divider strips. This extra cushioning allows for more expansion and contraction at the joint.

A method of preventing crack propagation near walkway ends has already been employed on the B and C bridges. By installing a neoprene strip between the access plate and its adjacent divider strip (Figure 2.68) in conjunction with composite dividers across the remainder of the bridge, terrazzo cracking can be minimized. These dividers minimize effects of corner stresses and potential slab control joint at the walkway boxout. This was used extensively on the B and C bridges. When these soft joints were used, terrazzo cracking was not observed.

Figure 2.68 Flexible Soft Joint, C Bridge, 6/2006

At expansion joints, details such as those used in the E bridge should be used (Figure 2.69). Divider strips should be placed on both sides of the expansion joint with a
strip of terrazzo in the middle. Another divider strip should be installed approximately three inches (75 mm) from each side of an expansion joint. The divider strip at the expansion joint should include a flexible, soft joint. This 3 in (75mm) separation allows much better control for matching elevations of adjoining sections of terrazzo, minimizes any possible separation from divider strips, and provides confinement to the terrazzo material.

![Image: Expansion Joint Detail](image)

**Figure 2.69 Expansion Joint Detail**

Minimizing terrazzo cracking at bumper supports requires minimizing stress concentrations in the terrazzo material. Avoiding sharp corners in support geometry can minimize stresses. Placing divider strips in line with the supports would reduce shrinkage stresses and eliminate some reentrant corner details. If this is done, the strip should continue through to the back side of the support as well. This was effective when used on the elevated walkways. The use of an oval box out around the support penetration would likely be even more effective. This could be formed during
construction or cored after terrazzo is placed. This was effective as shown in Figure 2.65. Another solution could be to use circular, rather than rectangular, supports though this would likely not be as effective as the other methods.

To prevent cracks at the corners of vent openings, terrazzo corners should be filleted with a radius of at least \( \frac{1}{2} \) in (13 mm). Corners would be hidden by vent covers, so the fillet edge should have no effect on appearance. The rounded corners can be part of the formwork or beveled with a grinder after construction. This will minimize crack propagation from the corners of vent openings. Further investigation may be required to determine a minimum effective radius of curvature. This technique could also be employed on all square corners at holes throughout a terrazzo flooring system to prevent cracking. Reentrant corners should be avoided.

Adding an ASTM strength requirement for all terrazzo (cementitious and epoxy) materials may be an effective means to control cracking. This has been found to be present in some specifications, specifically the NTMA specification for epoxy terrazzo and the EnviroGLAS epoxy terrazzo specification (8, 5). Compressive strengths are related to tension and impact capacity. Therefore, strength requirements would provide a minimum resistance due to stress concentrations and impact load. Master Terrazzo Technologies, LLC (6) includes such criteria for cementitious terrazzo floors, requiring a lower limit in compressive strength of 4,800 psi (33 MPa). This is a reasonable strength requirement but further testing may be needed to determine an appropriate value. Also, epoxy terrazzo flooring systems are more than cementitious based terrazzo and could also minimize floor cracking. Use of epoxy terrazzo over a sand cushion
worked well and should be considered for flexible structures. Table 2.1 summarizes crack prevention methods for terrazzo installation.

### Table 2.1 Crack Prevention Methods Summary

<table>
<thead>
<tr>
<th>Potential Crack Locations</th>
<th>Prevention Methods</th>
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<tbody>
<tr>
<td><strong>Divider Strips</strong></td>
<td>- Follow maximum spacing requirement of 5 feet (1.5 m)</td>
</tr>
<tr>
<td></td>
<td>(consider stricter criteria of 4 feet (1.2 m) for bridge structures)</td>
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<tr>
<td></td>
<td>- Use of soft joints at critical locations</td>
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<tr>
<td></td>
<td>- Minimum terrazzo strength requirement</td>
</tr>
<tr>
<td><strong>Moving Walkway Ends</strong></td>
<td>- Soft joints surrounding reentrant corner at housing cover</td>
</tr>
<tr>
<td></td>
<td>- Minimum terrazzo strength requirement</td>
</tr>
<tr>
<td><strong>Expansion Joints</strong></td>
<td>- Soft joints on each side of expansion joint</td>
</tr>
<tr>
<td></td>
<td>- 3 inch (75 mm) terrazzo strip adjacent to soft joints</td>
</tr>
<tr>
<td></td>
<td>- Additional divider strip adjacent to 3 inch (75mm) terrazzo strip</td>
</tr>
<tr>
<td></td>
<td>- Minimum terrazzo strength requirement</td>
</tr>
<tr>
<td><strong>Bumper Supports</strong></td>
<td>- Avoid sharp corners</td>
</tr>
<tr>
<td></td>
<td>- Divider strips in line with support, or provide box out</td>
</tr>
<tr>
<td></td>
<td>- Minimum terrazzo strength requirement</td>
</tr>
<tr>
<td><strong>Vent Opening Corners</strong></td>
<td>- Beveled corner</td>
</tr>
<tr>
<td></td>
<td>- Minimum terrazzo strength requirement</td>
</tr>
</tbody>
</table>

#### 2.7 Recommended Repair Methods

As there are various types of cracks found on the terrazzo floors at Logan International Airport, there are also different methods which have been employed for repairing cracks. Some cracks are more serious than others and require more intensive repairs. Other cracks are out of the way of traffic and sight and may be deemed unnecessary to repair. The following recommendations for repair techniques address the major types of cracks found on the terrazzo floors at Logan International Airport and how to effectively repair them. Recommendations include permanent repairs required to meet the recommendations of new construction, as well as recommendations for temporary maintenance type repairs.
When cracking or separation at a divider strip is significant along the entire length of the divider strip, a temporary solution is to patch the area with mortar such as in Figure 2.7. This method is inexpensive and quick to apply. However there are some obvious disadvantages. The first is that it is very visible and does not blend into the existing material. It also must be considered a temporary repair, as deterioration is expected due to non-compatible thermal properties and brittle nature of the material. Feathered edges of the patch material must be avoided, as these are subject to subsequent cracking. Some grinding to minimize a feather edge would be required. Despite the negative aspects, this can be an effective temporary mitigation against further deterioration of the terrazzo flooring until full repairs can be made.

A permanent and more extensive repair would involve removal of the area that is cracked back to sound terrazzo material. Removal should occur on both sides of the divider strip at a distance of at least 2 in (50 mm). Replacement of terrazzo material and a composite (flexible infill) divider strip would then occur. A composite divider strip would be required as damage indicates a tendency for significant separation at this location, which will be mitigated with this type of divider strip. An example of this type of repair was shown in Figure 2.48.

If cracking is only at a specific location (likely a corner) of divider strip a more localized repair is called for. This should include the removal of damaged terrazzo back to sound material, a minimum of 2 in (50 mm). A matched terrazzo of similar type and properties to the original can then be placed as shown in Figure 2.43. This repair requires significant equipment to provide a flush grinding of the new material to match the existing flooring and would likely require a terrazzo contractor.
For isolated cracks in the middle of a panel a method similar to that just
described could be used. Epoxy injection may also be effective, though it is noted that
this would be difficult if not impossible if a sand cushion is provided as epoxy would
propagate into this substrate material rather than the crack.

Cracks found at the corners of moving walkway ends are similar to cracks that
develop due to excessive separation from divider strips. In this regard, the repair
methods are similar. The best and most expensive repair involves removing terrazzo
beyond the crack so that a new flexible joint can be placed and new terrazzo material
placed against the existing terrazzo floor. When this type of repair is completed flexible
material should also be placed around the walkway opening as was shown in Figure
3.65. Once again, grout can be used as a temporary solution but feathered edges should
be minimized.

Expansion joints should be repaired as they were in Bridge A. The terrazzo
should be removed beyond the damaged area for a distance to accommodate a new
divider strip 3 in (75 mm) from the expansion joint as well as at least 2 in (50 mm) into
terrazzo beyond this. A soft joint should be installed adjacent to the expansion joint and
new, matching terrazzo should be installed where the damaged flooring was removed.

Bumper support and vent opening cracks are typically located away from foot
traffic and pedestrians’ lines of sight. In general, these cracks are not prone to
subsequent deterioration due to being out of the lane of traffic. As a result, expensive
repairs at these locations may not be worth the cost, particularly if the cracks are barely
visible and non-intrusive to travelers. The level of urgency to repair these cracks is up
to the discretion of the owner. If the cracks are out of the way and not expected to worsen, then leaving them alone is a perfectly viable option.

Bumper supports that are not in line with divider strips are prone to crack when the terrazzo floor shrinks while curing. A minimal repair may include filling, smoothing, and polishing the crack with epoxy. If cracking consists of a serious problem, a circular core could be removed to intentionally put a break in the terrazzo around the support, though this would require the removal/replacement of the bumper. The core could then be filled with terrazzo similar to the surrounding floor. This method was used to move bumper supports, not as a repair method, but was effective as seen in Figure 2.65. If the cracks are too long to effectively replace a core of terrazzo in such a fashion, such as in Figure 2.66, then filling, smoothing, and polishing the crack with epoxy is a low-cost alternative.

Vent opening cracks could similarly be repaired with filling, smoothing, and polishing the crack with epoxy. To prevent future cracking grinding of vent opening corners to remove sharp corners may be effective.

2.8 Evaluation of Existing Specifications

In order to evaluate existing specifications and determine the industry standard, available specifications in addition to those used on the Logan International Airport elevated walkways were sought. The NTMA website was an invaluable resource for this activity. The site includes guide specifications for sand cushion terrazzo, epoxy terrazzo and a specification for relatively flexible floors (9, 8, and 10). In addition, an extensive list of NTMA members is included on the web pages. The research team attempted to
email, call, or locate a web page for all companies listed as manufacturers and/or installers (43 suppliers, 127 contractors). Companies were asked to provide a reference specification that they typically use. Responses from 40 companies (16 suppliers, 24 contractors) were obtained. Others had outdated contact information or no response was received. Finally, specifications used on the Logan International Airport bridge structures and other sample terrazzo specifications were obtained from either MassPort or C7A.

In general, it was found that the NTMA guide specifications are an industry standard, being used by many companies with little or no modification. For this report, the NTMA sand cushion specification (9) is used as a point of reference for all comparisons. Other specifications felt to be representative of those obtained and included in this report are those from C7A (3) and comparison information used by Master Terrazzo Technologies LLC (6) (not a specification). These are cited for comparison purposes only, and are not meant to be an endorsement of any given specification. Those referenced herein are provided in Appendix A.

Each of these NTMA guide specifications (9, 8 and 10) is similar to one another. The organization includes sections on general requirements, products, and execution. Of particular interest are the matrix qualities required in the materials sections and the inspection and installation sections of the execution sections. The epoxy and sand cushion specifications address differences in installation of the two binding matrices. The third specification is for terrazzo installation over permanent metal forms. Although permanent metal forms were not used on the elevated walkways at Logan
International Airport, concerns regarding flexible floors may be of relevance to the Logan bridges due to their long spans.

The first major difference between the NTMA specifications is the thickness of the terrazzo system being installed. Epoxy terrazzo systems are only ¼ to 3/8 inch (5 to 10 mm) nominal thickness. This is because the epoxy system does not require a sand cushion underbed. Epoxy terrazzo can be applied directly to the slab, though it is noted that the Logan International Airport structures included a sand cushion below the epoxy terrazzo in order to maintain consistent terrazzo elevations. Typical cementitious terrazzo floors are 2.5 inch (65 mm) thick with a 2 inch (50 mm) sand cushion underbed and ½ inch (13 mm) thick nominal terrazzo topping. This differs from terrazzo systems placed over flexible metal forms, which require a minimum of 2.5 inch (65 mm) of sand cushion and, again, ½ inch (13 mm) of terrazzo topping, for a total of at least 3.0 inches (75 mm) thickness. Divider strips in cementitious terrazzo are embedded in the underbed, while epoxy placements require either an angle section to rest on the slab or a saw cut into the slab where control joints are placed.

The first part of the specifications, part 1, addresses general issues. Each subsection in this part is the same for all three specifications. The related works specified in other sections quality assurance, submittal, deliver, storage and handling, and guarantee, are all similar.

The second part of the specification is products. Clearly, the materials subsection begins to differ substantially. The cement and epoxy matrices are totally different materials. However, without regard to the fact that they are completely different materials, there are still additional differences between the specifications.
First, the epoxy specification calls for minimum strength requirements. These are hardness, tensile and compressive strengths, coefficient of thermal expansion, bond strength and chemical resistance. The criteria make reference to ASTM test methods and requirements for minimum strength or exposure. There are no such requirements for the cementitious terrazzo. Instead aggregate content to cement is specified, but “sufficient potable water to produce a workable mix” is left to the interpretation of the contractor. For cementitious materials the water to cement ratio is the major determinant of the compressive strength of the final material. Compressive strength is directly related to tensile strength and impact resistance, which are properties which would determine the resistance to cracking. The terrazzo for placement over permanent metal forms is also specified as having a cementitious binding matrix, therefore it too has the same materials section. However, the flexible form placement also requires specific strength for the underbed (4000 psi (28 MPa) at 3 in (75mm) slump). This is likely to ensure stiffness in the floor system. The provision of a structural slab under the flooring system in the Logan International Airport bridges would meet this requirement.

Second, under section 2.01.D (products, materials, strips) for the sand cushion terrazzo specification, a divider strip spacing of 5 feet (1500 mm) or less is required to “provide ample control of the anticipated shrinkage that will take place” in the terrazzo. In section 3.02.A.2 (execution, installation, underbed) for the specification on terrazzo over permanent metal forms, a divider strip spacing of 4 feet (1200 mm) or less is required. This is the only major discrepancy between each of these sand cushion specifications. This limitation on strip spacing for placement over metal forms is needed due to the increased movement associated with placement over such forms. The
movement on the large bridge spans, although not identical to movement from
placement over metal forms, may still be reason to limit spacing on similar bridge
projects to the lower value. At control joints in the slab the epoxy system requires a
control joint in the terrazzo as well. Cementitious systems only require divider strips at
intersections of precast decking, assuming that the “isolation membrane” will arrest
cracking and that sand cushion will absorb any slab cracking at control joints.

The final part of the specifications, part 3, describes the execution phase of the
flooring system. The inspection sub-section (3.01) is similar in all three, but more
specific for epoxy terrazzo. This is because the epoxy terrazzo does not have a sand
cushion beneath the terrazzo topping to absorb defects in the slab. Therefore, the
concrete slab must be inspected more closely to determine whether or not the surface is
suitable for terrazzo application. It is emphasized that “cracks in substrate will usually
be transmitted through topping to surface” for epoxy terrazzo.

Installation is different for each. While the cementitious mixes require the
installation of the sand cushion underbed, the epoxy terrazzo specifies the preparation of
the subfloor. Epoxy terrazzo is placed within divider strips and smoothed with a trowel.
Cementitious terrazzo is first smoothed with a trowel, then rolled and compacted to
extract excess cement and water, and finally smoothed again with a trowel. The
grinding and sealing is similar in each specification.

The specifications used in the installation of the terrazzo floors on the bridges at
Logan International Airport were developed specifically for the project by C7A (3).
These are included in Appendix A. As with all specifications evaluated, the C7A
specifications generally follow the NTMA guidelines for sand cushion terrazzo (9).
However, instead of having separate cementitious and epoxy terrazzo specifications, these are combined in C7A documents. The C7A specification frequently cites the NTMA guidelines and often directs readers to refer there for further information. The following summarizes the major differences in specifications.

The C7A specification was updated after the completion of the A and E bridges. Aside from minor editing changes, the only significant difference between the A and E bridge and the B and C bridge specifications is that a particular brand of surface sealer and application technique is called for in the latter specification. This change is not likely to affect terrazzo cracking.

C7A 09400 is developed specifically for individual projects. Comparison to a later version developed for a different project was made. Although the floors in this project are not located on bridges, differences in the guide specification are still relevant. In addition to format changes, there are stricter requirements for installation. The surface is required to vary less than 1/8 inch (3 mm) in 12 feet (3650 mm). Also, a minimum of 70% marble chips or custom aggregate in the mix is required to be visible at the surface of the floor. Flatness restrictions could affect terrazzo cracking from impact load by preventing uneven surfaces. The composition of the mix may increase hardness of the composite material. However, it these are not thought to be primary improvements to prevent cracking, but more closely related to aesthetics.

There is also a key difference in the divider strip requirements in the later C7A specification titled Bulletin No. 286. (3) This addition to the C7A terrazzo specification was included to address the use of flexible, or soft, joints in terrazzo floors and could provide a guide for incorporating these materials. The provision for neoprene filler
between two divider strips is new, and this may have a significant impact on cracks that result from expansion and contraction. As noted previously, the use of these divider strips was likely a primary cause for the improvement in performance in the B and C bridges. Also, the heavy-top divider strips are required to be plastic. This may also impact the propagation of separation and terrazzo cracking near divider strips. There is no mention of divider strip spacing in any C7A specification. Strip spacing is established in the NTMA guidelines. However, it appears that an allowance for an increase in spacing was allowed at Logan International Airport. This in itself was not the cause of crack formations in the bridges, but could exacerbate any problems.

One additional document that adds information to the NTMA documents comes from the Master Terrazzo Technologies, LLC web page (6). In this page a comparison of epoxy and typical sand cushion cementitious terrazzo properties are listed. While the purpose of this is to show the advantages of the company’s preferred material there are some valuable statements made. Epoxy strength requirements listed exceed NTMA values by 20%. Cementitious strengths are provided for the underbed (1,800 to 3,000 psi (12 to 21 MPa)) and grout (4,800 to 7,000 psi (14 to 48 MPa). These could be used as basis for required strengths. In addition, a comment notes that “independent maintenance have documented the lower maintenance costs of epoxy vs. cement due to density of the surface, resistance to staining, and the higher strength for resistance to loads and stress at strip locations.”

Strength and hardness requirements may be an effective means to reduce cracking and minimize propagation of damage to terrazzo. A lower limit of 4,800 psi (14 MPa) compressive strength is a suitable starting point. It appears that these
specification requirements are specific to terrazzo components (cementitious grout or epoxy matrix materials) rather than composite terrazzo material. It is then implied that performance of individual components will result in a minimum performance of the terrazzo material. These component requirements are simple to relate to ASTM testing standards for mortars, epoxies, and aggregates. No ASTM standards are directly applicable to a composite terrazzo material, in which placement thickness is much thinner than concretes, but the composite non-uniform nature of the composite makes testing of very small specimens subject to aggregate distribution and size. The relation of component requirements to composite performance is hampered by vague statements in the specifications such as “sufficient water to provide workability at as low a slump as possible” for the underbed and “sufficient potable water to produce a workable mix” for the cementitious terrazzo mix.
CHAPTER 3
EXPERIMENTAL SETUP AND TESTING

Three different tests were performed on terrazzo samples in order to evaluate certain strength and serviceability properties of the material. First, cementitious terrazzo was tested for compressive strength to help develop a minimum strength criterion for future terrazzo installations. Second, cementitious terrazzo samples were instrumented to measure linear shrinkage. This information was needed to establish an appropriate guideline on minimum divider strip spacing. It was also needed for a finite element analysis which modeled the shrinkage of terrazzo around a vent hole. (See chapter 5) Finally, precast cementitious terrazzo tiles were exposed to cyclic durability tests in which a weighted wheel was rolled across gaps between tiles. The purpose of these wheel tests was to examine wheel damage on tiles that were setup to mimic separation from divider strips.

3.1 Compressive Strength Tests

Compressive strength was tested following ASTM C 109, “Standard Test Method for Compressive Strength of Hydraulic Cement Mortars.” This involved pouring 2 inch (5.1 cm) cubes and loading them to failure. The cube molds can be seen in Figure 3.1. Newly poured samples were obtained from DePaoli Mosaic Company on two occasions from the same job site. The samples can be seen in Figure 3.2. The first
samples were poured on 10/10/2007 and the second samples were poured on 11/1/2007. Nine cubes were taken from each pour. Every sample from the first pour was moisture-cured for the first seven days. From the second pour, all but three were moisture-cured in the same fashion. The remaining three were allowed to cure in an air-dry condition. All samples were tested at 28 days.

Figure 3.1 Cube Molds
3.2 Linear Shrinkage Tests

Linear shrinkage data was determined following ASTM C 157, “Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete.” In this test, the terrazzo was poured in four 1 x 1 x 10 inch (2.5 x 2.5 x 25.4 cm) prism molds. Newly poured samples were obtained from DePaoli Mosaic Company on two occasions from the same job site. The first samples were poured on 10/10/2007 and the second samples were poured on 11/1/2007. The molds are shown in Figure 3.3 and the bars are shown on Figure 3.4. The instrument used to measure the linear shrinkage was a demountable mechanical strain gauge (DEMEC). This can be seen in Figure 3.5. After the terrazzo had cured sufficiently to allow the application of DEMEC points to the sides of the prisms, initial readings were taken. Linear shrinkage was then measured for 28 days.
Figure 3.3 Linear Shrinkage Bar Molds

Figure 3.4 Terrazzo Bars for Linear Shrinkage Testing
3.3 Durability Tests

Similar to concrete, terrazzo shrinks as it cures. On the Logan Airport walkways, the terrazzo shrank away from the divider strips after it was poured, leaving gaps. It is believed that part of the damage to the Logan walkways was caused by pedestrian traffic and wheeled suitcases rolling over the gaps adjacent to divider strips. The goal of these durability tests was to simulate damage from a suitcase and determine the critical variables which result in that damage.

Precast terrazzo tiles, generously supplied by DePaoli Mosaics Company, were used in the wheel durability tests. The tiles were each 6 x 6 x 5/8 inches (15 x 15 x 1.6 cm). These can be seen in Figure 3.6. The parameters examined in the tests were wheel diameter, gap size, a vertical offset, push or pull motion, and tile material. Eleven tests
were performed with two tile edges tested each time. This resulted in 22 tested tile edges.

![Image of terrazzo tiles](image)

**Figure 3.6 Terrazzo Tiles for Wheel Durability Test**

### 3.3.1 Durability Test Setup

The two tiles for each test were separated by a 2 inch (5.1 cm) wide steel divider bar. This simulated an adjacent divider strip that was still flush with terrazzo on one side. The tiles represented the terrazzo that had pulled away from the divider strip after curing. Gaps of one eighth inch, one quarter inch, and one half inch were created by inserting spacers in between the steel divider bar and the tiles. Two heavy steel bars were used to clamp the tiles onto the load frame. Sheets of rubber were placed in between every contact point along the clamp assembly for the tiles. The rubber prevented pieces from moving while the test was running. This setup can be seen in Figure 3.7.
A servo-controlled hydraulic actuator was used to automate the motion of the wheel. It was bolted to the load frame at the far end and rested freely on cribbing. This was sufficient, as there was very little force being applied from the actuator to the terrazzo tiles. The weight of the actuator held it in place.

A steel plate was mounted to a swivel at the free end of the actuator. The swivel was locked in place so it could not rotate; it was only used to adjust the position of the setup before each test. Welded to the steel plate was a 7.75 inch (20 cm) long section of square steel tube. This was positioned vertically and acted as a bracket. Slotted inside this was another smaller section of square steel tube. Welded to this section of tube, on the bottom end, was a small plate that acted as a wheel mount. The wheels were bolted
to the wheel mount, allowing them to be changed easily. Attached to the top end of the inner tube section was a bracket that allowed weights to be securely stacked. This setup can be seen in Figure 3.8 and Figure 3.9.

Figure 3.8 Wheel Durability Test Setup Drawing

Figure 3.9 Wheel Durability Test Setup
The wheels chosen were caster wheels. This allowed them to travel in a natural, unforced fashion that was intended to mimic typical wheel traffic at an airport. The wheels were 2.5, 2, and 1 inches (6.4, 5.1, and 2.5 cm) in diameter and all were 1 inch (2.5 cm) wide. The wheels can be seen in Figure 3.10.

![Figure 3.10 Wheels Used In Test](image)

### 3.3.2 Durability Test Parameters

Six test variables were examined. One test examined the difference in durability between epoxy and cementitious terrazzo tiles. The epoxy tile was expected to be much more durable than its cementitious counterpart. After that, the most important parameters were initially believed to be gap size and wheel diameter. Three gap sizes and three wheel diameters were used in the tests. Gaps of one eighth inch, one quarter inch, and one half inch were created by inserting spacers in between the steel divider bar and the tiles. These two variables were believed to be directly proportional to each other.
Two tests were performed with the tiles raised one quarter inch from being flush with the surface of the steel divider bar. This vertical offset was intended to simulate the damage possible if the terrazzo was to become elevated relative to the divider strip from its initially flat surface. Also, one test was performed to examine the effects of adding additional weight to the wheel. This test had 50 lbs (222 N) of vertical force applied to the wheel instead of the 30 lbs (133 N) that was used in all other tests. Finally, during each of the eleven tests, one tile simulated a wheel being “pushed” and another tile simulated a wheel being “pulled” across the setup. A summary of the test parameters can be seen in Table 3.1.

Table 3.1: Wheel Durability Test Parameters

<table>
<thead>
<tr>
<th>Variables</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Epoxy, Cementitious</td>
</tr>
<tr>
<td>Wheel Direction</td>
<td>Push, Pull</td>
</tr>
<tr>
<td>Wheel Diameter</td>
<td>1, 2, 2.5 inches (2.5, 5.1, 6.4 cm)</td>
</tr>
<tr>
<td>Gap Width</td>
<td>1/8, ¼, ½ inches (3.2, 6.4, 12.7 mm)</td>
</tr>
<tr>
<td>Vertical Offset</td>
<td>0, ¼ inches (6.4 mm)</td>
</tr>
<tr>
<td>Weight</td>
<td>30, 50 lbs (133, 222 N)</td>
</tr>
<tr>
<td>Cycles</td>
<td>100, 200, 500, 1000, 2000, 5000, 10000, 20000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Constants</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>5 inches (12.7 cm)</td>
</tr>
<tr>
<td>Frequency</td>
<td>1 Hz</td>
</tr>
<tr>
<td>Max. Speed</td>
<td>16 in/sec (41 cm/sec)</td>
</tr>
</tbody>
</table>

3.3.3 Durability Test Procedure

After the tiles were clamped to the load frame, the actuator was lowered into place such that the wheel was centered on the two inch steel bar. This was the set point for the actuator. The stroke was set at +/-2.5 inches (6.4 cm) from the set point to allow
for the wheel to move sufficiently beyond the gaps on every pass. The load function was a normal sine curve with amplitude of 2.5 inches (6.4 cm) and a frequency of 1 hertz. This resulted in a maximum wheel speed of 16 inches per second (41 cm/s) at the middle of the stroke. In one second the actuator travels exactly ten inches, but its maximum speed occurs every time the wheel crosses the set point and its velocity is zero at each end of the stroke.

The steel bars used to clamp the terrazzo tiles also served as a guide for the actuator. Since the shaft of the actuator was circular and not elliptical, it was free to rotate about its longitudinal axis. The steel bars were placed as close to the wheel mount assembly as possible to prevent the top-heavy setup from overturning.

A counter was used to automatically deactivate the hydraulic pump after a certain number of cycles was reached. The test was stopped eight times, ending at a maximum of 20,000 cycles. This represented heavy use on the tiles and was sufficient in showing trends in wheel damage. The testing outline is seen in Table 3.2.
Table 3.2 Wheel Durability Testing Outline

<table>
<thead>
<tr>
<th>Test</th>
<th>Tile</th>
<th>Edge</th>
<th>Wheel Direction</th>
<th>Gap Width (inches)</th>
<th>Wheel Diameter (inches)</th>
<th>Vertical Offset (inches)</th>
<th>Weight (lbs)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>E1</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>A</td>
<td>Pull</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>Pull</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>2</td>
<td>0</td>
<td>30</td>
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</tr>
<tr>
<td></td>
<td>B</td>
<td>Pull</td>
<td>0.5</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>5</td>
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<td>Push</td>
<td>0.5</td>
<td>1</td>
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<td>30</td>
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<td>0</td>
<td>30</td>
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</tr>
<tr>
<td></td>
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</tr>
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<td>1</td>
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<td>30</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>Push</td>
<td>0.25</td>
<td>2</td>
<td>0.25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Pull</td>
<td>0.25</td>
<td>2</td>
<td>0.25</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>A</td>
<td>Push</td>
<td>0.25</td>
<td>2</td>
<td>0</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Pull</td>
<td>0.25</td>
<td>2</td>
<td>0</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 4

RESULTS

The following shows the results from tests performed on terrazzo samples in the structural engineering laboratory in Gunness Hall. These results include compressive strength values, linear shrinkage curves, and visual analysis of the damage from the wheel durability tests.

4.1 Compressive Strength Tests

The compressive strength of terrazzo samples was obtained by crushing 2 inch (5.1 cm) cubes until failure. 18 samples were tested. 3 of these samples were left to cure in the open air, while the rest were moisture-cured for the first 7 days. The results for 28 day compressive strength can be seen in Table 4.1.

Table 4.1 Compressive Strength of Terrazzo Samples

<table>
<thead>
<tr>
<th>Indoor Sample</th>
<th>Outdoor Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poured on 10/10/2007</td>
<td>Poured on 11/1/2007</td>
</tr>
<tr>
<td>Sample</td>
<td>Compressive Strength (psi)</td>
</tr>
<tr>
<td>1</td>
<td>6410</td>
</tr>
<tr>
<td>2</td>
<td>5347</td>
</tr>
<tr>
<td>3</td>
<td>6615</td>
</tr>
<tr>
<td>4</td>
<td>7182</td>
</tr>
<tr>
<td>5</td>
<td>5508</td>
</tr>
<tr>
<td>6</td>
<td>6690</td>
</tr>
<tr>
<td>7</td>
<td>5185</td>
</tr>
<tr>
<td>8</td>
<td>6428</td>
</tr>
<tr>
<td>9</td>
<td>5605</td>
</tr>
<tr>
<td>avg</td>
<td>6108</td>
</tr>
<tr>
<td>std dev</td>
<td>666</td>
</tr>
</tbody>
</table>
The average compressive strength of the terrazzo obtained on 10/10/2007 was 6108 psi (42.1 MPa) with a standard deviation of 666 psi (4.6 MPa). The average compressive strength of the moisture-cured terrazzo poured on 11/1/2007 was 6366 psi (43.9 MPa) with a standard deviation of 404 psi (2.8 MPa). The slight increase in strength between pours may be attributed to the fact that it was raining on 10/10/2007. The terrazzo mix on that date had a noticeably higher slump than the mix from 11/1/2007. This would account for the slight discrepancy in values.

The average compressive strength of the dry-cured terrazzo samples poured on 11/1/2007 was 3110 psi (21.4 MPa) with a standard deviation of 56 psi (0.4 MPa). It is obvious that curing cementitious terrazzo in a moist environment increases its strength by approximately a factor of two.

4.2 Linear Shrinkage Tests

The linear shrinkage measurements were taken using the DEMEC strain gauge. Readings were taken multiple times within the first day after the samples were poured. Then readings were taken in regular increments until a 28 day measurement was obtained. Readings were taken from 3 sides of the first pour and all 4 sides of the second pour. Shrinkage curves for each bar were created by averaging the shrinkage on all sides of the bar. The shrinkage curves from the first pour can be seen on Figure 4.1. The shrinkage curves from the second pour can be seen on Figure 4.2.
Figure 4.1 Shrinkage Curves, Samples poured 10/10/2007

Figure 4.2 Shrinkage Curves, Samples poured 11/1/2007
The first samples did not begin moisture-curing until the fourth day after they
had been poured. They continued moisture curing until the seventh day, therefore were
moisture-cured a total of three days. This accounts for the sudden spike in the data.

One sample, however, was left to cure in the ambient air of the laboratory. This sample,
“A”, does not experience the same significant spike. However, it seems that all samples
from the pour do experience an expansion, generally between days 7 and 10. This may
be due to an increase in air moisture present at the time, but may also be the result of
human error reading the DEMEC gauge. This is expected to have little effect on the
final readings. The averaged shrinkage data for the samples from the first pour can be
seen in Table 4.2.

Table 4.2 Average Linear Shrinkage Data, Samples Poured 10/10/2007

<table>
<thead>
<tr>
<th>Time Elapsed (days)</th>
<th>Length Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A (dry)</td>
</tr>
<tr>
<td>0.38</td>
<td>0.00</td>
</tr>
<tr>
<td>0.46</td>
<td>-0.03</td>
</tr>
<tr>
<td>0.67</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
<td>-0.02</td>
</tr>
<tr>
<td>2</td>
<td>-0.07</td>
</tr>
<tr>
<td>5</td>
<td>-0.12</td>
</tr>
<tr>
<td>6</td>
<td>-0.14</td>
</tr>
<tr>
<td>9</td>
<td>-0.13</td>
</tr>
<tr>
<td>12</td>
<td>-0.14</td>
</tr>
<tr>
<td>21</td>
<td>-0.19</td>
</tr>
<tr>
<td>28</td>
<td>-0.23</td>
</tr>
</tbody>
</table>
The bars from the first pour contracted between 0.18 and 0.23%. After the first few days, the curves began to slowly taper off. The dry sample, “A”, had the largest shrinkage at 0.23% at 28 days. This was expected. Unfortunately, many of the DEMEC points fell off of the bars over time, ending useful data at 28 days. A few shrinkage measurements were taken beyond 28 days, but this was typically limited to one side of a bar, at best. Furthermore, linear shrinkage observed at 28 days represents the majority of shrinkage during the lifetime of terrazzo and will be adequate for use in the finite element model in Chapter 5.

Two of the samples from the second curve were moisture-cured throughout the first seven days of curing. These were samples “F” and “G”. Samples “E” and “H” were left to cure in the open air. The averaged shrinkage data for samples from the second pour can be seen in Table 4.3. As expected, the dry samples underwent more rapid contraction during the first seven days. However, it seemed that the curves all began to approach a similar value beyond 14 days. Sample “E” was cracked during removal from its mold, but a repair was attempted before DEMEC points and zero readings were attached. This can be seen in Figure 4.3. It was hoped that the crack would not affect the shrinkage data, but it may be a possibility. It contracted by 0.17% of its original length. The 28-day shrinkage of rest of the bars from the second pour is between 0.11 and 0.13%. These values are smaller than those from the first pour, but this may again be due to the fact that the first mix was slightly thinner. The slight increase in water content would certainly affect its shrinkage, and this coincides with the results.
Table 4.3 Average Linear Shrinkage Data, Samples Poured 11/1/2007

<table>
<thead>
<tr>
<th>Time Elapsed (days)</th>
<th>E (dry)</th>
<th>F</th>
<th>G</th>
<th>H (dry)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1.00</td>
<td>-0.06</td>
<td>-0.01</td>
<td>0.00</td>
<td>-0.03</td>
</tr>
<tr>
<td>2.00</td>
<td>-0.11</td>
<td>-0.03</td>
<td>-0.01</td>
<td>-0.09</td>
</tr>
<tr>
<td>5</td>
<td>-0.13</td>
<td>-0.06</td>
<td>-0.04</td>
<td>-0.10</td>
</tr>
<tr>
<td>7</td>
<td>-0.15</td>
<td>-0.05</td>
<td>-0.07</td>
<td>-0.12</td>
</tr>
<tr>
<td>14</td>
<td>-0.15</td>
<td>-0.08</td>
<td>-0.09</td>
<td>-0.10</td>
</tr>
<tr>
<td>21</td>
<td>-0.16</td>
<td>-0.10</td>
<td>-0.11</td>
<td>-0.11</td>
</tr>
<tr>
<td>28</td>
<td>-0.17</td>
<td>-0.11</td>
<td>-0.13</td>
<td>-0.11</td>
</tr>
</tbody>
</table>

Figure 4.3 Cracked and Repaired Linear Shrinkage Bar

The shrinkage data from each bar was then averaged to create a single shrinkage curve. This shrinkage estimate is conservative as all bars from the linear shrinkage tests were used. This curve can be seen in Figure 4.4. The shrinkage on the curve is 0.16%. This is the value that will be used in the finite element analysis for terrazzo shrinking around a steel vent hole.
4.3 Wheel Durability Tests

The wheel durability tests were examined visually. A numbering system was established in order to quantify the visual data from photographs. The numbering scheme went from zero to four, with four being the worst. A value of “0” indicates that no damage can be seen. A value of “1” indicates that light damage is visible and this is typically a small amount of material has chipped away. A value of “2” is used to quantify moderate damage. This involves larger pieces of aggregate missing from the terrazzo, often over the entire breadth of the contact area with the wheel. A value of “3” indicates heavy damage. This indicates full damage to the edge of the tile. A value of “3” represents full failure of the material with large pieces of aggregate missing from the entire width of the contact surface with the wheel. Tile edges with this value typically did not worsen, as eventually the sharp upper edge of the tile is worn down and
acts as a ramp for the wheel, minimizing further damage. A value of “4” indicates total
destruction of the terrazzo. This only occurred once in all of the testing and it was with
the worst possible combination of test variables. A visual outline of the numbering
scheme can be seen in Figure 4.5.

An outline of the damage observed in all tests can be seen in Table 4.4. This
displays the test outline sorted by the order in which the tests were performed. A
damage number is given to each test at five hundred, ten thousand, and twenty thousand
cycles. The damage observed on all tests at each of these cycles is displayed in Figure
4.6 through Figure 4.27. These figures are placed in the order of testing and located at
the end of this chapter.
Figure 4.5 Damage Scale
Table 4.4 Wheel Durability Test Damage Outline

<table>
<thead>
<tr>
<th>Test</th>
<th>Tile</th>
<th>Edge</th>
<th>Wheel Direction</th>
<th>Gap Width (inches)</th>
<th>Wheel Diameter (inches)</th>
<th>Vertical Offset (inches)</th>
<th>Weight (lbs)</th>
<th>Damage Value at Given Cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>500</td>
</tr>
<tr>
<td>1</td>
<td>E1</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>Pull</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>Pull</td>
<td>0.5</td>
<td>2.5</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>Pull</td>
<td>0.5</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>Push</td>
<td>0.5</td>
<td>1</td>
<td>0</td>
<td>30</td>
<td>4</td>
<td>x</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
<td>Pull</td>
<td>0.5</td>
<td>1</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>D</td>
<td>Push</td>
<td>0.25</td>
<td>1</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>Pull</td>
<td>0.25</td>
<td>1</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>A</td>
<td>Push</td>
<td>0.25</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>C</td>
<td>Pull</td>
<td>0.25</td>
<td>2</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>D</td>
<td>Push</td>
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<td>1</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>B</td>
<td>Pull</td>
<td>0.125</td>
<td>1</td>
<td>0</td>
<td>30</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>D</td>
<td>Pull</td>
<td>0.125</td>
<td>2</td>
<td>0.25</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>Pull</td>
<td>0.125</td>
<td>2</td>
<td>0.25</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>D</td>
<td>Pull</td>
<td>0.25</td>
<td>2</td>
<td>0.25</td>
<td>30</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>A</td>
<td>Push</td>
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<td>2</td>
<td>0</td>
<td>50</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>A</td>
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<td>0.25</td>
<td>2</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

4.3.1 Material Comparison

The very first test performed compared the durability of one epoxy tile and one cementitious tile. Using the 2.5 inch (6.4 cm) wheel and a ½ inch (1.3 cm) gap, the epoxy tile was placed in the push position, which was expected to be the more destructive of the two wheel directions. The 2.5 inch (6.4 cm) wheel was used in the first two tests because the 2 inch (5.1 cm) and 1 inch (2.5 cm) wheels were still being fabricated. The damage from the first test can be seen in Figure 4.6 and Figure 4.7.

Not surprisingly, the epoxy tile showed no sign of damage throughout the entirety of the test, which lasted through 20,000 cycles. The epoxy terrazzo has a
minimum required compressive strength of 10,000 psi (69.0 MPa), per the NTMA specifications. With an average cementitious terrazzo strength of only approximately 6,000 psi (41.4 MPa), it was expected that the epoxy tile would see less damage that its cementitious counterpart.

Because there already exists an NTMA guideline for minimum strength in epoxy terrazzo, but not in cementitious terrazzo, it was decided that the rest of the testing on durability would be focused on cementitious tiles. This was also chosen because visible damage occurred far earlier in the cementitious tile than the epoxy tile, which saw no visible damage. However, the cementitious tile saw damage immediately, even at only 100 cycles.

4.3.2 Wheel Direction Comparison

Each of the eleven tests performed compared the effects of pushing versus pulling the wheel. It was expected that the push direction would cause more damage, and this was almost always the case. Test numbers 3, 4, and 6 are all excellent examples of how the push direction causes greater damage. Damage from test 3 can be seen in Figure 4.10 and Figure 4.11. Damage from test 4 can be seen in Figure 4.12 and Figure 4.13. Damage from test 6 can be seen in Figure 4.16 and Figure 4.17.

First, the damage occurs faster in the push direction. Test number 6 shows quick development in damage on the push side, while the pull side sees almost no visible damage. Second, it seems that the greater damage can ultimately be produced by the push direction. The best example of this is test number 4, which did not make it past 500 cycles. With a ½ inch (1.3 cm) gap and 1 inch (2.5 cm) wheel, the impact from the
wheel onto the tile was much deeper than with other tests. This led to more force being applied to the edge of the tile before the wheel rolled up and over.

When the wheel is in the pull direction, as it hits a bump it has a tendency to ride up and over the obstacle. However, when the wheel is being pushed into a gap, the impact is more severe. This is because the angle of the bracket holding the wheel is aimed down in the push direction and up in the pull direction. In the push direction, the wheel has a tendency to push down and into the edge of the tile with greater force. On the other hand, the wheel has a tendency to move up and over the gap in the pull direction.

4.3.3 Wheel Size Comparison

It was expected that the wheel size would play an important role in the extent of the damage to the floors at Logan Airport. This was true in the tests performed in the laboratory, also.

Tests 2, 3, and 4 each had a ½ inch (1.3 cm) gap. With this and other parameters held constant, the wheel diameter was changed between 1, 2, and 2.5 inches (2.5, 5.1, and 6.4 cm). Focusing on the push direction, we can see that the damage developed at a slower rate with the bigger wheel in test number 2. The damage occurred faster with the 2 inch (5.1 cm) wheel in test number 3. Finally, the sample was totally destroyed in a mere 500 cycles with the 1 inch (2.5 cm) wheel in test number 4. Damage from test 2 can be seen in Figure 4.8 and Figure 4.9. Damage from test 3 can be seen in Figure 4.10 and Figure 4.11. Damage from test 4 can be seen in Figure 4.12 and Figure 4.13.
Tests 5 and 6 each had a gap of ¼ inch (6.4 mm). Looking at the pull direction in these two tests, the 2 inch (5.1 cm) wheel caused no noticeable damage through 20,000 cycles. Expectedly, the 1 inch (2.5 cm) wheel caused moderate damage after 20,000 cycles. However, there was little difference in damage between the push and pull direction for both of these tests. This is a trend that continued when looking at tests 7 and 8, the 1/8 inch (3.2 mm) gap tests. Damage from test 5 can be seen in Figure 4.14 and Figure 4.15. Damage from test 6 can be seen in Figure 4.16 and Figure 4.17.

In tests 7 and 8 it was more difficult to draw connections between the visible damage. In the push direction from each test, the damage was similar, but slightly worse with the 2 inch (5.1 cm) wheel, going against intuition. This may be attributed to differences in the individual tiles that were used. For example, tile 1 seemed to experience heavy damage more frequently that other tiles. Damage from test 7 can be seen in Figure 4.18 and Figure 4.19. Damage from test 8 can be seen in Figure 4.20 and Figure 4.21.

4.3.4 Gap Size Comparison

Gap size was expected to also have a major effect on tile damage. While an increase in wheel diameter typically resulted in less damage, and increase in gap size was expected to increase the damage. The two parameters are also inversely proportional from a geometric standpoint.

Tests 4, 5, and 7 all have a constant wheel diameter of 1 inch (2.5 cm). By varying the width of the gap between ½, ¼, and 1/8 inches (12.7, 6.4, and 3.2 mm), it is clear that the gap size affects the damage done to the tiles. In both the push and pull
directions damage occurs faster and heavier with the larger gap width, and progressively lessens as the gap size decreases. The pull direction of test 7 used tile number 1. This develops heavy damage towards the end of the test even though far less was expected. This may be due to the material properties of the individual tiles, however, as they were taken from different job sites. Damage from test 4 can be seen in Figure 4.12 and Figure 4.13. Damage from test 5 can be seen in Figure 4.14 and Figure 4.15. Damage from test 7 can be seen in Figure 4.18 and Figure 4.19.

Another strange result is the pull direction of test number 8. This test had a 2 inch (5.1 cm) wheel with a 1/8 inch (3.2 mm) gap, but saw more damage than the pull direction in test 5 which had a ¼ inch (6.4 mm) gap. It seems that as the gap size becomes smaller, the more strength of the tile becomes more critical. A stronger tile will hold up to wheel abuse longer than a weaker one. Damage from test 8 can be seen in Figure 4.20 and Figure 4.21.

4.3.5 Vertical Offset Comparison

Two tests were run with the tiles positioned ¼ inch (6.4 mm) higher than the steel divider bar. The expected result was that elevating the tiles with a vertical offset would increase the damage.

Tests 6 and 10 each had a gap width of ¼ inch (6.4 mm) and a wheel diameter of 2 inches (5.1 cm), but test 10 also had a vertical offset. In both the push and pull directions, the tiles in test 10 experienced more severe damage that occurred faster in the duration of the test. This supports the assumption that a vertical offset will poorly
affect the performance of terrazzo floors. Damage from test 6 can be seen in Figure 4.16 and Figure 4.17. Damage from test 10 can be seen in Figure 4.24 and Figure 4.25.

Interestingly, there is little difference between tests 9 and 10. Tests 9 and 10 each have a 2 inch (5.1 cm) wheel diameter and a ¼ inch (6.4 mm) vertical offset, but their gap sizes are 1/8 inch (3.2 mm) and ¼ inch (6.4 mm), respectively. It seems that with a large enough wheel and small enough gap, the vertical offset begins to control the failure of the terrazzo edge. With both tests having the same vertical offset and wheel diameter, the gap width did not have a significant effect on the damage to the tile edges. This stresses that it is quite important to maintain proper flatness over the surface of the terrazzo floor. It is also clear that a well installed sand cushion that will not move, crush, or otherwise fail, is equally valuable in the performance of a terrazzo flooring system. Damage from test 9 can be seen in Figure 4.22 and Figure 4.23. Damage from test 10 can be seen in Figure 4.24 and Figure 4.25.

4.3.6 Weight Comparison

The final test compared the effects of using a larger weight on the wheel. All other tests used 30 lbs (133 N) of weight above the wheel, so 50 lbs (222 N) was used in test number 11. With a 2 (5.1 cm) wheel diameter and ¼ inch (6.4 mm) gap, it was compared with the results of test number 6, which had the same wheel size and gap width. Damage from test 11 can be seen in Figure 4.26 and Figure 4.27. Damage from test 6 can be seen in Figure 4.16 and Figure 4.17.

The damage was visibly worse with the heavier weight. In test number 6, there was no damage seen in the pull direction. However, with more weight added to the
wheel, moderate damage was seen as soon as 10,000 cycles. The push direction in test 11 also had heavier damage at the end of the test when compared with test 6.

This is understandable, as a larger weight on the wheel has two negative effects. First, it is pushing downward on the tile with 66% greater force than the rest of the tests. However, with terrazzo having a typical compressive strength of 6,000 psi (41.4 MPa), it’s doubtful that 50 lbs (222 N) would have any major effect on the performance of the tiles. The real problem is the momentum of the wheel. With 66% greater mass, it is harder for the tile to redirect the wheel’s motion when it strikes. The wheel strikes the tile’s edge with increased momentum and inertia and causes amplified damage upon impact.
500 Cycles
Damage Number: 3

10,000 Cycles
Damage Number: 3

20,000 cycles
Damage Number: 3

Figure 4.6 Test 1 Pull
Figure 4.7 Test 1 Push
Figure 4.8 Test 2 Push
<table>
<thead>
<tr>
<th>Test</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tile-Edge</td>
<td>C3-A</td>
</tr>
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<td>Pull</td>
</tr>
<tr>
<td>Wheel Diameter</td>
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</tr>
<tr>
<td>Gap Width</td>
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</tr>
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</tr>
</tbody>
</table>

500 Cycles  
Damage Number: 1

10,000 Cycles  
Damage Number: 2

20,000 cycles  
Damage Number: 3

Figure 4.9 Test 2 Pull
Figure 4.10 Test 3 Push

<table>
<thead>
<tr>
<th>Test</th>
<th>3</th>
</tr>
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<tbody>
<tr>
<td>Tile-Edge</td>
<td>C4-A</td>
</tr>
<tr>
<td>Wheel Direction</td>
<td>Push</td>
</tr>
<tr>
<td>Wheel Diameter</td>
<td>2</td>
</tr>
<tr>
<td>Gap Width</td>
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</tr>
<tr>
<td>Vertical Offset</td>
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<tr>
<td>Weight</td>
<td>30</td>
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Figure 4.11 Test 3 Pull
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</tr>
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</tr>
<tr>
<td>Gap Width</td>
<td>0.5</td>
</tr>
<tr>
<td>Vertical Offset</td>
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<td>Weight</td>
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500 Cycles  
Damage Number: 4

Figure 4.12 Test 4 Push
Test 4

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<td>Pull</td>
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<td>Gap Width</td>
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<tr>
<td>Vertical Offset</td>
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<tr>
<td>Weight</td>
<td>30</td>
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500 Cycles
Damage Number: 1

10,000 Cycles
Damage Number: 2

20,000 cycles
Damage Number: 2

Figure 4.13 Test 4 Pull
Figure 4.14 Test 5 Push
Figure 4.15 Test 5 Pull
<table>
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<tbody>
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</tr>
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<td>Wheel Diameter</td>
<td>2</td>
</tr>
<tr>
<td>Gap Width</td>
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<tr>
<td>Weight</td>
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</table>

- 500 Cycles | Damage Number: 1
- 10,000 Cycles | Damage Number: 2
- 20,000 cycles | Damage Number: 2

Figure 4.16 Test 6 Push
Figure 4.17 Test 6 Pull
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<td>Tile-Edge</td>
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<td>Push</td>
</tr>
<tr>
<td>Wheel Diameter</td>
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<tr>
<td>Gap Width</td>
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<td>Weight</td>
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Figure 4.18: Test 7 Push
Figure 4.19: Test 7 Pull

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<td>Pull</td>
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<td>Wheel Diameter</td>
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<tr>
<td>Gap Width</td>
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<td>Vertical Offset</td>
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<tr>
<td>Weight</td>
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</tr>
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500 Cycles Damage Number: 0

10,000 Cycles Damage Number: 1

20,000 cycles Damage Number: 3*
Figure 4.20 Test 8 Push
Test 8

<table>
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<td>C2-C</td>
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<td>Pull</td>
</tr>
<tr>
<td>Wheel Diameter</td>
<td>2</td>
</tr>
<tr>
<td>Gap Width</td>
<td>0.125</td>
</tr>
<tr>
<td>Vertical Offset</td>
<td>0</td>
</tr>
<tr>
<td>Weight</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 4.21 Test 8 Pull
Figure 4.22 Test 9 Push
Figure 4.23 Test 9 Pull
Figure 4.24 Test 10 Push
<table>
<thead>
<tr>
<th>Test</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tile-Edge</td>
<td>C8-D</td>
</tr>
<tr>
<td>Wheel Direction</td>
<td>Pull</td>
</tr>
<tr>
<td>Wheel Diameter</td>
<td>2</td>
</tr>
<tr>
<td>Gap Width</td>
<td>0.25</td>
</tr>
<tr>
<td>Vertical Offset</td>
<td>0.25</td>
</tr>
<tr>
<td>Weight</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 4.25 Test 10 Pull
Figure 4.26 Test 11 Push
Test 11

- Tile-Edge: C10-A
- Wheel Direction: Pull
- Wheel Diameter: 2
- Gap Width: 0.25
- Vertical Offset: 0
- Weight: 50

500 Cycles  Damage Number: 0

10,000 Cycles  Damage Number: 2

20,000 cycles  Damage Number: 2

Figure 4.27 Test 11 Pull
A finite element model was used to determine an appropriate fillet radius around reentrant corners specific to vent holes at Logan Airport. Tensile cracks at these locations are likely caused by the sharpness of the corners and a rounded corner is a solution to this problem. The following discusses the finite element model that was created to simulate stress concentrations at reentrant corners around vent holes.

### 5.1 Summary of Reentrant Corner Cracking Problem

Although there are many different types of cracks found in the terrazzo floors at Logan, the most frequently found cracks are located at vent openings. These cracks all run diagonally away from the reentrant corners at the vents. The vents are approximately 6 x 14 inches (15 x 36 cm), positioned just 3 inches (7.6 cm) away from the edge of a 7 x 7 foot (2.1 m) terrazzo slab.

Clearly shown in Figure 5.1, one can see the ¼ inch (6.4 mm) steel edge strips that are used to keep the vent hole open when the terrazzo is poured. Since the terrazzo is bound by a cementitious binding matrix, it shrinks during curing just like a grout, mortar, or concrete. However, the steel edge strips do not shrink while the terrazzo cures. This contraction around an effectively rigid boundary results in stress concentrations at corners and, in turn, cracking. Finite element analysis was used to
model the shrinkage around the vent holes and show that this is a major reason behind this type of cracking.

Figure 5.1 Vent Hole Crack

5.2 Summary of Cementitious Terrazzo Properties

In cementitious terrazzo, Portland Cement is used as the binding matrix. The cementitious terrazzo used on the bridges at Logan Airport is supported by a sand cushion. A misnomer, the sand cushion is not a layer of sand but rather a mix or sand, cement, and very little water. This is placed over the concrete slab to absorb any defects in the slab, allowing more freedom in divider strip spacing as the strips do not need to be matched over corresponding concrete slab joints. Directly over the concrete slab is a thin dusting of sand and then an isolation membrane, separating the sand cushion and terrazzo surface from the slab.

One finite element model was created using an estimated value of shrinkage. Assuming the terrazzo is essentially a mortar, curing of mortar typically results in shrinkage of ½ to 3/4 inch (13 to 19 mm) per 100 feet (30.5 m) or around 0.063%. (ref
15) This is approximately 2.5 times less than the shrinkage value obtained from testing, which was 0.16%. Three additional finite element models were created using the shrinkage value from the laboratory. (Refer to section 4.2) The material properties of the terrazzo floor and steel edge strips that were used in the finite element model can be seen below in Table 5.1.

<table>
<thead>
<tr>
<th>Material</th>
<th>Modulus of Elasticity (psi)</th>
<th>Poisson’s Ratio</th>
<th>Coeff. of Thermal Expansion (deg F⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrazzo</td>
<td>3.6e6</td>
<td>0.2</td>
<td>5.5e-6</td>
</tr>
<tr>
<td>Steel</td>
<td>2.9e7</td>
<td>0.3</td>
<td>n/a (zero)</td>
</tr>
</tbody>
</table>

**5.3 Preliminary Finite Element Model**

A preliminary finite element model was created before the shrinkage results from the laboratory were completed. The estimated contraction of 0.063% during curing was used in this model, which was created with ADINA. The model only needed to focus around one vent hole so the 7 x 7 foot (2.1 x 2.1 m) slab was cut in half. This was confirmed by analyzing a full 7 x 7 foot (2.1 x 2.1 m) model and comparing it to the results of the 7 x 3.5 foot (2.1 x 1.1 m) model. Cutting the model size in half effectively reduced the time required to analyze the model. Because only the terrazzo contracts while curing, the sand cushion was left out of the model. The floor was modeled as a two dimensional solid ½ inch (13mm) thick in plane stress. Nine-node quad elements
were used in the mesh which becomes increasingly fine towards the vent hole where the mesh is approximately 0.325 inches (8.3 mm).

The lower left of the slab was restrained with a pin and the lower right was restrained with a roller. This was to allow the entire slab freedom to contract around the vent holes. The meshing can be seen in Figure 5.2. Note the global axes; X is normal to the page, Z is vertical, and Y is horizontal.

Figure 5.2 Geometry and Mesh Refinement of Preliminary FE Model

To simulate the contraction from curing, a thermal load was applied. Since the terrazzo shrinks approximately ¾ inch (19 mm) over 100 feet (30.5 m), it was easy to relate this to 7 foot (2.1 m) slab, which shrinks approximately 0.054 inches (1.4 mm) during curing. Using the equation of thermal expansion and contraction, $\delta T = \alpha(\Delta T)L$, it was determined that an appropriate load of negative 116 degrees Farenheit should be
applied to produce an equivalent contraction with a coefficient of thermal expansion of 5.5e-6/deg F.

5.4 Results From Preliminary Finite Element Model

After analyzing the model, stress concentrations at the corners were immediately apparent. Because the cracks occur along the plane perpendicular to the principal tensile stresses, the most important stress plots are of principal stresses. To check that ADINA was properly computing stresses, a quick check was done. Table 5.2 shows the Y, Z, shear, and principal stresses at each integration point of element 546, which is located immediately adjacent to the upper left corner of the vent hole. The Y stresses are horizontal while the Z stresses are vertical. The X stresses, which are not shown, run in and out of the page and are zero. P1 stresses are the first principal stress, or tension, while P3 stresses are the third principal stresses, or compression. The values from the check are shown in Table 5.3.

<table>
<thead>
<tr>
<th>Element 546</th>
<th>Stress (psi, from ADINA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration Point</td>
<td>YY</td>
</tr>
<tr>
<td>11</td>
<td>-51</td>
</tr>
<tr>
<td>12</td>
<td>-508</td>
</tr>
<tr>
<td>13</td>
<td>-2112</td>
</tr>
<tr>
<td>21</td>
<td>-340</td>
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<td>22</td>
<td>-668</td>
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<td>23</td>
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<td>32</td>
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<tr>
<td>33</td>
<td>-869</td>
</tr>
<tr>
<td>AVG</td>
<td>-829</td>
</tr>
</tbody>
</table>

The following equation was used to roughly verify the ADINA values by taking the average of all the stresses at each integration point and using the following equation:
\[
\sigma_{1,2} = (\sigma_y + \sigma_z)/2 + \text{SQRT}[\left\{\frac{(\sigma_y - \sigma_z)}{2}\right\}^2 + \tau_{yz}^2]
\]

Table 5.3 Rough Check of Principal Stresses.

<table>
<thead>
<tr>
<th>Check of Stresses</th>
<th>1st term</th>
<th>2nd term</th>
<th>P1</th>
<th>P3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st term</td>
<td>-663.2994111</td>
<td>1538.735</td>
<td>875.436</td>
<td>-2202.03</td>
</tr>
<tr>
<td>2nd term</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values for the average principal stresses from the check were close enough to the ADINA values that the ADINA values were used in examining later models. The principal directions were found using the equation: \(\tan(2\theta_p) = 2\tau_{yz}/(\sigma_y - \sigma_z)\) The principal directions were found to be tilted 42 degrees below the y axis, as shown in Figure 5.3.

Recall that element 546 is located at the top left corner of the vent hole. Figure 5.4 shows the 1st principal stresses around this location. The tensile stress at this location is 962 psi (6.6 MPa). It is clear that the direction of this tensile stress corresponds to the direction of cracks seen in Figure 5.1.
The compressive stresses (third principal stress) can be seen below in Figure 5.5. This figure clearly shows the location of the steel edge strips and also illustrates the degree to which the stresses are localized at the reentrant corners. The steel edge strip is uniformly in compression. This makes sense, as it the terrazzo is contracting around the steel strips uniformly.
5.5 Continued Finite Modeling

Three additional finite element models were also created with ADINA in order to establish a minimum radius recommendation for future terrazzo installation. These models all used terrazzo shrinkage of 0.16% instead of 0.063%. The first additional model used a square corner, similar to the existing condition at Logan Airport and the preliminary model described at the beginning of this chapter. The next model was identical except for its quarter inch radius corners that replaced the original right angles. The final model was also identical except it had a radius of one inch at the corners.

The same procedure that was used to results in the preliminary model was used in the three models with the greater contraction. A terrazzo element nearest to the upper left corner of the vent hole was chosen in each case. Average stresses are shown in Table 5.4. Figure 5.6 shows band plots of the tensile stresses for each model and Figure 5.7 shows band plots of the compressive stresses for each model.
<table>
<thead>
<tr>
<th>Integration Point</th>
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<th>ZZ</th>
<th>YZ</th>
<th>P1</th>
<th>P3</th>
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<td></td>
</tr>
<tr>
<td>Integration Point</td>
<td>YY</td>
<td>ZZ</td>
<td>YZ</td>
<td>P1</td>
<td>P3</td>
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<td>One Inch Radius</td>
<td>Stresses (psi) from ADINA output</td>
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<tr>
<td>Integration Point</td>
<td>YY</td>
<td>ZZ</td>
<td>YZ</td>
<td>P1</td>
<td>P3</td>
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<td>-1065</td>
<td>1499</td>
<td>1434</td>
<td>-1986</td>
</tr>
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</table>
Figure 5.6 Tensile Stress in Finite Element Models
Figure 5.7 Compressive Stress in Finite Element Models
Figure 5.5.1 clearly shows that the tensile stress concentration near the corner lessens as the corner is broadened. Figure 5.5.2 also shows that the compressive stress concentration near the corner becomes more spread out across the corner as the radius increases. This is certainly an effect method to dissipate local stress concentrations due to sharp reentrant corners within contracting floors.

Comparing the tensile stress values from the two models with square corners, it is easy to see the effect of increased shrinkage. When the terrazzo contracts 0.063%, the tensile stress near the corner is 962 psi (6.6 MPa). When the terrazzo contracts 0.16%, the tensile stress at the same location is 1942 psi (13.4 MPa). Just over double the shrinkage leads to just over twice as much tensile stress.

The quarter inch radius reduces the tensile stress to 1749 psi (12.1 MPa). This is an improvement, but still not good enough for terrazzo flooring systems. The one inch radius brought the tensile stress down to 1434 psi (9.9 MPa) near the corner. If shrinkage of 0.063% were to be used instead, an approximate tensile stress of 700 psi (4.9 MPa) would occur with the one inch radius. This is an acceptable value, although the best way to avoid these cracks is to place perpendicular divider strips at each corner.

It is important to note that the cracks around the vent holes are not dependant upon the divider strips spacing. Cracking from improper divider strip placement is typically seen as chipping after separation from the strip has occurred. A smaller terrazzo slab would not eliminate shrinkage cracks around vent holes.

The discrepancy between shrinkage values is interesting. When using typical mortar and concrete shrinkage data, the percent contraction is much less than the data obtained from the laboratory tests. This is discussed further in chapter 6.
CHAPTER 6
CONCLUSIONS

Terrazzo is generally a versatile, durable and low maintenance flooring material. However, methods of installation and construction are generally based on past experience rather than specific data. NTMA guide specifications have become industry standards, but there are many practical considerations that are left up to the installation contractor. Therefore there is not a clear indication of expected performance resulting from the guide specifications.

The elevated walkways at Logan International Airport have provided an excellent case study on terrazzo installation and repair methods. The first two series of bridges (A and E) exhibited an unacceptable level of cracking in the terrazzo. Cracking was broadly defined to include separation of terrazzo from divider strips and deterioration from impact loadings. Cracking typically occurred shortly after opening of the walkways, but some new cracking has appeared after a period of time in service. For the next two series of bridges (B and C) installation techniques and construction methods were altered based on experiences in the first two bridges. While there is still some cracking in the latter terrazzo placements, it is relatively minor. In addition, terrazzo flooring in the A bridge and a portion of the E bridge have undergone a series of repairs since construction. An evaluation of a variety of repair techniques is therefore possible.
Objectives of this research project were to determine the causes of terrazzo cracking at the walkway bridge structures at Logan International Airport, develop specifications for terrazzo installation to prevent cracking in future structures and develop guidelines for repairing existing cracks. In order to provide a means for impacting current practice, QA/QC and implementation procedures were also addressed.

Observed cracks were identified as five basic types: divider strip separation and cracking, cracking at the ends of moving walkway openings, expansion joint cracks, bumper support cracks, and vent opening cracks. Each type of damage was addressed and examined for causes, prevention methods, and repair methods. The causes of terrazzo cracking include stress concentrations, differential movement, and/or impact loads. It was found that terrazzo at many cracks and excessive separations deteriorated due to loading from foot traffic and luggage wheels. In order to mitigate deterioration of terrazzo, several areas need more attention than is provided in current specifications. Shrinkage, re-entrant or sharp corners, and material properties are some of these issues. To address these, guidance on divider strip types and spacing, and specific details at walkway box outs, expansion joints, and penetrations and embedments were provided. Some additional criteria for cementitious terrazzo minimum strengths have also been recommended.

Recommendations for repair techniques, both permanent and temporary were also included. In general, permanent repairs require removal of flooring to an extent that new material can be provided to match new construction criteria. Temporary repairs are worthwhile to prevent further deterioration of terrazzo, but are expected to deteriorate.
Avoidance of feather edges and better matching of materials could make these temporary solutions more effective.

The recommendations for changes to existing specifications and proposed repair methods should provide significant improvements to the performance found in the A and E bridges. The cost of these changes does not appear to be prohibitive based on contracts to the B and C bridges where many of these methods were incorporated. Compared to the repair costs incurred to date in the A and E bridges any additional initial costs are easily offset by reductions in maintenance expenditures.

With the completion of the compression tests, a final recommendation for a minimum compressive strength of terrazzo tiles is 5,000 psi. Divider strips should be spaced no greater than 5 feet (1500 mm) (consider 4 feet (1200 mm)) when using cementitious terrazzo. This is already listed in the NTMA sand cushion specification, but emphasis must be placed on adhering to this guideline. Divider strip spacing is critical in separation minimization and crack prevention. Also, soft joints should be added in addition to standard divider strips. These should be made of two standard divider strips spaced, with ¼ to ½ inch (5 to 15 mm) of flexible durable material (such as neoprene or silicone based material. It is also important that the locations of control joints are shown on design drawings and construction documents.

The wheel durability tests provide further evidence supporting the importance of divider strip placement. It is clear that the larger gaps sizes are more susceptible to wheel damage.

Also, there were a small number of instances where the tiles formed diagonal cracks during the durability tests. There are two reasons for this, and both are the result
of placing the steel clamping bars on the test setup too tightly. The first occurs because
the tile is flexure laterally across the test setup. When the wheel runs over the center of
the tile, they crack towards the clamping bars. This can be seen in Figure 4.21. The
second occurs when the tiles are clamped so tightly that they are only engaged near the
clamp point, which is the center of the test setup longitudinally (the center of the
stroke). Being clamped tightly at their centers, the clamping bars become less engaged
with the tiles towards the end of the bars. The portion of the tile that is clamped is
closest to the center of the clamping bars on either side of the test setup. As the wheel
strikes, the tile wants to move but is only being held by the two small corners closest to
the center divider bar. This causes diagonal cracks as the tile shears away from where it
is clamped. This can be seen in Figure 4.14.

From examining the results of the finite element analysis, a minimum radius of
one inch (2.54 cm) is recommended for all similar installations. If a radius cannot be
installed, perpendicular divider strips should be placed at the corners of vent holes and
other reentrant corners.

Additional examination of terrazzo strength and shrinkage is also advised. It
would be valuable to examine the shrinkage from a larger sample size. Furthermore, it
may be of interest to construct a test that simulates the shrinkage of terrazzo around a
reentrant corner. This physical test could be compared to finite element models in order
to further understand the stresses that arise from terrazzo contraction around effectively
rigid objects.
APPENDIX A

SELECTED TERRAZZO GUIDE SPECIFICATIONS
GUIDE SPECIFICATION FOR SAND CUSHION TERRAZZO
(Revised 6/94 Supersedes all previous specifications for Sand Cushion Terrazzo)

SECTION 09
SAND CUSHION TERRAZZO
Minimum of 2-1/2 inches thick (1/2 inch nominal terrazzo topping, 2 inch nominal underbed includes sand dusting on concrete substrate.) See Architectural Details.

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED IN OTHER SECTIONS
Note: Delete nonapplicable items.
A. Furnishing and installation of metal lath and scratch coat, Section
B. Attachment of metal stairs, any welding and/or reinforcing, Section
C. Furnishing and setting floor drains, Section
D. Furnishing and setting surface hardware, Section
E. Setting of metal base beads and wood ground, Section

Note: Delete where jurisdiction permits terrazzo contractor to install.
F. Concrete subfloor, Section

Note: Subfloor shall not vary more than 1/4 inch from true plane in 10 foot span with float finish.
G. Broom clean area to receive terrazzo of loose chips and all foreign matter.
H. Sufficient water, temporary heat and light, and adequate electric power with suitable outlets connected and distributed for use within 100 feet of any working space.

Note: Ambient temperatures shall be maintained at minimum of 50 degrees Fahrenheit.

1.02 QUALITY ASSURANCE
A. Acceptable Suppliers:
   1. Suppliers shall provide materials in accordance with the NTMA standards.
B. Acceptable Installer:
   1. Installer shall be a contractor member of NTMA and shall perform all work in accordance with NTMA standards.
   2. If installer is not a contractor member of NTMA, installer shall submit a list of completed projects of similar magnitude and complexity.

1.03 SUBMITAL
A. Samples:
   1. Submit a minimum of three samples, sizes 6 inches x 6 inches for each color and type of terrazzo specified.
   2. Submit two, 6-inch lengths of each type and kind of divider strip as specified.
B. Maintenance Literature:
   1. Submit two copies of NTMA maintenance recommendations.
C. Certification:
   1. Suppliers shall furnish certification attesting that materials meet specification requirements.

1.04 DELIVERY, STORAGE AND HANDLING
A. Delivery of Materials:
   1. Deliver materials in a manner to prevent damage to containers and/or bags.
B. Storage of Materials:
   1. Store materials in a clean, dry, heated location furnished by others.

1.05 GUARANTEE
One year from date of completion of terrazzo installation.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Portland Cement: ASTM C 150, Color
   Note: Select white or gray. White cement is uniform in color. Gray Portland cement may not be uniform in color and may produce a variation of shade in the matrix. (See Product Information.)
B. Sand: Clean, washed, locally available sand.
C. Marble Chips:
   1. Size: To conform with NTMA graduation standards.
   Note: See Product Information
   2. Abrasion and impact resistance when testing in accordance with ASTM C 131-89 shall not exceed 40% loss.
   3. 24-hour absorption rate not to exceed 0.75%.
   4. Chips shall contain no deleterious or foreign matter.
   5. Dust content less than 1% by weight.
D. Strips:
   1. Divider Strips (gauge) (material)
      (inches)
      (inches)
   with a depth of
   for a topping thickness of

   Note: (See Divider Strips.) Select gauge, material, depth and topping thickness. Gauge: 18, 16, 14 B & S gauge or 1/8, 1/4, or 3/8 inch heavy top. Material: White alloy of zinc, brass or plastic. Depth: 1-1/4 inches for 1/2 inch standard topping; 1-1/2 inches for a 5/8 inch Venetian topping.

Employment of the normal angle divider strips, regardless of gauge,inserted in the Sand Cushion underbed up to five feet or less on centers, provide ample control of the anticipated shrinkage that will take place when the terrazzo work is installed in accordance to these specifications as each divider picks up a minute amount of the contraction. Construction joints in the structural slab have no bearing on the placement of divider strips in a Sand Cushion systems due to the use of an isolation membrane. Designed expansion plates are the responsibility of others to design, furnish and properly install in the event that they are required.

132
E. Colorants: Alkali-resistant color stable pigments.  
Note: Refer to NTMA Information Guide for further information.
F. Reinforcement: ASTM A 185 16 or 18 gauge galvanized welded wire mesh.
G. Isolation Membrane: ASTM D 2103 Type 15900, 4 mil polyethylene sheeting or ASTM D 226, 15 pound unperforated roofing felt.
H. Curing Materials: Water, wet sand, or polyethylene sheeting.

I. Terrazzo Cleaner:
1. Ph factor between 7 and 10, where applicable.
2. Biodegradable and phosphate free.

J. Sealer:
1. Ph factor between 7 and 10, where applicable.
2. Shall not discolor or amber.
3. Penetrating type specially prepared for use on terrazzo.
   Fabersted minimum, where applicable.
5. UL listed as “Slip Resistant.”

2.02 MIXES
A. Terrazzo Selection:
1. Type:
   Note: Select type or types: Standard or Venetian.
2. NTMA Plate #
   Note: Select color and design from NTMA Information Guide or Color Plates. Any deviation from NTMA plates must be clearly stipulated.

B. Proportions:
1. Underbed: One part Portland cement to four parts sand and sufficient water to provide workability at a low slump as possible.
2. Terrazzo Topping: One 94 pound bag of Portland cement per 200 pounds of marble chips, color pigment if required and sufficient potable water to produce a workable mix.

C. Mixing:
1. Underbed:
   a. Charge and mix sand and Portland cement.
   b. Add water and mix.
2. Terrazzo Topping:
   a. Charge and mix marble chips, Portland cement and color pigment if required.
   b. Add water and mix to a uniform workable consistency.

PART 3 - EXECUTION

3.01 INSPECTION
A. Examine areas to receive terrazzo for:
1. Defects in existing work that affect proper execution of terrazzo work.
2. Deviations beyond allowable tolerances for the concrete slab work.
B. Start work only when all defects have been corrected by others.

3.02 INSTALLATION
A. Underbed:
1. Cover entire surface to receive terrazzo with dusting of sand.
2. Install isolation membrane overlapping ends and edges a minimum of 3 inches.
3. Install welded wire reinforcement:
   a. Overlap wire at edges and ends at least 2 squares.
4. Place underbed mix.
5. Spread underbed to elevation 1/2 inch below finished floor elevation or slope.  
Note: Select 1/2 inch for standard topping or 3/4 inch for Venetian topping.
6. Install divider strips as shown on drawings in 1/4 inch diaphragm underbed and travel firmly along edges.
B. Placing Terrazzo:
1. Saturate underbed with water.
2. Place terrazzo mixture in panels formed by divider strips and travel mixture to top of strips.
3. Seeding of additional marble chips is optional.
4. Roll and compact surface until all excess cement and water has been extracted.
5. Trowel to a dense, uniform, flat surface displacing lines of divider strips.

C. Curing:
1. After completing placement of terrazzo and composition has sufficiently set, cover with water, wet sand or polyethylene sheeting.
2. Cure until topping develops sufficient strength to prevent lifting or pulling of terrazzo chips during grinding.

D. Finishing:
1. Rough Grinding:
   a. Grind with 24 or finer grit stones or with comparable diamond plates.
   b. Follow initial grind with 80 or finer grit stones.
2. Grooving:
   a. Cleanse floor with clean water and rinse.
   b. Remove excess water and debris by hand or apply grout, taking care to fill voids.
3. Cure grout:
   Note: Grout may be left on terrazzo until all heavy and messy work on project is completed.
4. Fine Grinding:
a. Grind with 80 or finer grit stone until all grout is removed from surface.
b. Upon completion, terrazzo shall show a minimum of 70% marble chips.

E. Cleaning and Sealing:
   1. Wash all surfaces with a neutral cleaner.
   2. Rinse with clean water and allow surface to dry.
   3. Apply water in accordance with manufacturer’s directions.

F. Protection:
   1. Upon completion, the work shall be ready for final inspection and acceptance by the owner or his agent.
   2. The General Contractor shall protect the finished floor at the time that the Terrazzo Contractor completes the work.
GUIDE SPECIFICATION FOR EPOXY TERRAZZO
(Revised 6/94 Supersedes all previous Specifications for Epoxy Terrazzo)

SECTION 40
EPOXY TERRAZZO
1/4" OR 3/8" nominal thickness.

PART I-GENERAL

1.01 RELATED WORK SPECIFIED IN OTHER SECTIONS
NOTE: DELETE NONAPPLICABLE ITEMS

A. Furring and/or installation of metal lath and scratch coat.
Section
B. Attachment of metal bars, any welding and mesh reinforcing.
Section
C. Furring and setting of floor drains.
Section
D. Furring and setting surface hardware.
Section
E. Setting of metal base beads and wood ground.
Section
NOTE: DELETE IN CASES WHERE JURISDICTION PERMITS TERRAZZO CONTRACTOR TO INSTALL
F. Backing for Epoxy Terrazzo base must be cement board or exterior grade plywood, concrete block, concrete or cement plaster.
G. Concrete surfaces,
Section
NOTE: CONCRETE SUBFLOOR TO BE LEVEL (MAXIMUM VARIATION NOT TO EXCEED 1/4 INCH IN 10 FEET) AND TO HAVE A STEEL TROWEL FINISHED SURFACE. NO CURING AGENTS OR OTHER ADDITIVES WHICH COULD PREVENT BONDING SHOULD BE USED. THE SLAB SHOULD HAVE AN EFFICIENT MOISTURE BARRIER UNDER THE CONCRETE SLAB WHEN PLACED DIRECTLY ON GRADE. SAW CUTTING OF CONTROL JOINTS MUST BE DONE BETWEEN 12-24 HOURS AFTER PLACEMENT OF THE STRUCTURAL CONCRETE.
H. Sufficient water, temporary heat and light, and adequate electric with suitable outlets connected and distributed for use within 50 feet of any working space.
NOTE: AMBIENT TEMPERATURE SHALL BE MAINTAINED AS PER MANUFACTURERS RECOMMENDATIONS, MINIMUM 50 DEGREES FAHRENHEIT.

1.02 QUALITY ASSURANCE

A. Acceptable supplier:
1. Materials furnished shall meet NTMA Specifications.
B. Installations specifications:
1. Supplier shall be a contractor member of NTMA and shall perform all work in accordance with NTMA standards.
2. If installer is not a contractor member of NTMA, they shall submit a list of completed projects of a similar magnitude and complexity.

1.03 SUBMITAL

A. Samples:
1. Submit a minimum of three samples, minimum 6" x 6" for each color and type of terrazzo.
2. Submit two, 6" minimum lengths of each type and kind of divider strips.
B. Maintenance Literature:
1. Submit two copies of maintenance recommendations of NTMA or maintenance product members of NTMA.
C. Certification:
1. Suppliers shall furnish certification stating that materials meet specification requirements.
2. Suppliers shall furnish properly labeled material and Material Safety Data Sheets which comply to current state and federal requirements.
1.04 DELIVERY, STORAGE AND HANDLING

A. Delivery of materials:
1. Deliver materials in a manner to prevent damage to containers and/or bags.

B. Storage of materials:
1. Store materials in a clean, dry and heated (if necessary) location (50 - 90 degrees Fahrenheit) furnished by others.

1.05 GUARANTEE

One year from date of substantial completion of Terrazzo installation.

PART 2: PRODUCTS

2.01 MATERIALS

A. Primer: As recommended by Epoxy Resin Supplier.

B. Epoxy Resin: Mixed according to manufacturer's recommendation and tested without aggregate added. All specimens cured for 7 days at 75 degrees plus or minus 2 degrees Fahrenheit and 50% plus or minus 2% R.H. The product shall meet the following requirements:

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEST METHOD</th>
<th>REQUIREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>HARDNESS</td>
<td>ASTM D-2240 using Shore D Drometer</td>
<td>60 - 85</td>
</tr>
<tr>
<td>TENSILE STRENGTH</td>
<td>ASTM D-638 run at 3&quot; min.</td>
<td>3,000 psi</td>
</tr>
<tr>
<td>COMPR. STRENGTH</td>
<td>ASTM D-695, Specimen B cylinder</td>
<td>10,000 psi</td>
</tr>
</tbody>
</table>
| CHEMICAL RESISTANCE       | ASTM D-1108 - 7 days at room temperature by immersion method have no deleterious effects. The following contaminants used:
  - Distilled Water .......... 1% Sulfur Solution
  - Methyl Alcohol .......... 10% Sodium Hydroxide
  - Isopropanol ............. 10% Hydrochloric Acid
  - Ethanol .................. 5% Sulfuric Acid
  - 0.2% Detergent Solution | 5% Acetic Acid |

C. Epoxy Resin mixed according to manufacturer's recommendations and blended with 3 volumes of Georgia White marble blended 60% 0.1" chips and 40% 0.06" chips, ground and mixed with epoxy resin according to ASTM 02-320-2 to a nominal 0.65" thickness. All specimens cured 7 days at 75 degrees plus or minus 2 degrees Fahrenheit and 50% plus or minus 2% R.H. The finished epoxy terrazzo shall meet the following requirements:
1. Flexibility: When tested in accordance with ASTM-D-695, the epoxy terrazzo shall comply with the following value: Self-extruding, extent of bumping 0.25 inches maximum.
2. Thermal Coefficient of Linear Expansion: when tested in accordance with ASTM-D-695, the epoxy terrazzo will comply with the following value: 0.75 x 10^-6 inches per inch per degree Fahrenheit maximum. Temperature range -12 degrees to 140 degrees Fahrenheit.
3. Bond Strength: When tested in accordance with Field Test Method for surface soundness and adhesion as described in ACI Committee No. 403 Bulletin 92-35 (Pages 1139-1141) the epoxy terrazzo shall comply with the following value: 100% concrete failure maximum, with 500 PSI minimum bond strength. NOTE: THIS TEST IS INTENDED TO EVALUATE THE BOND TO THE CONCRETE SUBFLOOR. A 100% CONCRETE FAILURE INDICATES A GOOD BOND

D. Marble Chips
1. Size: To conform with NTMA gradation standards.

NOTE: SEE PRODUCT INFORMATION

2. Absorption and liquid resistance when tested in accordance with ASTM C 114-88 shall not exceed 4% loss.
3. 24 hour absorption rate not to exceed 0.175 percent.
4. Chips shall contain no discolorations or foreign matter.
5. Dust content less than 1.5% by weight.

E. Strips:
1. Step and divider "L" strips: gauge.
   (Select gauge while alloy of zinc or plastic. Consult with manufacturer of epoxy resin if brass strips are desired.)

NOTE: SELECT GAUGE FROM FOLLOWING GAUGE 18, 16, 14, 12, 10, 8, 6, 4, 3, 2, 1, 1/4, 1/8, 1/16, 1/32, 1/64, 1/64 INCH HEAT TOP "L" OR "K" TYPE 1 CONSTRUCTION J OINT DOUBLE "L" STRIPS, BACK TO BACK, 18 GAUGE WHITE ALLOY OF ZINC MATERIAL

F. Terrazzo Cleaner:
1. PH factor between 7 and 10, where applicable.
2. Biodegradable and phosphate free.

G. Sealer:
1. PH factor between 7 and 10, where applicable.
2. Shall not discolor or alter color.
3. Finsh point: ASTM D-55, 30 degrees Fahrenheit minimum, where applicable.
4. UL listed as "Bis Keenepeace"

2.02 MIXES

A. Terrazzo Selection:
1. Type:
NOTE: SELECT COLOR AND DESIGN FROM MTMA INFORMATION GUIDE OR COLOR PLATES. ANY DEVIATION MUST BE CLEARLY STIPULATED.

B. Preparation:
1. Epoxy Terrazzo Topping: In accordance with resin supplier's recommendations.

C. Mixing:
1. Terrazzo Topping: Charge and mix marble chips, fillers and epoxy resin in accordance with manufacturer's recommendations.

PART 3 EXECUTION

3.01 INSPECTION

A. Examine area to receive terrazzo for defects in existing work that affect proper execution of Epoxy Terrazzo.
1. Defects in existing work that affect proper execution of terrazzo.

NOTE: CRACKS IN SUBSTRATE WILL USUALLY BE TRANSMITTED THROUGH TOPPING TO SURFACE.
2. Deviations beyond allowable tolerance for the concrete slip work.

NOTE: SURFACE NOT TO VARY MORE THAN 1/4 INCH FROM TRUE PLANE IN 10 FEET. EPOXY TERRAZZO, AS SPECIFIED IS NOT INTENDED TO LEVEL SUBSTRATE AND WILL ONLY FOLLOW THE CONTOUR OF THE CONCRETE SLAB IF, FOR ANY REASON, THE SUBCONTRACTOR QUESTIONS THE SUITABILITY OF THE SUBSTRATE FOR BONDING, ANY WORK REQUIRED TO ELIMINATE NON-COMFORMITY OF SUBSURFACE SPECIFICATIONS IS THE RESPONSIBILITY OF OTHERS, ANY MATERIALS USED TO CORRECT NON-COMFORMITY MUST BE COMPATIBLE WITH EPOXY SYSTEM SELECTED AND BE APPROVED BY THE TERRAZZO CONTRACTOR.

B. Start work only when all defects have been corrected by others.

3.02 INSTALLATION

A. Subfloor:
1. Prepare substrate to receive epoxy terrazzo in accordance with manufacturer's recommendations.
2. Install control joints directly above control joints in subfloor.
3. Install divider strips as shown on drawings.

B. Finishing Terrazzo:
1. Prepare subfloor in accordance with manufacturer's recommendations.
2. Pour terrazzo mixture in panels formed by divider strips. Trowel mixture to top of strips.

C. Polishing:
1. Rough Grinding:
   a. Grind with 54 or finer grit stones or with comparable diamond plate.
   b. Follow initial grind with 80 or finer grit stones.
2. Cleaning:
   a. Clean terrazzo with soap water and rinse.
   b. Remove excess soap water and hand apply grout using identical color as used in topping, taking care to fill voids.
   c. Cure grout.

NOTE: GROUT MAY BE LEFT ON TERRAZZO UNFIL ALL HEAVY AND MESSY WORK IN PROJECT IS COMPLETED.
3. Fine Grinding:
   a. Grind with 60 or finer grit stones until all grout is removed from surface.
   b. Upon completion, terrazzo shall show a minimum of 70% of marble chips.

D. Cleaning and Sealing:
1. Wash all surfaces with a neutral cleaner.
2. Rinse with clean water and allow surface to dry.
3. Apply sealer in accordance with manufacturer's directions.

E. Protection:
1. Upon completion, the work shall be ready for final inspection and acceptance by the owner or his agent.
2. The General Contractor shall protect the finished work from the time that the terrazzo contractor completes the work.
GUIDE SPECIFICATION FOR TERRAZZO OVER PERMANENT METAL FORMS

(Revised 9/84 Supersedes all previous Specifications for Terrazzo Over Metal Forms)

SECTION 09
TERRAZZO OVER PERMANENT METAL FORMS
Minimum thickness 3 inches from the point of the high ridge of the metal decking (1/2 inch Terrazzo topping with 2-1/2 inches of
substrate).

PART 1 - GENERAL

1.01 RELATED WORK SPECIFIED IN OTHER SECTIONS

   NOTE: DELETE NONAPPLICABLE ITEMS.

A. Furnishing and installation of metal lath and scratch coat.
   Section
B. Attachment of metal strips, any welding and/or reinforcing.
   Section
C. Furnishing and setting surface hardware.
   Section
D. Furnishing and setting floor drains.
   Section
E. Setting of metal base treads and wood ground.
   Section

NOTE: DELETE IN CASES WHERE JURISDICTION PERMITS TERRAZZO CONTRACTOR TO INSTALL.

F. Clean area to receive Terrazzo of loose chips and all foreign matter.
   Section
G. Sufficient water, temporary heat and light, and adequate electrical outlets and outlets connected and distributed for use within 100 feet of any working space.
   Section

NOTE: AMBIENT TEMPERATURES SHALL BE MAINTAINED AT A MINIMUM OF 55 DEGREES FAHRENHEIT

H. Furnishing and setting reinforcement mesh.
   Section

NOTE: 6 x 6 x 10-16 WELDED TO METAL FORMS 2 FEET APART AND ELEVATE 1/2" ABOVE METAL DECK AS DESIGNED BY ARCHITECT

1.02 QUALITY ASSURANCE

A. Acceptable supplier:
   1. Materials furnished shall meet NTMA Specification.

B. Installer qualifications:
   1. Installer shall be a contractor member of NTMA and shall perform all work in accordance with NTMA standards.
   2. If installer is not a contractor member of NTMA, installer shall submit a list of completed projects of a similar magnitude and complexity.

1.03 SUBMITTAL

A. Samples:
   1. Submit a maximum of three samples, minimum 6" x 6" for each color and type of rustic terrazzo.

B. Maintenance Literature:
   1. Submit two copies of maintenance recommendations of NTMA or maintenance product member of NTMA.

C. Certification:
   1. Suppliers shall furnish certification stating that materials meet specification requirements.

1.04 DELIVERY, STORAGE AND HANDLING

A. Delivery of materials:
   1. Deliver materials in a manner to prevent damage to containers and/or bags.

B. Storage of materials:
   1. Store materials in a clean, dry and heated (if necessary) location.

1.05 GUARANTEE

One year from date of substantial completion of Terrazzo installation.
PART 2-PRODUCTS

2.01 MATERIALS

A. Portland cement: ASTM C 150, Color
Note: Select and specify white or gray for terrazzo topping. White cement is uniform in color.
Gray Portland cement may not be uniform in color and may produce a variation of shade in the
matrix (see product information).
B. Sand: Clean, washed, locally available sand.
C. Aggregate: 3/8” - 1/2” crushed stone.
D. Marble Chips:
1. Size to conform with NTMA publication standards.
Note: See product information.
2. Abutment and impact resistance when tested in accordance with ASTM C 131-89 shall not exceed 40% loss.
3. 24-Hour absorption rate not to exceed 0.75%.
4. Chips shall contain no detritus or foreign matter.
5. Dist content less than 1% by weight.
E. Strips:
1. Divider Strips:
   - (gauge)
   - (material)
   - (sticker)
   - (inches)
   - (inches)
Note: Select divider strip with gauge material. Strip depth: gauge, 18, 16 or 14 or 8 to 2 gauge or
1/8, 1/4, 1/2, 1/4 INCH HEAVY TOP. MATERIAL: WHITE ALLOY OF ZINC, BRASS OR PLASTIC. STRIP DEPTH: 1/4
INCHES FOR 1/2 INCH STANDARD TABBING; 1/4 INCHES FOR A 3/4 INCH VENETIAN TABBING.
F. Coloring: Alcohols-solvent acid stable pigments.
Note: Refer to NTMA Information Guide for Further Information.
G. Membrane: Material: WATER, WET SAND, OR POLYETHYLEN SHEETING.
   1. Ph factor between 7 and 9, where applicable.
   2. Biodegradable and phosphate free.
H. Sealer:
   1. Ph factor between 7 and 9, where applicable.
   2. Shall not flake or crack.
   3. Penetrating type specially prepared for use on terrazzo.
   4. Flash Point ASTM 56, 50 degrees Fahrenheit minimum, white applicable.
   5. ULC listed as “Ship resistant.”

2.02 MIXES

A. Terrazzo selection:
   1. Type:
      - NTMA Type #
      - NTMA Type #
Note: Select color and design from NTMA color plates. Any deviation from NTMA plates must
be clearly stipulated.
B. Proportions:
   1. Underlaid: Portland cement, sand, aggregate, and sufficient water to achieve 4,000 psi at a 7" slump.
   Note: Allow underlaid area to cure for 72 HOURS BEFORE PLACING TERRAZZO TOPPING.
   2. Terrazzo Topping: One 94 pound bag of Portland cement per 200 - 220 pounds of marble chips, color pigment if required and
sufficient possible water to produce a workable mix.
C. Mixing:
   1. Underlaid:
      a. Charge and mix sand, aggregate and Portland cement.
      b. Add water and mix.
   2. Terrazzo topping:
      a. Charge and mix marble chips, Portland cement and color pigment, if required.
      b. Add water and mix to a uniform workable consistency.

PART 3-EXECUTION

3.01 INSPECTION

A. Ensure areas to receive terrazzo for:
   1. Defects in existing work that affect proper execution of terrazzo.
   2. Deviations beyond allowables tolerances.
B. Start work only when all defects have been corrected by others.

3.02 INSTALLATION

A. Underlaid:
   1. Place underlaid over reinforcement mesh placed and anchored by others in Section.
   2. Install divider strips as underlaid over center of area.
   3. Install 24-Hour absorption rate not to exceed 0.75%.
   4. Secure underlaid 1/2 inch below finished elevation.
Note: See Section on Strips, Select Desired Spacing Not to Exceed 4 Feet.
B. Installing:
   1. Saturate underlaid with water.
   2. Place terrazzo mixture in panels framed by divider strips and trowel mixture to top of surface.
   3. Seeding of additional marble chips is optional.
4. Roll and compact surface until all excess cement and water has been extracted.
5. Trowel to dense uniform flat surface disclosing lines of divider steps.

C. Curing:
1. After completing placement of terrazzo and the composition has sufficiently set, cover with water, wet sand or polyethylene sheeting.
2. Cure until topping develops sufficient strength to prevent lifting or pulling of terrazzo chips during grinding.

D. Finishing:
1. Rough Grinding:
   a. Grind with 24 or finer grit stones or with comparable diamond plates.
   b. Follow initial grind with 80 or finer grit stones.
2. Grooving:
   a. Cleanse floor with clean water and rinse.
   b. Remove excess resin water and machine or hand apply grout using identical Portland cement, color and pigments as used in topping, taking care to fill voids.
3. Cure Grout:
   a. Allow grout to set.

**NOTE: GROUT MAY BE LEFT ON TERRAZZO UNTIL FINE GRINDING WHICH SHOULD NOT BE SCHEDULED UNTIL ALL HEAVY AND MESY WORK ON PROJECT IS COMPLETED**

4. Fine Grinding:
   a. Grind with 80 or finer grit stones until all grout is removed from surface.
   b. Upon completion, terrazzo shall show a minimum of 70% marble chips.

E. Cleaning and Sealing:
1. Wash all surfaces with a neutral cleaner.
2. Rinse with clean water and allow surface to dry.
3. Apply sealer in accordance with manufacturer's directions.

F. Protection:
1. Upon completion, the work shall be ready for final inspection and acceptance by the owner or his agent.
2. The General Contractor shall protect the finished floor from the time that the last terrazzo installer completes the work.
SECTION 09400
TERRAZZO

PART 1 - GENERAL

1.01 GENERAL PROVISIONS

A. Attention is directed to the GENERAL REQUIREMENTS AND COVENANTS - DIVISION I, the SPECIAL PROVISIONS - DIVISIONS IIA and IIB, the SAMPLE CONTRACT FORMS - DIVISION IV, and the APPENDICES - DIVISION V, which are hereby made a part of this Specification Section.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the work of this Section.

1.02 SCOPE

A. The work of this Section consists of furnishing and installation of terrazzo work and related items, as indicated on the Drawings and/or as specified herein, and includes, but is not limited to, the following:

1. Sand cushion terrazzo flooring finish on all floors where and as scheduled and indicated on the Drawings.

   a. Attention is directed to the requirement that the terrazzo work for this project shall be of an artistic nature, required to reproduce the artwork in the various colors as shown on the Drawings.

   b. The Architect will furnish to this Subcontractor, electronic CADD files (Autocad Version 12 or better) containing all of the artistic figures indicated on the Drawings for the layout of the divider strips that create the artistic figures.

   c. Terrazzo finish layer at artistic work shall be thin-set epoxy resin matrix type. At these installations the thickness of the underbed shall be adjusted to accommodate the lesser thickness of the finish layer such that floor level remains constant throughout any overall application.

   d. Terrazzo finish layer at all other locations shall be standard thickness Portland cement matrix type.

2. Thin-set epoxy terrazzo flooring finish and base at cab of Elevators A-1, consisting of marble chips set in epoxy resin matrix, in conformance with the published standards of the National Terrazzo and Mosaic Association, Inc., referenced elsewhere herein. Selection of matrix colors and chips shall be as selected for sand cushion terrazzo flooring finish, described hereinbelow. Divider strips and joint strips shall
be as specified for sand cushion terrazzo flooring finish, below, except of Type 304 stainless steel.

The elevator cab flooring work is not further specified in detail herein. However all general statements herein applicable to the elevator cab flooring shall apply.

3. Precast terrazzo stair tread/risers at all stairs, as indicated on the Drawings.

1.03 RELATED WORK UNDER OTHER SECTIONS

A. The following items of related work are specified and included in other Sections of the Specifications.

1. Concrete sub-slabs and sub-stairs constructed to specified tolerances.

2. Expansion joints.

3. Joint backing and sealant at control joints between terrazzo and abutting different finish materials.

1.04 SUBMITTALS

A. Shop Drawings: Submit complete shop drawings of work of this Section to Architect for approval, indicating layout of all work, showing locations of metal divider strips, edgings, control joints, and large scale sections through divider strips, edgings, base, precast elements, and at other typical and special conditions.

B. Samples: Prior to ordering finish materials, submit representative samples of materials to the Architect for selection and approval, as follows. Retain a duplicate sample at the shop for subsequent color matching. Do not order materials until Architect’s approval has been obtained. Delivered materials shall closely match the approved materials.

1. Provide a total of three sample panels of actual cast terrazzo, at least 6 in. by 6 in., for each requested terrazzo color. Samples will be required for both epoxy resin matrix and Portland cement matrix types.

a. Samples will be required for each color to be used for Portland cement matrix type terrazzo.

b. Samples will also be required for each color to be used for the epoxy resin matrix terrazzo artwork, which shall also include Variations A and B, consisting of approximately seven (7) colors having fixed matrix and gradation of aggregate color.

2. 12 in. long sample each of precast terrazzo stair tread/-riser unit.
3. 12 in. length of each type of divider strip.

C. Product Data: Submit complete product data to Architect for approval, consisting of complete product description and specifications, complete test data and technical characteristics, complete installation instructions, complete maintenance instructions, and other pertinent technical data required for complete product and product use information.

D. Obtain Architect's approval of submittals data before proceeding with installation or application of the terrazzo work.

1.05 SITE SAMPLES

A. Construct at the site, at the remote location indicated or directed by the Architect, a sample area of both epoxy resin matrix and Portland cement matrix types of terrazzo flooring, approximately 6 ft. by 6 ft. flooring, to show proposed materials, method of installation, jointing, control joints, and other pertinent details of construction, as indicated on the Drawings. The sample area shall be of an area of artwork designated by the Architect, as indicated on the Drawings. Replace as necessary until Architect's approval has been obtained. Upon Architect's approval, the sample area shall thereupon become the project standards for the subsequent terrazzo flooring.

1.06 APPLICATOR'S QUALIFICATIONS

A. Terrazzo shall be installed only by a firm fully experienced, and normally engaged, in the installation of terrazzo work similar in type and quality to that specified, and the firm shall, upon written request of the Architect, submit a list of at least five (5) major installations that they have made with similar materials during the preceding five (5) years.

B. It is essential that the firm be fully capable of executing artistic terrazzo work of the type and quality required for this project, and evidence to this effect must be submitted to the Architect.

1.07 COORDINATION

A. The work of this Section shall be coordinated with that of other trades affecting, or affected by, this work, as necessary to assure the steady progress of all work under the contract.

1.08 REFERENCE STANDARDS

A. Applicable provisions of the following trade standard publications shall apply work of this Section, and are hereby incorporated into and made a part of this Section:

1. "Specifications for Sand Cushion Terrazzo" published by the National Terrazzo and Mosaic Association, Inc.
2. "Specifications for Thin-Set Epoxy Resin Terrazzo" published by the National Terrazzo and Mosaic Association, Inc. (NTMA).

3. "Guide Specifications for Precast Terrazzo Stairs" published by the National Terrazzo and Mosaic Association, Inc.

1.09 GUARANTEE

A. In addition to the specific guarantee requirements of DIVISION IIB, the General Contractor shall obtain in the Owner’s name the standard written manufacturer’s guarantee of all materials furnished under this Section where such guarantees are offered in the manufacturer’s published product data. All manufacturer’s guarantees shall be in addition to, and not in lieu of, other liabilities which the General Contractor may have by law or other provisions of the Contract Documents.

B. Include precast concrete terrazzo manufacturer’s guarantee covering all precast terrazzo stair tread/risers against all defects of materials and workmanship for a period of one (1) year.

PART 2 – PRODUCTS

2.01 MANUFACTURER AND SYSTEMS

A. Precast terrazzo stair tread/risers shall be as manufactured by Romaco, Inc., or equal approved by Architect. Other terrazzo work shall conform to standards of the National Terrazzo and Mosaic Association, Inc. (NTMA).

2.02 MATERIALS

A. Portland Cement: ASTM C150, Type I, White and/or other colors as selected by Architect to conform to the various terrazzo colors required for the terrazzo work, in conformance with NTMA standards. Refer to Drawings which indicate Pantone colors representative of each color.

B. Epoxy Resin: Two-part, thermo-setting epoxy resin, 100% non-volatile, in conformance with NTMA standards. Refer to Drawings which indicate Pantone colors representative of each color.

C. Sand: ASTM C33 for fine aggregates.

D. Marble Chips:

1. Size shall conform to NTMA standards. Nos. 1 and 2 sizes shall predominate in the field of the terrazzo work. A combination of No. 0 to 2 size chips shall be required for artistic figures.

2. Shall conform to abrasion resistance test, ASTM C241 with 0.10 minimum.

3. 24-hour absorption rate shall not exceed 0.75%.
4. Chips shall contain no deleterious or foreign matter.

5. Dust content shall be less than 1% by weight.

6. Bags shall be labeled legibly with correct name and size of chip.

E. Special Aggregates: All artistic figures shall contain 50% premium color aggregates, such as mother of pearl and glass aggregate.

F. Divider and Stop Strips:

1. 16 ga. wide white metal for the field of the work and at edges of terrazzo where abutting different finish materials. At edges, stop strips shall be of angle section.

2. 1/8 in. to 1/4 in. brass for artistic figures.

G. Colorants:

1. At Portland Cement Matrix Type Terrazzo: Alkali-resistant non-fading cement color pigments.

2. At Epoxy Resin Matrix Type Terrazzo: Organic color pigments manufactured for use with, and compatible with, epoxy resin.

H. Reinforcement for Underbed: ASTM A185 welded steel wire mesh. 16 ga. or 18 ga., hot-dip galvanized.

I. Isolation Membrane for Underbed: 4 mil polyethylene sheeting, ASTM D2103, Type 13300, or unperforated roofing felt, ASTM D226, 15 lb.

J. Curing Materials for Portland Cement Matrix Type Terrazzo: Liquid membrane, ASTM C305, wet sand, or polyethylene sheeting.

K. Terrazzo Cleaner Portland Cement Matrix Type Terrazzo: Shall be equal to products of Hillyards, Co., Huntington Laboratories, or Merit Paper and Chemical Co., as approved by Architect.

1. PH factor between 7 and 10.

2. Free from crystallizing salts or water soluble alkaline salts.

L. Terrazzo Sealer Portland Cement Matrix Type Terrazzo: Shall be equal to products of Hillyards, Co., Huntington Laboratories, or Merit Paper and Chemical Co., as approved by Architect.

1. PH factor between 7 and 10.

2. Shall not discolor or amber.

2.03 MIXES

A. Terrazzo Colors: Colors of terrazzo shall be as shown on the Drawings. Colors shall generally be per custom color plates cast to the Architect’s and Artist’s requirements, and shall conform to the approved sample panels specified above. Field colors shall have subtle variations in color in specific areas, as denoted on the Drawings. The Drawings indicate Pantone indicate Pantone colors representative of each color.

1. Certain of the colors may be available on NTMA printed color plates. Certain of the colors are represented on samples on file at the Architect’s office and must be matched.

2. The approved color plates shall determine the sizes and colors of the marble chips and the colors of the matrix for the various installations, including precast work.

B. Proportions of Portland Cement Matrix Type Terrazzo:

1. Underbed: 1 part Portland cement to 4 to 5 parts sand and sufficient water to provide workability at as low a slump as possible.

2. Terrazzo Topping: One 94 lb. bag of Portland cement per 200 to 220 lbs. of marble chips, proportions and sizes as approved on sample panels, coloring pigment (if required), and sufficient potable water to produce a workable mix (approximately 5 gallons of water).

C. Proportions of Epoxy Matrix Type Terrazzo (At Artistic Figures): Proportions of epoxy resin matrix to marble chips, mother of pearl chips, glass chips, etc., shall be as required to conform to custom color plates approved for the work, described elsewhere herein.

D. Mixing of Portland Cement Matrix Type Terrazzo:

1. Underbed: Charge and mix sand and Portland cement. Add water and mix. Do not overmix. Use water sparingly to produce low slump mix.

2. Terrazzo Topping: Charge and mix marble chips, Portland cement, and color pigment (if used). Add water and mix to a uniform workable consistency.
E. Mixing of Epoxy Resin Matrix Type Terrazzo: Conform to instructions of the epoxy resin system manufacturer.

2.04 PRECAST STAIR TREADS

A. Precast Stair Treads: Shall be combination tread and riser units, "Type 45" by Romoco, or equal approved by Architect. Three continuous aluminous oxide grit edge strips, equal to Romoco "Type 12" or "Alundum Strips" by Norton Co., shall be inserted in each tread in accordance with NTMA "Figure 7, Page 7" detail. Backs shall have sufficient texture to assure positive bond to substructure.

B. Colors of precast units shall conform to the approved color samples, and shall be carefully controlled to assure uniformity of color and pattern throughout. Finish shall match other project terrazzo work.

PART 3 - EXECUTION

3.01 PREPARATION OF SUBSTRATES

A. Initial Preparation Under Other Sections: Surfaces to receive materials of this Section shall be turned over to this trade, level, plumb true, and clean, free of projections, ridges, cracks, etc., and free of loose dirt, dust, grease, oil, and other deleterious materials such as resin-type curing compounds, paint, glue and similar materials, ready to receive work of this Section.

B. Inspection of Surfaces and Final Preparation under this Section:

1. Thoroughly examine all surfaces to receive work of this Section and notify the Architect in writing of all conditions which would adversely affect this work. Do not commence work in any area where such notice of adverse conditions has been sent until corrective work has been completed. Starting of work in any area without issuances of such notice shall constitute acceptance of conditions in the area as suitable to receive the work of this Section.

3.02 INSTALLATION

A. Underbed (at Portland Cement Matrix Type Terrazzo):

1. Install edge strip wherever terrazzo abuts other finish materials. Provide 3/8 in. wide open joint at these locations, filled with non-contaminating removable filler, ready to receive joint backing and sealant by Joint Sealants trade.

2. Cover entire surface to receive terrazzo with dusting of sand.

3. Install isolation membrane overlapping ends and edges a minimum of 3 in.
4. Install welded wire reinforcement. Overlap wire at ends and edges at least two squares.

5. Place underbed mix.

6. Screed underbed to elevation 1/2 in. below finished floor elevation or slope.

7. Install divider strips as shown on the approved shop drawings in semi-plastic underbed and trowel firmly along edges to assure positive anchorage. Locate strips as indicated on the approved shop drawings, but in any case not farther than recommended by the NTMA printed standards, as directed or approved by Architect.

8. Install artistic figures and strips as shown on the approved shop drawings.

9. Assure that edge angles, dividers, and strips for artistic figures are straight or properly curved, as appropriate, true, and with tops at proper levels.

B. Placing Portland Cement Matrix Type Terrazzo: Place and finish terrazzo finish in strict accordance with NTMA long-form specifications, and to closely match the quality and appearance of the approved site sample installations, generally as follows. Carry terrazzo finish over flanges of expansion joints (expansion joints furnished and installed under EXPANSION CONTROL Section).

1. Saturate underbed with water.

2. Slush underbed with neat cement paste of same color as specified for the topping, including pigment if used in topping.

3. Broom paste into underbed surface.

4. Place terrazzo mixture in panels formed by divider strips and strips for artistic figures, and trowel mixture to level of top of strips.

5. Seed troweled surface with additional chips in same proportions as contained in terrazzo mix and trowel.

6. Roll seeded surface with heavy rollers until all excess water has been extracted.

7. Trowel to a dense, uniform, flat surface disclosing lines of divider strips and strips for artistic figures.

C. Placing Epoxy Resin Type Terrazzo: Place and finish terrazzo finish over plywood substrates at elevator cab floors in strict accordance with NTMA long-form specifications, generally in same manner as Portland
cement matrix terrazzo, except making allowances for the different characteristics of the epoxy resin matrix and the artistic requirements of the Architect and Artist.

D. Curing:

1. After completing placement of terrazzo, and the terrazzo has set sufficiently, apply curing material in accordance with manufacturer’s instructions (curing material not required at epoxy resin matrix terrazzo).

2. Cure until topping develops sufficient strength to prevent lifting or pulling of terrazzo chips during grinding.

D. Finishing:

1. Rough Grinding:
   a. Grind with 24 or finer grit stones or with comparable diamond plates.
   b. Follow initial grind with 80 or finer grit stones.

2. Grouting:
   a. Cleanse terrazzo with clean water and rinse thoroughly.
   b. Remove excess rinse water and machine or hand apply grout using identical Portland cement, color and pigments as used in topping, taking care to fill all voids completely.

3. Curing of Grout:
   a. As soon as grout has attained initial set install curing material.
   b. Cure grout a minimum of 72 hours unless a cement modifier is used. Grout may be left on terrazzo until fine grinding, which should not be scheduled until all heavy and messy work in project is completed.

4. Fine Grinding:
   a. Grind with 80 or finer grit stones until all grout is removed from surface.
   b. Upon completion, terrazzo shall show a minimum of 70% to 75% of marble chips, or as otherwise required by the color plates selected.
3.03 CLEANING AND SEALING OF PORTLAND CEMENT MATRIX TERRAZZO

A. Thoroughly wash all surfaces with neutral cleaner after grinding.
B. Rinse with clean water and allow surface to dry thoroughly.
C. Apply sealer in accordance with manufacturer’s printed instructions.

3.04 INSTALLATION OF PRECAST TREAD AND EDGINGS

A. Install precast terrazzo treads and edgings plumb, level, and true, over indicated substrates in full bed of Portland cement mortar, using mix as specified for underbeds, hereinabove.

3.05 PROTECTION

A. The General Contractor shall protect all finished terrazzo flooring (excluding stair tread/risers for safety reasons) installations with non-staining protective covering, seams taped and overlapped, such protection to be placed immediately after cleaning and sealing of the terrazzo work, to prevent damage by other trades. It shall be the responsibility of the General Contractor to maintain this protection throughout the construction period and to remove same upon substantial completion of the project. Any areas damaged by other trades or separate contractors shall be thoroughly repaired to new appearance at completion of all project work.

B. Just prior to inspection for substantial completion, all additional final cleaning and sealing required to bring the installation to optimum appearance shall be performed by the General Contractor using materials as specified above.

PART 4 - PAYMENT

4.01 METHOD OF MEASUREMENT

A. The work of this Section will be measured on a Lump Sum Basis.

4.02 BASIS OF PAYMENT

A. Payment for the work of this Section will be included as part of Payment Item No. 1.

-END OF SECTION-
SECTION 09400
TERRAZZO

PART 1 - GENERAL

1.01 GENERAL PROVISIONS

A. Attention is directed to the GENERAL REQUIREMENTS AND COVENANTS - DIVISION I, the SPECIAL PROVISIONS - DIVISIONS IIA and IIB, the SAMPLE CONTRACT FORMS - DIVISION IV, and the APPENDICES - DIVISION V, which are hereby made a part of this Specification Section.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the work of this Section.

1.02 SCOPE

A. The work of this Section consists of furnishing and installation of terrazzo work and related items, as indicated on the Drawings and/or as specified herein, and includes, but is not limited to, the following:

1. Sand cushion terrazzo flooring finish on all floors where and as as scheduled and indicated on the Drawings.

   a. Attention is directed to the requirement that the terrazzo work for this project shall be of an artistic nature, required to reproduce the artwork in the various colors as shown on the Drawings.

   b. The Architect will furnish to this Subcontractor, electronic CADD files (Autocad Version 14 or better) containing all of the artistic figures indicated on the Drawings for the layout of the divider strips that create the artistic figures.

   c. Terrazzo finish layer at artistic work shall be thin-set epoxy resin matrix type. At these installations the thickness of the underbed shall be adjusted to accommodate the lesser thickness of the finish layer such that floor level remains constant throughout any overall application.

   d. Terrazzo finish layer at all other locations shall be standard thickness Portland cement matrix type.

2. Thin-set epoxy terrazzo flooring finish and base at elevator cabs, consisting of marble chips set in epoxy resin matrix, in conformance with the published standards of the National Terrazzo and Mosaic Association, Inc., referenced elsewhere herein. Selection of matrix colors and chips shall be as selected for sand cushion terrazzo flooring finish, described hereinbelow. Divider strips and joint strips shall be as
specified for sand cushion terrazzo flooring finish, below, except of Type 304 stainless steel.

The elevator cab flooring work is not further specified in detail herein. However all general statements herein applicable to the elevator cab flooring shall apply.

3. Precast terrazzo stair tread/risers at all stairs, as indicated on the Drawings.

1.03 RELATED WORK UNDER OTHER SECTIONS

A. The following items of related work are specified and included in other Sections of the Specifications.

1. Concrete sub-slabs and sub-stairs constructed to specified tolerances.

2. Expansion joints.

3. Joint backing and sealant at control joints between terrazzo and abutting different finish materials.

1.04 SUBMITTALS

A. Shop Drawings: Submit complete shop drawings of work of this Section to Architect for approval, indicating layout of all work, showing locations of metal divider strips, edgings, control joints, and large scale sections through divider strips, edgings, base, precast elements, and at other typical and special conditions.

B. Samples: Prior to ordering finish materials, submit representative samples of materials to the Architect for selection and approval, as follows. Retain a duplicate sample at the shop for subsequent color matching. Do not order materials until Architect's approval has been obtained. Delivered materials shall closely match the approved materials.

1. Provide a total of three sample panels of actual cast terrazzo, at least 6 in. by 6 in., for each requested terrazzo color. Samples will be required for both epoxy resin matrix and Portland cement matrix types.

a. Samples will be required for each color to be used for Portland cement matrix type terrazzo.

b. Samples will also be required for each color to be used for the epoxy resin matrix terrazzo artwork, which shall also include Variations A and B, consisting of approximately seven (7) colors having fixed matrix and gradation of aggregate color.

2. 12 in. long sample each of precast terrazzo stair tread/riser unit.

MPA CONTRACT NO. 1.719C

09400-2

TERRAZZO
3. 12 in. length of each type of divider strip.

C. Product Data: Submit complete product data to Architect for approval, consisting of complete product description and specifications, complete test data and technical characteristics, complete installation instructions, complete maintenance instructions, and other pertinent technical data required for complete product and product use information.

D. Obtain Architect's approval of submittals data before proceeding with installation or application of the terrazzo work.

1.05 SITE SAMPLES

A. Construct at the site, at the remote location indicated or directed by the Architect, a sample area of both epoxy resin matrix and Portland cement matrix types of terrazzo flooring, approximately 6 ft. by 6 ft. flooring, to show proposed materials, method of installation, jointing, control joints, and other pertinent details of construction, as indicated on the Drawings. The sample area shall be of an area of artwork designated by the Architect, as indicated on the Drawings. Replace as necessary until Architect's approval has been obtained. Upon Architect's approval, the sample area shall thereupon become the project standards for the subsequent terrazzo flooring.

1.06 APPLICATOR'S QUALIFICATIONS

A. Terrazzo shall be installed only by a firm fully experienced, and normally engaged, in the installation of terrazzo work similar in type and quality to that specified, and the firm shall, upon written request of the Architect, submit a list of at least five (5) major installations that they have made with similar materials during the preceding five (5) years.

B. It is essential that the firm be fully capable of executing artistic terrazzo work of the type and quality required for this project, and evidence to this effect must be submitted to the Architect.

1.07 COORDINATION

A. The work of this Section shall be coordinated with that of other trades affecting, or affected by, this work, as necessary to assure the steady progress of all work under the contract.

1.08 REFERENCE STANDARDS

A. Applicable provisions of the following trade standard publications shall apply work of this Section, and are hereby incorporated into and made a part of this Section:

1. "Specifications for Sand Cushion Terrazzo" published by the National Terrazzo and Mosaic Association, Inc.
2. "Specifications for Thin-Set Epoxy Resin Terrazzo" published by the National Terrazzo and Mosaic Association, Inc. (NTMA).

3. "Guide Specifications for Precast Terrazzo Stairs" published by the National Terrazzo and Mosaic Association, Inc.

1.09 GUARANTEE

A. In addition to the specific guarantee requirements of DIVISION IIB, the General Contractor shall obtain in the Owner’s name the standard written manufacturer’s guarantee of all materials furnished under this Section where such guarantees are offered in the manufacturer’s published product data. All manufacturer’s guarantees shall be in addition to, and not in lieu of, other liabilities which the General Contractor may have by law or other provisions of the Contract Documents.

B. Include precast concrete terrazzo manufacturer's guarantee covering all precast terrazzo stair tread/risers against all defects of materials and workmanship for a period of one (1) year.

PART 2 - PRODUCTS

2.01 MANUFACTURER AND SYSTEMS

A. Precast terrazzo stair tread/risers shall be as manufactured by Romoco, Inc., or equal approved by Architect. Other terrazzo work shall conform to standards of the National Terrazzo and Mosaic Association, Inc. (NTMA).

2.02 MATERIALS

A. Portland Cement: ASTM C150, Type I, White and/or other colors as selected by Architect to conform to the various terrazzo colors required for the terrazzo work, in conformance with NTMA standards. Refer to Drawings, which indicate Pantone colors representative of each color.

B. Epoxy Resin: Two-part, thermo-setting epoxy resin, 100% non-volatile, in conformance with NTMA standards. Refer to Drawings which indicate Pantone colors representative of each color.

C. Sand: ASTM C33 for fine aggregates.

D. Marble Chips:

1. Size shall conform to NTMA standards. Nos. 1 and 2 sizes shall predominate in the field of the terrazzo work. A combination of No. 0 to 2 size chips shall be required for artistic figures.

2. Shall conform to abrasion resistance test, ASTM C241 with Ha10 minimum.

3. 24-hour absorption rate shall not exceed 0.75%.

MPA CONTRACT NO. 1.719C  09400-4  TERRAZZO
4. Chips shall contain no deleterious or foreign matter.

5. Dust content shall be less than 1% by weight.

6. Bags shall be labeled legibly with correct name and size of chip.

E. Special Aggregates: All artistic figures shall contain 50% premium color aggregates, such as mother of pearl and glass aggregate.

F. Divider and Stop Strips:

1. 16 ga. wide white metal for the field of the work and at edges of terrazzo where abutting different finish materials. At edges, stop strips shall be of angle section.

2. 1/8 in. to 1/4 in. brass for artistic figures.

G. Colorants:

1. At Portland Cement Matrix Type Terrazzo: Alkali-resistant non-fading cement color pigments.

2. At Epoxy Resin Matrix Type Terrazzo: Organic color pigments manufactured for use with, and compatible with, epoxy resin.

H. Reinforcement for Underbed: ASTM A185 welded steel wire mesh, 16 ga. or 18 ga., hot-dip galvanized.

I. Isolation Membrane for Underbed: 4 mil polyethylene sheeting, ASTM D2103, Type 13300, or unperforated roofing felt, ASTM D226, 15 lb.

J. Curing Materials for Portland Cement Matrix Type Terrazzo: Liquid membrane, ASTM C309, wet sand, or polyethylene sheeting.

K. Terrazzo Cleaner Portland Cement Matrix Type Terrazzo: Shall be equal to products of Hillyards, Co., Huntington Laboratories, or Merit Paper and Chemical Co., as approved by Architect.

1. pH factor between 7 and 10.

2. Free from crystallizing salts or water soluble alkaline salts.

L. Terrazzo Sealer Portland Cement Matrix Type Terrazzo: Shall be water-based acrylic sealer equal to "Sealer 341" by Hillyards, Co., or equivalent by Huntington Laboratories or Merit Paper and Chemical Co., as approved by Architect.

1. pH factor between 7 and 10.
2. Shall not discolor or amber.
3. Slip resistant with rating of 0.5 or greater.
4. Classified by Underwriter’s Laboratories.

2.03 MIXES

A. Terrazzo Colors: Colors of terrazzo shall be as shown on the Drawings. Colors shall generally be per custom color plates cast to the Architect’s and Artist’s requirements, and shall conform to the approved sample panels specified above. Field colors shall have subtle variations in color in specific areas, as denoted on the Drawings. The Drawings indicate Pantone indicate Pantone colors representative of each color.

1. Certain of the colors may be available on NTMA printed color plates. Certain of the colors are represented on samples on file at the Architect’s office and must be matched.
2. The approved color plates shall determine the sizes and colors of the marble chips and the colors of the matrix for the various installations, including precast work.

B. Proportions of Portland Cement Matrix Type Terrazzo:

1. Underbed: 1 part Portland cement to 4 to 5 parts sand and sufficient water to provide workability as low a slump as possible.
2. Terrazzo Topping: One 94 lb. bag of Portland cement per 200 to 220 lb. of marble chips, proportions and sizes as approved on sample panels, coloring pigment (if required), and sufficient potable water to produce a workable mix (approximately 5 gallons of water).

C. Proportions of Epoxy Matrix Type Terrazzo (At Artistic Figures): Proportions of epoxy resin matrix to marble chips, mother of pearl chips, glass chips, etc., shall be as required to conform to custom color plates approved for the work, described elsewhere herein.

D. Mixing of Portland Cement Matrix Type Terrazzo:

1. Underbed: Charge and mix sand and Portland cement. Add water and mix. Do not overmix. Use water sparingly to produce low slump mix.
2. Terrazzo Topping: Charge and mix marble chips, Portland cement, and color pigment (if used). Add water and mix to a uniform workable consistency.

E. Mixing of Epoxy Resin Matrix Type Terrazzo: Conform to instructions of the epoxy resin system manufacturer.

2.04 PRECAST STAIR TREADS

A. Precast Stair Treads: Shall be combination tread and riser units, "Type 45" by Romoco, or equal approved by Architect. Three continuous aluminous oxide grit edge strips, equal to Romoco "Type 12" or "Alundum Strips" by Norton Co., shall be inserted in each tread in accordance with NTMA "Figure 7, Page 7" detail. Backs shall have sufficient texture to assure positive bond to substructure.

B. Colors of precast units shall conform to the approved color samples, and shall be carefully controlled to assure uniformity of color and pattern throughout. Finish shall match other project terrazzo work.

PART 3 - EXECUTION

3.01 PREPARATION OF SUBSTRATES

A. Initial Preparation Under Other Sections: Surfaces to receive materials of this Section shall be turned over to this trade, level, plumb, true, and clean, free of projections, ridges, cracks, etc., and free of loose dirt, dust, grease, oil, and other deleterious materials such as resin-type curing compounds, paint, glue and similar materials, ready to receive work of this Section.

B. Inspection of Surfaces and Final Preparation under this Section:

1. Thoroughly examine all surfaces to receive work of this Section and notify the Architect in writing of all conditions which would adversely affect this work. Do not commence work in any area where such notice of adverse conditions has been sent until corrective work has been completed. Starting of work in any area without issuances of such notice shall constitute acceptance of conditions in the area as suitable to receive the work of this Section.

3.02 INSTALLATION

A. Underbed (at Portland Cement Matrix Type Terrazzo):

1. Install edge strip wherever terrazzo abuts other finish materials. Provide 3/8 in. wide open joint at these locations, filled with non-contaminating removable filler, ready to receive joint backing and sealant by Joint Sealants trade.
2. Cover entire surface to receive terrazzo with dusting of sand.

3. Install isolation membrane overlapping ends and edges a minimum of 3 in.

4. Install welded wire reinforcement. Overlap wire at ends and edges at least two squares.

5. Place underbed mix.

6. Scree underbed to elevation 1/2 in. below finished floor elevation or slope.

7. Install divider strips as shown on the approved shop drawings in semi-plastic underbed and trowel firmly along edges to assure positive anchorage. Locate strips as indicated on the approved shop drawings, but in any case not farther than recommended by the NTMA printed standards, as directed or approved by Architect.

8. Install artistic figures and strips as shown on the approved shop drawings.

9. Assure that edge angles, dividers, and strips for artistic figures are straight or properly curved, as appropriate, true, and with tops at proper levels.

B. Placing Portland Cement Matrix Type Terrazzo: Place and finish terrazzo finish in strict accordance with NTMA long-form specifications, and to closely match the quality and appearance of the approved site sample installations, generally as follows. Carry terrazzo finish over flanges of expansion joints (expansion joints furnished and installed under EXPANSION CONTROL Section).

1. Saturate underbed with water.

2. Slush underbed with neat cement paste of same color as specified for the topping, including pigment if used in topping.

3. Broom paste into underbed surface.

4. Place terrazzo mixture in panels formed by divider strips and strips for artistic figures, and trowel mixture to level of top of strips.

5. Seed troweled surface with additional chips in same proportions as contained in terrazzo mix and trowel.

6. Roll seeded surface with heavy rollers until all excess water has been extracted.
7. Trowel to a dense, uniform, flat surface disclosing lines of divider strips and strips for artistic figures.

C. Placing Epoxy Resin Type Terrazzo: Place and finish terrazzo finish over plywood substrates at elevator cab floors in strict accordance with NTMA long-form specifications, generally in same manner as Portland cement matrix terrazzo, except making allowances for the different characteristics of the epoxy resin matrix and the artistic requirements of the Architect and Artist.

D. Curing:

1. After completing placement of terrazzo, and the terrazzo has set sufficiently, apply curing material in accordance with manufacturer's instructions (curing material not required at epoxy resin matrix terrazzo).

2. Cure until topping develops sufficient strength to prevent lifting or pulling of terrazzo chips during grinding.

D. Finishing:

1. Rough Grinding:
   a. Grind with 24 or finer grit stones or with comparable diamond plates.
   b. Follow initial grind with 80 or finer grit stones.

2. Grouting:
   a. Cleanse terrazzo with clean water and rinse thoroughly.
   b. Remove excess rinse water and machine or hand apply grout using identical Portland cement, color and pigments as used in topping, taking care to fill all voids completely.

3. Curing of Grout:
   a. As soon as grout has attained initial set install curing material.
   b. Cure grout a minimum of 72 hours unless a cement modifier is used. Grout may be left on terrazzo until fine grinding, which should not be scheduled until all heavy and messy work in project is completed.

4. Fine Grinding:
   a. Grind with 80 or finer grit stones until all grout is removed from surface.
b. Upon completion, terrazzo shall show a minimum of 70% to 75% of marble chips, or as otherwise required by the color plates selected.

3.03 CLEANING AND SEALING OF PORTLAND CEMENT MATRIX TERRAZZO

A. Thoroughly wash all surfaces with neutral cleaner after grinding.

B. Rinse with all surfaces clean water and allow surface to dry thoroughly.

C. Apply two coats of specified water-based acrylic sealer in accordance with manufacturer's printed instructions.

3.04 INSTALLATION OF PRECAST TREAD AND EDGINGS

A. Install precast terrazzo treads and edgings plumb, level, and true, over indicated substrates in full bed of Portland cement mortar, using mix as specified for underbeds, hereinabove.

3.05 CLEANING AND PROTECTION

A. The General Contractor shall protect all finished terrazzo flooring (excluding stair tread/risers for safety reasons) installations with non-staining protective covering, seams taped and overlapped, such protection to be placed immediately after cleaning and sealing of the terrazzo work, to prevent damage by other trades. It shall be the responsibility of the General Contractor to maintain this protection throughout the construction period and to remove same upon substantial completion of the project. Any areas damaged by other trades or separate contractors shall be thoroughly repaired to new appearance at completion of all project work.

B. Just prior to inspection for substantial completion, and not less than 30 days after application of sealer, provide the following:

1. Strip the surfaces with floor renovator and a red pad.
2. Rinse thoroughly with clean water.
3. Apply two coats of specified sealer and buff as required to achieve a gloss finish.

PART 4 - PAYMENT

4.01 METHOD OF MEASUREMENT

A. The work of this Section will be measured on a Lump Sum Basis.
4.02 BASIS OF PAYMENT

A. Payment for the work of this Section will be included as part of Payment Item No. 1.

-END OF SECTION-
SECTION 05800
EXPANSION CONTROL

PART I - GENERAL

1.01 GENERAL PROVISIONS

A. Attention is directed to the GENERAL REQUIREMENTS AND COVENANTS - DIVISION I, the SPECIAL PROVISIONS - DIVISIONS IIA and IIB, the SAMPLE CONTRACT FORMS - DIVISION IV, and the APPENDICES - DIVISION V, which are hereby made a part of this Specification Section.

B. Examine all Drawings and all Sections of the Specifications for requirements and provisions affecting the work of this Section.

1.02 SCOPE

A. Furnish (except as otherwise scheduled herein), deliver to project site, and unload in designated storage area all expansion joints. Where any expansion joint item is to be furnished and/or installed by another trade, it shall be specified as such below.

1.03 SUBMITTALS

A. Shop Drawings: Submit to Architect for approval, complete shop drawings and setting drawings of all expansion joint work wherever the expansion joints are scheduled herein to be furnished and installed or furnished only under this Section, showing all pertinent details of construction and installation. Deliver duplicate copies of approved shop drawings for any particular expansion joint to the trade designated to install that particular expansion joint.

1. Shop drawings shall indicate full extent of expansion joint covers; including large-scale details showing profiles of each type of expansion joint cover, splice joints between sections, joinery with other types, special end conditions, anchorages, fasteners, and relationship to adjoining work and finishes. Include description of materials and finishes. Show all internal gutter systems, locating water run-off points, pitch of gutters, and connections to drainage systems.

2. Setting Drawings: Provide setting drawings, blockout dimensions and templates for the location of items and anchorages that are to be embedded in or anchored to concrete, precast concrete or masonry.

B. Samples: Submit samples of each metal and gasket material specified. Provide sample (for each type expansion joint) as a composite showing all components, external and internal with specified gutters, and attachment devices. Provide sample of each type of joint showing intended method of transition in all aspects (T's, L's, X's, and horizontal and vertical offsets).
C. Product Data: Submit complete manufacturer's product data of all work of this Section to Architect for approval, consisting of complete catalog cuts, product description and specifications, installation instructions, and other descriptive data required for complete product and product use information. Deliver duplicate copies of approved installation instructions for any particular expansion joint to the trade designated to install that particular expansion joint.

D. Statement of Application: Submit copy of statement, signed by Contractor, Manufacturer and subcontractor in an approved form, stating that the work complies with this Specification, that the component parts were properly designed or selected for the applications made, and that the installation methods complied with the manufacturer's printed instructions and their field representatives' verbal instructions and were proper and adequate for the conditions of installation and use and are not in conflict with the manufacturer's guarantee specified herein.

E. Certificate of Substrate Acceptability: Submit a certified statement issued by the manufacturer of the expansion joint materials, and countersigned by the installer, attesting that all areas to receive expansion joints have been inspected and found satisfactory for the reception of this Work; and are not in conflict with the Guarantee requirements. Application will be construed as acceptance of surfaces.

F. Do not order materials or begin fabrication or installation of expansion control items until Architect's approval of submittals has been obtained.

1.04 PERFORMANCE CRITERIA

A. Design, engineer, fabricate and install expansion joints so that the installed joints will withstand the live and dead loads and the inward and outward pressures (including wind uplift) of 90 psf normal to the plane of the covers at roofs and 53 psf normal to the plane of the covers at walls.

B. Design, fabricate and install expansion joints so that the installed joints will withstand the following:

1. Vertical Shear: upward and downward
2. Horizontal Shear: outward and inward
3. Rotation: outward and inward

C. Design, fabricate and install component parts to provide for expansion and contraction of the joint covers over an ambient temperature range of 120 degrees F. and a surface temperature range of 180 degrees F. without buckling, joint failure, undue stress on members or anchors, and other detrimental effects.
D. Design, fabricate and install expansion joints so that each joint exposed to the weather shall contain an internal, concealed, continuous, pitched gutter with sealed downspouts draining to locations shown or where not shown, draining to the exterior of the building. Indicate on shop drawings, the location of all drains or weeps pertaining to gutter system.

E. Design Modifications: Make design modifications of work shown as may be necessary to meet performance requirements and coordinate the Work. Maintain the general design concept without altering profiles and alignments shown and submit to the Massport for review, variations in details and materials which do not adversely affect appearance, durability or strength.

1.05 QUALITY ASSURANCE

A. Single-Source Responsibility: Obtain expansion joint covers, gutters, and accessories from one source from a single manufacturer for each type of expansion joint cover. Manufacturer awarded the Project shall be experienced in successfully producing assemblies similar to those indicated for this Project, with sufficient production capacity to produce required units without causing delay in the Work.

B. Installer Qualifications: Arrange for installation of expansion joints by a firm having 5 years experience in the installation of materials specified herein on projects comparable to this Project, and approved by the expansion joint manufacturer.

C. Manufacturer's Representatives: Do not install expansion joints until the manufacturer has a qualified representative at the project site at the start of the Work and periodically during the work, to ensure proper installation of his system.

D. Reference Standards: Except as modified by governing codes and by the Contract Documents, comply with the applicable provisions and recommendations of the following:

1. Industrial Fasteners Institute "Fastener Standards Book".

1.06 QUALITY CONTROL

A. Inspection of Manufacturer's Shop: Manufacturer's fabrication facilities shall remain open and accessible to Massport Contracting Officer, and to Massport's independent testing agency, if any, and shall allow and facilitate random testing of expansion joints and splices.

B. Manufacturer's Testing Program: Comply with the following testing program for each splice, and furnish report to Massport, as follows:

1. Visual Inspection: Check all splices to insure that a full splice has occurred within the part. The splice shall be inspected and to insure that there is not lack of fusion in the splice. Any splice which exhibits lack of fusion shall be rejected and a totally new splice shall be made.
2. Mechanical Inspection: Upon completion of visual inspection procedures outlined above, perform mechanical testing of the splice. Bend legs of each splice 30 degrees both in the horizontal and vertical plane. Examine the splice as described under "visual inspection". Reject splices which exhibit any defects and prepare a new splice. Continue this procedure until a successful splice has been made.

3. Qualitative Non-Destructive Test: Upon completion of the above inspection, test the splice shall non-destructively in compliance with ASTM D2527 for Class 1 seals. Engage a testing laboratory acceptable to Massport. All costs in connection with such tests shall be included in the Contract Price. Furnish test reports to Massport.

4. Report: Prepare documentation, signed by the manufacturer, identifying each shop fabricated splice, the date of inspection, and results of the inspection. Perform non-destructive qualitative test and provide report to Massport. Certify that splice complies with these requirements.

G. Field Quality Control: Comply with the following testing program for each splice, and furnish report to Massport, as follows:

1. Inspection: Perform visual and mechanical inspection specified in manufacturer's testing program in the field under the supervision of manufacturer's representative. Inspect each and every field splice.

2. Report: Prepare documentation, signed by the manufacturer's representative, identifying the location of each field splice, the date of inspection, and results of the inspection. Certify that installation complies with the requirements of these specifications.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in manufacturer's unopened containers fully identified to show name, brand, type, grade and thickness. Store, protect and keep materials dry.

B. Cover joints with exposed finished metal with manufacturer's standard protective paper or wrapping.

C. Store in clean, dry locations, away from uncured concrete and masonry. Cover with waterproof paper, tarpaulin or polyethylene sheeting in a manner that permits air circulation within covering.

1.08 GUARANTEE

A. In addition to the specific guarantee requirements of DIVISION IIB, the General Contractor shall obtain in the Owner's name the standard
written manufacturer's guarantee of all materials furnished under this Section where such guarantees are offered in the manufacturer's published product data. All manufacturer's guarantees shall be in addition to, and not in lieu of, other liabilities which the General Contractor may have by law or other provisions of the Contract Documents.

B. Include manufacturer's 5-year guarantee against leaks resulting from defects of materials or workmanship. Upon notification of such defects, within the guarantee period, make the necessary repairs and replacements at the convenience of the Authority.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Aluminum Extrusions: ASTM B221; sizes and minimum gages as shown, standard with the manufacturer and as required to fulfill performance requirements. Suitable alloy and proper temper for forming and fabricating with adequate structural characteristics, and suitable for finishing as specified.

B. Aluminum Sheet: ASTM B209; sizes and minimum gages as shown, standard with the manufacturer and as required to fulfill performance requirements. Suitable alloy and proper temper for forming and fabricating with adequate structural characteristics, and suitable for finishing as specified.

C. Stainless Steel: ASTM A167, Type 304 with 2B finish, unless indicated otherwise, for plates, sheet, and strips.

D. Steel Extrusions: ASTM A588; Hot dipped galvanized as per ASTM A153 Class A and ASTM A123 Class A, O90 designation.

E. Elastomeric Gutter: Minimum 60 mil thick fabric reinforced ethylene propylene diene monomer (EPDM) obtained in sheet 36 in. wide by min. 120 ft. long, supported to underside of slab with manufacturer's standard extruded aluminum retainers. Provide endcap and pipe connection with down spouts where shown.

F. Exposed Fasteners and Anchorage Devices: Stainless steel Type 300 Series; type, grade, class and style best suited for the respective purpose. Use countersunk flathead Phillips type machine screws for exposed fasteners except where Allen head screws are required.

G. Concealed Fasteners and Anchorage Devices: Hot dipped galvanized; type, grade, class and style best suited for the respective purpose.

H. Paints:

1. Dielectric Separator: "Bitumastic 50" (Koppers Co., Inc.) or "Jennite J-16" (Maintenance Inc.).
2. Galvanizing Repair Paint: Zinc rich paint for repairing abraded or damaged galvanized surfaces.

J. All Other Materials: Provide all standard materials recommended by the manufacturer of expansion joint covers as required for the complete airtight and watertight installation.

2.02 FABRICATION

A. General: Provide expansion joint covers of design, basic profile, materials, and operation indicated. Select units comparable to those indicated or required to accommodate joint size, variations in adjacent surfaces, and structural movement. Furnish units in longest practicable lengths to minimize number of end joints. Provide water-tight hairline mitered corners where joint changes directions or abuts other materials. Include closure materials and transition pieces, tee-joints, corners, curbs, cross-connections, and other accessories as required to provide complete and continuous joint covers.

B. Field Measurements: Before fabrication, take field measurements of locations of walls and other construction to which expansion joint covers must fit, and show recorded measurements on shop drawings (with particular attention given to the installation of items embedded in precast concrete, concrete, roofing and masonry). Coordinate fabrication schedule with construction progress to avoid delaying Work.

1. Where field measurements cannot be made without delaying the work, obtain guaranteed dimensions and proceed with fabrication of assemblies without field measurements. Coordinate construction to ensure that actual opening dimensions correspond to guaranteed dimensions. Allow for trimming and fitting.

C. Provide prefabricated sections of joint covers for all tee, crossover, corner and horizontal directional changes and for transitions and terminations at vertical surfaces. Provide size of joint covers as recommended by the manufacturer to suit the joint sizes shown and to comply with performance criteria specified. Provide joint covers in maximum manufactured lengths.

D. Separate aluminum surfaces in contact with concrete or masonry, and dissimilar metals with a dielectric separator. Do not extend coatings onto exposed surfaces.

E. Preassemble items in shop to greatest extent possible to avoid field seaming. Shop fabricate all corners and transitions. Following trial fit, disassemble units only as necessary for shipping and handling. Clearly mark units for reassembly. Provide alignment and splice plates for accurate field fit.

F. Fabricate expansion joint covers true to line and level with accurate angles, surfaces and edges. Make joints as strong and rigid as adjoining sections. Make welds continuous along entire line of contact.

MPA CONTRACT NO. 1.719C 05800-6 EXPANSION CONTROL
2.02 EXPANSION JOINTS

A. Furnish and install prefabricated extruded aluminum expansion joints at building expansion joints at exterior roofs and walls and interior ceilings, floors, and walls, where and as indicated. Refer to Drawings for quantities and locations.

B. Aluminum extruded sections shall be of 6063-T5 alloy. A coat of zinc chromate primer shall be factory applied to all contact surfaces of aluminum secured in or to concrete or masonry, or in contact with mortar.

C. Expansion joints shall be sizes, types, and configurations as indicated and/or required to accommodate the field conditions, as selected or approved in each case by the Architect, equal to products of Construction Specialties, Inc. (C/S Group), Allway, Architectural Art, Balco Co., Metalines Inc., as approved by Architect. The following schedule is based on specification standards of Construction Specialties, Inc. (C/S Group) to establish required quality and not to limit competition. Moderate and reasonable variations of manufacture of products of other manufacturers will be permitted, upon Architect’s approval.

D. Expansion Joint Schedule:

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<th>Type</th>
<th>Model No.</th>
<th>Joint Size</th>
<th>Trade Furnishing</th>
<th>Trade Installing</th>
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<tr>
<td>F1</td>
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<td>SJ-800HD w/ stainless steel cover plate:</td>
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<td>MPA CONTRACT NO. 1.719C</td>
<td></td>
<td></td>
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<td>GFR-400HD</td>
<td>4 in.</td>
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**Ceilings**

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MPA CONTRACT NO. 1.719C 05800-8 EXPANSION CONTROL
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<td>BRJW-400</td>
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<tr>
<td>R2</td>
<td>SF-800</td>
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<td>This Section</td>
</tr>
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<td>W2</td>
<td>AFW-2, stainless steel finish</td>
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<td>W3</td>
<td>SJ-800HD w/ stainless steel cover plate</td>
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</table>

MPA Contract No. 1.719C 05800-9 Expansion Control
ADDENDUM NO. 4
10 SEPTEMBER 1999

W4
AFW-6 w/ stainless steel finish, customized-width center plate. 4 in. This Section Stainless Steel Wall Panel Trade

W5
AFWC-4 w/ custom center plate and finished to match curtain-wall. 4 in. This Section Aluminum Curtain-wall

PART 3 - EXECUTION

3.01 CONDITION OF SURFACES

A. Examine the substrates, adjoining construction and the conditions under which the Work is to be installed with expansion joint manufacturer's representative. Follow manufacturer's instructions for the repair of block-out and substrates and obtain manufacturer's acceptance of substrate prior to the start of work. Do not proceed with the Work until unsuitable conditions have been corrected.

3.02 PREPARATION

A. Coordinate and furnish anchorages, setting drawings, templates, and instructions for installation of expansion joint covers to be embedded in concrete or have recesses formed into edges of concrete slab for later placement and grouting-in frames.

3.03 INSTALLATION BREAKDOWN

A. All items scheduled to furnished and installed as work of this Section shall be installed in strict accordance with the approved shop drawings and the manufacturer's printed instructions and recommendations, required to be submitted as specified hereinabove.

B. All items scheduled to be furnished under this Section which are specified to be installed as work under another trade Section shall be delivered to site and turned over to General Contractor for installation by the other designated trades.

C. All items scheduled to be furnished and installed as work under another trade Section will be totally the work of those other designated trades.
3.04 INSTALLATION REQUIREMENTS

A. Fastening to In-Place Construction: Provide anchorage devices and fasteners and steel supports and/or shims where necessary for securing expansion joint covers to in-place construction, including threaded fasteners with drilled-in expansion shields for masonry and concrete where anchoring members are not embedded in concrete. Provide fasteners of metal, type, and size to suit type of construction indicated and provide for secure attachment of expansion joint covers.

B. Cutting, Fitting and Placement: Perform all cutting, drilling, and fitting required for installation of expansion joint covers. Install expansion joint covers in true alignment and proper relationship to expansion joints and adjoining finished surfaces measured from established lines and levels. Allow adequate free movement for thermal expansion and contraction of metal to avoid buckling. Set covers at elevations to be flush with adjacent finished floor materials. Securely attach in place with all required accessories. Locate anchors at interval recommended by manufacturer, but not less than 3 in. from each end and not more than 24 in. o.c.

C. Joinery and Continuity: Maintain continuity of expansion joint covers with end joints held to a minimum. Cut and fit ends to produce joints that will accommodate thermal expansion and contraction.

D. Joints Between Different Systems (Types): Follow manufacturer's strict guidelines for transition between different joint types and different joint systems, as required for a complete air and water tight installation.

PART 4 - PAYMENT

4.01 METHOD OF MEASUREMENT

A. The work of this Section will be measured on a Lump Sum Basis.

4.02 BASIS OF PAYMENT

A. Payment for the work of this Section will be included as part of Payment Item No. 1.

-END OF SECTION-
SECTION 09400

TERRAZZO

PART 1 GENERAL

1.01 DESCRIPTION OF WORK

A. Work of this Section includes but is not limited to the following:

2. Epoxy terrazzo flooring.
3. Precast terrazzo treads and wall base.

1.02 RELATED WORK

A. Examine Contract Documents for requirements that affect work of this Section. Other Specification Sections that directly relate to work of this Section include, but are not limited to:

1. Section 05500, METAL FABRICATIONS; Stairs to receive precast treads.
2. Section 07900, JOINT SEALERS; Sealing of control joints.
3. Section 09650, RESILIENT FLOORING; Resilient accessories.

1.03 SUBMITTALS

A. Shop Drawings: Show terrazzo fabrication and installation requirements including plans, elevations, sections, component details, and attachments to other work.

1. Show layout of divider and control- and expansion-joint strips.
2. Show large-scale details of terrazzo patterns.
3. Show large-scale details of precast terrazzo components and anchorage.

B. Samples: Submit three 12 in. x 24 in. square samples of each color and type of terrazzo required, and 12 in. long samples of each type accessory item. Submit samples as many times as is necessary to secure the Architect's approval, at no additional cost. Terrazzo samples shall be ground, grouted, cleaned and sealed using specified materials. Each set of approved terrazzo samples shall represent the range of color and aggregate distribution to be present in the finished work. Also, submit one sample set of available colors for grout and sealants. Review will be for color, pattern and texture only, compliance with all other requirements is solely the responsibility of the Contractor.

C. Maintenance Instructions: Submit two copies of written instructions for recommended periodic maintenance of each type of terrazzo, including recommended maintenance materials and equipment.

D. Product Data: Furnish manufacturers' product data for flooring, latex Portland cement bed materials, latex Portland cement grout materials, sealants, and all other required materials.

E. Certification: Submit suppliers'/manufacturers' written certification that terrazzo materials meet or exceed specified National Terrazzo and Mosaic Association, Inc. (NTMA) properties.

1.04 QUALITY ASSURANCE

A. NTMA Standards: All work shall be installed in strict accordance with requirements of the latest revision of the "Guide Specifications" of the National Terrazzo and Mosaic Association, Inc. (NTMA).
B. Manufacturer's Instructions: In addition to specified requirements for monolithic cementitious terrazzo, comply with manufacturer's instructions and recommendations for substrate preparation, priming, material storage, mixing application, finishing, and curing.

C. Contractor Qualifications: Contractor shall be an experienced installer who has completed at least three terrazzo installations similar in materials, complexity and scope to that required for this Project that have a record of successful in-service performance.

1. Contractor shall be a contractor member of NTMA or be certified by NTMA to perform all work in accordance with NTMA standards.

D. Terrazzo Surfaces: Upon completion, terrazzo surfaces shall have a minimum of 70% marble chips or custom aggregate.

E. Finished Levelness and Flatness of Terrazzo: The levelness and flatness of the finished terrazzo is a prime requisite of this work. Terrazzo surface shall not vary more than 1/8" in 12 ft. (non-cumulative) from the indicated finished floor plane, measured from any point on the floor.

F. The terrazzo flooring specified has been selected as an integral part of a coordinated interior design scheme. Therefore, it shall be understood that the Architect will be the sole judge of a proposed products' acceptability, and rejection of a proposed substitute shall not entitle the Contractor to any claims for additional compensation or for extension to the Time of Completion.

1.05 PROJECT CONDITIONS

A. Maintain temperature a minimum temperature of 50 degree F during flooring work and for 7 days after completion.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in a manner to prevent damage to containers and/or bags. Store materials in a clean, dry, heated location.

B. Deliver all materials to the site in manufacturers' unopened containers with grade seals unbroken and labels intact.

1.07 GUARANTEE

A. Provide a full written guarantee for a period of one year from date of completion of all terrazzo installations against defects in materials of workmanship.

PART 2 - PRODUCTS

2.01 SAND-CUSHION TERRAZZO

A. Portland Cement - ASTM C 160, Type I:

1. Color: For terrazzo topping matrix, as required by mix indicated:

B. Water: Potable.


D. Marble Chips: Sizes conforming to NTMA gradation standards for mix indicated, with Hs 10 minimum abrasive hardness value when tested according to ASTM C 241, 0.75 percent maximum 24-hour absorption rate, dust content of less than 1 percent by weight, and
containing no deleterious or foreign matter.

E. Matrix Pigments: Pure mineral or synthetic pigments, alkali resistant, color stable, and compatible with matrix binder.

F. Air-Entraining Agent: Complying with NTMA's written recommendations and recommended by supplier for intended use.

G. Underbed Isolation Membrane: 4 mils thick polyethylene sheeting, ASTM D-2403, Type I3700.

H. Reinforcement for Underbed: ASTM A 185 welded wire mesh, 16 or 18 gauge, hot-dip galvanized.

I. Topping Bonding Agent: Neat portland cement, or epoxy or acrylic bonding agents formulated for use with topping indicated.

J. Heavy Top Divider Strips: Straight or angle type as required by terrazzo type indicated, with anchoring device, in depth required for topping thickness indicated, and as follows:

2. Top Section Width: 1/8 inch and 1/4 inch, as indicated.

K. Control Joint Strips: Separate, double Ltype angle or straight strips positioned back-to-back, matching material, thickness, and color of divider strips in depth required for topping thickness indicated.

L. Abrasive Strips: Silicon carbide or aluminum oxide in epoxy-resin binder.

M. Isolation and Expansion Material: Closed-cell polyethylene foam, nonabsorbent to liquid water and gas, and nonoutgassing in unruptured state; butyl rubber, rubber, or cork; in width indicated or, if not indicated, minimum 1/2 inch.

N. Cleaner: Chemically neutral cleaner with pH factor between 7 and 12 that is biodegradable, phosphate free, and recommended by cleaner manufacturer for use on terrazzo type indicated.

O. Sealer: Slip and stain resistant, penetrating-type sealer that is chemically neutral with pH factor between 7 and 12, does not affect color or physical properties of terrazzo type indicated, is recommended by sealer manufacturer for this use, and complies with NTMA Guide-Specification for terrazzo type indicated.

1. Use solvent acrylic-type sealer for rustic terrazzo.

P. Mixes:

1. Concrete Underbed: As specified in Section 03300, CAST-IN-PLACE CONCRETE.

   a. Color and Pattern: As selected by Architect from NTMA standard terrazzo plates.

2.01 THIN-SET EPOXY TERRAZZO MATERIALS

A. Epoxy-Resin Terrazzo Matrix: Epoxy resins and matrix and materials complying with NTMA "Guide Specification for Epoxy Terrazzo" and as required to match approved color sample to
the satisfaction of the Architect.

B. Marble Chips: Natural, sound, crushed marble chips, colors selected and graded to match Architect's samples, but with maximum size within limits of workability for terrazzo thickness indicated, and as follows:

1. Size shall be No. 0 to No. 2, in accordance with NTMA standards.
2. Marble chips shall conform to abrasion resistance test ASTM C 241 with Ha10 minimum.
3. 24 hour absorption rate shall not exceed 0.75%.
4. Chips shall contain no deleterious or foreign matter.
5. Dust content shall be less than 1% by weight.
6. Bags shall be labeled legibly with correct name and size of chip.

C. Custom Aggregate: Provide custom aggregate, including but not limited to, Mother-of-Pearl, glass, zinc nuggets, plastic; as selected by the Architect.

D. Flexible Epoxy Membrane: Epiflex Flexible Epoxy Membrane, 100% solids for crack preparation:

1. Tensile Strength: ASTM D 2370, 20°C - 1,500 psi.
2. Elongation: ASTM D 2370, 20°C - 130%.

E. Heavy-Top Divider Strips: Straight or angle type as required by terrazzo type indicated, with anchoring device, in depth required for topping thickness indicated, and as follows:

2. Top-Section Width: 1/8 inch and 1/4 inch, as indicated.

F. Control Strips: Double or split units, 1/8 inch wide, of same material as divider strips with 1/8-inch-wide full-depth filler, laminated between strips. All strips shall be securely fastened to substrate with concealed fasteners.

1. Filler: Black neoprene.

2.02 PRECAST TERRAZZO

A. Precast Terrazzo Units: Comply with NTMA's written recommendations for fabricating precast cementitious terrazzo units in sizes and profiles indicated. Reinforce units as required by unit sizes, profiles, and thicknesses and as recommended by manufacturer.

B. Precast Terrazzo Base: Furnish and install precast terrazzo base in sizes and profiles indicated on the Drawings. Color and finish to match epoxy terrazzo.

C. Precast Terrazzo Treads: Furnish and install precast terrazzo stair tread and riser units, in sizes and profiles indicated on the Drawings. Treads shall have three continuous aluminum oxide grit edge strips equal to Ramoco Type 12. Color and finish to match epoxy terrazzo.

C. Fabrication: Minimum 1 in. thick, reinforced-cementitious terrazzo units cast in maximum lengths possible, but not less than 54 in., in configurations as indicated on the Drawings.

D. Accessories: Provide fasteners and anchors as required to secure treads to risers and adhesives to secure base to wall.

2.03 SUBSTRATE CLEANER

A. Concrete cleaner shall be "Renovator" heavy duty cleaner manufactured by Hillyard, Inc., St. Joseph, MO, or approved equal by Butcher Co., Marlborough, MA or S.C. Johnson, Racine, WI.
Cleaner shall be compatible with bonding agent.

2.04 NEUTRAL CLEANER

A. Shall be "Super Shine-All" neutral cleaner by Hillyard, Inc., St. Joseph, MO, or approved equal by Butcher Co., Marlborough, MA of S.C. Johnson, Racine, WI.

2.05 SEALANTS

A. General: Provide polyurethane floor joint sealant in a custom color in accordance with requirements of Section 07900, JOINT SEALERS.

PART 3 - EXECUTION

3.01 PREPARATION

A. Before commencing work, be sure variations of surfaces to receive terrazzo flooring are within the tolerances specified below, and that all fixtures, fittings, connections, fixtures, outlets, etc., are in place and surfaces are free of curing membranes, oil, grease, wax and dust.

1. Tolerances in level shall not exceed those given in ACI 302.1R, ACI 117, and ASTM E 1155 as follows:

   a. All Slabs on Grade and Structural Slabs: Floor shall conform to a Floor Flatness Number of not less than F(F) = 25 and a Floor Levelness Number of not less than F(L) = 20.

   b. Testing of F(F) and F(L) tolerances shall be conducted in accordance with the provisions set forth in ASTM E 1155-87 and ASTM Committee E.6.21.1 using a measuring device specifically designed to measure floor flatness.

B. Concrete must cure for at least 30 days prior to stone installation, and the moisture content shall be acceptable to the Architect and setting material manufacturers.

C. Do not proceed until adjoining work is satisfactorily protected.

D. Provide the Architect with written acceptance of substrate preparation before commencing terrazzo work.

3.02 GENERAL REQUIREMENTS

A. Keep containers in which setting materials are packed dry until materials are removed and checked. Take every precaution so that materials are not stained in storage.

B. Carefully lay out work so that grout lines are true, straight and of uniform width.

3.03 INSTALLATION—SAND-CUSHION TERRAZZO

A. General: Comply with NTMA Guide Specification for terrazzo type indicated and NTMA's written recommendations for substrate preparation and terrazzo installation.

B. Spread sand on surfaces to receive sand-cushion terrazzo to comply with NTMA's "Guide Specification for Sand-Cushion Terrazzo."

C. Install isolation membrane according to NTMA Guide Specification for terrazzo type indicated.

D. Concrete Underbed: Install according to requirements specified in Section 03001, CONCRETE.

TERRAZZO 09400 - 5
3.03 THIN-SET EPOXY TERRAZZO

A. Placing Flexible Reinforcing Membrane: Prepare and prefll substrate cracks with membrane materials. Install membrane to produce full substrate coverage in areas to receive terrazzo. Install fiberglass reinforcing membrane over cracks previously filled. Prepare membrane according to manufacturer’s written instructions before beginning installation of terrazzo.

B. Comply with NTMA guide specifications previously referenced under “Thin-Set Terrazzo Materials” and with matrix manufacturer’s directions for installing and finishing thin-set terrazzo. Match Architect’s sample and provide total material thickness indicated.

C. Exercise extreme care to ensure fluids from grinding operation do not react with divider or control strips to produce a stain on aggregate.

D. Delay grinding and finishing until heavy trade work is completed and construction traffic through the area is restricted.

E. At completion of grinding and finishing operations, terrazzo shall show a minimum of 70% to 75% of marble chips and custom aggregate.

3.04 PRECAST TERRAZZO TREADS AND WALL BASE

A. Install precast terrazzo units using method recommended by NTMA and manufacturer, unless otherwise indicated. Set units with alignment level and true to dimensions, varying 1/8 inch maximum in length, height, or width.

3.05 CLEANING, SEALING, AND PROTECTION

A. Clean terrazzo after all operations are completed using the specified neutral cleaner, in accordance with the cleaner manufacturer’s instructions. Rinse all areas twice and let dry.
B. After installations are thoroughly dry, apply three coats of anti-slip sealer in strict accordance with the sealer manufacturer’s instructions and recommendations.

3.06 PROTECTION

A. Protect installed floors with homasote or other heavy covering during the construction period to prevent damage and wear.

B. Prohibit all foot and wheel traffic from floors for at least three days, and when possible, for seven days.

END OF SECTION
5. Dust content shall be less than 1% by weight.
6. Bags shall be labeled legibly with correct name and size of chip.

C. Custom Aggregate: Provide custom aggregate, including but not limited to, Mother-of-Pearl, glass, zinc nuggets, plastic, as selected by the Architect.

D. Flexible Epoxy Membrane: Epiflex Flexible Epoxy Membrane, 100% solids for crack preparation.
   1. Tensile Strength: ASTM D 2370, 20°C - 1,500 psi.
   2. Elongation: ASTM D 2370, 20°C - 150%.

E. Heavy Top Divider Strips: Straight or angle type as required by terrazzo type indicated, with anchoring device, in depth required for topping thickness indicated by Manhattan American; and as follows:
   2. Top Section Width: 1/8 inch and 1/4 inch, as indicated.
   3. Color: Custom Color to match Pantone Color 648 CVC.

F. Control Strips: Double or spilt units, 1/8 inch wide, of same material as divider strips with 1/8-
   inch-wide full-depth filler, laminated between strips. All strips shall be securely fastened to
   substrate with concealed fasteners.
   1. Filler: Black neoprene.

2.02 PRECAST TERRAZZO

A. Precast Terrazzo Units: Comply with NTMA's written recommendations for fabricating precast
   cementitious terrazzo units in sizes and profiles indicated. Reinforce units as required by unit
   sizes, profiles, and thicknesses and as recommended by manufacturer.

B. Precast Terrazzo Base: Furnish and install precast terrazzo base in sizes and profiles indicated
   on the Drawings. Color and finish to match epoxy terrazzo.

C. Precast Terrazzo Treads: Furnish and install precast terrazzo stair tread units, in sizes and
   profiles indicated on the Drawings. Treads shall have three continuous aluminum oxide grit
   edge strips equal to Ramoco Type 12. Color and finish to match epoxy terrazzo.

C. Fabrication: Minimum 1 in. thick, reinforced-cementitious terrazzo units cast in maximum
   lengths possible, but not less than 94 in., in configurations as indicated on the Drawings.

D. Accessories: Provide fasteners and anchors as required to secure treads to risers and
   adhesives to secure base to wall.

2.03 SUBSTRATE CLEANER

A. Concrete ceiling cleaner shall be "Renovator" heavy duty cleaner manufactured by Hillyard, Inc., St.
   Joseph, MO, or approved equal by Butcher Co., Marlborough, MA or S.C. Johnson, Racine, WI.
   Cleaner shall be compatible with bonding agent.

2.04 NEUTRAL CLEANER

A. Shall be "Super Shine-All" neutral cleaner by Hillyard, Inc., St. Joseph, MO, or approved equal
   by Butcher Co., Marlborough, MA or S.C. Johnson, Racine, WI.
REFERENCES


15) TK Products, “Concrete Curing”.
http://www.tkproduct.com/Curing%20Concrete.PDF